PHYSICS

CHEMISTRY
BIOLOGY

ENGINEERING

# LD DIDACTIC

# PHOTONIC
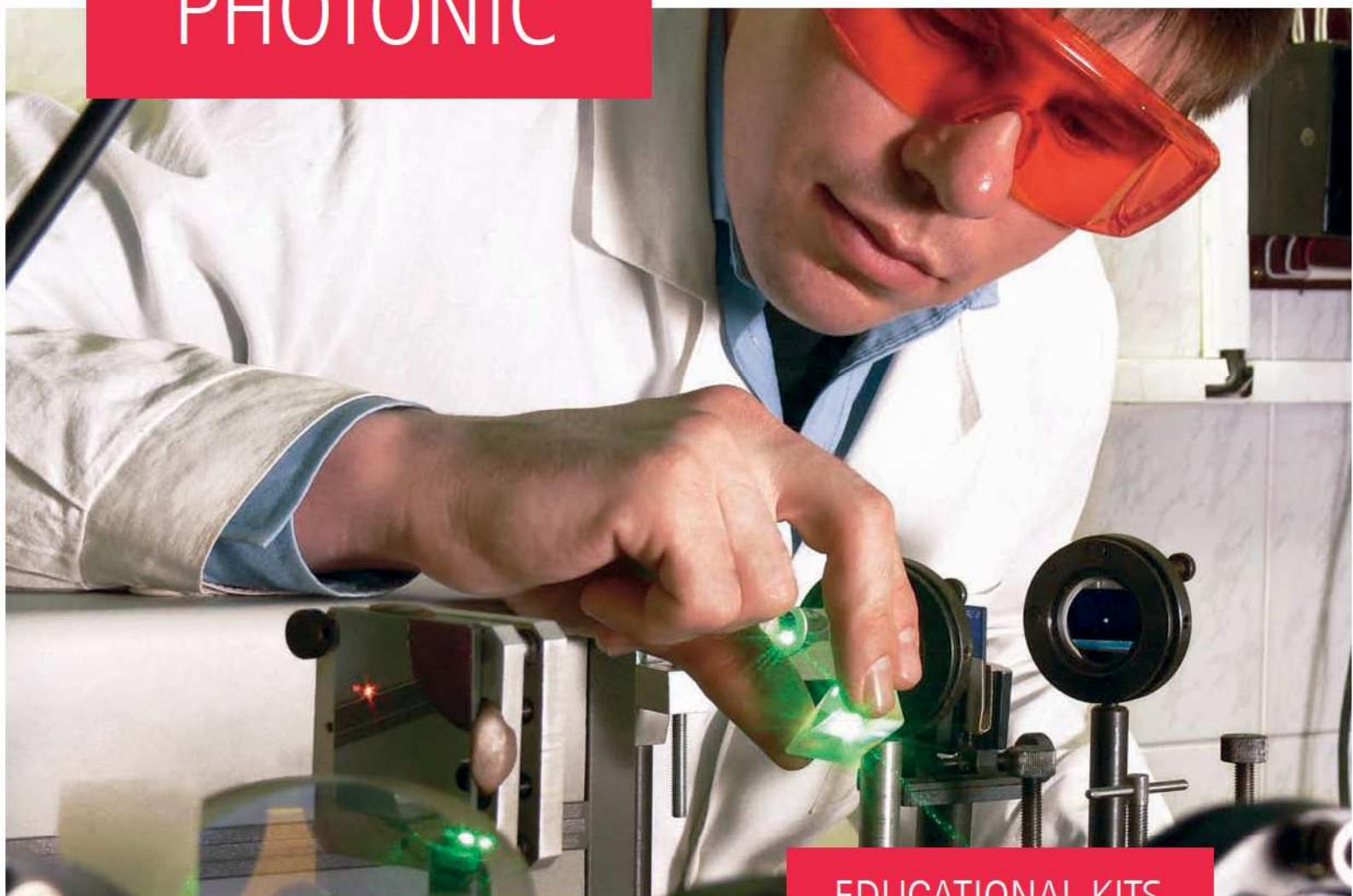
EDUCATIONAL KITS

# LEYBOLD®

Modern physics shows that photons are neither particles nor waves.
The term photonics takes into account the dualism of light.
The science of photonics covers all technical applications of light
including generation, emission, transmission, modulation, signal
processing, switching, amplification, detection and sensing.
This catalogue presents the LEYBOLD range of experiments
– designed and engineered by Dr. W. Luhs – covering topics from
basic geometrical optics up to quite sophisticated set-ups in laser
interferometry and technical applications.
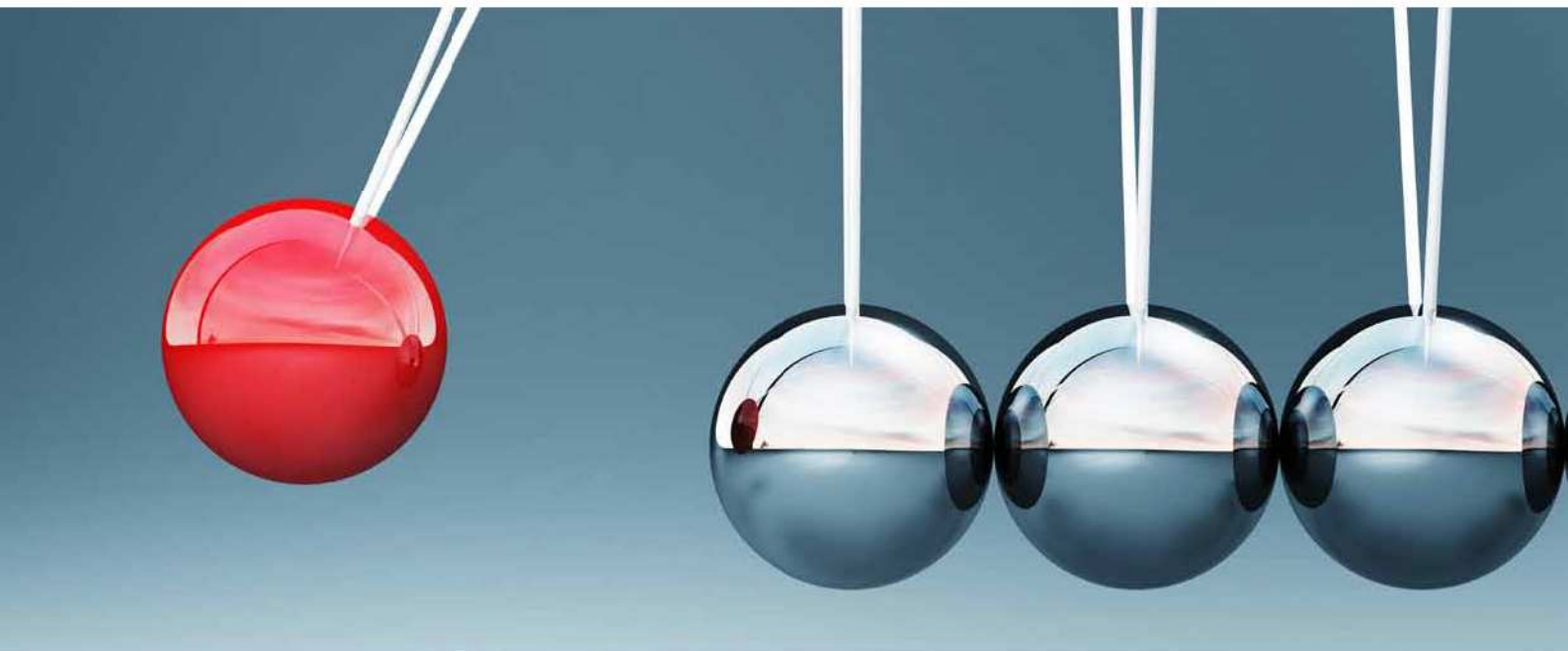
LD DIDACTIC GmbH is a worldwide leading manufacturer of premium science and engineering equipment
for academic education and vocational training. LD DIDACTIC distributes its products and solutions under
the brand LEYBOLD.

LD DIDACTIC is dedicated to visualize complex topics with transparent experiments increasing students
experience and knowledge step by step. Committed to LEYBOLDs 150 year tradition serving customers with
long lasting educational equipment LD DIDACTIC provides experimental solutions of premium quality and usability.

The LEYBOLD range offers complete solutions for the subjects physics chemistry and biology. The educational
systems of the LEYBOLD technology segment help to convey complex topics of automotive engineering,
electrical engineering and renewable energies effectively.

**LEYBOLD**®

# PHOTONIC EXPERIMENTS

**LEYBOLD**®

# P582 Basic Optics

# P5821 Absorption and Emission

- ✓ *Absorption*
- ✓ *Beer – Lambert law*
- ✓ *Fluorescent plates*
- ✓ *Stimulated Emission*
- ✓ *Phosphorescence*
- ✓ *LED – Emission*



## Examples of investigation and measurement

### Lambert–Beer Law

The Lambert-Beer law relates the absorption of the light to the properties of the material where the light is propagating. 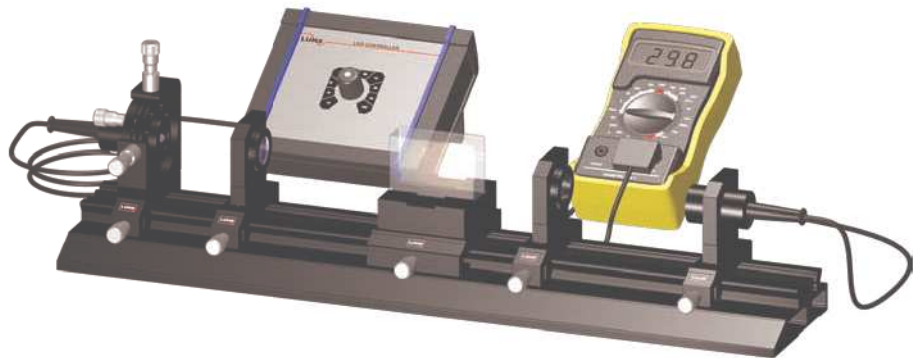Within a first experiment the influence of the absorbing material on the intensity of transmitted light is investigated. The absorbing probe is made from PMMA also known as acrylic glass or Plexiglas (17). It is positioned on top of the carrier in such a way that three different lengths are used to measure the resulting intensity. In the same way the LED can be changed to observe the relation to different wavelengths.
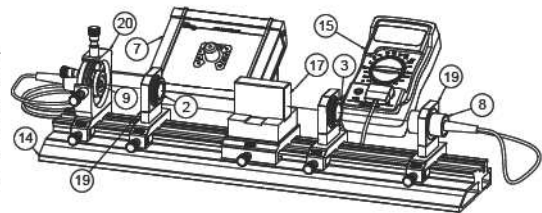


### Absorption spectrum

With the white light LED (9) and the provided optical grating (6) the spectral distribution of the absorption spectrum of the fluorescent filter (5) can be observed on the optical screen. The absorption spectrum is imaged by means of the lenses (3) to the optical screen (13). The emission of the LED is collimated by the lens (2) and passes the fluorescent filter. The white LED mainly consists of red, green and blue lines and serves as spectral lamp in this concept.
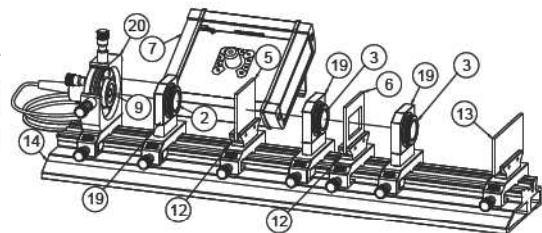


### Fluorescence spectrum

Within the same set-up as before the excitation of the provided fluorescing samples (5) with LED's of different wavelengths is performed. By means of the grating and the lenses the spectra of the LED is imaged to the optical screen. When inserting the fluorescent plates (5) additional lines will appear and others vanish.
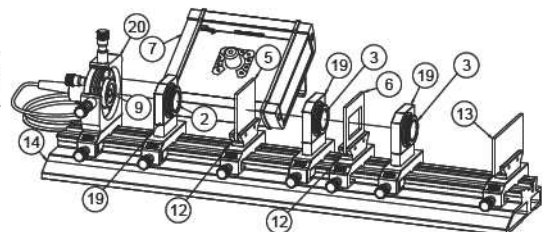


### Phosphorescence

The phosphorescing sample (4) is irradiated with different wavelengths provided by the LED (9, 10, 11). The wavelength dependant sensitivity is measured by the provided photodetector (8) and the multimeter (15). Once the sample is irradiated for a certain time it is turned in its holder facing the photodetector.
In the same way the phosphorescence decay is measured as a function of time. The provided sample has a decay time of a couple of minutes so that the measurement can easily be taken by the multimeter reading.
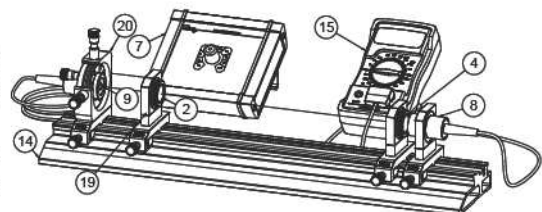


### P5821 Absorption and Emission consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | BNC–Banana adapter connection leads |
| 2 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 3 | 2 | Plano-convex lens f=60 mm, click 30 |
| 4 | 1 | Phosphorescing sample, click 25 |
| 5 | 1 | Set of 3 fluorescent filters |
| 6 | 1 | T – grating 600 l/mm |
| 7 | 1 | Adaptive power supply APS-05 |
| 8 | 1 | Photodetector Si PIN |
| 9 | 1 | LED white in C25 housing |
| 10 | 1 | LED red in C25 housing |
| 11 | 1 | LED blue in C25 housing |
| 12 | 1 | Screen holder on carrier 20 |
| 13 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 14 | 1 | Optical rail MG 65, 500 mm |
| 15 | 1 | Digital multimeter 3 1/2 digits |
| 16 | 2 | Plate holder on carrier 20 |
| 17 | 1 | Absorption unit |
| 18 | 1 | Mounting plate C25 with carrier 20 mm |
| 19 | 3 | Mounting plate, including carrier 20 mm , C30 |
| 20 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

**LEYBOLD®**

# P5822 Refraction of light

- ✓ *Rainbows*
- ✓ *Refraction of light*
- ✓ *Total reflection*
- ✓ *Snell – Descartes law*
- ✓ *Guiding of light*
- ✓ *Optical fibre*



## Examples of investigation and measurement
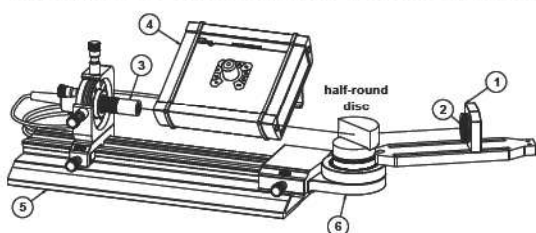


### Snell's law

A half-round transparent disc is used to verify Snell's law of refraction and total reflection. The advantage of such a disc is that the leaving beam passes the curved surface always under 90° avoiding additional refraction. The disc is mounted on a turn table which can be rotated perpendicularly with respect to the optical axis of the collimated laser beam (3). On the rotatable arm of the swivel unit (6) a crossed hair target (2) is mounted into its holder (1) serving as goniometer to measure the angle of refraction. This experimental set-up allows measuring the deflection of the beam in relation to the angle of incidence verifying Snell's law for the transition of light from air to a dense medium and vice versa.
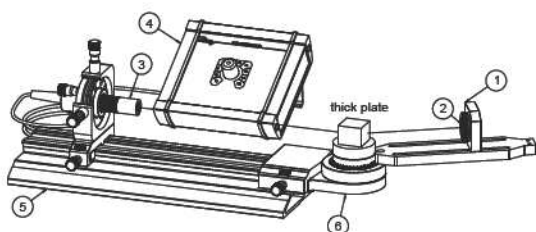


### Refraction on plates

When a beam passes a transparent plate a particular kind of deflection occurs, it is shifted parallel with respect to the incident beam. This parallel offset depends on the thickness and angle of incidence of the beam. The plate is mounted on a turn table as part of the swivel unit (6). The rotatable arm is turned into the zero position without the plate. By turning the table different angles of incident can be set and the deviation can be observed by the crossed hair target(2).
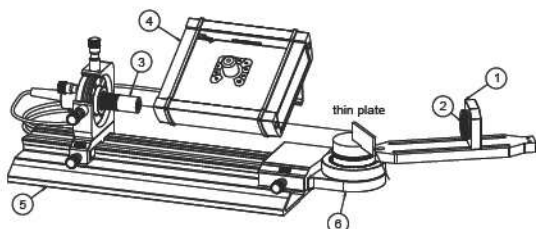


### Total reflection inside a slab

A laser beam entering an inclined transparent slab or thin plate, is propagating in a zig-zag course due to multiple reflections throughout its way inside the slab. This effect is exploited in a variety of laser systems which are also termed as slab laser. In this way the length of the beam path inside the amplifying media is extended, resulting in a higher output of the system. The zigzag beam path can be observed inside the slab. By tilting the slab the numbers of reflection can be changed impressively.
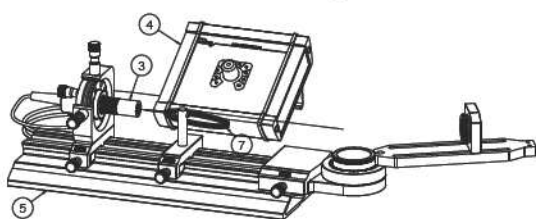


### Optical fibres

The light propagation in optical fibres is based on the same principle as for the total reflection in slabs. As a "light pipe" or an optical fibre a piece of plastic optical fibre (7) is used. It demonstrates how light is confined in a narrow tunnel by total internal reflection. The optical fibre is mounted onto a holder in such a way that the green beam of the DPSS laser (DPSS = diode pumped solid state) enters the fibre. If necessary the beam can be aligned by adjusting the fine pitch screws of the adjustment holder (4) in XY direction as well as its azimuth and elevation angle.
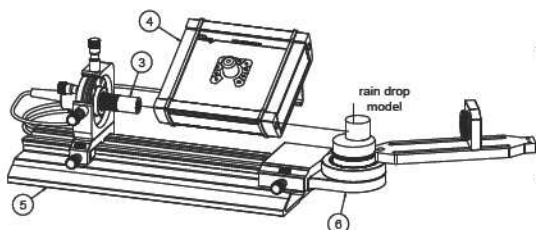


### Rainbow

"The rainbow has a place in legend owing to its beauty and the historical difficulty in explaining the phenomenon." The mystery of the rainbow is lifted by using a transparent cylinder as a two dimensional model of a raindrop. A laser beam acts in the same way as sun rays, which are affected by the raindrops to generate a rainbow. The process of refraction and total reflection is demonstrated and explained in an impressive way. The "rain drop model" is asymmetrically mounted onto a turn table and allows the simulation of different angles of incidence of the laser beam

## P5822 Refraction of light consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Mounting plate 40, C25 |
| 2 | 1 | Crossed hair target |
| 3 | 1 | Dimo diode laser module, 532 nm (green), YAG |
| 4 | 1 | Adaptive power supply APS-05 |
| 5 | 1 | Profile Rail MG-65, 300 mm |
| 6 | 1 | Triple swivel unit |
| 7 | 1 | Optical fibre model |
| 8 | 1 | Collection of mounted models |
| 9 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

# P5823 Refraction through prisms

✓ *Refraction of prisms*

✓ *Angle of minimum deflection*

✓ *Complementary colour*

✓ *Dispersion*

✓ *Prism spectrometer*

## Examples of investigation and measurement

### Refraction on a prism

A set of two prisms each mounted on a turn table (13) is used to measure the deflection of the beam in relation to the angle of incidence. The angle of incidence is changed by turning the prism in its holder. The provided scale allows the reading of the incident angle. The rotatable arm of the swivel unit (1) is turned in such a way that the beam of the green probe laser (5) always hits the centre of the scale on the white screen (10). The rotatable arm also has a angle scale providing the information of the beam deflection in units of degrees. The recorded results will show a particular angle - the angle of the minimum deflection. In this case the beam propagates parallel to the base of the prism. Especially the knowledge of the minimum angle of deflection allows the calculation of the index of refraction index for the specific material. The experiment comes with an SF10 and PMMA prism.

### Spectrum of white light LED

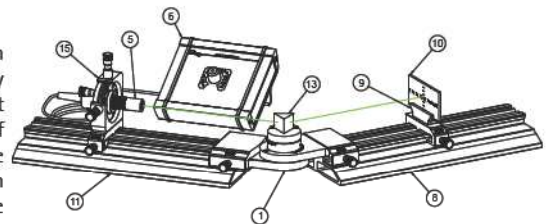As a white light source a high brightness white LED (7) is used. By means of the controller (6) the LED is provided with the necessary voltage. Each light source connected to it will be recognised by the internal microprocessor and the proper voltage and current range is set. Although the light appears white, it consists in fact of three dominant lines: green, red and blue. The lines spectrum is separated by the prism and can be observed on the optical screen (10). By means of the lens (4) mounted in its holder (14) the spatial recombination of the spectrum results in the original white light. With the small beam block (12) which can be moved between the imaging lenses certain colour in the spectrum can be blocked and generates its complementary colour when recombined on the screen.
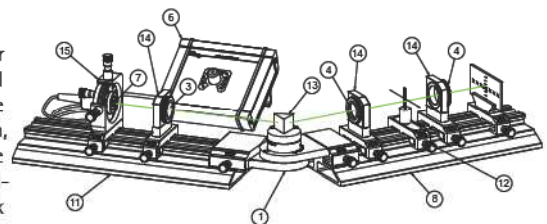
### Fraunhofer's prism spectroscope

The principle of a Fraunhofer's apparatus is demonstrated by the set-up as shown on the right. The spectral lines of the LED (7) are used to determine the dispersion of the SF10 and PMMA prism's. The spectral lines are imaged by means of the lens (4) mounted in its holder (14) onto the optical screen (10) having a vertical and horizontal scale. The screen is mounted onto the holder (9).
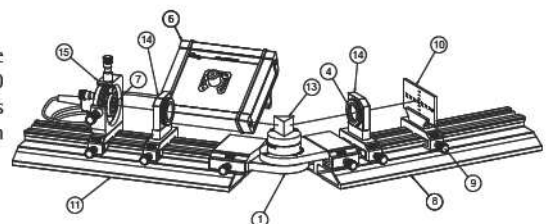
## P5823 Refraction through prisms consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Joint angle connector with socket |
| 2 | 1 | Biconcave lens f=-20 mm, Ø 10 mm, C25 mount |
| 3 | 1 | Achromat f=40 mm, mounted in click 30 mm |
| 4 | 2 | Biconvex lens f=100 mm, Ø 22.4 mm, C25 mount |
| 5 | 1 | Dimo diode laser module, 532 nm (green), YAG |
| 6 | 1 | Adaptive power supply APS-05 |
| 7 | 1 | LED white in C25 housing |
| 8 | 1 | Profile Rail MG-65, 200 mm |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 1 | Screen holder on carrier 20 |
| 10 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 11 | 1 | Profile Rail MG-65, 300 mm |
| 12 | 1 | Carrier with magnetic beam block on post |
| 13 | 1 | Prism assembly |
| 14 | 3 | Mounting plate, including carrier 20 mm , C30 |
| 15 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

**LEYBOLD**®

# P5824 Refraction through lenses

✓ *Convex lens*

✓ *Concave lens*

✓ *Spherical aberration*

✓ *Chromatic aberration*

✓ *Ray tracing*

✓ *Telescopes*
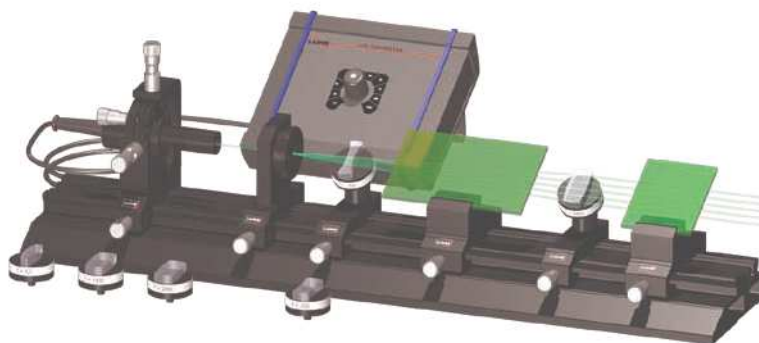
## Examples of investigation and measurement
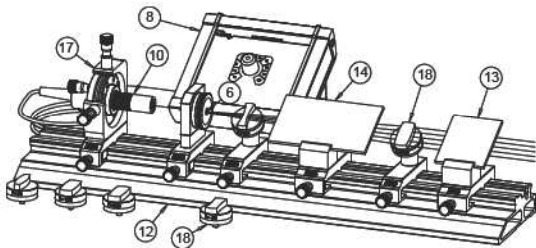
### Properties of lenses

By means of the DPSS laser (10) and the beam fan generator (6) a beam fan is generated and serves as a ray tracer. It passes the first lens and the beam track display (13). Inside the display the beam becomes visible due to embedded nano fluorescent particles. A set of various lenses like convex, concave, thin and thick lenses (17) is provided to study the respective properties of a single lens as well as combinations of it.
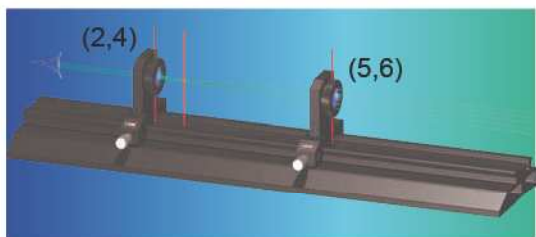
### Keplerian telescopes or refractor

Pairs of lenses combined out of the provided lenses (2,4,5,6) are used to set up a telescope which has been invented by Kepler. John Dolland improved the optical arrangement by using an achromat as a front lens. Both types can be set up on the rail and their properties determined. The rail can be taken into one's own hands and a view through the lenses impressively demonstrates focusing, lens error and magnification.
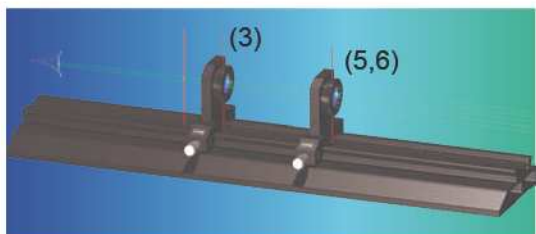
### Galilei's telescope

Whereas the Keplerian telescope used a convex lens as eye piece the genius idea of Galilei was to apply a concave lens (3) for it. This reduces also the length of the telescope. In the same way as for the Keplerian telescope this type also can be taken into one's own hands. For the front lens or objective either a simple convex lens or an achromat having the same focal length are used to understand the problem of spherical and chromatic lens errors.
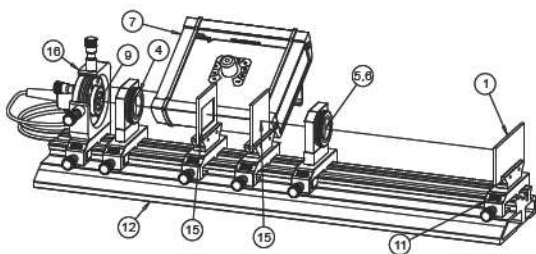
### Spherical and chromatic aberration

The laser (10) is substituted by a white light LED (9) which emission consists of green red and blue radiation. By means of the filters provided (15) either the whole spectrum is used or just one of its components. A test slide (15) and the lens to be investigated (5,6) are used to create an image on the screen(1). It will be noticed that the quality of the image like focus and distortions depends on the wavelength as well as the type of lens. It will be noticed that the lens errors will increase towards the edge of the lens. By blocking these rays with a piece of paper with a hole for example the image improves, however the intensity reduces. The method is often used to improve the imaging quality of optical instruments.

## P5824 Refraction through lenses consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Optical screen, 40 x 80 horizontal and vertical scale |
| 2 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 3 | 1 | Biconcave lens f=-20 mm, Ø 10 mm, C25 mount |
| 4 | 1 | Achromat f=40 mm, C25 mount |
| 5 | 1 | Biconvex lens f=150 mm, C25 mount |
| 6 | 1 | Achromat f=150 mm, C25 mount |
| 7 | 1 | Beam fan 5 x mounted in C25 |
| 8 | 1 | Adaptive power supply APS-05 |
| 9 | 1 | LED white in C25 housing |
| 10 | 1 | DIMO diode laser module, 532 nm |
| 11 | 2 | Screen holder on carrier 20 |
| 12 | 1 | Optical rail MG 65, 500 mm |
| 13 | 1 | Beam track display, 50 mm |
| 14 | 1 | Beam track display, 100 mm |
| 15 | 1 | Set of filters and mask |
| 16 | 3 | Mounting plate, including carrier 20 mm , C30 |
| 17 | 1 | Adjustment holder, 4 axes, carrier 20 mm |
| 18 | 1 | Lens demonstrator assembly |

www.ld-didactic.com

# P5825 Double refraction of light

✓ *Extra and extraordinary beam*

✓ *Jones matrix*

✓ *Conoscopic imaging*

✓ *Crystalline quartz*

✓ *Iceland spar (Calcite)*

✓ *Lithium Niobate*

✓ *Pockels cell*
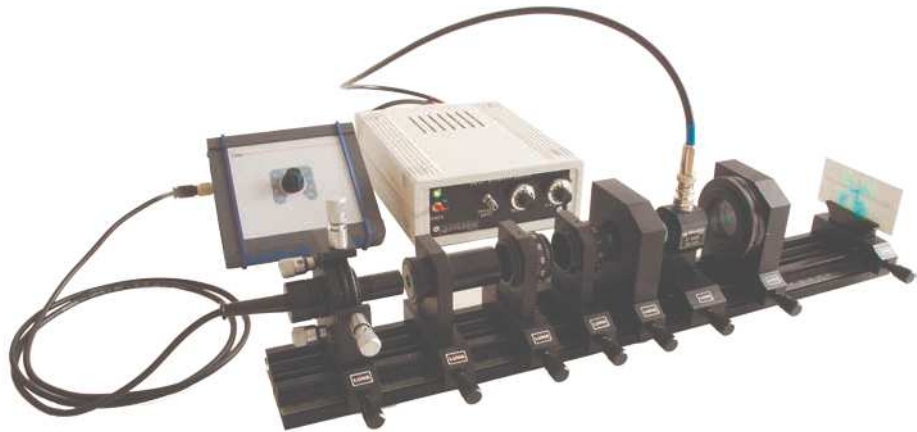


## Examples of investigation and measurement

### Conoscopic image of a quartz plate

A birefringent quartz plate (4) is used as a test object which is placed between two crossed polariser (3). The beam of the DPSS laser (6) is expanded by means of the beam expander (2) and focused with a convex lens (1) into the probe (4). Depending on the orientation of the optical axes of the quartz crystal with respect to the laser beam a specific pattern is imaged onto the screen (10). Because the focussed laser beam has the shape of a symmetric cone this method is also termed as conoscopy. Only those parts of the beams will pass the arrangement for which the crystal added a phase shift of λ/4 or λ/2 or multiples of it. This creates a shape on a screen with symmetrical dark and light patterns depending of the kind and orientation of the crystal.
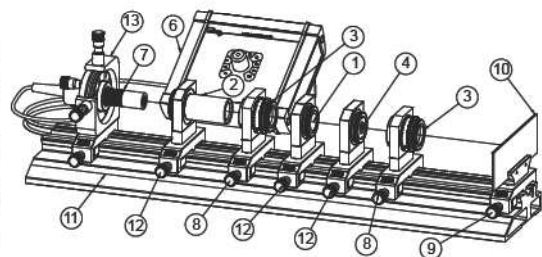


### Calcite (Iceland spar)

The most prominent crystal to demonstrate double refraction is the Calcite crystal. It has many names like Iceland crystal, spar, calcium carbonate. It is said that the Vikings used the Iceland spar for navigation based on the polarisation of the sky light. "Sunstone" is therefore also one of the historic names for this famous crystal, which also plays an important role in alternative medicine.

However in this experiment we will get insights into the double refraction by using a calcite crystal (5) which is mounted onto a rotatable disk. The crystal is placed between crossed polariser (3,3) and the double refraction is observed on the screen (10). In a next step the beam expander is removed and the direction of the laser beam is tracked for different orientation of the calcite crystal. The beam splitting due to polarisation is studied.



### Pockels cell

In 1893 the German Friedrich Carl Alwin Pockels discovered that an electric field applied to certain birefringent materials causes the refractive index to change, approximately linearly to the strength of the applied electrical field. Within this experiment a Lithium Niobate crystal is used. The conoscopic image of the Pockels cell (14) is created in t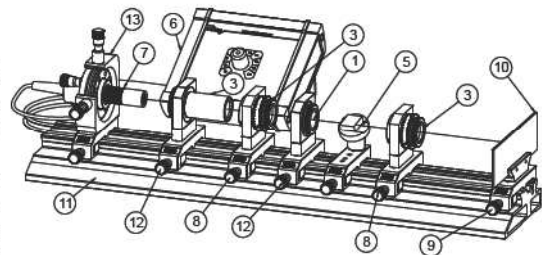he same way as for the quartz plate. The conoscopic image is studied for different values of the DC voltage. The half wave voltage is determined by using a parallel beam and the crossed polariser. The half wave voltage is reached when no light passes the initially parallel adjusted polariser. In this case the cell turns the polarisation of the laser light by 90 degrees demonstrating the modulation capability of such an arrangement.
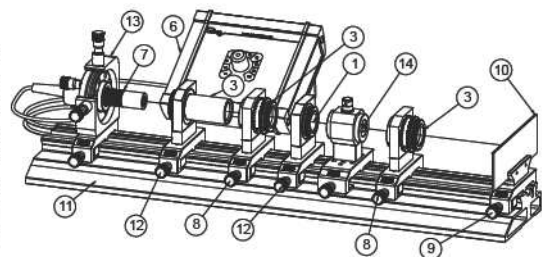
## P5825 Double Refraction consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 2 | 1 | Beam expander magnification 6x |
| 3 | 2 | Polariser, C25 mount |
| 4 | 1 | Quarter wave plate, click 25 |
| 5 | 1 | Calcite crystal |
| 6 | 1 | Adaptive power supply APS-05 |
| 7 | 1 | DIMO diode laser module, 532 nm |
| 8 | 2 | Mounting plate 40, rotator, carrier 20 mm |

| Item | Qty | Description |
|---|---|---|
| 9 | 1 | Screen holder on carrier 20 |
| 10 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 11 | 1 | Optical rail MG 65, 500 mm |
| 12 | 3 | Mounting plate C25 with carrier 20 mm |
| 13 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

Option:

| Item | Qty | Description |
|---|---|---|
| 14 | 1 | Pockels's cell assembly with power supply |

**LEYBOLD®**

# P5826 Polarisation of light

- ✓ *Polarisation of light*
- ✓ *Malus Law*
- ✓ *Optical activity, chirality*
- ✓ *Double refraction*
- ✓ *Phase retarder*
- ✓ *Jones matrices*



# Examples of investigation and measurement
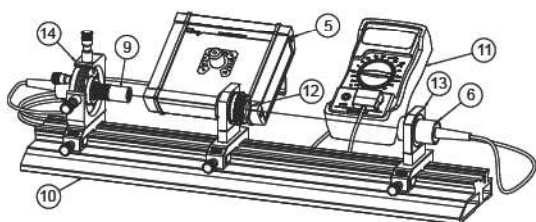


## Polarization of light sources



In a first experiment the polarization state of the provided DPSS laser (9) is recorded. For this purpose one polarisation analyser (12) is placed in front of the laser. The light passing the polariser is measured by means of the photodetector (6) which is connected to the digital meter (11).

In a next experiment the laser is replaced by one of the provided LED which is connected to the controller in the same way as the laser was before. The microprocesso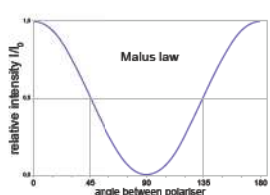r operated unit detects what is connected and provides the proper voltage and current. To collimate the emitted light of the LED a collimating lens (1) is provided. The measured results are plotted against the angle of the polariser which can be set in steps of 5 degrees.

## Malus Law (1775 – 1812)

The transmission of light passing two polarisers for different angle orientation to each other was firstly derived by the French scientist Etienne-Louis Malus (1775 –1812). To verify this law a set-up with two polariser (12) is used.

As light source we again use one of the provided LEDs. Either the light source (7 or 8) or the first polariser (12) is rotated in such a way that maximum intensity will be observed. The second polariser is turned in steps of 5 degrees and the resulting intensity is measured by the photodetector (6). Beside the law of Malus the results are modified by the quality of the polariser. That means that the polariser absorbs already a certain amount of the radiation and the intensity will not drop completely to zero at the 90 degree crossing. To characterise the quality of a polariser the extinction ratio is introduced and discussed.

It will be shown that the film polariser used in this case is very useful for common application, however for high precision measurements crystal polariser are still required.
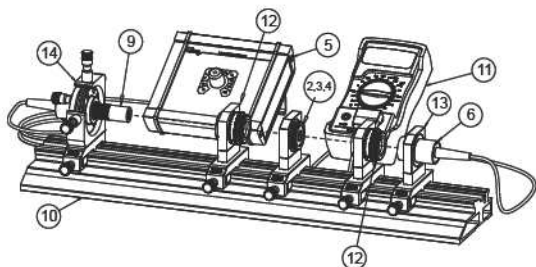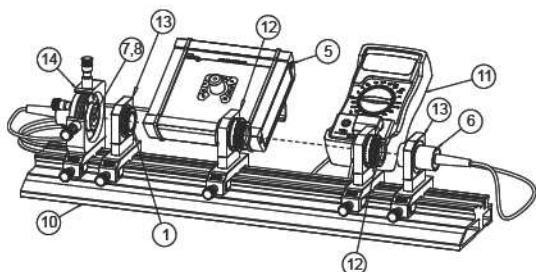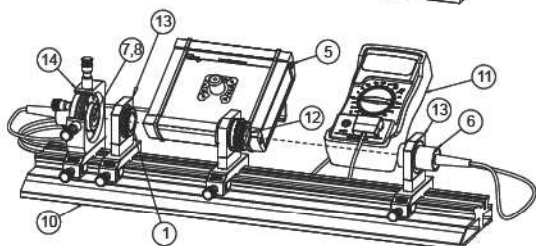
## Optical activity

The set-up is modified in such a way that an optically active quartz sample (2) is placed between the two crossed polariser (90°) . By readjusting the analyser for maximum extinction the phase retardation of the probe material is determined. It will be experimentally verified that the retardation depends on the rotational orientation of the sample.

## Half- and quarter-wave plates

A speciality in light polarisation are the quarter and half wave plates. The property of both kinds are investigated by recording the respective transmission diagrams.

## P5826 Polarisation of light consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 2 | 1 | Optical quartz plate, click 25 |
| 3 | 1 | Quarter wave plate, click 25 |
| 4 | 1 | Half wave plate, click 25 |
| 5 | 1 | Adaptive power supply APS-05 |
| 6 | 1 | PIN Photodetector, BPX61 with connection leads |
| 7 | 1 | LED white in C25 housing |

| Item | Qty | Description |
|---|---|---|
| 8 | 1 | LED red in C25 housing |
| 9 | 1 | DIMO diode laser module, 532 nm |
| 10 | 2 | Profile rail MG-65, 500 mm |
| 11 | 1 | Digital multimeter 3 1/2 digits |
| 12 | 1 | Polariser / Analyser with rotator |
| 13 | 2 | Mounting plate C25 with carrier 20 mm |
| 14 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

www.ld-didactic.com

# P5827 Reflection and transmission

✓ *Reflection law*

✓ *Fresnel's law*

✓ *Brewster's angle*

✓ *Polarisation by reflection*

✓ *Dielectric coating*



## Examples of investigation and measurement

### Reflection, Fresnel law and Brewster's angle

For this series of experiments a laser (12) emitting a wavelength of 532 nm is used. The individual probe (6, 7, 8) is placed into its holder of the swivel unit (16). By means of a scale the angle with respect to the optical axis can be set and read. A polarisation analyser (1), a focussing lens (4) and the photodetector (3) are mounted onto the swivel arm of the unit (16). The swivel arm can be rotated continuously around the probe and data series can be recorded for different angles of the probe. The reading of the light intensity is done by a digital meter which is switched into the µA mode to obtain a linear relation of the light intensity and photo current.

The measurements can be carried out with defined polarisation of the light source which are set by the two polariser (15). The polarisation state of the reflected or transmitted light is measured by means of the polarisation analyser mounted to the swivel arm (1). Using this setup the full Fresnel equations are verified yielding the Brewster's angle and also verifying the law of reflection.
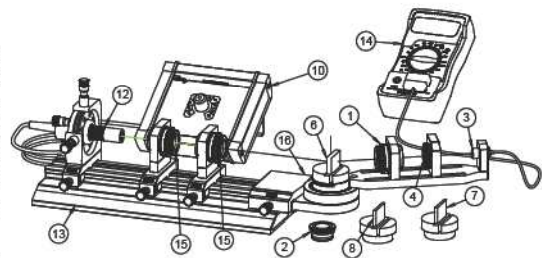


### Dielectric coating

A dielectric or optical coating consists of one or more thin layers of material which is deposited on the surface of an optical component. Such a coating alters the way in which the optic reflects and transmits light. In general the properties of these coatings depends on the angle of incidence which is investigated in this series of measurements. To demonstrate the spectral behaviour of the coating a white light source and a grating is used.

Within the measurements an antireflection coating and one dichroic thin-film optical filter or mirror is used. The antireflection coating (common abbreviation: AR) reduces the normal Fresnel reflection of about 4 % per surface down to around 0.1 %.

The dichroic mirror transmits light of one wavelength and reflects another one. The wavelength for which reflection or transmission occurs depends on the design of the coating.
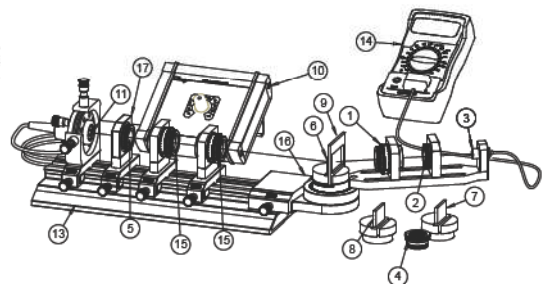


### White light source

For the spectral characterization of coated optics a white light source (11) consisting of a high brightness LED is used. The spectrum of the lamp is shown in the figure on the right. Beside a peak at 440 nm a broad range from 500 to 700 nm is available.

The light source is connected to the adaptive power supply (10) which allows the variation of the injection current and that way the intensity of the emitted light.

The divergent radiation is collimated by means of a lens (5) having a focal length of 40 mm.
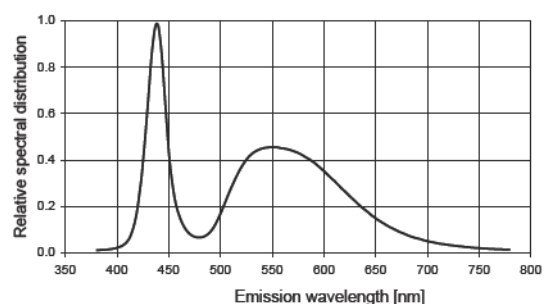


## P5827 Reflection and Transmission consisting of:

| Item | Qty | Description | Item | Qty | Description |
|------|-----|-------------|------|-----|-------------|
| 1 | 1 | Polarisation analyser 40 mm | 11 | 1 | LED white in C25 housing |
| 2 | 1 | Collimation optics in mounting plate 40 | 12 | 1 | DIMO diode laser module, 532 nm |
| 3 | 1 | Photodetector for pivot arm | 13 | 1 | Profile Rail MG-65, 300 mm |
| 4 | 1 | Crossed hair target | 14 | 1 | Digital multimeter 3 1/2 digits |
| 5 | 1 | Plano convex lens f=40 mm, C25 mount | 15 | 2 | Polariser / Analyser with rotator |
| 6 | 1 | Glas plate on rotary disc | 16 | 1 | Triple swivel unit |
| 7 | 1 | Dichroic mirror on rotary disc | 17 | 1 | Mounting plate C25 with carrier 20 mm |
| 8 | 1 | Face mirror on rotary disc | 18 | 1 | Adjustment holder, 4 axes, carrier 20 mm |
| 9 | 1 | T - grating 600 l/mm | | | |
| 10 | 1 | Adaptive power supply APS-05 | | | |

**LEYBOLD**®

# P5828 Diffraction of light

✓ *Huygens' principle*
✓ *Diffraction single and dual slit*
✓ *Diffraction by circular aperture*
✓ *Diffraction by a wire*
✓ *Babinet's principle*
✓ *Diffraction of:*
✓ *White Light*
✓ *Monochromatic light*



## Examples of investigation and measurement
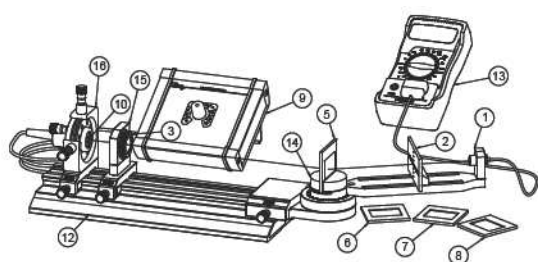


### Diffraction of white light

In this setup the diffraction of white light is demonstrated and measured. As diffraction objects a set of 4 different patterns are used (5, 6, 7, 8), circular holes, single and double slit and finally a fine mesh gauze to demonstrate two dimensional diffraction.

The selected diffraction probe is placed into the holder (14) of the swivel unit. The diffraction pattern is imaged on the screen (2) which is mounted to the swivel arm. By means of the photodetector (1) and the digital multimeter (13) the intensity distribution can be measured.

To obtain sufficient light the collimator (3) is provided for an almost parallel beam of the white LED.
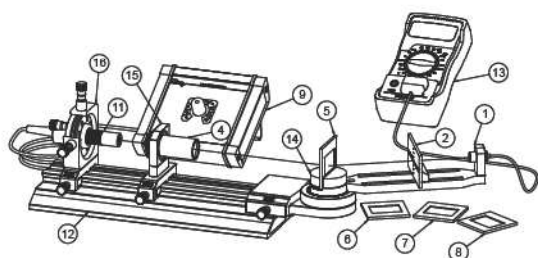


### Diffraction of monochromatic light

The white light source is substituted by a "green" laser (11) emitting a wavelength of 532 nm. The beam is expanded by means of the beam expander (4) by a factor of 6 resulting in a beam diameter of about 9 mm.

The beam is directed to the selected diffraction probes (5, 6, 7, 8) and the resulting diffraction pattern is imaged onto the screen (2). The angular resolved intensity distribution is measured by using the photodetector (1).

The reading of the light intensity is done by a digital meter (13) which is switched into the µA mode to obtain a linear relation of the light intensity and photo current.



### White light source

The white light source (10) consists of a high brightness LED. The spectrum of the lamp is shown in the figure on the left. Beside a peak at 440 nm a broad range from 500 to 700 nm is available.

The light source is connected to the adaptive power supply (9) which allows the variation of the injection current and that way the intensity of the emitted light.

The divergent radiation is collimated by means of a lens (3) having a focal length of 40 mm.

## P5828 Diffraction of Light consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Photodetector for pivot arm |
| 2 | 1 | Optical screen with XY scale on block |
| 3 | 1 | Plano convex lens f=40 mm, Ø 22.4 mm, C25 mount |
| 4 | 1 | Beam expander magnification 6x |
| 5 | 1 | Circular apertures |
| 6 | 1 | Gauze 300 mesh |
| 7 | 1 | Single slit 0.06 mm |
| 8 | 1 | Double slit |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 1 | Adaptive power supply APS-05 |
| 10 | 1 | LED white in C25 housing |
| 11 | 1 | DIMO diode laser module, 532 nm |
| 12 | 1 | Profile Rail MG-65, 300 mm |
| 13 | 1 | Digital multimeter 3 1/2 digits |
| 14 | 1 | Triple swivel unit |
| 15 | 1 | Mounting plate C25 with carrier 20 mm |
| 16 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

# P5829 Interference of light

✓ *Coherence*

✓ *Interference*

✓ *Fresnel's mirror*

✓ *Fresnel's zone plate*

✓ *Newton's rings*

✓ *Fabry-Perot's optical cavity*

## Examples of investigation and measurement

### Newton's rings, interference of thin plates

To demonstrate the famous Newton's rings a combination of glass plate and plano-convex lens is used. Typically the lens has a fairly long focal length of about 2 to 4 m. If one uses a coherent light source the radius of curvature of the lens can be smaller resulting in a shorter focal length which is more practical. In this assembly a l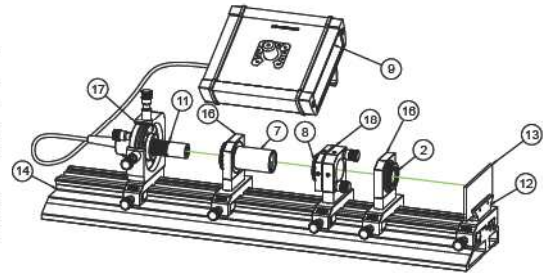ens with 100 mm focal length is applied providing excellent Newtons's ring when illuminated with the provided "green" laser (11).

The beam of the laser is expanded by a factor of 6 with the beam expander (6) which is mounted into a mounting plate for C25 mounts. The resulting image pattern is imaged by means of the biconcave lens (2) to the white screen (13).

### Fresnel mirror (15)

Two mirrors are arranged in such a way that they are simultaneously illuminated by an expanded laser beam. One of the mirrors is slightly tilted with respect to the other providing the required phase shift to observe the interference fringes. Both mirrors are mounted onto adjustment holders allowing the azimuthal and elevational alignment.
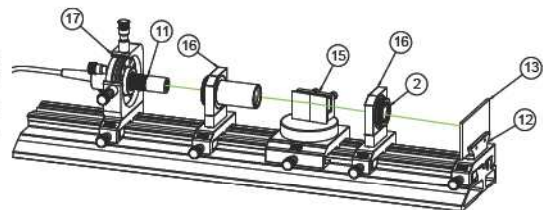
### Fresnel's zone plate (5)

A fresnel plate designed for 532 nm, 99 fringes and a focal length of 100 mm is mounted into a "click 25" holder fitting into the mounting plate. The fresnel plate is made from a computer graph which has been exposed to a black and white film.
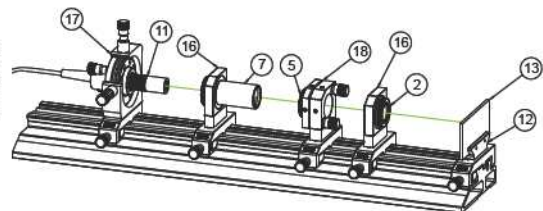
### Fabry Perot cavity (6)

Two glass plates are mounted into a click 25 optics holder with a spacing of 3 mm. Each plate is coated for 50% transmission on one side. These sides are facing each other forming a coplanar resonator.

The click 25 optics holder is placed into the adjustment holder which can be tilted in two angles by means of two precision fine pitch screws. To mount the click holder a 2 mm hexagon key is needed.

The adjustment holder is attached to a 20 mm carrier which will be placed onto the provided optical rails.
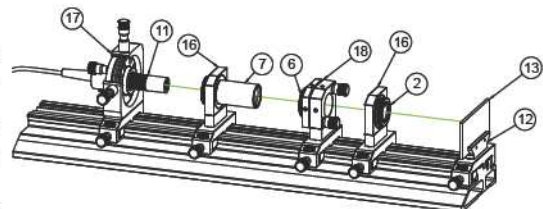
## P5829 Interference of light consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 2 | 1 | Biconcave lens f=-20 mm, Ø 10 mm, C25 mount |
| 3 | 1 | Half wedge plate, C25 mount |
| 4 | 1 | Half lens f=100 mm, C25 mount |
| 5 | 1 | Fresnel zone plate, C25 mount |
| 6 | 1 | Fabry Perot insert, C25 mount |
| 7 | 1 | Beam expander magnification 6x |
| 8 | 1 | Newton's rings optics |
| 9 | 1 | Adaptive power supply APS-05 |

| Item | Qty | Description |
|------|-----|-------------|
| 10 | 1 | LED white in C25 housing |
| 11 | 1 | DIMO diode laser module, 532 nm |
| 12 | 1 | Screen holder on carrier 20 |
| 13 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 14 | 1 | Optical rail MG 65, 500 mm |
| 15 | 1 | Fresnel mirror assembly |
| 16 | 4 | Mounting plate C25 with carrier 20 mm |
| 17 | 1 | Adjustment holder, 4 axes, carrier 20 mm |
| 18 | 1 | Adjustment holder 40 mm on carrier 20 mm |

**LEYBOLD®**

# P583 Optical Applications

www.ld-didactic.com

# P5831 Interferometer

✓ *Michelson's interferometer*

✓ *Mach Zehnder interferometer*

✓ *Interference*

✓ *Index of refraction of air*

✓ *Wavelength of light*

✓ *Beam expander*

✓ *Beam splitter*
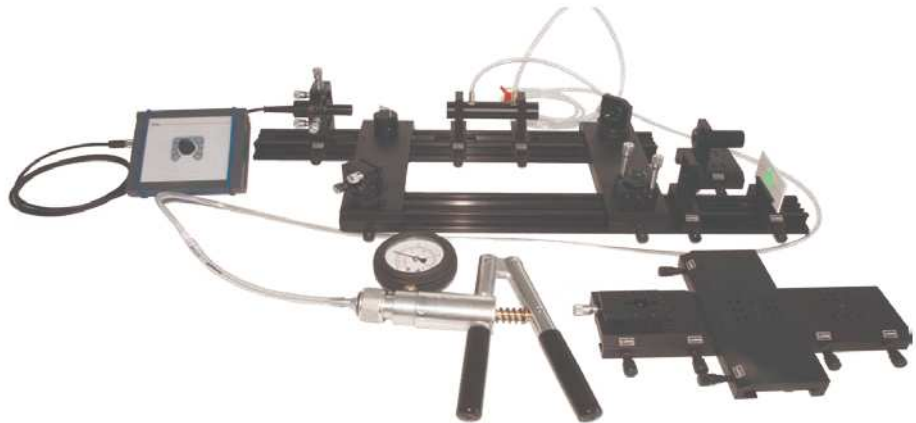


## Examples of investigation and measurement

### Michelson Interferometer

The emission of the laser (5) has a wavelength of 532 nm. The beam is expanded by a factor of 2.7 by the beam expander (3) which is mounted into a mounting plate. The beam splitter of module (A) divides the beam into two beams with equal intensity. The reflected beams are recombined by the beam splitter in such a way that the interference pattern is imaged to the white screen (8). To enlarge the image a biconcave lens(2) is used and this is placed in front of the white screen (8).

The interference of both beams can be aligned by the adjustment screws of the mirror adjustment holder (B) as well as by the fine pitch adjustment screws of the 4 axes laser adjustment holder (15). In case of almost plane wave fronts the interference pattern will show stripes and turns into rings when the divergence of the laser beam is changed by misaligning the beam expander (3).
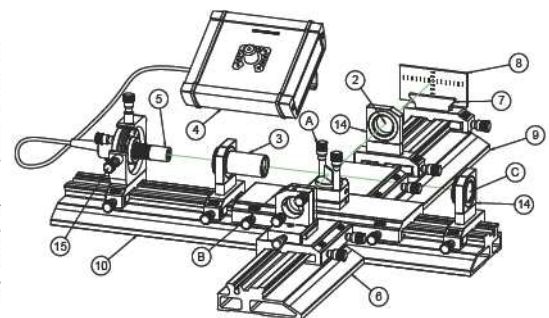


### Mach Zehnder Interferometer

A Mach Zehnder interferometer is composed by rearranging the components. In contrast to the Michelson setup the beam splitter and combiner are separate components. The beam of the laser (5) is directed without expansion to the beam splitter of the module (13). One part of the beam is deflected by means of the adjustable mirror of the module (13). The other beam is deflected by the mirror of the module (12). Both beams are superimposed with the adjustable beam splitter unit of module (12). The resulting interference pattern is enlarged by means of the biconcave lens (2) and imaged to the white screen.

Once the interferometer has been aligned the impressive high precision measurements of the index of the air are performed.
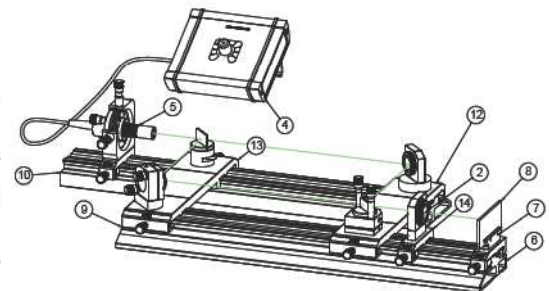


### Measuring index of refraction of gases

$$n_{air} = 1 + 7.86 \times 10^{-4} \times \frac{p}{T}$$

The index of refraction of air depends mainly on the pressure (p) and the absolute temperature (T). The task of this experiment is to measure the index of refraction by using a cell as shown in the figure on the right. The change in the pressure inside the cell is done by the provided manual pump which operates from vacuum (100 mBar) up to 3 Bar. The pressure cell has a separate inlet and outlet so that also other gases than air can be measured.
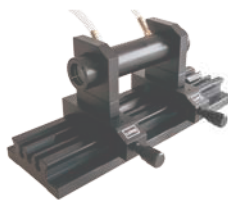
The cell is placed in one arm of the Mach Zehnder interferometer. The number of fringes is counted when changing the pressure. With the known optical length of the cell the index of refraction can be calculated
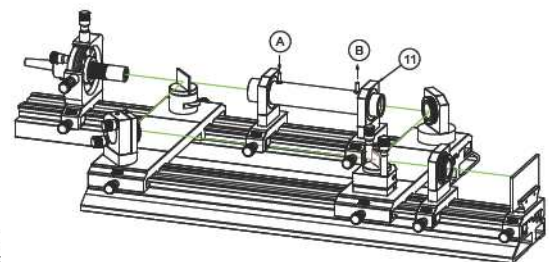




## P5831 Optical Interferometer consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Angle joint, four way cross type |
| 2 | 1 | Biconcave lens f=-10 mm, Ø10 mm, C25 mount |
| 3 | 1 | Beam expander magnification 2.7x |
| 4 | 1 | Adaptive power supply APS-05 |
| 5 | 1 | DIMO diode laser module, 532 nm |
| 6 | 1 | Profile Rail MG-65, 200 mm |
| 7 | 1 | Screen holder on carrier 20 |
| 8 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 9 | 1 | Profile Rail MG-65, 300 mm |
| 10 | 1 | Optical rail MG 65, 500 mm |
| 11 | 1 | Gas cuvette assembly |
| 12 | 1 | Mach Zehnder beam combining assembly |
| 13 | 1 | Mach-Zehnder beam splitting assembly |
| 14 | 2 | Mounting plate C25 with carrier 20 mm |
| 15 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

**LEYBOLD**®

# P5832 Refractometer

✓ *Index of refraction*
✓ *Reflection by prism*
✓ *Abbé's refractometer*
✓ *Index of refraction of liquids*
✓ *LED Beam collimating*



## Principle of operation

The spectral narrow-band emission of a LED is collimated and polarised. Passing the lens 1 the converging beam enters the prism. Due to the multitude of incident angles with respect to the hypotenuse of the prism a couple of rays leaving the prism whereas some rays are reflected and imaged via lens 2 on the optical screen forming a half shade. Under ideal conditions the shade is completely black. The position of the dark limit depends on the index of refraction at the hypotenuse.
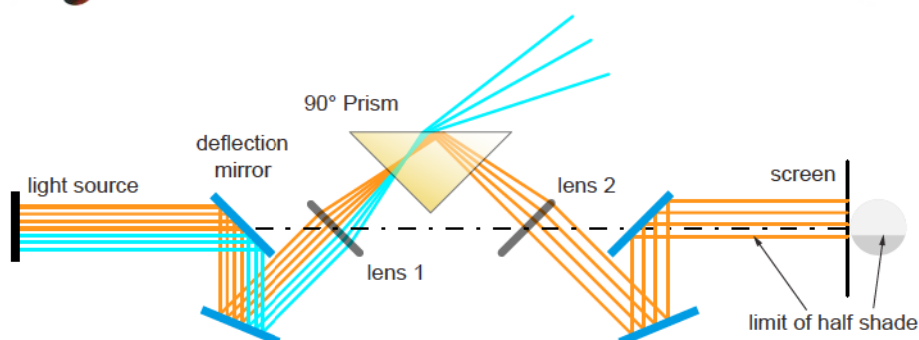


## Examples of investigation and measurement

An narrow-band chromatic LED (5) is used as light source. The output power is controlled by a digital controller (4) which recognises automatically the kind of connected LED and sets the proper injection current range by its software. The emission is polarised (2) by rotating the film polariser which is mounted into the holder (11). The left beam bending mirror assembly guides the beam via the lens 1 inside the prism assembly. The reflected beams are guided by the right beam bending assembly (19) and imaged on the optical screen (1). The liquid to be measured is applied to the hypotenuse of the prism and the offset of the limit of the half shade is measured by means of the vertical scale of the optical screen (1).

Finally the index of refraction is calculated by using the given formula for the instrument factor.
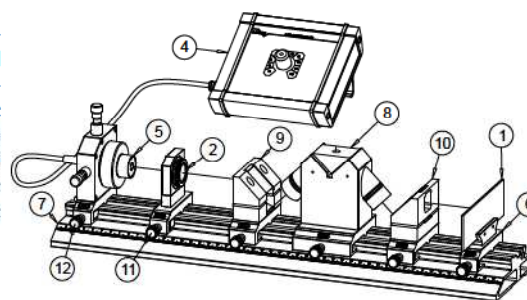


## Measurements

The figures on the right shows two test measurements. The figure A has been taken without any test liquid, that means zero measurement against air. The other one (figure B) has been taken with water on top of the prism. It clearly can be seen that in this case the half shade limit drops by 3 mm.

Entering this value into the respective equation the related index of refraction can be calculated and if necessary the instrument factors adapted.



A. Measurement against air          B. Measurement with water

## Set of test liquids

Water, acetone and a 60 Brix sugar solution (each contained in 15 ml dropping bottles) are provided as test liquids.

Brix is a definition of the content of the dry matter in a solution. If 1 g of sugar is solved in 99 g of water the solution has 1 Brix.

Other sugar solutions thus can be made very simple, the corresponding index of refractions are to be found in the provided manual.



The index of refraction of the provided liquids are:

| | |
|---|---|
| Water | 1.33 |
| Acetone | 1.36 |
| sugar solution (60 Brix) | 1.44 |

## P5832 Abbe Refractometer consisting of:

| Item | Qty | Description | Item | Qty | Description |
|---|---|---|---|---|---|
| 1 | 1 | Screen, 40 x 80 mm, horizontal and vertical scale | 7 | 1 | Profile Rail MG 65, 500 mm |
| 2 | 1 | Polariser, C25 mount | 8 | 1 | Prism assembly |
| 3 | 1 | Set of test liquids | 9 | 1 | Bending mirror assembly 22.5° – 45°, left |
| 4 | 1 | Adaptive power supply APS–05 | 10 | 1 | Bending mirror assembly 22.5° – 45°, right |
| 5 | 1 | LED amber in C25 housing | 11 | 1 | Mounting Plate, including carrier 20 mm, C 25 |
| 6 | 1 | Screen holder on carrier 20 | 12 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

# P5833 Holography

- ✓ *Setup for stability check*
- ✓ *Transmission hologram*
- ✓ *Reflection hologram*
- ✓ *Preparation of development chemicals*
- ✓ *Recording and developing*



## Examples of investigation and measurement
### General setup

The holography setup consists of the laser (4) which emits a wavelength of 532 nm and an output power of 3 mW. The laser is monitored by the timer and injection current controller (5). The beam is separated into two (S) whereby one forms the reference and the other the object beam. Each beam is expanded by the provided biconcave lenses (1,2). By means of the mirrors M1 and M2 the beams are directed either to the object (O) or to the holographic plate (3).

By arranging the position of the object with respect to the holographic plate different types of holograms can be recorded.

The recording of the hologram is one task. The other most exciting part is the development and subsequent reproduction of the recorded hologram. The second part starts with the composition and mixing of the developer and bleacher chemistry. Since the lifetime of the ready mixed solution is limited to a couple of hours fresh solutions needs to be prepared.
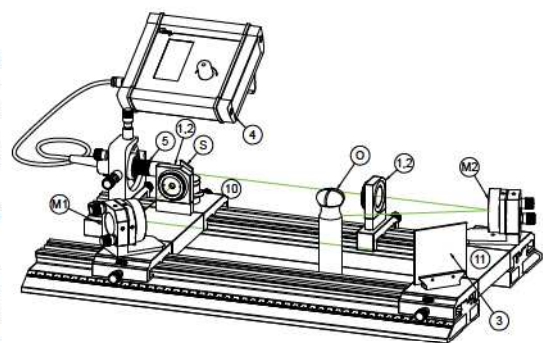


### The holographic film and required chemistry
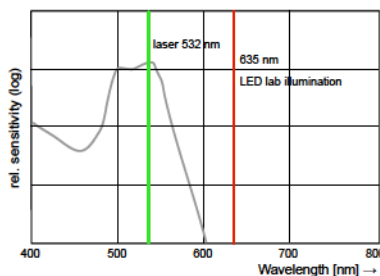


Sensitivity curve of VRP-M film plates

The VRP-M film is developed for the use with green emitting laser. The maximum sensitivity is located around 500 to 535 nm which allows the use of common DPSS laser emitting at 532 nm.

Already at 600 nm the sensitivity decreased in such a way that a red LED can be used to illuminate the dark room lab. The plates have a size of 2.5 inches in square and coming in a box of 30 plates. The lifetime of the plate's emulsion is about 2 years when kept in a dry and cool place.



For the development and bleaching of the film plates all necessary equipment is provided. For the composition of the chemicals a precise lab balance with 0.1 g accuracy is provided. As developer the CW-C2 two-part developer and for the bleaching the PBU Amidol recipe is applied. Three special bottles are used to contain the two parts of the developer and the Amidol bleach.

### Practical setup configurations

For the recording of the holograms a quiet environment is an indispensable prerequisite. To check this the holographic setup is modified to a Michelson interferometer (A). If the fringes are stable within 30 seconds than the environment is suitable.

The first setup for recording transmission holograms is shown on the right in figure (B). The next configuration (C) is used to create reflexion holograms. Here the object is located behind the plate and the scattered light penetrates to the emulsion where the interference with the reference beam takes place.

Finally the arrangement (D) named after Denisyuk makes use of only one beam. Actually a fraction of the laser beam passing the plate shines on to the object whereby the back scattered light interferes with the light on the emulsion. This type of holograms are termed as Denisyuk holograms.
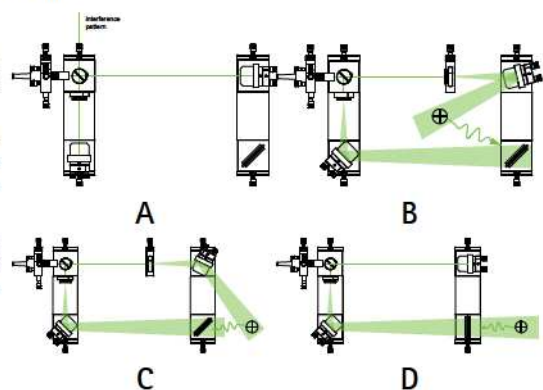


## P5833 Holography consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 2 | Biconcave lens f=-5 mm, Ø7 mm, C25 mount |
| 2 | 2 | Biconcave lens f=-10 mm, Ø10 mm, C25 mount |
| 3 | 30 | Photographic plate VRP-M, 532 nm, 63 x 63 mm |
| 4 | 1 | Digital laser controller & timer |
| 5 | 1 | DIMO diode laser module, 532 nm |
| 6 | 2 | Optical rail MG 65, 500 mm |
| 7 | 1 | Plate holder on carrier 20 |
| 8 | 1 | Set of development equipment |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 1 | Set of developer chemicals |
| 10 | 1 | Holography combining assembly |
| 11 | 1 | Holography beam splitting assembly |
| 12 | 1 | Mounting plate C25 with carrier 20 mm |
| 13 | 1 | Adjustment holder, 4 axes, carrier 20 mm |
| Options: | | |
| | 1 | Photodetector, mini Si PIN, connection lead |
| | 1 | Digital multimeter 3 1/2 digits |

# P5834 Diffraction Gratings

- ✓ *Principle of gratings*
- ✓ *Diffraction order*
- ✓ *Transmission grating*
- ✓ *Measuring wavelength*
- ✓ *Spectral lamp*
- ✓ *Line spectrum*
- ✓ *Spectral resolution*
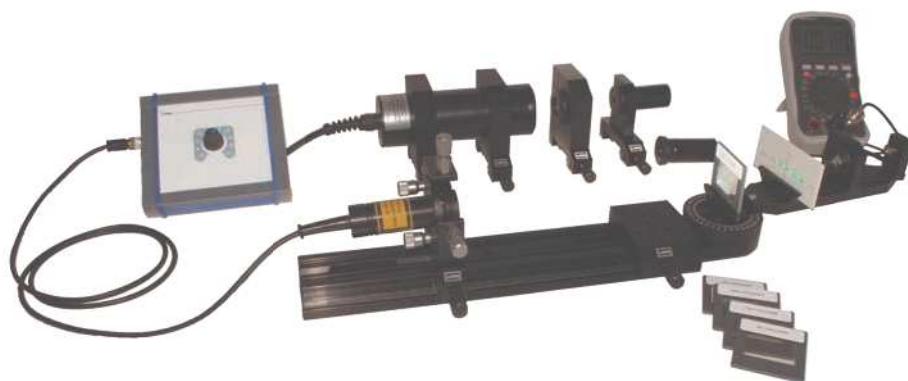


## Examples of investigation and measurement



### Measuring the laser wavelength
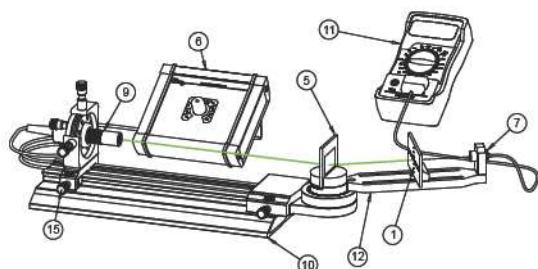


By means of the provided green laser (9) its wavelength is determined by using a grating with known grating constants.

A set of 5 gratings with:

80 lines / mm
100 lines / mm
300 lines / mm
600 lines / mm
1200 lines / mm

are provided to demonstrate and measure the spatial intensity distribution. By using a crossed second grating in addition, an impressive two dimensional Intensity pattern will be observed.

### Spectral resolution
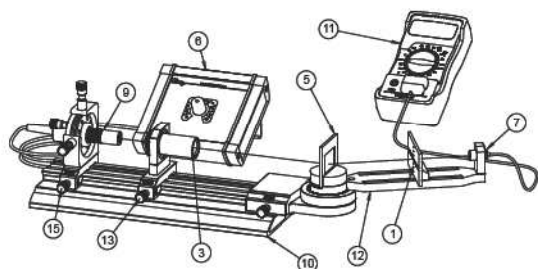


The intensity distribution can either be determined by the optical scale or the pro-

vided photodetector. For each grating and beam expander a different pattern will be generated. Already from the visual impression the resolution can be determined but however also be measured by means of the provided photo detector and digital voltmeter. It should be noted that the µA range is recommended for a linear relation between the photocurrent and the light intensity.

### Diffraction of a line spectrum
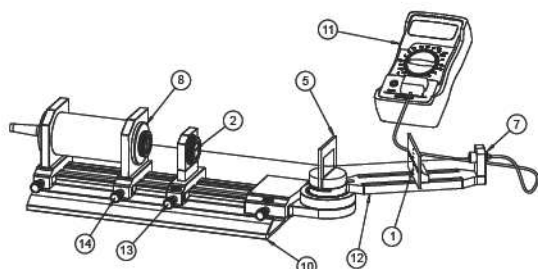


| | | |
|---|---|---|
| a | purple | 405 nm |
| b | blue | 436 nm |
| c | turquoise | 492 nm |
| d | green | 546 nm |
| e | yellow | 578 nm |
| f | red | 615 nm |

The spectral lamp contains a modern energy saving lamp with integrated 220 VAC power supply and emits a spectrum as shown on the right.
The spectral lamp is used in connection with the set of gratings to analyse the effect of the grating constant with respect to the resolution of a line spectrum.
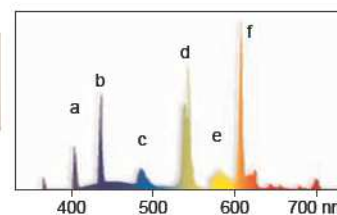


Spectrum of the lamp provided by manufacturer



Spectrum taken with grating with 1200 lines/mm

## P5834 Diffraction Grating consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Optical screen with XY scale on block |
| 2 | 1 | Achromat f=40 mm, C30 mount |
| 3 | 1 | Beam expander magnification 6x |
| 4 | 1 | Beam expander magnification 2.7x |
| 5 | 1 | Set of 5 transmission gratings consisting of: |
| | 1 | T – grating 80 l/mm |
| | 1 | T – grating 100 l/mm |
| | 1 | T – grating 300 l/mm |
| | 1 | T – grating 600 l/mm |
| | 1 | T – grating 1200 l/mm |

| Item | Qty | Description |
|---|---|---|
| 6 | 1 | Adaptive power supply APS–05 |
| 7 | 1 | PIN Photodetector, BPX61 with connection leads |
| 8 | 1 | Spectral lamp with slit and power supply |
| 9 | 1 | DIMO diode laser module, 532 nm |
| 10 | 1 | Profile Rail MG-65, 300 mm |
| 11 | 1 | Digital multimeter 3 1/2 digits |
| 12 | 1 | Triple swivel unit |
| 13 | 1 | Mounting plate C25 with carrier 20 mm |
| 14 | 2 | Mounting plate C50 with carrier 20 mm |
| 15 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

# P5835 Spectral analysis

- ✓ *Principle of gratings*
- ✓ *Reflection grating*
- ✓ *Spectrograph*
- ✓ *Czerny-Turner monochromator*
- ✓ *Measuring wavelength*
- ✓ *Spectral resolution*
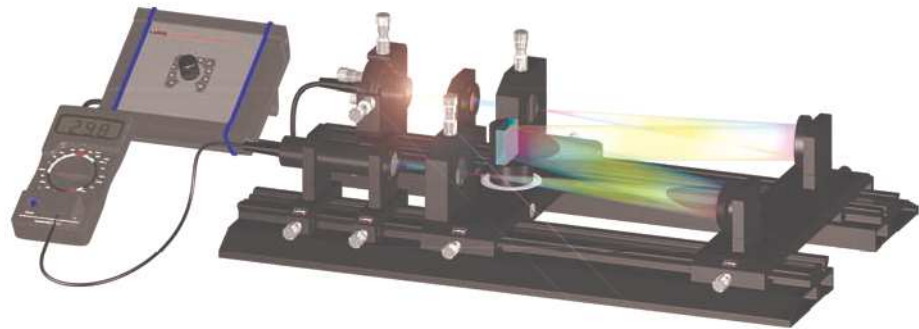


## Examples of investigation and measurement

### General setup

The spectrometer is formed by the adjustable entrance (S1) and exit (S2) slits, the rotary grating (G1) and the two spherical mirrors M1 and M2. Behind the exit slit (S2) a lens with protective tube (3) images the slit (S2) onto the photodetector (5). The intensity is determined by measuring the photo current of the photodiode by means of the digital multimeter.

The grating is mounted onto a rotary unit which allows the precise rotation of the grating. The provided scale informs about the angle and is a reference for the selected wavelength. The scale is calibrated by using the known wavelength of the spectral lamp (7). This measurement shows the sinusoidal relation between the angle and the wavelength. The setup shown in the figure on the right represents a spectrometer for separating a specific wavelength of a light source (6) and measuring its intensity. Such a setup is also known as Czerny-Turner arrangement.
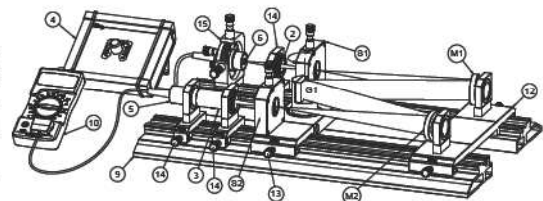


### Grating spectrograph and monochromator

A spectrograph can also be used to characterise the spectral properties of a probe or optical filter which is inserted into the beam path of the spectrometer. A light source (7) providing the required wavelength range is placed to the entry slit of the spectrometer. Firstly the spectrum without the probe is recorded. After this, the same measurements are repeated however with the probe. The plot of the intensity versus the wavelength is normalized with the data measured without probe. Within this series of measurements also the influence of the slit width on the spectral resolution is investigated.



### White light LED

The white light source (10) consists of a high brightness LED. The spectrum of the lamp is shown in the figure on the right. Beside a peak at 440 nm a broad range from 500 to 700 nm is available.

The light source is connected to the adaptive power supply (9) which allows the variation of the injection current and by that the intensity of the emitted light.

The divergent radiation is collimated by means of a lens (3) having a focal length of 40 mm.
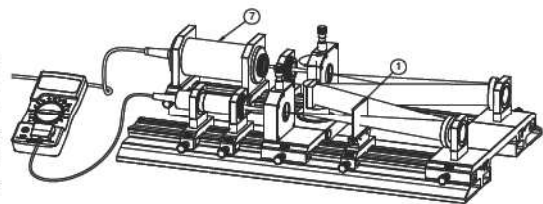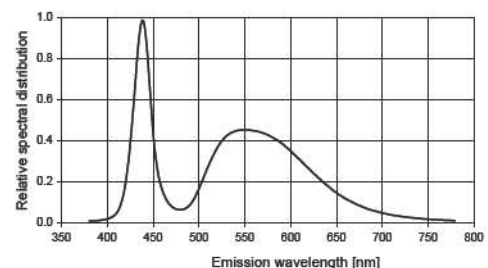


### Spectral lamp

The spectral lamp contains a modern energy saving lamp with integrated 220 VAC power supply and emits a spectrum as shown on the right.

The spectral lamp is used in connection with the set of gratings to analyse the effect of the grating constant with respect to the resolution of a line spectrum.
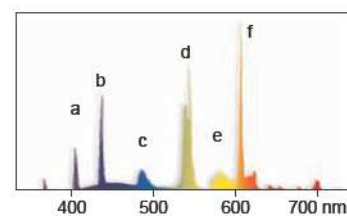


Spectrum of the provided spectral lamp

## P5835 Spectral Analysis consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Absorption filter, acrylic, 50 x 50 x 3 mm |
| 2 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 3 | 1 | Plano-convex lens f=20 mm, C25 light tube |
| 4 | 1 | Adaptive power supply APS-05 |
| 5 | 1 | PIN Photodetector, BPX61 with connection leads |
| 6 | 1 | LED white in C25 housing |
| 7 | 1 | Spectral lamp with slit and power supply |
| 8 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 9 | 2 | Optical rail MG 65, 500 mm |
| 10 | 1 | Digital multimeter 3 1/2 digits |
| 11 | 1 | Plate holder on carrier 20 |
| 12 | 1 | Spectrometer mirror assembly |
| 13 | 1 | Spectrometer grating assembly with two gratings |
| 14 | 3 | Mounting plate C25 with carrier 20 mm |
| 15 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

**LEYBOLD**®

# P5836 Beam deflection

- ✓ *Beam deflection by prisms*
- ✓ *Beam splitting cubes and plates*
- ✓ *Polarizing beam splitter*
- ✓ *Corner cube retroreflector*
- ✓ *Principle of periscope*
- ✓ *Principle of binocular*
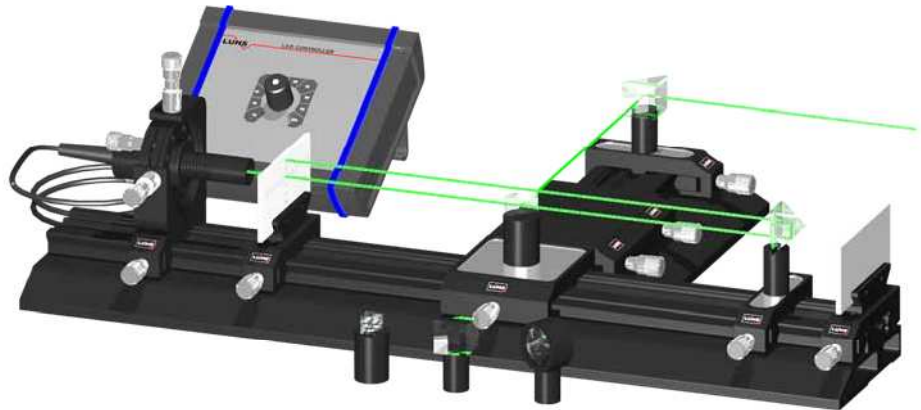


## Examples of investigation and measurement
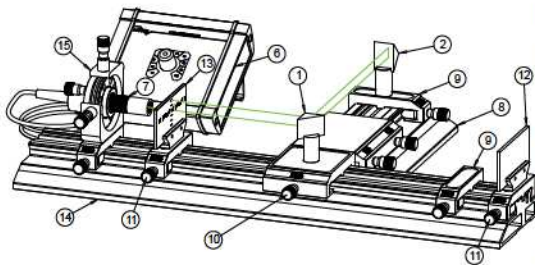


### Beam deflection by prisms

As light source a laser is used which emits a wavelength of 532 nm and is controlled by the adaptive power supply (6). In the first series of experiments the beam deflection by prisms is demonstrated. Single (1) and double reflection (2) inside the prisms are studied and the offset of a retro -reflected beam is measured by means of the white screen with scale (13).

Both prisms are mounted on rods with a magnet at the bottom so that they can be positioned freely on the carrier with magnetic top layer (9,10). One of the provided prism (1) is mounted horizontally and the other one (2) vertical allowing a vertical and horizontal retro reflection.
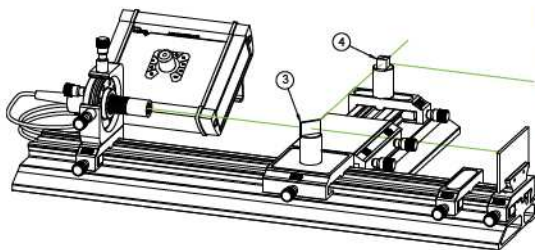


### Beam splitting and deflection

Another important component is the beam splitter plate (3) and beam splitter cube (4) which are also mounted on posts with magnetic bottom. The beam deflection and the deviation of the transmitted beam is measured.

In the same way the beam splitter cube is investigated revealing the fact that no offset of the transmitted beam will be observed.

Both components are important for a variety of applications. One of it is their use in laser interferometer.
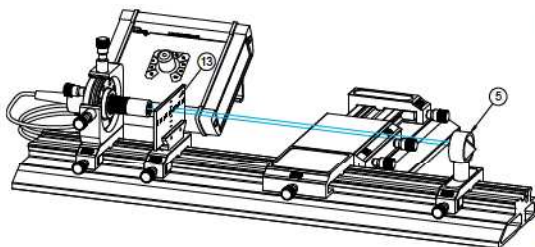


### Beam deflection by triple reflection in a corner cube
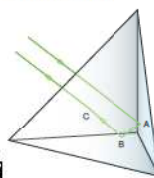
If one cuts a corner off a quadratic cube one gets the important optical components of a triple reflector. Every light beam, which is led into the corner of this cube under any given angle, goes through three different reflections (A,B,C) and is finally reflected back into the same direction. There is, however, an offset between the incoming and outgoing beam, which is dependent on the place in the triple reflector onto which it falls.

Such a component is important in laser interferometry as well as in geodesy.

## P5836 Beam deflection consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Prism 20 mm on post, horizontal |
| 2 | 1 | Prism 20 mm on post, vertical |
| 3 | 1 | Beam splitter plate 15x20 mm on post |
| 4 | 1 | Neutral beam splitter cube 10 mm on post |
| 5 | 1 | Triple reflector on post |
| 6 | 1 | Adaptive power supply APS-05 |
| 7 | 1 | DIMO diode laser module, 532 nm |
| 8 | 1 | Profile Rail MG-65, 200 mm |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 2 | Carrier with magnetic top |
| 10 | 1 | Carrier T-piece with magnetic top |
| 11 | 2 | Screen holder on carrier 20 |
| 12 | 1 | Screen 80 x 40 mm, horizontal and vertical scale |
| 13 | 1 | Screen 80 x 40 mm, dual scale, hole 3 mm |
| 14 | 1 | Optical rail MG 65, 500 mm |
| 15 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

www.ld-didactic.com

# P5837 LED and diode laser

✓ *Principle of semiconductor*

✓ *Electroluminescence*

✓ *LED and laser diode*

✓ *Emission properties*

✓ *Spatial distribution*

✓ *Polarisation properties*

✓ *Spectral properties*



## Examples of investigation and measurement

### General set–up

For a comprehensive study of the properties of LED and laser diodes the setup comes with four different light sources. One diode laser (12) having a wavelength of 630 nm and three high brightness LED emitting white (9), red (10) and blue (11) radiation. The respective light source is plugged into the four axes adjustment holder (17) and connected to the adaptive power supply (8). The internal microprocessor recognises the connected type of light source and sets the electrical parameters accordingly. One lens (4) is used for the beam collimation and lenses (4) and (5) are cylindrical lenses for transforming the elliptical beam of the laser diode (12) into an almost circular one.



### Spatial and polarisation properties of LED and laser diode

The light source to be characterised is plugged into the holder (17). Besides the XY and angular tilting adjustment screws the light source can be rotated around its axis. The rotation is read by means of the attached scale. The entire holder is moved towards the swivel unit (15). A photodetector (2) is attached to the swivel arm and measures the intensity of the emitted light. The photocurrent is displayed by the 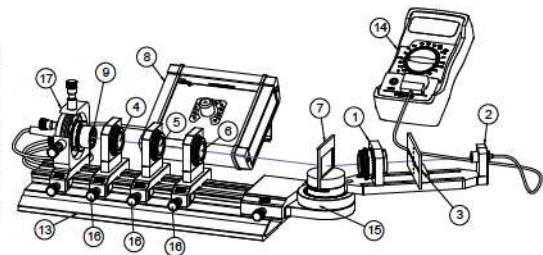provided digital meter which is switched to the µA mode. By rotating the swivel arm the angle resolved intensity distribution is measured. Additional rotation of the light source in its holder allows the recording of the three dimensional intensity distribution. By using the polarisation analyser (1) attached to the swivel arm the polarisation of the respective light source is measured with respect to the injection current.
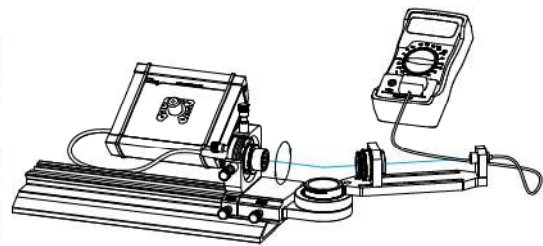


### Spectral properties of LED and laser diode

The grating (7) is placed into the fixed part of the swivel unit (15) and serves in conjunction with the swivel arm and photodetector as spectrometer. For each of the provided light sources the spectrum is recorded. Especially for the LED an influence of the maximum emission wavelength will be observed for different values of the injection current.
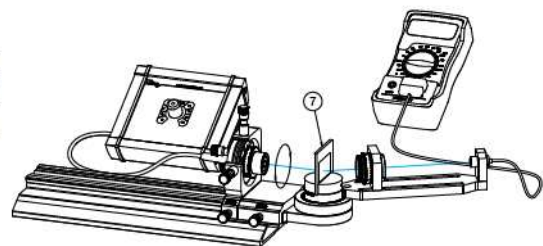


### Provided light sources

The figure shown on the right illustrates the spectral properties of the provided LED and the laser diode. The maximum wavelength of the "blue" emitting LED is about 450 nm and 635 nm for the diode laser and the LED respectively. The spectral width of the emission of the LED is much broader than that of the laser diode and can be measured by means of the provided grating.

The emission spectrum of the white light LED is shown on the previous page.
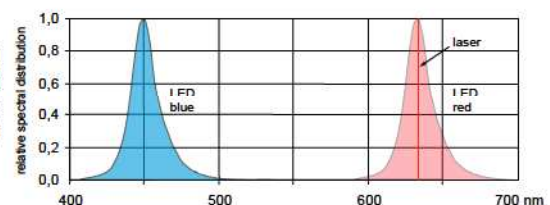


### P5837 LED and Laser Diode consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Polarisation analyser 40 mm |
| 2 | 1 | Photodetector for pivot arm |
| 3 | 1 | Optical screen with XY scale on block |
| 4 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 5 | 1 | Cylindrical lens f=25 mm, C25 mount |
| 6 | 1 | Cylindrical lens f=80 mm, C25 mount |
| 7 | 1 | T - grating 600 l/mm |
| 8 | 1 | Adaptive power supply APS-05 |
| 9 | 1 | LED white in C25 housing |
| 10 | 1 | LED red in C25 housing |
| 11 | 1 | LED blue in C25 housing |
| 12 | 1 | Dimo diode laser module, 630 nm (red) |
| 13 | 1 | Profile Rail MG-65, 300 mm |
| 14 | 1 | Digital multimeter 3 1/2 digits |
| 15 | 1 | Triple swivel unit |
| 16 | 3 | Mounting plate C25 with carrier 20 mm |
| 17 | 1 | Adjustment holder, 4 axes, rotary insert , C20 |

**LEYBOLD**®

# P5838 Detection of Light

✓ *White light lamp*
✓ *Prism refractometer*
✓ *Black body radiation*
✓ *Si, InGaAs photodetector*
✓ *Thermoelectric Detector*
✓ *Photometer*
✓ *Characterization of detectors*
✓ *Characterization of filter*
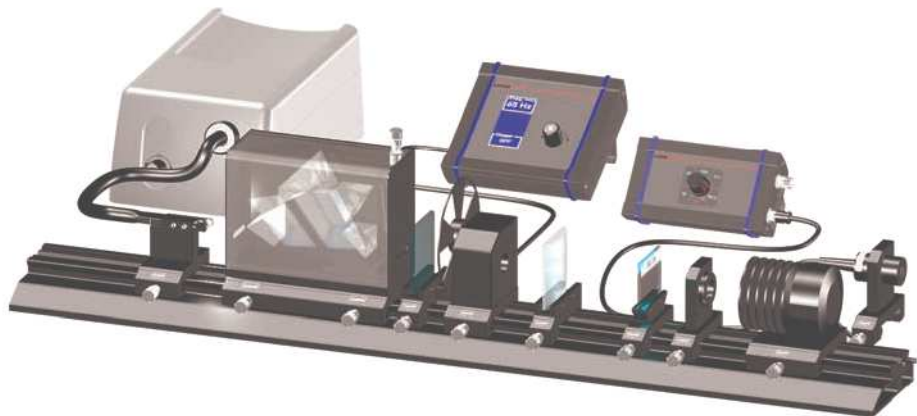
## Examples of investigation and measurement
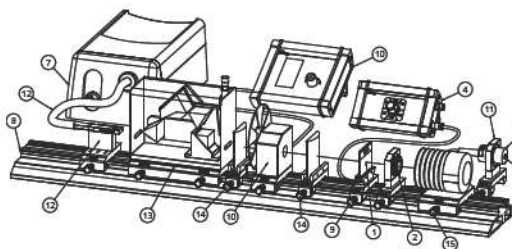
### General setup

A tunable light source consisting of the white light tungsten lamp (7) and the prism tuner (13). The light from the tungsten lamp is guided by means of a glass fibre bundle (12) with circular to rectangular cross section transformer (12). A prism tuner has been chosen because no ghost images due to higher order of a grating spectrometer exist for prism. Using a grating tuner would require a set of high order blocking filters which makes the setup complex and unhandy.

The advantage of the special prism arrangement lies also in the fact that the optical axis is the same for the entrance and exit for all wavelength. The tuning is of the wavelength is done by turning the micrometer screw and using the provided linear calibration curve. For the measurement of the intensity of the particular wavelength a wavelength independent sensor (15) is used.
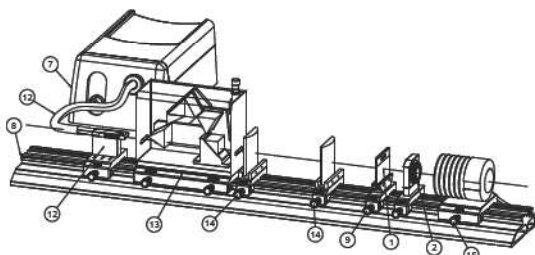
### Characterization of optical filter

The emission leaving the prism tuner is shaped by a set of cylindrical lenses (14) in such a way that almost the entire radiation reaches the photodetector. The final focussing is done by the lens (2).

By placing an optical filter (1, 3) into the beam path the spectral transmission curve can be recorded. For this purpose the wavelength is tuned in useful steps and the transmitted intensity is measured. The plot of the intensity versus the wavelength is the spectral transmission of the particular filter.

During the measurement series the filter is removed for each wavelength to obtain the spectral intensity distribution curve of the tungsten lamp. Using this information the normalised filter curve is obtained.
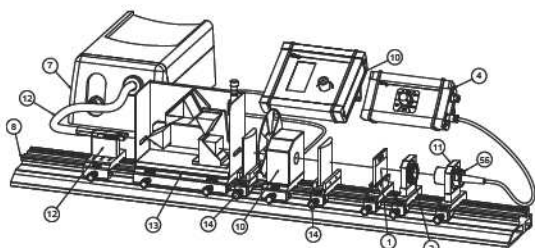
### Spectral and temporal properties of photodetectors

To measure the spectral sensitivity of a photodetector it is simply plugged into the setup instead of the power sensor (16). Two types of detectors are provided, one for the visible (5) and one for the near infrared part of the spectrum. The particular detector is connected to the signal conditioning box (4) which output can be connected to a digital voltmeter but preferable to an oscilloscope. In conjunction with the light chopper high sensitive AC measurements can be carried out. Furthermore the signal conditioning box allows the variation of the series resistor of the photodiode. This allows also to measure the temporal behaviour of photodiodes.
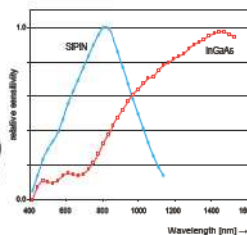
## P5838 Detection of light consisting of

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | IR block filter |
| 2 | 1 | Biconvex lens, f=60 mm, mount C25 |
| 3 | 1 | Coloured glass filter BG39, 50 x 50 x 3 mm |
| 4 | 1 | Photodetector signal conditioning box |
| 5 | 1 | PIN Photodetector, BPX61 with connection leads |
| 6 | 1 | Photodetector, InGaAs with connection leads |
| 7 | 1 | White light source 150 W |
| 8 | 1 | Profile rail MG-65, 800 mm |
| 9 | 1 | Screen holder on carrier 20 |

| Item | Qty | Description |
|------|-----|-------------|
| 10 | 1 | Light chopper on carrier, controller |
| 11 | 1 | Mounting plate C25 with carrier 20 mm |
| 12 | 1 | Imaging optics with fibre bundle |
| 13 | 1 | Tunable wavelength selector |
| 14 | 2 | Imaging cylindrical optics |

Required Options:

| Item | Qty | Description |
|------|-----|-------------|
| 15 | 1 | Laser power meter LabMax-TO |
| 16 | 1 | High sensitive power sensor, 0.3–11 µm |
| 17 | 1 | Oscilloscope 100 MHz digital, two channel |

# P5839 Radio and Photometry

✓ *Black Body Radiator*

✓ *Thermal and cold light*

✓ *Spectral sensitivity of human eye*

✓ *V(λ) filter*

✓ *Photometric units*

✓ *Calibrated radiometer*

✓ *Photometry of:*

✓ *LED and incandescent light*

✓ *Modern energy saving lamps*

✓ *1/r² Law*



## Examples of investigation and measurement

### V(λ) Filter

The figure shown on the right illustrates the relation of the spectral sensitivity of the human eye (A) to the emissions spectrum of an incandescent lamp (B). It becomes clear that most of the energy is waisted which in turn is the reason for the worldwide action to banish incandescent lamps and substitute it against fluorescent or energy saving lamps. The radiometry measures the power of the entire curve (B) and uses Watt as dimension for this power. However the engineer who is responsible for the illumination takes only the fraction of the overlap of curve (A) and (B) because only this part can be seen by the human eye. The dimension of his photometric measurement is the Lumen. For the practical measurements of this photometric units a so called V(λ) filter is used. It has the same spectral curve as the human eye and is placed in front of a radiometer. The combination of such a filter and a calibrated power meter allows the characterization of light sources in photometric units .
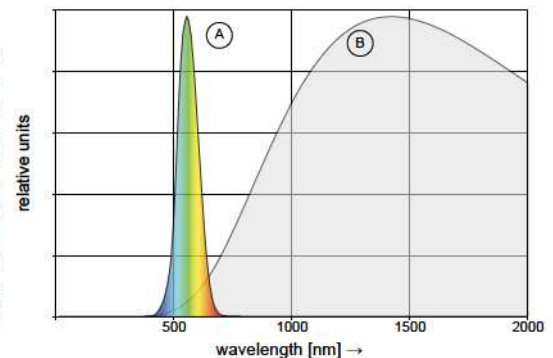


### Photometry of LED

The measurements start with the calibration of a green LED (7). The emission spectrum of the LED is completely covered by the V(λ) filter so that the power meter (8) reading should not be effected by an ideal filter. The comparison of the measurement with and without filter allows the calibration of the filter, provided the entire light spectrum is covered by the filter which is the case for the green emitting LED. In a next step a white light emitting LED is explored and the emission measured in radio and photometric units.
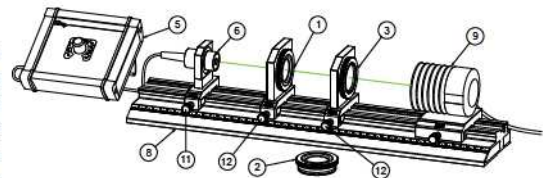


### Photometry of incandescent and energy saving lamps

In this experiment a modern energy saving lamp (4) which is screwed into the regular E27 socket (13) is compared to an incandescent lamp with the same electrical consumption.

This experiment verifies in an impressive way the advantage of energy saving lamps by applying the science of photometry.
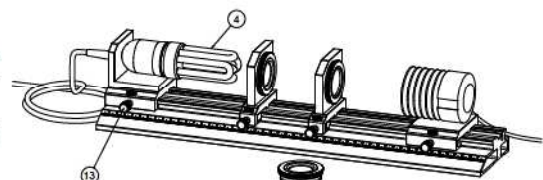


## P5839 Radio–and Photometry consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | V(λ) filter in C50 mount |
| 2 | 1 | Diaphragm Ø 30 mm in C50 mount |
| 3 | 1 | Imaging optics, C50 mount |
| 4 | 1 | Energy saving lamp E27, 20W/220V |
| 5 | 1 | Adaptive power supply APS-05 |
| 6 | 1 | LED white in housing |
| 7 | 1 | LED green  in C25 housing |

| Item | Qty | Description |
|------|-----|-------------|
| 8 | 1 | Profile rail MG-65, 500 mm |
| 9 | 1 | High sensitive power sensor, 0.3-11 μm, CR65 |
| 10 | 1 | Laser power meter LabMax-TO |
| 11 | 1 | Mounting plate C25 with carrier 20 mm |
| 12 | 2 | Mounting plate C50 with carrier 20 mm |
| 13 | 1 | Lamp socket E27, CR65 |

**LEYBOLD**®

## P584 Optical Imaging and Colour

# P5841 Optical Filter

✓ *Absorption*

✓ *Lambert-Beer's law*

✓ *Neutral density filter*

✓ *Colour filter high and low band*

✓ *Infrared filter*

✓ *Dichroitic filter*



## Examples of investigation and measurement

### Neutral density, coloured and infrared filter

The emission of a white light source (LED 10) will be separated by an optical grating and can be observed on the white screen with scale (2). The beam of the white LED is collimated with the lens (3). In the collimated beam filters (13) will be placed and the change in the spectrum is observed and detected by the photodiode (9). The reading of the intensity is done by a digital meter which is switched into the µA Mode to obtain a linear relation to the photo current. The change of the spectrum is compared to the provided filter curves.
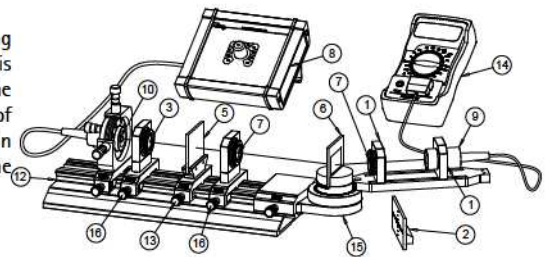
### Interference filter

An interference filter is an optical filter composed out of multiple layers with different indexes of refraction forming a kind of Fabry Perot cavity however with a much broader transmission bandwidth. The centre wavelength of the interference filter used here (4) is 550 nm with a bandwidth of 10 nm. When the interference filter is tilted with respect to the incidence beam, the transmission peak changes.
The filter is placed in front of the collimated white light beam with subsequent optical filters also to check their transmission at 550 nm.
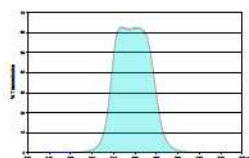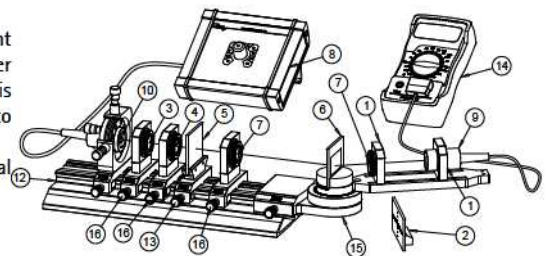
Transmission curve of the interference filter (4) | Short pass blue filter | Band pass green filter | Long pass filter red | Band pass filter NIR
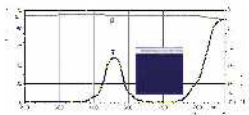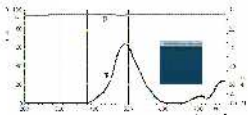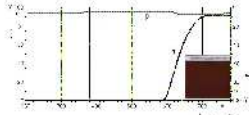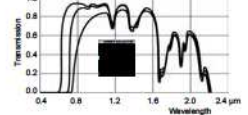
## P5841 Optical Filter consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Mounting plate 40, C25 |
| 2 | 1 | Optical screen with XY scale on block |
| 3 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 4 | 1 | Interference filter 550 /10 nm, C25 mount |
| 5 | 1 | Set of 8 optical filters consisting of: |
|   | 1 | Short pass filter blue, 50 x 50 x 3 mm |
|   | 1 | Band pass filter green , 50 x 50 x 3 mm |
|   | 1 | Long pass filter red , 50 x 50 x 3 mm |
|   | 1 | Violet block filter |
|   | 1 | IR band pass Filter , 50 x 50 x 3 mm |
|   | 1 | IR block filter |
|   | 1 | Neutral filter T = 50 % |
|   | 1 | Neutral filter T = 80% |
| 6 | 1 | T - grating 600 l/mm |
| 7 | 1 | Biconvex lens f = 60 mm, Ø 22.4 mm, C25 mount |
| 8 | 1 | Adaptive power supply APS-05 |
| 9 | 1 | PIN Photodetector, BPX61 with connection leads |
| 10 | 1 | LED white in C25 housing |
| 11 | 1 | LED NIR  in C25 housing |
| 12 | 1 | Profile rail MG-65, 300 mm |
| 13 | 1 | Screen holder on carrier 20 |
| 14 | 1 | Digital multimeter 3 1/2 digits |
| 15 | 1 | Triple swivel unit |
| 16 | 3 | Mounting plate C25 with carrier 20 mm |
| 17 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

**LEYBOLD**®

## P5842 Colour Mixing

✓ *LED additive colour mixing*

✓ *Subtractive colour filtering*

✓ *Optical grating*

✓ *Spectral analysis of composed colour*
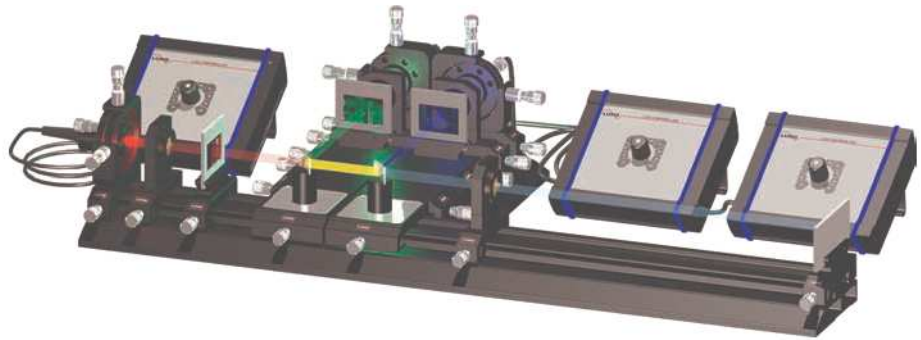
## Examples of investigation and measurement
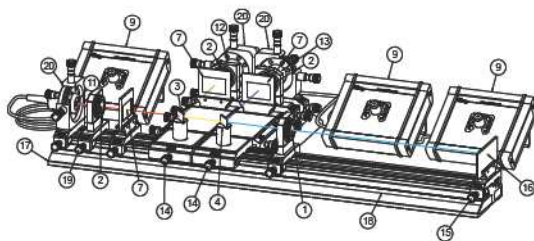
### Additive colour mixing

The most exiting experiment with light is the mixing of the fundamental colours. For this purpose three LEDs, one for red (11), one for green (12) and one for blue (13) are provided. Each LED has its own controller (9) so that the intensity of each LED can be controlled independently.

In front of each LED a slide (7) with a grey structure is placed and imaged to the white screen (16). When the images are perfectly aligned to each other the image becomes impressively coloured.
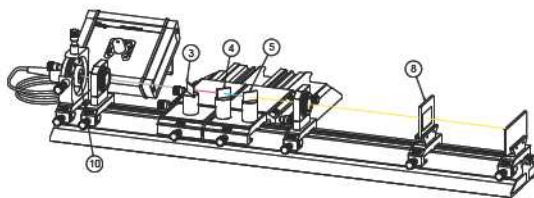
### Subtractive colour filtering and spectral analysis

This experiment uses a white light LED (10) whose radiation is collimated by the lens (2). By means of the dichroic mirrors (3, 4, 5) different colours are removed from the white light resulting in a coloured one.

The composition of this colour is analysed by means of a grating (8) which is placed in front of the white screen (16).

### P5842 Color Mixing consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Biconvex lens f=150 mm, C25 mount |
| 2 | 3 | Plano-convex lens f=40 mm, C25 mount |
| 3 | 1 | Dichroic mirror HRG/HTRB on magnetic post |
| 4 | 1 | Dichroic mirror HRB/HTRG on magnetic post |
| 5 | 1 | Dichroic mirror HRR/HTBG on magnetic post |
| 6 | 1 | Slide with chromatic circle |
| 7 | 3 | Test slide grey scale |
| 8 | 1 | T – grating 600 l/mm |
| 9 | 3 | Adaptive power supply APS-05 |
| 10 | 1 | LED white in C25 housing |
| 11 | 1 | LED red in C25 housing |
| 12 | 1 | LED green  in C25 housing |
| 13 | 1 | LED blue in C25 housing |
| 14 | 2 | Carrier T-piece with magnetic top |
| 15 | 4 | Screen holder on carrier 20 |
| 16 | 1 | Optical screen, 40 x 80 mm without scale |
| 17 | 3 | Profile Rail MG-65, 300 mm |
| 18 | 1 | Optical rail MG 65, 500 mm |
| 19 | 4 | Mounting plate C25 with carrier 20 mm |
| 20 | 3 | Adjustment holder, 4 axes, carrier 20 mm |

# P5843 Camera and imaging

- ✓ *CCD imaging chip*
- ✓ *Camera objective*
- ✓ *Objective magnification*
- ✓ *Iris and depth of sharpness*
- ✓ *NIR and night vision*
- ✓ *Computer control*

## Examples of investigation and measurement

### General set-up

A high performance industrial CCD zoom camera (7) with computer interface is subject of a variety of investigations. The rapid development in the area of CCD sensors created a great variety of new possibilities. Most of them are introduced here and one get experienced in the manifold of parameters which needs to be set according to the requirements. The CCD camera used can be operated as day as well as night camera. In the latter case an IR filter is switched between the objective and the CCD chip enabling the sensitivity in the near infra red region (NIR).

The camera is fully controlled by a PC Pad, the video output is connected to the provided TFT monitor.
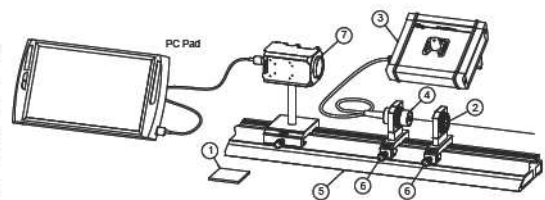
### CCD Camera properties and control

The camera is internally controlled by digital signal processor (DSP) which also creates the image out of the pixel information of the CCD chip. By means of the common VISCA protocol commands are send and received via RS232 bus.

Beside the common controls like auto focus (AF), optical zoom, digital zoom, auto iris, shutter speed also the implemented motion detection and masking are controlled by the provided software.

Image flipping, black and white, negative distribution, white balance, back light compensation just to name a few special settings are accessible by the software.

Due to the possibility to control the iris, focus and zoom the optical relations of the depth of sharpness is impressively verified.
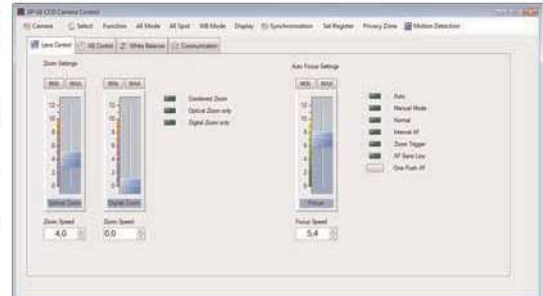
### Active night vision

The figure shows the sensitivity of the human eye and a CCD camera. The maximum of the CCD camera peaks at 900 nm where the human eye is completely blind. Using an NIR light source like a laser or LED a complete dark night can be illuminated without be seen by humans or animals. This technology is termed as active night vision and plays an important role in surveillance tasks even in complete darkness.

To demonstrate this effect a NIR LED (4) controlled by the adaptive power supply (3) is provided. The divergent emission of the LED is collimated by a lense (2).

The camera is switched by the software into the NIR mode. A filter is removed electromechanically out of the front of the CCD chip allowing NIR radiation to access the chip.
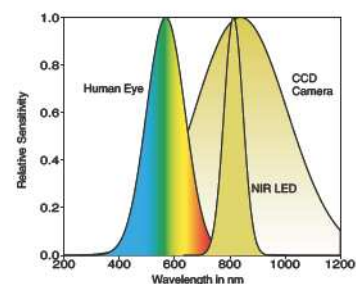
## P5843 Camera consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | IR block filter |
| 2 | 1 | Plano convex lens f=60 mm, C25 mount |
| 3 | 1 | Adaptive power supply APS-05 |
| 4 | 1 | LED NIR in C25 housing |
| 5 | 1 | Profile Rail MG-65, 300 mm |
| 6 | 2 | Mounting plate C25 with carrier 20 mm |
| 7 | 2 | CCD day and night camera module |

| Item | Qty | Description |
|------|-----|-------------|
| 8 | 1 | CCD camera control software |

Required Options:

| | Qty | Description |
|--|-----|-------------|
| | 1 | Flat panel TV 20 inch |
| | 1 | PC Pad |

**LEYBOLD®**

# P5844 Image projection

- ✓ *Light source and condenser*
- ✓ *Imaging objective*
- ✓ *Image generation*
- ✓ *Vignetting*
- ✓ *Impact on image*



## Examples of investigation and measurement
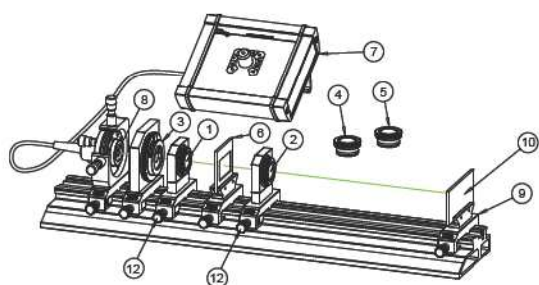


### Set-up of the image projector

As light source a white emitting LED with an optical power of 3 W is used. The emission is collimated by means of the lens (1) having a focal length of 40 mm. The test slide (8) is placed in front of the collimating lens in such a way that in connection with the imaging lens (2) a clear image is created on the white screen (10) or on an adjacent wall.

Using the lenses (4,5) in addition and measuring the distances of the optical components to each other the lens equations are verified, the magnification determined and the 2f or 4 f arrangements discussed.

By using the adjustable iris at different locations the impact on the intensity and depth of sharpness are explored.
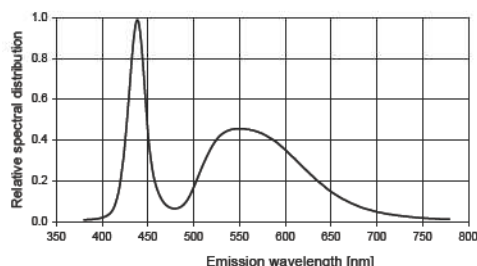


### White light source

The white light source (8) consists of a high brightness LED. The spectrum of the lamp is shown in the figure on the left. Beside a peak at 440 nm a broad range from 500 to 700 nm is available.

The light source is connected to the adaptive power supply (7) which allows the variation of the injection current and that way the intensity of the emitted light.

The divergent radiation is collimated by means of a lens (1) having a focal length of 40 mm.



### Test slide #22

This slide allows to check the spatial as well as colour resolution of imaging devices. The slide has the regular dimension of 50 x 50 x 3 mm. The centre structure is designed in accordance with the so called "Siemens star". It is used to analyse the resolution of the imaging device by determining the "grey circle" of the centre of unresolved lines.

## P5844 Image Projection consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Plano-convex lens f=40 mm, C25 mount |
| 2 | 1 | Planoconvex lens f=60 mm, C25 mount |
| 3 | 1 | Iris aperture, 36 mm, C50 mount |
| 4 | 1 | Biconvex lens f=150 mm, C25 mount |
| 5 | 1 | Biconvex lens f=100 mm, Ø 22.4 mm, C25 mount |
| 6 | 1 | Test slide #22 |
| 7 | 1 | Adaptive power supply APS-05 |
| 8 | 1 | LED white in C25 housing |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 1 | Screen holder on carrier 20 |
| 10 | 1 | Optical screen, 40 x 80 mm without scale |
| 11 | 1 | Optical rail MG 65, 500 mm |
| 12 | 2 | Mounting plate C25 with carrier 20 mm |
| 13 | 1 | Mounting plate C50 with carrier 20 mm |
| 14 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

## P585 Laser Basics

LEYBOLD®

# P5852 Laser safety

- ✓ *Pulsed Diode and DPSS laser*
- ✓ *Beam divergence*
- ✓ *Laser energy and power*
- ✓ *Laser intensity*
- ✓ *Laser scattering*
- ✓ *Laser classification*
- ✓ *Determine safety goggles*
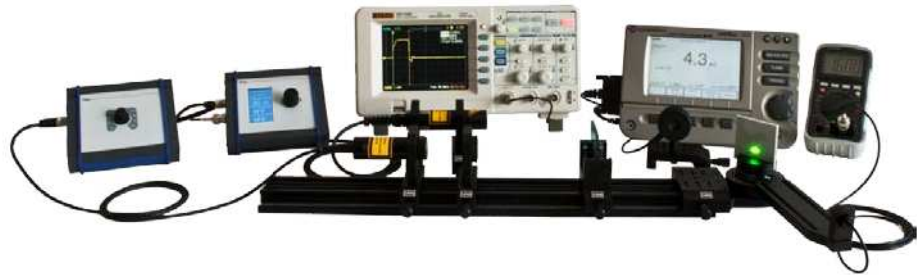


## Examples of investigation and measurement

Laser can emit dangerous radiation. To protect against any injure international safety rules are like IEC 60825 or ANSI Z136 are created and strictly applied. The lasers are classified into different classes with the individual maximum permissible exposure limit (MPE) which is defined as intensity, power per square centimetre (W/cm²). Under no circumstances this intensity should be exceeded. To classify a laser one needs to know its intensity in order to compare it with the MPE values. For pulsed laser its energy is used instead of the power of continuous wave (cw) laser. Within this experiment one pulsed and one cw laser are classified. For this purpose the intensity needs to be determined. To calculate this value the power, the beam diameter and the beam divergence are measured. For the pulsed laser its repetition rate and the emitted energy is measured.



ANSI Z136 / IEC 60825

## Measuring the laser power or energy

To measure the laser power a calibrated sensor head (11) is used in conjunction with the display (10). The particular laser is placed onto the rail (8) and the sensor in front of it. Once the emitted power or energy is measured the repetition rate of the pulsed laser is measured by means of the photodetector which is connected to the oscilloscope along with the 50 ohms shunt resistor.
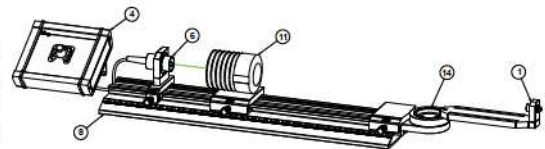


## Measuring beam diameter and divergence

The beam of the laser is expanded by a concave lens (2) with known focal length. The expanded intensity profile is measured by using the photodetector (1) which is mounted to the swivel arm of (14). The measurements are repeated for different positions of the expanding lens. The respective position is noted by reading the scale of the optical rail. Out of this measurements and related plots of the intensity distribution the beam diameter and divergence without the lens (2) is calculated.
The intensity of the probe laser can now be calculated and compared to the related MPE value.
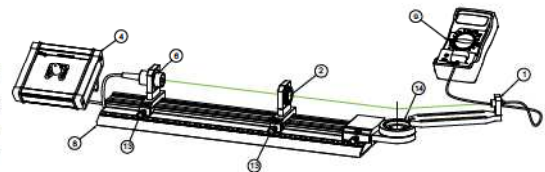


## Laser light scattering

The laser safety rules are not only concerned about direct laser beams but also about scattered laser light which intensity might become hazardous.
To evaluate this situation the angular resolved intensity distribution of the scatter probe is measured. For this purpose the probe (16) is placed under a certain angle with respect to the incident laser beam. The maximum intensity is located and the intensity value determined and compared with the NOHD values for diffuse radiators.
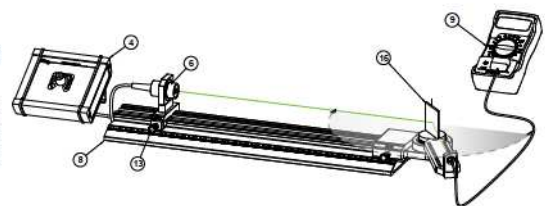


## Measuring filter transmission

According to the safety rules the user must wear safety goggles in case it cannot made sure that direct exposition to the laser beam is impossible. In principle such goggles are optical filters with specific properties. One important one is the optical density (OD) for a specific wavelength.
The kit comes with one filter (3) which optical density is measured by using the cw as well as pulsed laser.
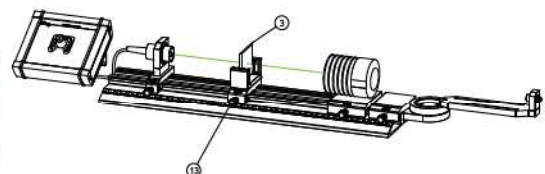


## P5852 Laser safety consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Photodetector for pivot arm |
| 2 | 1 | Biconcave lens f=-10 mm, C25 mount |
| 3 | 1 | Coloured glass filter BG39, 50 x 50 x 3 mm |
| 4 | 1 | Adaptive power supply APS-05 |
| 5 | 1 | Pulsed laser diode controller PLDC-01 |
| 6 | 1 | DIMO diode laser module, 532 nm |
| 7 | 1 | Pulsed diode laser in housing |
| 8 | 1 | Profile Rail OCM 650, 500 mm with ruler |
| 9 | 1 | Digital multimeter 3 1/2 digits |

| Item | Qty | Description |
|------|-----|-------------|
| 10 | 1 | Laser power meter LabMax-TO |
| 11 | 1 | LM-2 VIS power sensor 50 mW / 1 nW |
| 12 | 1 | Laser energy sensor head 300 nJ – 600 µJ |
| 13 | 1 | Plate holder on carrier 20 |
| 14 | 1 | Triple swivel unit |
| 15 | 3 | Mounting plate C25 with carrier 20 mm |
| 16 | 1 | Scatter probe on holder |

Required Options:

| | | |
|------|-----|-------------|
| | 1 | Oscilloscope 100 MHz digital, two channel |

    www.ld-didactic.com

# P5853 Emission and Absorption (Optical Pumping)

- ✓ *Diode laser*
- ✓ *Nd:YAG crystal*
- ✓ *Optical pumping*
- ✓ *Absorption spectra*
- ✓ *Lifetime of excited states*
- ✓ *Einstein coefficients*
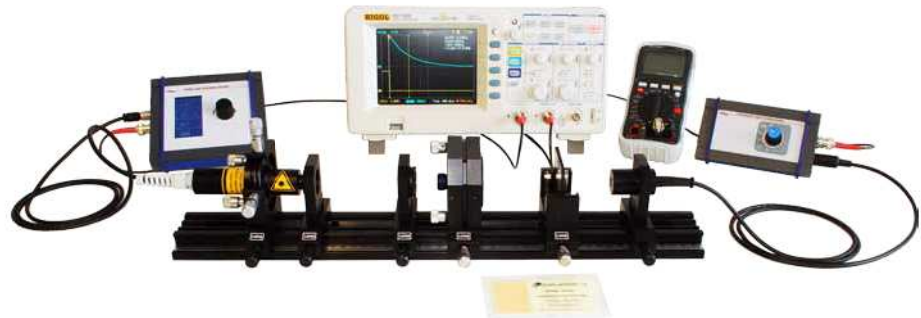


## Principle of operation

The radiation of the diode laser is focused by means of the collimator(B) and lens (C) into the Nd:YAG rod (D). The filter (F) absorbs the residual pump light and transmits the stimulated emission. The relative intensity is measured by the photodetector (G). Without the filter the transmission or absorption of the pump light is measured.



## Examples of investigation and measurement



### Characterization of the diode laser

In a basic set-up the characteristic parameters of the laser diode are measured. The diode laser is mounted into a housing (9) in contact with a Peltier element to control the temperature. The full digitally controller (2) sets and maintains the value for injection current, temperature and modulation frequency of the diode laser (9). The characteristic data of the diode laser is measured in relative units. For this purpose the signal conditioner (3) is used. The photodiode (14) is connected to this box where the input impedance can be selected. The output is available at a BNC connector for further connection to an oscilloscope or multimeter. The collimator (9) is used to set the beam divergence in such a way that the photodetector will not be saturated.



### Absorption and Emission

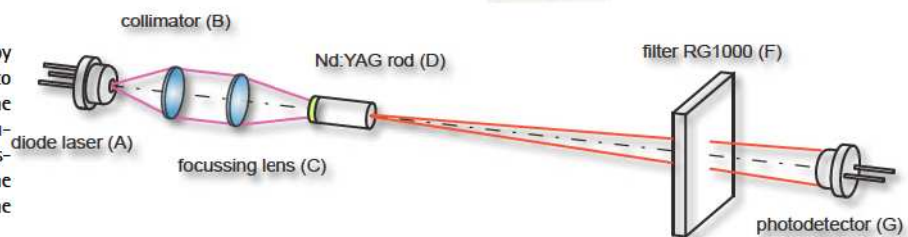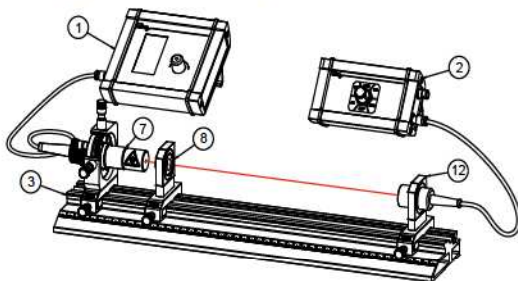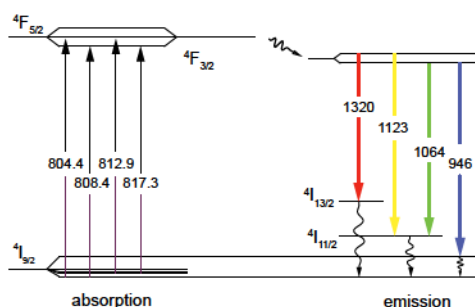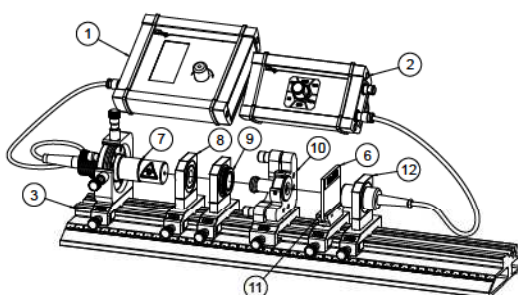The relevant energy levels of Nd:YAG for optical pumping with laser diodes having wavelengths around 805 nm. Some energy levels of the Nd atom are illustrated in the figure shown on the left. Here, only those are shown which are important for optical pumping with laser diodes. The levels are labelled with their spectroscopic notations. Since the Nd atoms are situated within the YAG host crystal, the otherwise degenerated energy levels of the isolated Nd atom split into a number of states.
This gives rise to the ground state $^4I_{9/2}$ from 5 sub-states and the state $^4F_{5/2}$, which can be pumped from 5 sub-states. Since the wavelength of the pump-light source (diode laser) can vary within low limits, a total of three to four transitions can be pumped with high efficiency.



### Optical pumping and spectroscopy

To the previous set-up the focussing lens (10) and the Nd:YAG rod (11) with its holder are added. The transmission spectrum of the laser diode radiation is measured by changing the temperature and therewith the emission wavelength. By means of the well known absorption lines the emission wavelength of the laser diode can be determined exactly. Adding the filter RG1000 (7) in front of the detector blocks the diode laser radiation and the fluorescence caused by optical pumping can be measured as function of the pump laser wavelength (temperature). At the maximum of the fluorescence emission the modulation of the diode laser is activated and the timely response displayed on an oscilloscope. From this curve the mean lief time of the exited laser state of the Nd:YAG material can be derived which inverse value represents the important Einstein coefficient for spontaneous emission.

### P5853 Emission & Absorption / Optical Pumping consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Digital diode laser controller |
| 2 | 1 | Photodetector signal conditioning box |
| 3 | 1 | Profile rail MG-65, 500 mm |
| 4 | 1 | Crossed hair target mounted in holder 25 mm |
| 5 | 1 | Infrared display card, spectral range 0.8 -1.6 µm |
| 6 | 1 | RG1000 Coloured glass filter 50x50x4 mm |
| 7 | 1 | Module A - Diode laser head, adjustment holder |
| 8 | 1 | Module B - Collimating optics on carrier MG-65 |
| 9 | 1 | Module C - Focussing optics, f=60 mm |

| Item | Qty | Description |
|------|-----|-------------|
| 10 | 1 | Module D - Adjustment holder with Nd:YAG rod |
| 11 | 1 | Module F - Filter plate holder |
| 12 | 1 | Module G - SiPIN photodetector |

Required Options:

| | | |
|--|--|--|
| | 1 | BNC-Banana adapter connection leads 2 x 4 mm |
| | 1 | Digital multimeter 3 1/2 digits |

Options:

| | | |
|--|--|--|
| | 1 | Oscilloscope 100 MHz digital, two channel |

**LEYBOLD®**

# P5854 Fabry Perot resonator

- ✓ *Two mode HeNe laser*
- ✓ *Multiple beam interference*
- ✓ *Finesse and free spectral range*
- ✓ *Visibility, contrast and coherence length*
- ✓ *Stability criterion for optical resonator*
- ✓ *Spectral frequency and mode analysis*

## Examples of investigation and measurement

### Setup and alignment

The initial setup uses the pilot laser (13) which is a HeNe laser emitting two orthogonally polarised modes. The first mirror (2) of the Fabry Perot cavity is mounted into a precise adjustment holder. The second mirror is attached to the piezo element (E) which is mounted into a precise adjustment holder (16). Both mirrors are aligned visually to each other in such a way that interference can be observed at the exit of the cavity. The piezo is connected to its controller (11) and the modulation is switched on. The photodetector (12) is connected to the signal conditioning box (10) which output is connected to the oscilloscope. As trigger the slope of the triangularly modulated piezo voltage is used which is displayed on the second channel of the oscilloscope. By slightly moving the adjustment holder (16) by turning the pinion drive of it gives an oscilloscope trace as per figure (A). At the maximum of the upper signal the position of the adjustment holder is fixed and the Fabry Perot aligned for a clear representation as shown in figure (B). In the next step the finesse is measured (figure C) and finally the mode spectrum of the probe laser (figure D)
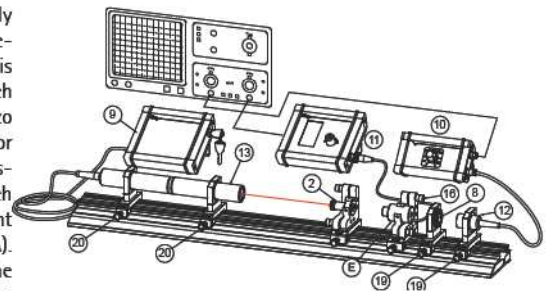
### Plane mirror Fabry Perot

The aim of this experiment is to demonstrate the difference between the plane and the spherical mirror Fabry Perot. The light of the probe laser is first lead into the resonator, now equipped with plane mirrors. The adjustment procedure is the same as for the spherical Fabry Perot. It will be noticed that the adjustment is obviously more critical than in the case of a spherical Fabry Perot.
The same measurements are carried out as in the spherical FP's. Moreover, the beam will be expanded with the telescope formed by (17) and (18) , having a lens of =-5 mm and the achromatic lens f = 20 mm. Contrary to the spherical FP's, an increase in the finesse will be observed.
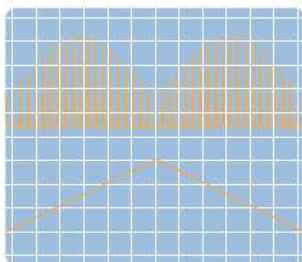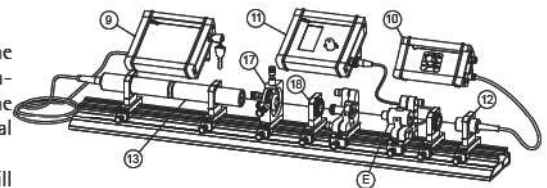
| A. Search of confocal case | B. Determine free spectral range | C. Measurement of finesse | D. Mode spectra of probe laser |
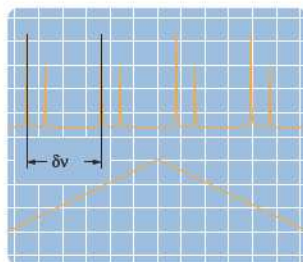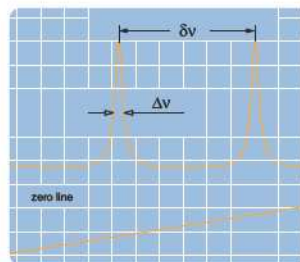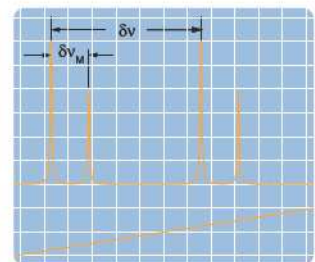
## P5854 Fabry Perot Mode Analyser, full options consisting of:

| Item | Qty | Description | Item | Qty | Description |
|------|-----|-------------|------|-----|-------------|
| 1 | 1 | Achromat f=20 mm, C25 mount | 13 | 1 | HeNe Pilot laser Ø30 mm |
| 2 | 1 | Laser mirror in holder, flat, T 4% @ 632 nm | 14 | 1 | Optics cleaning set |
| 3 | 1 | Laser mirror in holder, R=75 mm, T 4% @ 632 nm | 15 | 1 | Laser mirror adjustment holder, on carrier 30 mm |
| 4 | 1 | Laser mirror in holder, R=100 mm, T 4% @ 632 nm | 16 | 1 | Piezo element with adjustment holder, pinion drive and carrier 30 |
| 5 | 1 | Laser mirror with PZ mount, flat, T 4% @ 632 nm | 17 | 1 | Beam expander lens with adjustment holder |
| 6 | 1 | Laser mirror, PZ mount, R=75 mm, T 4% @ 632 nm | 18 | 1 | Telescope lens f = 150 mm, C25 mounting plate |
| 7 | 1 | Laser mirror, PZ mount, R=100 mm, T 4% @ 632 nm | 19 | 1 | Mounting plate C25 with carrier 20 mm |
| 8 | 1 | Biconvex lens, f=60 mm, C25 mount | 20 | 2 | Mounting plate, including carrier 20 mm , C30 |
| 9 | 1 | HeNe Laser high voltage supply | 21 | 1 | Profile Rail 800 mm with gear rack |
| 10 | 1 | Photodetector signal conditioning box | | | |
| 11 | 1 | Piezo controller PC-01 | | | Required Options: |
| 12 | 1 | PIN Photodetector, BPX61 with connection leads | | 1 | Oscilloscope 100 MHz digital, two channel |

## P5855 Helium Neon Laser

✓ *HeNe Energy level diagram*

✓ *Resonator stability*

✓ *Gaussian beams*

✓ *Double refractive crystal*

✓ *Line & mode selection*

✓ *Single mode etalon*

The first demonstration of laser action based on a gas mixture of Helium Neon has been demonstrated by Javan et. al. in 1961. Nowadays their initial major applications have been substituted by much more cheaper visible diode laser. However for high precision interferometric measurement tasks the Helium Neon is still in use.

One important application is the use in laser gyroscopes for the navigation of air planes and missiles.

Still the Helium Neon laser is used to introduce the concept of a laser and is widely used in beginners lectures on lasers.

Generally the HeNe-Laser is the first laser which students encounter when they start their training in laser technology. Therefore a number of practical aspects are transferred when performing this experiment. The very first observation of laser oscillation after successful initial adjustment is doubtless an unforgettable experience of this experiment.

The selection of the 611 nm line (orange) will still enhance this experience. There is also a series of quantitative measurements to be studied and executed. An open frame experimental laser based on a He-Ne tube with two Brewster's windows (2) is used to demonstrate the laser operation. By means of the provided power supply (1) the discharge current can be adjusted to measure its influence on the laser operation.

The optical resonator or cavity is formed by two common 1/2 " exchangeable mirrors with different radii of curvature mounted in high precision adjustment holders (3 + 4).

For ease of adjustment a pilot Laser is attached as an alignment aid at the beginning. By means of the provided crossed hair target the pilot laser is aligned to the optical axis of the set-up. The laser tube is mounted into XY-adjustments to align the tube with respect to the pilot laser. Finally the mirrors are aligned with respect to the beam of the pilot laser.

A birefringent filter (15) or a Littrow prism (14) is used to select a specific wavelength. By means of an etalon (14) placed into the cavity the laser is forced to single mode operation.

A photodetector (8) and an alignment laser (6) are supplied on a 1 metre optical rail (10), along with all necessary mounts and adjusters.

## Helium Neon Laser Basic Set-up
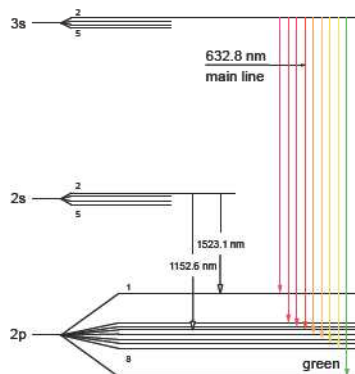


Energy level diagram showing the origin
and manifold of the visible emission lineS
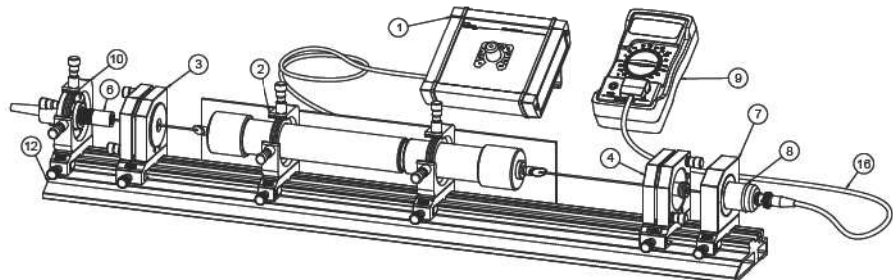
With the basic set-up the optical resonator will be understood and verified. By means of the provided pilot laser the initial alignment is easy and reproducible.

By changing the distance of the cavity mirrors to each other, the optical stability criterion can be verified and the optimum output power determined. By means of a simple sliding calliper the diameter of the intracavity beam can be measured and discussed with respect to Gaussian beams.

When the mechanism of excitation and the relevant energy level scheme is learnt the operation of the HeNe-Laser at different wavelengths is realised in the next step.

## Set-up with a Littrow prism for line selection
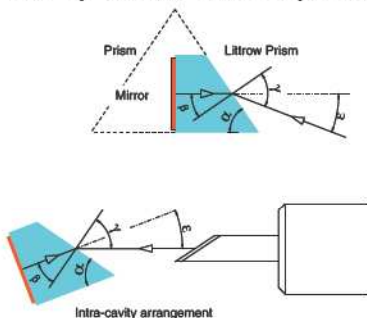


The Littrow prism is a combined optical
component consisting of a coated prism.
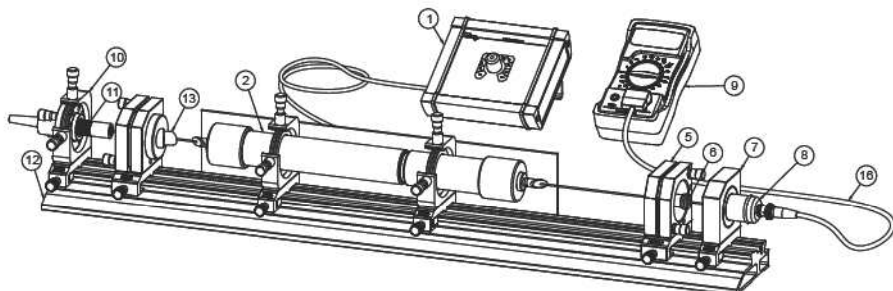
By replacing the flat mirror of the cavity with the Littrow prism (13), the selection of a different wavelength becomes possible. The selection of the wavelengths is carried out by means of a dispersion prism ( Littrow set-up ) or by using a birefringent filter, known as a tuning element from Dye-lasers.

**LEYBOLD**®

## Set–up with birefringent tuner for line selection
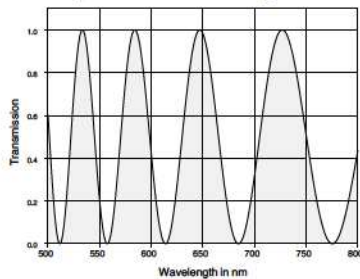


By using the Jones matrix formalism the behaviour of a birefringent (double refractive) plate with a specific thickness, orientation and wavelength dependant transmission can be calculated
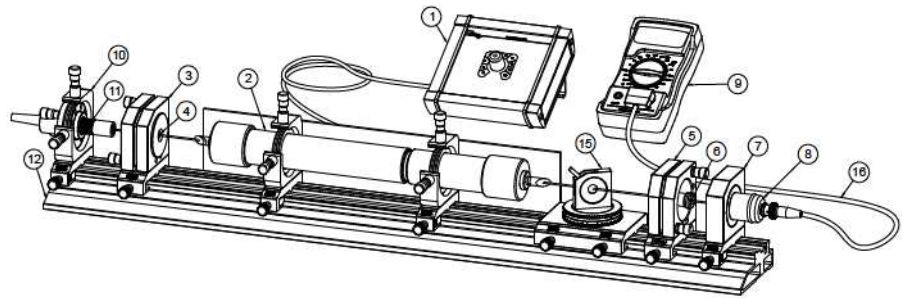
This experiment enhances the understanding of the participating atomic energy levels and renders basic knowledge with regard to crystal optics, Brewster's angle and amplification of a lasing medium. By means of the birefringent filter, a total of five visible lines can be selected. The significant influence of the discharge current on the output power is measured and discussed emphasizing on the weak lines.

## Set–up with etalon for single mode operation
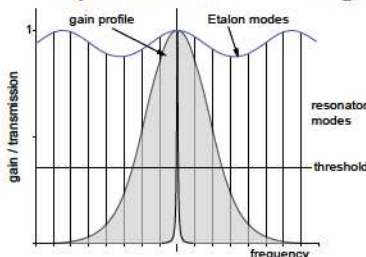


The single mode operation can only be verified by using an additional electronic or optical spectrum analyser. When using an electronically spectrum analyser the provided photodetector is connected to it. In single mode operation the beat frequency of multimodes vanishes.
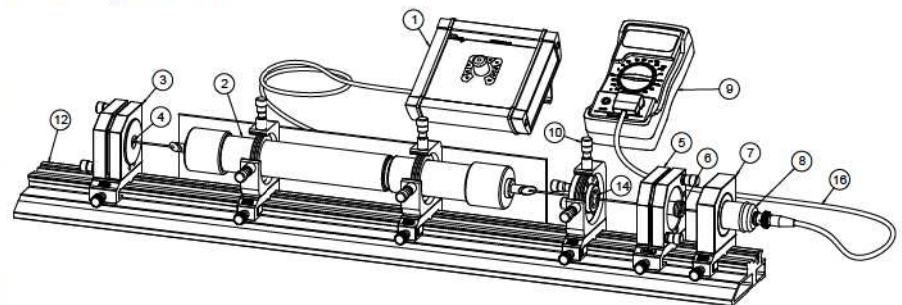
To obtain the purest possible spectral emission the laser should operate on a single mode only. This can be achieved by using a so called Etalon, which in fact is a piece of glass with two exact parallel faces. Based on the natural reflectivity (Fresnel laws) of the faces it forms also a cavity. Placed into the Helium Neon laser master cavity it introduces extra losses. By choosing a particular length of the etalon, the system can be adjusted by tilting the etalon to operate in single mode only.



XP-06 Helium Neon Laser Basic Set-Up



4B-0456/80 Laser mirror in holder



LS-0170 Pilot laser 532 nm (green) with power supply

## P5855 Helium Neon Laser Basic Set-Up consisting of:

| Item | Qty | Description |
| --- | --- | --- |
| 1 | 1 | HeNe Laser high voltage supply and controller |
| 2 | 1 | Main laser tube with XY-adjustment |
| 3 | 1 | Module D Laser mirror adjustment holder left with 1/2" mount |
| 4 | 1 | Laser mirror - 1/2", R=700 mm, HR @ 632 nm |
| 5 | 1 | Module D Laser mirror adjustment holder right with 1/2" mount |
| 6 | 1 | Laser mirror - 1/2", flat, HR @ 632 nm |
| 7 | 1 | Mounting Plate, including carrier 20 mm, C 25 |
| 8 | 1 | Module G - SiPIN photodetector |
| 9 | 1 | Digital multimeter 3 1/2 digits |
| 10 | 1 | Adjustment holder, 4 axes, carrier 20 mm |
| 11 | 1 | Pilot laser DIMO 532 nm |
| 12 | 1 | Optical rail MG-65, 1000 m |
| 16 | 1 | BNC / Banana connection leads 1 m |
| 17 | 1 | Optic cleaning set |
| 18 | 1 | Manual HeNe Laser |



Set-up with Littrow prism

| | | |
| --- | --- | --- |
| 13 | 1 | Littrow prism with adjustment holder |



The Littrow prism is a combined optical component consisting of a coated prism. It acts as laser mirror and selective element simultaneously. A high quality BK7 Littrow prism is supplied with a high reflectivity (>99,98 %) coating in the range from 580 to 650 nm.



Set-up with etalon

| | | |
| --- | --- | --- |
| 14 | 1 | Single mode etalon with adjustment holder |



A glass body with parallel faces is mounted into the 4 axis adjustment holder which is placed inside the cavity. By tilting the etalon multiple order of the tuner are demonstrated. To verify the single mode operation either an optical spectrum analyser (parts of XP-03) or an electronic one is needed.



Setup with birefringent tuner

| | | |
| --- | --- | --- |
| 15 | 1 | Birefringent tuner (Lyot filter) with adjustment holder |



A plate of natural birefringent quartz is mounted in an rotator which allows the turning of the plate for tuning different lines of the main laser. With an additional rotator the plate can be tuned precisely to the Brewster's angle resulting in lowest reflection losses.

# P5856 Laser frequency stabilisation

- ✓ *Laser cavity*
- ✓ *Doppler broadened gain profile*
- ✓ *Two mode HeNe-laser*
- ✓ *Frequency pulling and pushing*
- ✓ *Mode separation*
- ✓ *Digital - controller*
- ✓ *Zeeman effect*
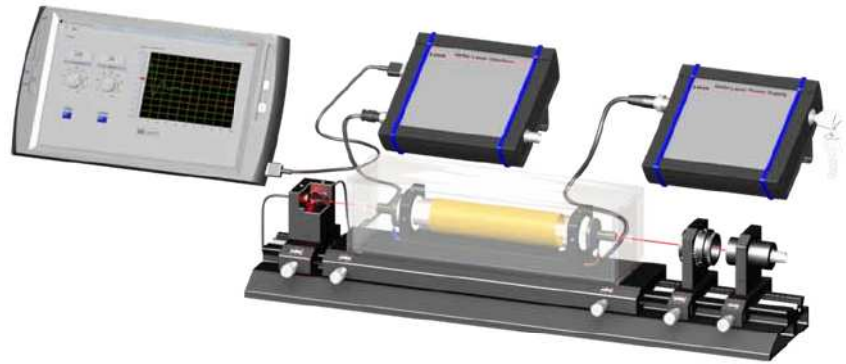


## Principle of operation

The two longitudinal modes emitted by a Helium Neon laser are orthogonally polarised to each other. Their individual intensity is measured by using a polarising beam splitter cube (PBSC) as mode separator and a photodiode for each mode. If the intensity of both modes equals, they are symmetrically centred to the centre frequency of the laser transition. By controlling the temperature of the laser tube the intensity of both modes is kept constant resulting in a fixed frequency of the modes. A PI controller with variable coefficients is used for the stabilisation.



## Examples of investigation and measurement

### General set-up

A helium Neon laser tube (6) is covered by a acrylic housing for security reasons. The beam leaves on the right side and passes a polariser (8) before it hits the photodetector(3). On the left side of the tube a small fraction of the main las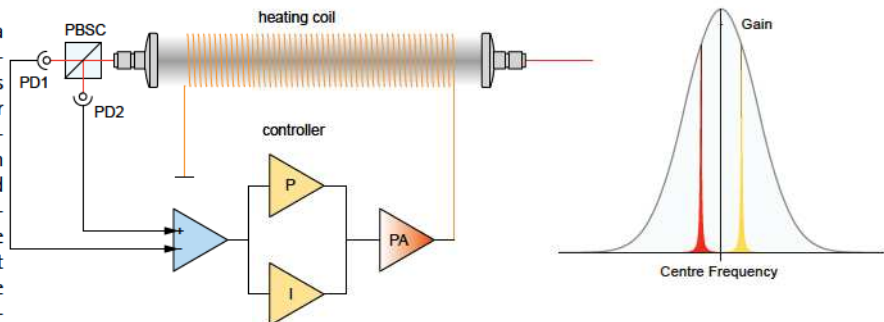er intensity leaves the tube which is used for the stabilisation. The tube is supplied with the necessary high voltage of the unit (1). The interface (2) provides the preamplifier for the photo diodes as well as the control amplifier for the bifilar heater winding. The pad computer (7) is connected to the interface (2) with a USB bus. The provided software running on the pad computer allows the configuration of the parameter of the control loop and monitoring of the stabilisation.
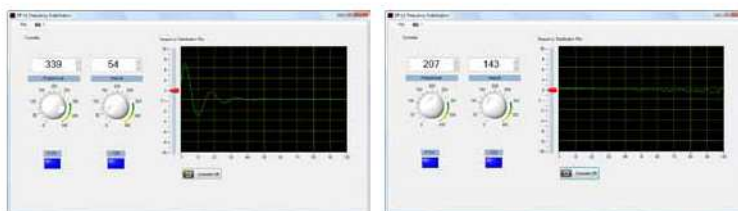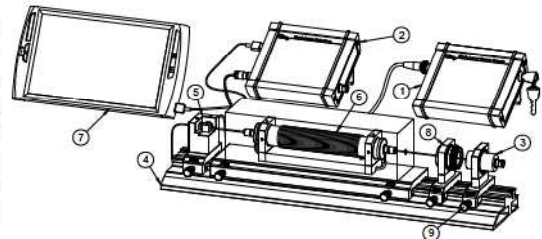




| Aperiodic limit | Almost perfect parameters |
| --- | --- |

### Operate and optimise a PI Controller

Each engineer or physicist will be faced with control tasks. This experiment therefore addresses also the operation of a proportional and integral controller. The software based controller allows the configuration of all relevant parameters. The reaction of the system is monitored and recorded so that the cases of the aperiodic limit, oscillating and stable state by modifying the control parameter can be observed. The monitor signal is the difference in intensity of both modes and the set point of the controller is zero.

## Zeeman effect

The Zeeman effect describes the splitting of atomic energy levels under the presence of an static magnetic field. To observe this effect in classical way very strong magnetic fields are required. Using an active laser material like the HeNe gas in our case even smallest splitting can be observed as beat frequency of both modes. For this purpose a photodetector (3) and a polariser (8) is used to detect the beat frequency. To create a weak magnetic field one element of the bifilar heater winding is switched off resulting in the creation of a weak longitudinal magnetic field causing the splitting of the energy levels. As a result a beat frequency of the two modes of some kHz occurs and can easily be measured with a simple oscilloscope.
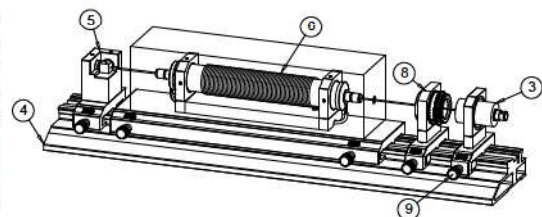


## P5856 Laser frequency stabilisation consisting of:

| Item | Qty | Description |
| --- | --- | --- |
| 1 | 1 | HeNe Laser high voltage supply |
| 2 | 1 | Laser frequency stabilizer LSF-01 |
| 3 | 1 | Photodetector Si PIN |
| 4 | 1 | Optical rail MG 65, 500 mm |
| 5 | 1 | Mode separator and photodiode |
| 6 | 1 | Two mode HeNe-laser |

| Item | Qty | Description |
| --- | --- | --- |
| 7 | 1 | PC Pad |
| 8 | 1 | Polarisation analyser, rotator, mounting plate |
| 9 | 1 | Mounting plate C25 with carrier 20 mm |

Option:

| | | |
| --- | --- | --- |
| | 1 | Oscilloscope 100 MHz digital, two channel |

**LEYBOLD**®

## P586 Solid State Laser

# P5861 Diode laser

✓ *Basics of semiconductors*
✓ *Types of laser diodes*
✓ *Spatial intensity distribution*
✓ *Spectral properties*
✓ *Polarisation properties*
✓ *Beam shaping*



# Examples of investigation and measurement
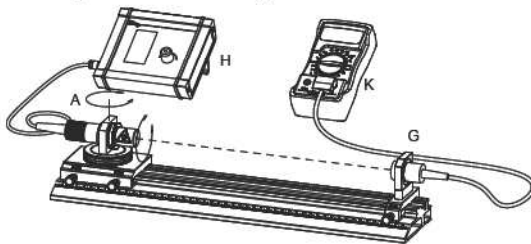


## Spatial intensity distribution

With the above set-up the beam geometry of the laser diode will be measured. The module A (laser diode with two axes rotational stage) and the photo detector (module G) are used.

The laser diode can be turned around its optical axis as well perpendicular to it. Turning the diode around its optical axis is needed to align the elliptical cross section of the diodes with respect to the plane of the horizontal rotational stage. By rotating this stage the angle resolved intensity distribution of the laser diode emission is measured.
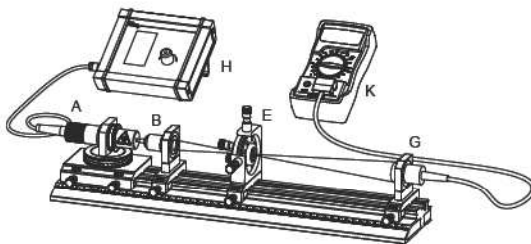


## Spectral Properties

The wavelength of a laser diode is determined by the maximum gain and the optical length of its resonator, which in turn depends on the temperature and the optical density inside the resonator relying on the injection current. The goal of this experiment is the measurement of these relations. To determine the wavelength, the Nd:YAG rod with its well known absorption transitions will be used. The rod is mounted into the module E and has a diameter of 3 mm and a length of 5 mm. The beam of the diode laser is focused by means of the module B into the rod. For different temperatures of the laser diode the maximum of absorption will be determined.
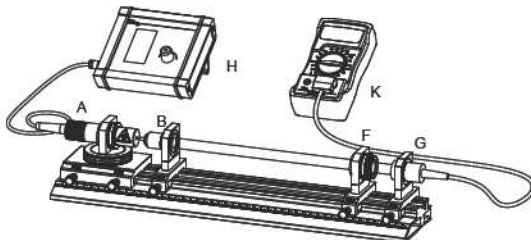


## Polarisation properties

To the set-up the module F is added. The module consists of a rotator with scale for rotating and reading the angle position of the polariser mounted into it. To obtain unambiguous polarisation states with respect to the polarisation analyser the laser light of the diode is collimated by means of the module B containing the focussing optics. The parallelism of the beam is checked with the IR screen and adjusted by the distance of the module B from the diode. The polarisation analyser is turned to a position for a sufficient signal. Now the injection current is varied and the intensity behind the analyser is measured.
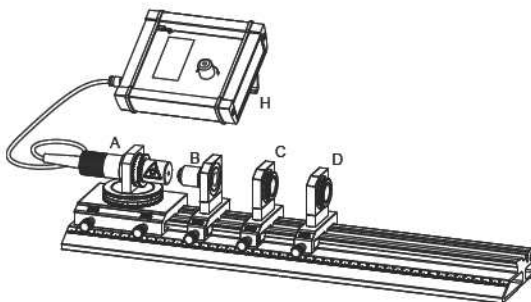


## Beam shaping

From the basics and carried out measurements it is known that the emitted beam of the laser diode exhibits a more or less strong divergence which in addition posses an significant astigmatism. Within this optional experiment different sets of lenses shall be used to correct the beam. Without optics which corrects for these errors, the use of diode lasers is very limited. Applications of laser diodes are only successful if one is able to transform the beam into the desired shape.

For this reason in this experiment three different optical element are used:

| | | |
|---|---|---|
| module B | Microscope objective | f=8.2 mm |
| module C | cylindrical lens | f=20 mm |
| module D | cylindrical lens | f=80 mm |

## P5861 Diode laser consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | BNC–Banana adapter connection leads |
| 2 | 1 | Collimating cylindrical lens f = 20 mm (C) |
| 3 | 1 | Collimating cylindrical lens f= 80 mm (D) |
| 4 | 1 | Digital diode laser controller (H) |
| 5 | 1 | Profile rail MG-65, 500 mm |
| 6 | 1 | Crossed hair target mounted in holder 25 mm |
| 7 | 1 | Infrared display card, spectral range 0.8 –1.6 µm |
| 8 | 1 | Digital multimeter 3 1/2 digits (K) |
| 9 | 1 | Module A - Diode laser head, adjustment holder |

| Item | Qty | Description |
|---|---|---|
| 10 | 1 | Module B - Collimating optics on carrier MG-65 |
| 11 | 1 | Module E - Adjustment holder with Nd:YAG rod |
| 12 | 1 | Module G - SiPIN photodetector |
| 13 | 1 | Polarisation analyser, mounting plate, rotator (F) |
| 14 | 1 | Optics cleaning set |
| 15 | 2 | Mounting plate C25 with carrier 20 mm |

Options:

| | | |
|---|---|---|
| | 1 | Oscilloscope 100 MHz digital, two channel |

**LEYBOLD**®

# P5862 Diode pumped Nd:YAG Laser

✓ *Properties of diode laser*

✓ *Nd:YAG crystal*

✓ *Rate Equation Model*

✓ *Static and dynamic solution*

✓ *Laser output power*

✓ *Laser resonator*

✓ *Transversal modes*

✓ *Cavity stability criterion*

✓ *Demonstration of Spiking*



## Principle of operation

The radiation of the diode laser is focused by means of the collimator (B) and lens (C) into the Nd:YAG rod (D). The laser cavity is formed by the coating (1) of the rod and the mirror (2). The filter (F) absorbs the residual pump light and transmits the laser radiation. The relative intensity is measured by the photodetector (G)



## Examples of investigation and measurement

### Characterization of the diode laser

In a basic set-up the characteristic parameters of the laser diode are measured. The diode laser is mounted into a housing (9) in contact with a Peltier element to control the temperature. The full digitally 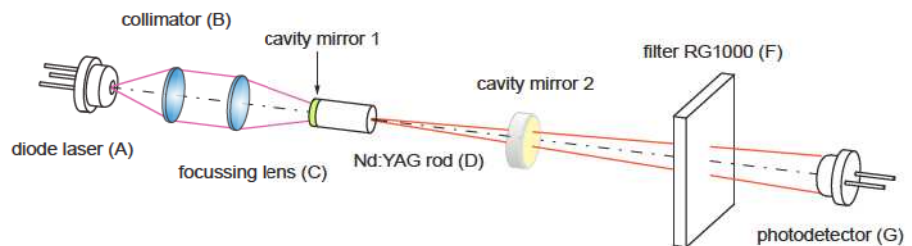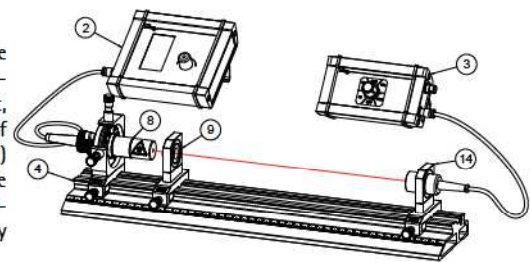controller (2) sets and maintains the value for injection current, temperature and modulation frequency of the diode laser (9). The characteristic data of the diode laser is measured in relative units. For this purpose the signal conditioner (3) is used. The photodiode (14) is connected to this box where the input impedance can be selected. The output is available at a BNC connector for further connection to an oscilloscope or multimeter. The collimator (9) is used to set the beam divergence in such a way that the photodetector will not be saturated.



### Optical pumping and spectroscopy

To the previous set-up the focussing lens (10) and the Nd:YAG rod (11) with its holder are added. The transmission spectrum of the laser diode radiation is measured by changing the temperature and therewith the emission wavelength. By means of the well known absorption lines the emission wavelength of the laser diode can be determined exactly. Adding the filter RG1000 (7) in front of the detector blocks the diode laser radiation and the fluorescence caused by optical pumping can be measured as function of the pump laser wavelength (temperature). At the maximum of the fluorescence emission the modulation of the diode laser is activated and the timely response displayed on an oscilloscope. From this curve the mean lief time of the exited laser state of the Nd:YAG material can be derived which inverse value represents the important Einstein coefficient for spontaneous emission.



### Laser operation

Adding the second cavity mirror (12) to the set-up and aligning it properly laser oscillation at the wavelength of 1064 nm is obtained. The optimum laser parameters with respect to pump power and wavelength are ascertained. The laser threshold and efficiency are determined and by modulating the pump laser diode the so called spiking effect is demonstrated. By changing the length of the laser cavity the stability criterion is verified. This is accomplished by moving the adjustment holder (12) and reading its position with respect to the holder (11) containing the Nd:YAG rod including the coating for cavity mirror (1).
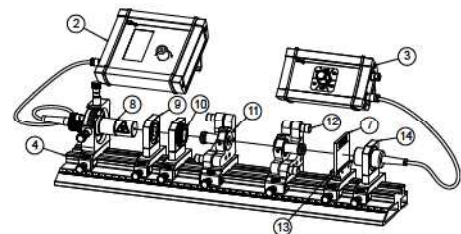


## P5862 Diode laser pumped Nd:YAG laser consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 3 | BNC cable, BNC connector both sides, 1,5 m |
| 2 | 1 | Digital diode laser controller |
| 3 | 1 | Photodetector signal conditioning box |
| 4 | 1 | Profile rail MG-65, 500 mm |
| 5 | 1 | Crossed hair target in holder 25 mm |
| 6 | 1 | Infrared display card, range 0.8 -1.6 µm |
| 7 | 1 | RG1000 Coloured glass filter 50x50x4 mm |
| 8 | 1 | Module A - Diode laser in adjustment holder |
| 9 | 1 | Module B - Collimating optics on carrier |

| Item | Qty | Description |
|---|---|---|
| 10 | 1 | Module F - Focussing optics, f=60 mm |
| 11 | 1 | Module D - Adjustment holder with Nd:YAG rod |
| 12 | 1 | Module E - Adjustment holder "right" with laser mirror SHG 100 |
| 13 | 1 | Module F - Filter plate holder |
| 14 | 1 | Module G - SiPIN photodetector |
| 15 | 1 | Optics cleaning set |

*Required Option:*

| | | |
|---|---|---|
| | 1 | Oscilloscope 100 MHz digital, two channel |

www.ld-didactic.com

# P5863 Frequency doubling

✓ *P5862 Nd:YAG laser*

✓ *Nonlinear optics*

✓ *Phase matching condition*

✓ *Conversion efficiency*

✓ *Verification of quadratically relationship SHG power*

✓ *Clear demonstration of higher transversal modes*

✓ *Intra cavity iris diaphragm for TEM$_{00}$ operation*

## Principle of operation

Inside the cavity formed by the mirror (M1) and (M2) a KTP crystal is placed. The frequency of the fundamental radiation is doubled generating visible green radiation at the wavelength of 532 nm. The filter (F) blocks the pump as well as fundamental radiation in such a way that only green radiation can be characterised.
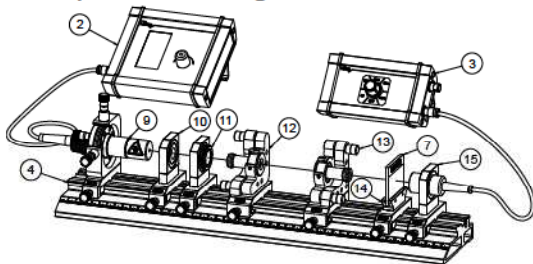


collimator (B)
laser mirror (M1)
Nd:YAG rod (D)
filter BG 39 (F)
diode laser (A)
focussing lens (C)
KTP crystal (K)
laser mirror (M2)
photodetector (G)

# Examples of investigation and measurement



## Characterization of diode pumped Nd:YAG laser

All experiments and measurements performed with P5862 Nd:YAG laser can be done as well with this setup.
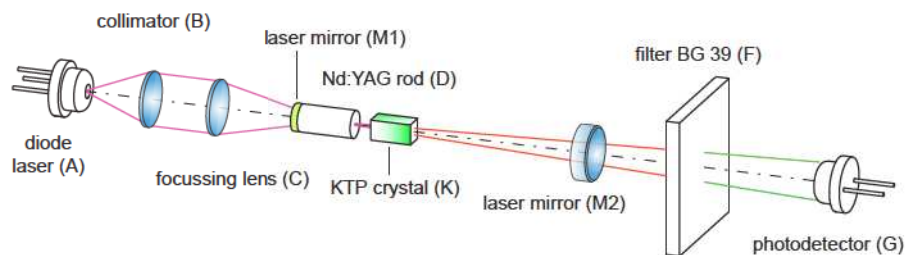In addition a KTP crystal (K) and the filter BG-39 (F) is provided which turns the P5862 experiment into a set-up for frequency doubling.
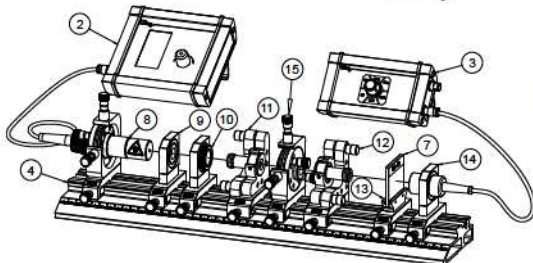
## Second harmonic generation

After aligning the basic set-up in the same way as already shown in XP-06 the KTP crystal assembly (16) is inserted inside the cavity It can be turned inside the adjustment holder for best phase matching indicated by highest green output power. Four fine pitch adjustment screws are used to align the crystal with respect to the optical axis of the laser cavity. The intensity of the second harmonic is measured as function of the fundamental power and the injection current of the pump laser respectively. The evaluation of the data will show the expected quadratic behaviour.
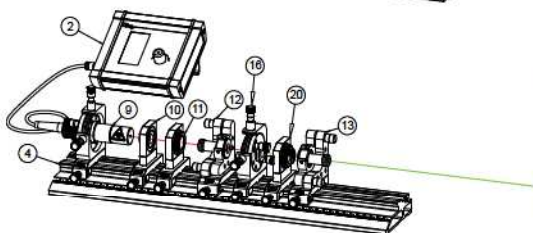
## Demonstration of transverse modes

Due to the high gain of the Nd:YAG material a lot of transverse modes are generated. Also from these modes second harmonics are generated and are visible due to their wavelength of 532 nm.
By placing the adjustable iris into the cavity close to the right mirror (12) the number of transverse modes can be reduced significantly down to pure TEM$_{00}$. This can be observed on a wall or white sheet of paper when the photodetector and filter is removed. In principle the BG-39 filter (7) can remain to avoid infrared emission leaving the system.

## P5863 Non linear optics, Second Harmonic Generation consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 2 | BNC cable, BNC connector both sides, 1,5 m |
| 2 | 1 | Digital diode laser controller |
| 3 | 1 | Photodetector signal conditioning box |
| 4 | 1 | Profile rail MG-65, 500 mm |
| 5 | 1 | Crossed hair target in holder 25 mm |
| 6 | 1 | Infrared display card, range 0.8 -1.6 μm |
| 7 | 1 | RG1000 Coloured glass filter 50 x 50 x4 mm |
| 8 | 1 | BG39 Coloured glass filter |
| 9 | 1 | Module A - Diode laser in adjustment holder |
| 10 | 1 | Module B - Collimating optics on carrier |
| 11 | 1 | Module F - Focussing optics, f=60 mm |

| Item | Qty | Description |
|---|---|---|
| 12 | 1 | Module D - Adjustment holder with Nd:YAG rod |
| 13 | 1 | Module E - Adjustment holder "right" with laser mirror SHG 100 |
| 14 | 1 | Module F - Filter plate holder |
| 15 | 1 | Module G - SiPIN photodetector |
| 16 | 1 | Module K - KTP crystal for SHG |
| 17 | 1 | Optics cleaning set |

*Required Option:*

| | | |
|---|---|---|
| 18 | 1 | Oscilloscope 100 MHz digital, two channel |

*Option:*

| | | |
|---|---|---|
| 20 | 1 | Spatial filter with adjustable iris diaphragm |

**LEYBOLD**®

# P5864 Red Second harmonic generation option

- ✓ Nd:YAG laser, 1.3 µ operation
- ✓ InGaAs photodetector
- ✓ Nd:YAG rod 1.3 µm coating
- ✓ KTP crystal 1.3 / 0.66 µm
- ✓ Second harmonic generation
- ✓ Bright red 660 nm radiation



## Principle of operation

Within the same setup as P5863 the Nd:YAG rod is replaced by a rod with a high reflectivity at 1.320 µm. In the same way the cavity mirror M2 is replaced against one with also a high reflectivity at 1.320 µm. The diode pumped Nd:YAG laser is now operating at this wavelength. A KTP crystal which is cut under such an angle with respect to its optical axis so that the phase matching condition for the second harmonic generation to 660 nm is obtained. The result is a bright red laser output.



collimator (B)
laser mirror (M1)
Nd:YAG rod (D)
filter KG5
diode laser (A)
focussing lens (C)
KTP crystal (K)
laser mirror (M2)
photodetector (G)



absorption

emission
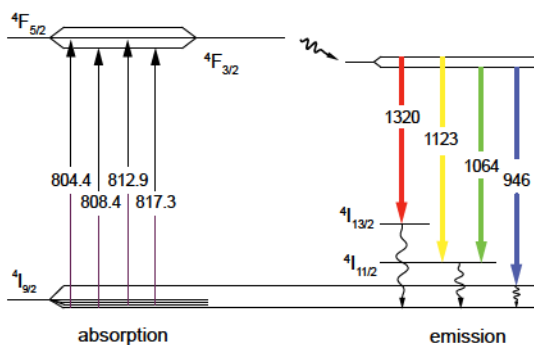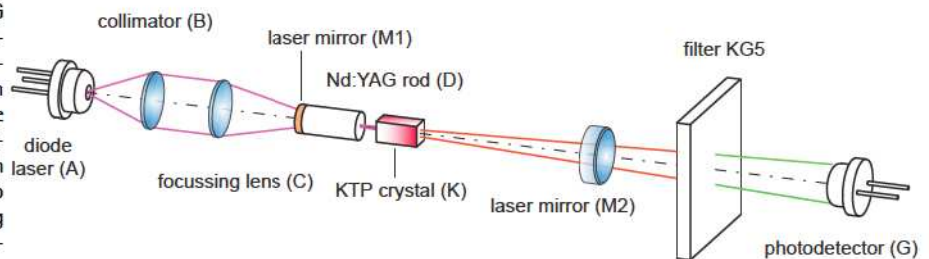
The system is switched from the 1.064 to the 1.320 nm laser operation

## Generation of "red" second harmonic radiation

After aligning the basic set-up in the same way as already shown in P5682 the Nd:YAG rod and the mirror SHG 100 are exchanged against the components coated for 1.3 µm. The system will operate immediately provided the basic setup was already aligned. The laser operation at 1.3 µm is verified with the IR card behind the RG1000 filter. Now the KTP crystal is inserted inside the cavity and already red laser emission should be visible on a piece of white paper. Turning the KTP inside the adjustment holder results in best phase matching indicated by highest red output power. Four fine pitch adjustment screws are used to align the crystal with respect to the optical axis of the laser cavity for further increase of the red light intensity. The intensity of the second harmonic is measured as function of the fundamental power and the injection current of the pump laser respectively. The evaluation of the data will show the expected quadratic behaviour.

## Upgrade kit for SHG 660 nm consisting of:

| Item | Qty | Description |
| --- | --- | --- |
| 1 | 1 | Nd:YAG rod 1.3 µm in mirror holder |
| 2 | 1 | Mirror SHG 1.3 µm In mirror holder |
| 1 | 1 | Coloured glass filter KG5, 50 x 50 x 3 mm |
| 3 | 1 | Red SHG Crystal in holder |

# P5865 Q-switch operation

- ✓ *P8562 Nd:YAG laser*
- ✓ *Q - switch by saturable absorption*
- ✓ *Peak power of laser pulse*
- ✓ *Width of laser pulse*
- ✓ *Repetition rate of pulses*
- ✓ *Maximum repetition rate*
- ✓ *Determining the average laser output power*
- ✓ *Optional active Q-switch*



## Principle of operation

The basic set-up of P8562 is enhanced by the saturable absorber module L which is placed into the laser cavity formed by mirror $M_1$ and $M_2$. The initial absorption prevents the laser oscillation. Under increasing induced emission due to the optical pump process the absorption decreases under the threshold of the laser.



## Examples of investigation and measurement
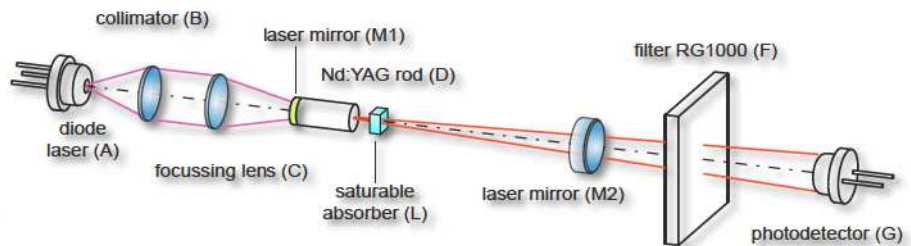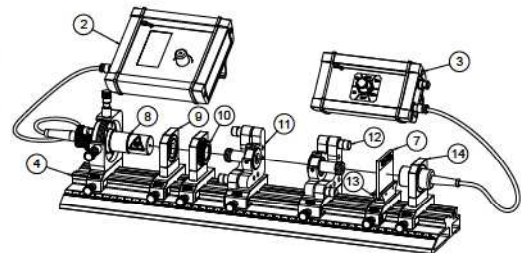### Characterization of diode pumped Nd:YAG laser

All experiments and measurements performed with P5862 laser can be done as well with this setup.
In addition a saturable absorber is provided which turns the P5862 experiment into a set-up for demonstrating passive Q-switch (L).



## Passive, mechanical and active Q-switch

After aligning the basic set-up in the same way as already shown in XP-06 the Q-switch crystal assembly (16) is inserted inside the cavity It can be turned and tilted inside the adjustment holder for highest peak output power. The output is monitored by means of the provided photodetector (14) which is connected to the signal conditioning box (3). The output of this box is connected via the BNC connector to an oscilloscope. As a result of the Q-switch crystal the output shows a train of pulses which peak power and repetition rate depends on the losses like pump efficiency as well as cavity losses. To demonstrate active Q-switch operation the optional Pockels's cell (22) including the necessary high voltage driver is applied. The cell comes with an adjustable brewster window to set the optimum polarisation parameter.
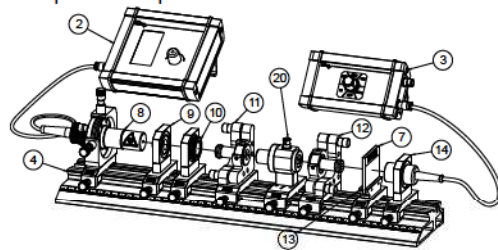


For the demonstration of basic Q-switching the optional mechanical light chopper is applied. Although no real Q-switching is obtained it shows the significant increase of the initial spike indicating the begin of Q-switching.
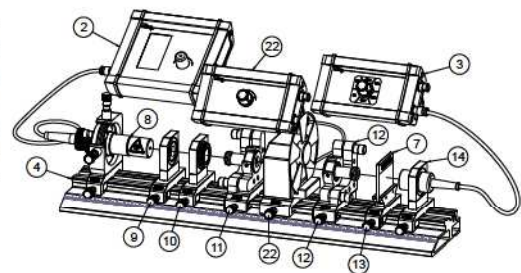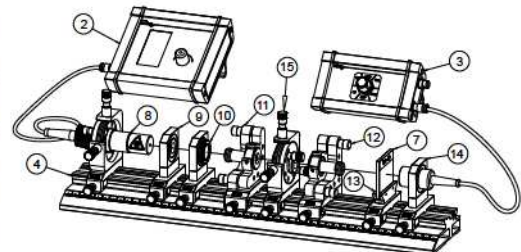


## P5865 Demonstration of short pulses with saturable absorber consisting of:

| Item | Qty | Description | Item | Qty | Description |
|---|---|---|---|---|---|
| 1 | 2 | BNC cable, BNC connector both sides, 1,5 m | 12 | 1 | Module E - Adjustment holder "right" with laser mirror SHG 100 |
| 2 | 1 | Digital diode laser controller | 13 | 1 | Module F - Filter plate holder |
| 3 | 1 | Photodetector signal conditioning box | 14 | 1 | Module G - SiPIN photodetector |
| 4 | 1 | Profile rail MG-65, 500 mm | 15 | 1 | Module P - Crystal for passive q-switch operation |
| 5 | 1 | Crossed hair target mounted in holder 25 mm | 16 | 1 | Optics cleaning set |
| 6 | 1 | Infrared display card, range 0.8 -1.6 µm | **Required Option:** | | |
| 7 | 1 | RG1000 Coloured glass filter 50x50x4 mm | | 1 | Oscilloscope 100 MHz digital, two channel |
| 8 | 1 | Module A - Diode laser, adjustment holder | **Options:** | | |
| 9 | 1 | Module B - Collimating optics on carrier | 20 | 1 | Active Q-switch with Pockels's cell and HV driver |
| 10 | 1 | Module F - Focussing optics, f=60 mm | 22 | 1 | Mechanical light chopper, intracavity |
| 11 | 1 | Module D - Adjustment holder with Nd:YAG rod | | | |

**LEYBOLD**®

# P5866 Pulsed diode laser

- ✓ *Fundamentals of semiconductor laser*
- ✓ *Types of pulsed diode laser*
- ✓ *Peak power of laser pulse*
- ✓ *Duty cycle*
- ✓ *Repetition rate of pulses*
- ✓ *Average output power*
- ✓ *Spatial radiation distribution*

## Examples of investigation and measurement

Measuring the repetition rate    Measuring the pulse width

### Temporal properties

Pulsed diode lasers emit a sequence of short pulses with a pulse width of 50 - 100 nanoseconds. The repetition rate depends on the duty cycle which is typically 0.1 %. Similar to a flash lamp the laser can emit a very high peak power in a short time. This qualifies pulsed diod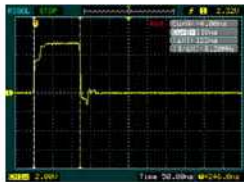e laser for remote sensing application like LIDAR and range finding. Within this experiment the temporal and spatial properties of a diode laser emitting a peak power of 70 W within a pulse width of 100 ns. The electrical as well as optical pulse is monitored on an digital oscilloscope with USB connection for plotting or saving the measured plots.

### Spatial energy distribution

As already known from continuous working laser diodes the elliptically shaped emission is strongly divergent. Within this parts of the experiments the spatial intensity distribution is measured by using the photodetector (2) which is mounted onto the swivel arm of the unit (13). The photodetector is connected to a digital meter which is operated in the A mode measuring the photo current of the detector. By turning the swivel arm the angle resolved intensity distribution is recorded.

The laser (7) is mounted into a 4 axes adjustment holder with additional rotary insert so that the laser can be turned around its axis. By means of the scale the rotation angle can be read. Turning the laser to the main axes of the elliptical beam and measure the angle resolved intensity distribution provides three dimensional plot of the emission cross section.

### Polarisation properties

This experiment shall provide information about the polarisation properties of pulsed diode laser. For this purpose a polarisation analyser (1) is placed onto the swivel arm in front of the photodetector (2). The polarisation extinction is measured for different values of the injection current by rotating the polariser firstly to the maximum and subsequently to the minimum of the transmitted radiation.

### Collimated radiation

From the measurements of the spatial intensity it is known that for a application the emissions needs to be collimated. This done within this section of the experiments. From the measurements can be concluded what focal length and aperture a lens should have to get an almost parallel beam. The requirements for a short focal length with a large aperture can not be fulfilled by a single lens.

Typically three element collimators are used to obtain the highest collimation and subsequently highest transmission of the divergent light. The provided module B (10) contains such a collimator mounted in a holder which is placed in front of the diode laser. The adjustment screws of the holder of the diode laser are aligned in such a way that the beam passes the collimaotr centrically.

## P5866 Pulsed diode laser consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Polarisation analyzer 40 mm |
| 2 | 1 | Photodetector for pivot arm |
| 3 | 1 | IR converter screen  0.8 - 1.6 µm |
| 4 | 1 | BNC T - connection piece |
| 5 | 1 | BNC shunt resistor 50 Ohm |
| 6 | 1 | Pulsed laser diode controller PLDC-01 |
| 7 | 1 | Pulsed diode laser module |
| 8 | 1 | Profile Rail OCM 650, 500 mm with ruler |
| 9 | 1 | Digital multimeter 3 1/2 digits |

| Item | Qty | Description |
|------|-----|-------------|
| 10 | 1 | Module B - Collimating optics on carrier MG-65 |
| 11 | 1 | Triple swivel unit |
| 12 | 1 | Adjustment holder, 4 axes, rotary insert , C20 |

Required Option:
|  | 1 | Oscilloscope 100 MHz digital, two channel |

Options:
|  | 1 | Laser power meter LabMax-TO |
|  | 1 | Laser energy sensor head 300 nJ - 600 µJ |

www.ld-didactic.com

# P5867 Diode pumped Nd:YVO4 Micro Laser

✓ *Diode laser*

✓ *Optical pumping*

✓ *Nd:YVO$_4$ laser*

✓ *Spiking*

✓ *Laser threshold*

✓ *Slope efficiency*

✓ *Second harmonic generation*

## Principle of operation

A green core laser (GCL) has a size of 1.3 x 1.3 x 3 mm and consists of a Neodymium Yttrium Vanadate (Nd:YVO$_4$) crystal which is cemented to a KTP crystal. The outer side (M1) of the Nd:YVO$_4$ is coated in such a way that it transmits the emission of the pump diode laser and reflects the fundamental radiation at 1064 nm and the second harmonic at 532 nm. The mirror M2 forms the second cavity mirror and is designed of high reflectivity of the fundamental wave and high transmission for the second harmonic. Once the laser reaches the threshold radiation at 1064 and 532 nm is emitted.
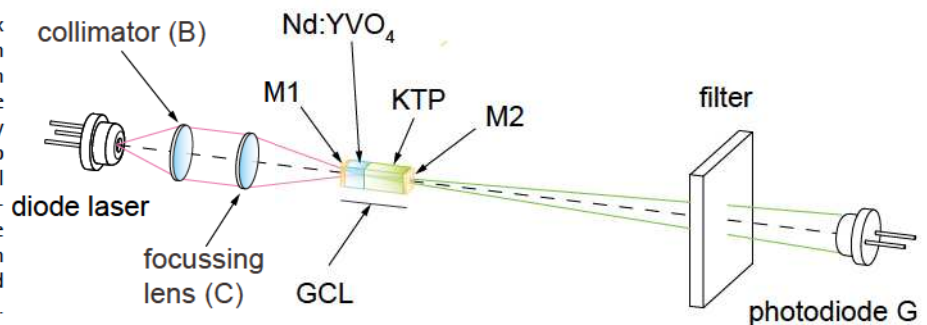


## Examples of investigation and measurement

### General setup



The laser diode (8) emits the pump radiation at 808 nm and the divergent radiation is collimated by a three element lens system (9) and subsequently focussed with the single lens (10) having a focal length of 60 mm. The GCL (14) is mounted into a special holder to provide efficient passive heat dissipation. The GCL is positioned in such a way that the focus of the pump radiation lies well within the Nd:YVO$_4$ crystal. As soon as the laser reaches its threshold also green light is created. To study only the fundamental radiation a RG1000 filter(6) is placed in front of the photodetector (12). The signal conditioning box (2) provides a BNC output which is connected to the oscilloscope.
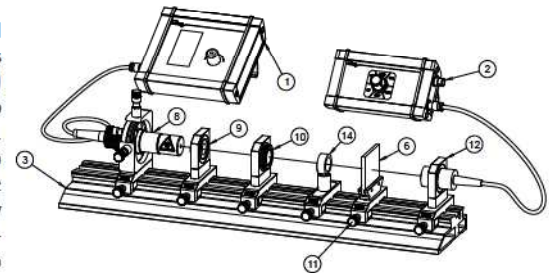
### Alignment procedure

The pump laser radiation is collimated (9) and centred to the optical axis of the optical axis of the rail. The pump radiation can be seen on white or black background, thus a crossed hair target (4) can serve as an alignment aid. Once the radiation is almost parallel and aligned to the optical axis the focussing lens (10) is placed onto the rail. With a white sheet of paper the position of the focus is searched and noted by the reading the ruler attached to the rail. At this position the GCL is placed. The output power is maximised by realigning the pump laser and moving the focussing lens.
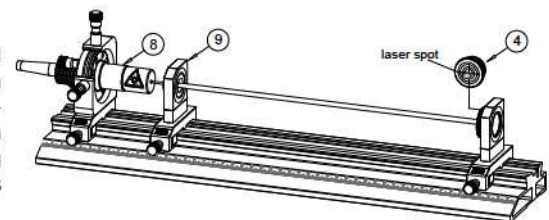
### Measurements

The pump laser diode is connected to the digital controller (1) which allows the variation of the injection current and temperature. In a first step the laser diode is characterised by this parameters. Operating the GCL allows the measurement of the static laser properties like threshold and out put power related to the pump power. The controller also allows the modulation of the injection current of the pump laser so that the dynamic properties like spiking and pump depletion can be studied.
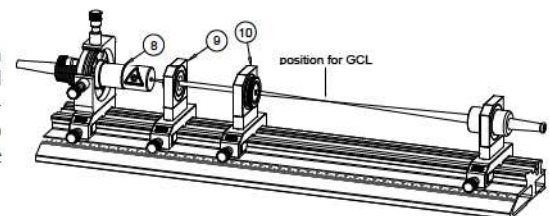
## P5867 DPSS Micro laser consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Digital diode laser controller |
| 2 | 1 | Photodetector signal conditioning box |
| 3 | 1 | Profile rail MG-65, 500 mm |
| 4 | 1 | Crossed hair target mounted in holder 25 mm |
| 5 | 1 | Infrared display card, spectral range 0.8 -1.6 µm |
| 6 | 1 | RG1000 Coloured glass filter 50 x 50 x 4 mm |
| 7 | 1 | Set of 3 BNC cables each 1 m |
| 8 | 1 | Module A – Diode laser head, adjustment holder |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 1 | Module B – Collimating optics on carrier MG-65 |
| 10 | 1 | Module C – Focussing optics, f=60 mm |
| 11 | 1 | Module F – Filter plate holder |
| 12 | 1 | Module G – SiPIN photodetector |
| 13 | 1 | Optics cleaning set |
| 14 | 1 | GLC, mounted on carrier 20 mm |

Required Option:

| | 1 | Oscilloscope 100 MHz digital, two channel |
|--|---|---------------------------------------------|

**LEYBOLD**®

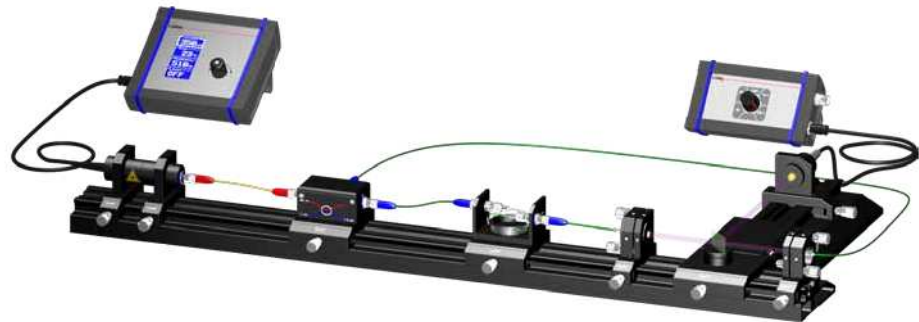# P587 Optical Fibres

# P5871 Fibre Laser

✓ *EDF – Erbium doped fibre*

✓ *WDM coupler*

✓ *Optical pumping*

✓ *Linear and ring fibre laser*

✓ *Passive mode locking*

✓ *Femto second pulses*

✓ *Spectral condensation*

## Examples of investigation and measurement

### Principle of operation

An Erbium doped fibre is used as active material. To form a ring laser a WDM is used to couple the pump light into the fibre and to close the ring structure. The ring is opened where a thin glass plate couples a small fraction of the clockwise (cw) and counter clockwise (ccw) laser modes. By means of a SiPIN photodetector the radiation of the pump laser of 980 nm is detected and a InGaAs photodiode is used for the laser oscillation of 1.5 μm. The pump laser is controlled by the controller (3) allowing the change of the temperature, injection current and modulation frequency.
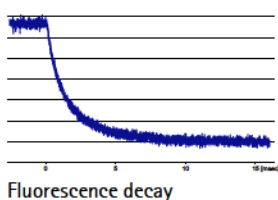
### Linear fibre laser

One end of the Erbium doped fibre (10) is connected to the pump laser and the other one to the fibre collimator (13). The emitting radiation is reflected back into the fibre with the mirror (1). A fraction of the radiation passes the mirror and is detected by the photodiode (6). Before the laser operation at 1.5 μm is studied, the lifetime of the exited state is measured.

Fluorescence decay
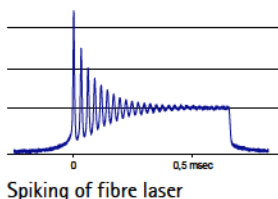
### Ring fibre laser

The WDM coupler as well as the output coupling assembly is placed onto the rail. Due to the high gain the adjustment is not critical and laser oscillation is obtained once the fibre collimator are aligned to each other. The alignment is monitored on an oscilloscope using the signal of the photodetector.

Spiking of fibre laser

### Spectral condensation
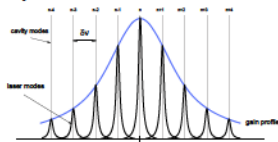
The mode spacing δν of a ring laser is c/2L whereby c is the speed of light inside the fibre and L the length of the ring laser. With the 16 m long fibre the beat frequency of the modes is 6.2 MHz. Extending the length by 100 m neutral fibre results in 0.8 MHz which can be observed on the oscilloscope. Reducing the spectral distance of the modes results in single mode operation due to spectral condensation

Mode spectra of a cavity

### Passive Mode locking

The feedback mirror (1) of the linear set-up is replaced by a semiconductor saturable absorber mirror (SESAM) as a passive mode locker. The fibre length determines the pulse repetition rate and the pulse duration which will be some hundred femtoseconds determined by the dispersion and the gain. The gain also depends on the pump power and is controlled by the injection current of the pump laser diode.

The femtosecond pulses can be measured by using the manual optical delay line.
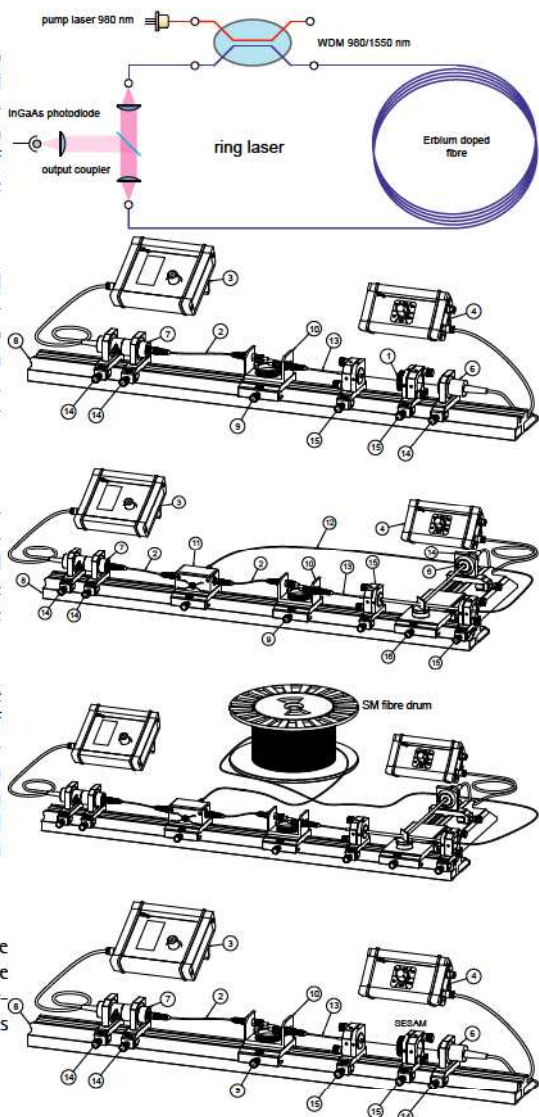
## P5871 Fibre Laser consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Front surface mirror, C25 mount |
| 2 | 2 | Fibre Patch cable ST, length 0.25 m |
| 3 | 1 | Digital diode laser controller |
| 4 | 1 | Photodetector signal conditioning box |
| 5 | 1 | Photodetector Si PIN with connection leads |
| 6 | 1 | Photodetector InGaAs with connection leads |
| 7 | 1 | Diode laser module, ST fibre connector |
| 8 | 1 | Profile rail MG-65, 800 mm |
| 9 | 1 | Carrier 65 mm |
| 10 | 1 | Erbium doped fibre 8 m module, ST connectors |
| 11 | 1 | WDM 980/1550 nm with ST connector on carrier |
| 12 | 1 | Fibre collimator with ST connector 1 m |
| 13 | 1 | Fibre collimator with ST connector, 15 cm |

| Item | Qty | Description |
|---|---|---|
| 14 | 3 | Mounting plate C25/40, carrier 20 mm |
| 15 | 2 | Adjustment holder 40-20, carrier 20 mm |
| 16 | 1 | Output coupling module |
| Required Option: | | |
| | 1 | Oscilloscope 100 MHz digital, two channel |
| Options: | | |
| | 1 | Passive mode locker module 1.5 μm |
| | 1 | Optical isolator, 1,5 μm, SM Fiber, ST |
| | 1 | SM Fibre 100 m on drum, ST connector |
| | 1 | Erbium doped fibre 2 m module, ST connectors |
| | 1 | Erbium doped fibre 4 m module, ST connectors |
| | 1 | Erbium doped fibre 16 m module, ST connectors |
| | 1 | Manual optical delay line |

# LEYBOLD®

# P5872 Plastic optical fibre (POF)

✓ *Plastic optical fibre POF*

✓ *Dual LED modulator*

✓ *Dual colour LED head, F-SMA*

✓ *Y POF coupler*

✓ *Signal transmission*

✓ *Dichroitic beam splitter*

✓ *Si Photodetector receiver*

✓ *Wavelength dependant losses in POF*
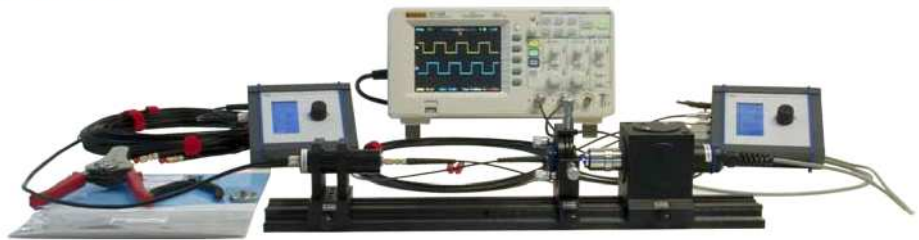


## Principle of operation:

The radiation of the blue and red LED is merged and launched into the plastic optical fibre by means of the Y coupler. The lens (L1) focuses the radiation after passing the fibre onto the two photo detectors ("blue") and ("red"). The dichroic beam splitter plate separates the radiation into the initial two wavelength ranges blue and red. The quality of the channel separation depends mainly on the separation quality of the dichroic beam splitter.
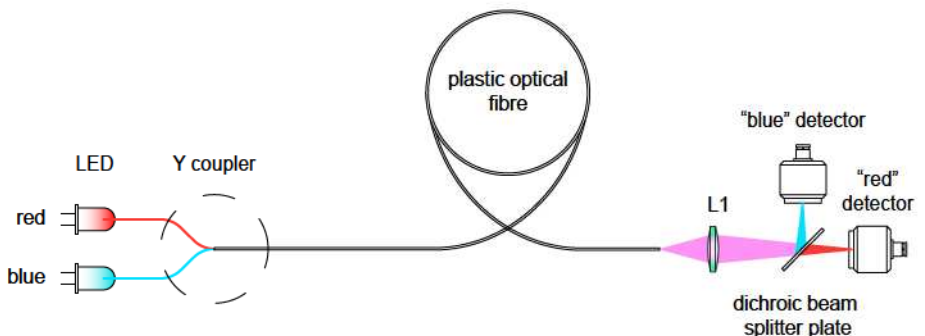


# Examples of investigation and measurement

## Preparing the fibre

The experimental kit provides all tools and materials to train the preparation of the plastic optical fibre like cutting, stripping (A), assembling the F-SMA connector (B) and polishing support as well as polishing (C). For the polishing fine grinding and polishing paper are provided. A comprehensive explanation on professional grinding and polishing of plastic optical fibre is given inside the manual which comes along with the kit.
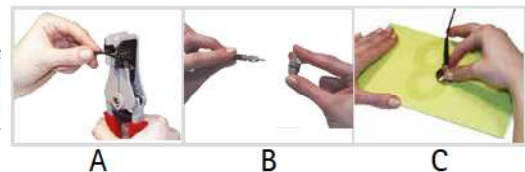


## Characterising the LED

Two independent LED, one emitting in the blue and the other one in the red spectral range are attached to the input of a Y - coupler in such a way that both emissions are coupled into one optical fibre. This arrangement is built into one housing (11) having one F-SMA fibre connector. The dual LED head is inserted into its holder (13) which is placed close to the detection unit (15). The dual LED head is further connected to the dual channel transmitter (10) allowing the individual control of injection current and modulation of each LED. The aim of this measurement is the characterization of the LED, demonstration of a WDM (wavelength division multiplexing) and WDDM (wavelength division de-multiplexing).
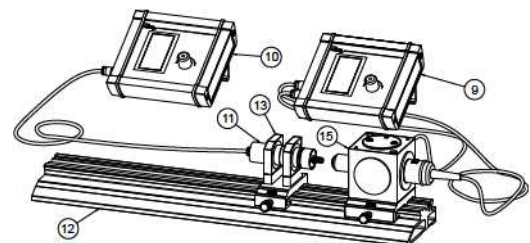


## Measuring the attenuation of the plastic optical fibre

The set-up is modified in such a way that the plastic fibre holder with XY-adjustment is added. The output of the inserted fibre (5) is measured for the provided three different length of the plastic optical fibre. From the recorded values the attenuation of the fibre is determined. In addition two or three fibres can be coupled together by means of the provided F-SMA coupler (1) and the losses of the connectors determined.
In additional measurements the crosstalk of the setup is determined and the component causing the crosstalk is identified.
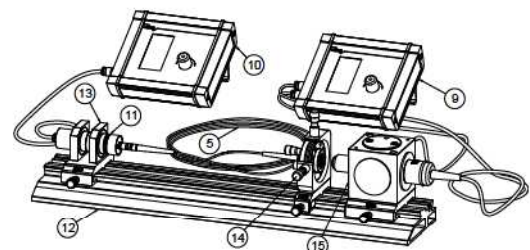


## P5872 Plastic Fibre Optics consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 2 | Coupler F-SMA for POF |
| 2 | 2 | BNC mini to BNC connection leads 1m |
| 3 | 1 | Connection cable 7 pin jack on both sides |
| 4 | 1 | Wall Mount Power Adapter 12V/12W |
| 5 | 1 | Plastic optical fibre, length 10 m |
| 6 | 1 | Plastic optical fibre, length 20 m |
| 7 | 1 | Plastic optical fibre, length 30 m |
| 8 | 1 | F-SMA connector mounting set |

| Item | Qty | Description |
|------|-----|-------------|
| 9 | 1 | Dual channel receiver PFR-040 |
| 10 | 1 | Dual channel transmitter PFD-030 |
| 11 | 1 | Dual LED - FSMA |
| 12 | 1 | Profile Rail MG 65, 500 mm |
| 13 | 1 | Mounting assembly for dual LED head |
| 14 | 1 | Plastic fibre holder with XY-adjustment |
| 15 | 1 | Mounting cube, focusing optics, dichroitic beam splitter, 2 photo diodes |

# P5873 Glass fibre optics

- ✓ *Coupling of light to fibres*
- ✓ *Coupling Optics*
- ✓ *Diode laser*
- ✓ *Characterization of glass fibres*
- ✓ *Cutting of fibres*
- ✓ *Signal transfer via glass fibres*
- ✓ *Speed of light*

## Examples of investigation and measurement
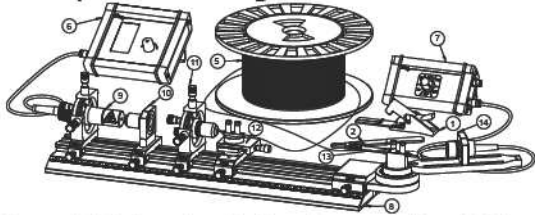
### General set-up

This set-up has been made with a multimode fibre. Because of didactic reasons a bare fibre without extra protective coating has been selected. The cut and cleaved fibre is put into the groove of holder (12) and carefully fixed with the two magnets. The laser diode in its housing (9) is mounted on a four axes fine adjustment holder. A Peltier cooler and a thermistor for measuring the laser diode temperature are built into the housing. The laser diode emits a maximum power of 50 mW as laser of class 3B.
A microscope objective (10) collimates the laser diode radiation.

The module (11) consists of a fine adjustment holder with four axes and an objective of smaller focal length to focus the collimated laser diode radiation in such a way that an effective coupling to the fibre is ensured. 1000 m multimode fibre (5) are coiled up on a drum.
The second fibre holder (13) is mounted on a hinged joined angle connector.
The module (14) consists of the detector with a PIN photodiode and is mounted on top of the pivot arm. By turning the arm the angle resolved intensity distribution either of the laser diode or the fibre output can be measured. The module is connected to the signal conditioner box (7) where a BNC socket is provided to connect the output either to an oscilloscope or digital multimeter.
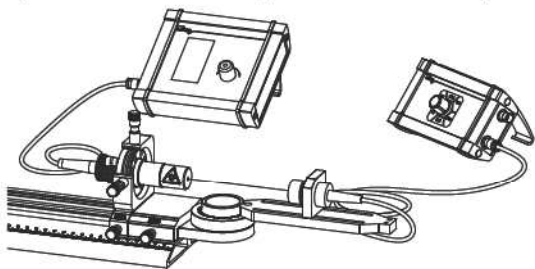
### Properties of diode laser

By means of the set-up shown on the left the intensity distribution of the laser diode is measured. For this reason the laser diode module is set quite near to the rotation joint so that the unavoidable distance L from the axis of the rotation joint is a minimum. To measure the intensity distribution as a function of the angle with reference to another axis of the laser diode, the latter one can be rotated in its holder. With the same set-up, but the detector under 0º to the laser diode, the output power is measured as a function of the injection current and the temperature of the laser diode. Attention has to be paid to the fact that the detector does not approach saturation, which can be assured by choosing the distance to the laser diode in an appropriate manner.

### Characterization of glass fibres

The pivot arm carrying the photodetector (14) is used to measure the angle resolved intensity distribution. The smallest distance is predetermined by the rotation joint. The power is measured for different angles. Here, too, we use modulated light to eliminate the influence of environmental disturbances.
In determining the numerical aperture we will meet some physical effects which make the interpretation of the measured values a bit difficult. We are speaking about the cladding waves which leave the fibre together with the core waves simulating an aperture which is just too high. At larger distances of the detector this influence is remarkably reduced.

### Speed of light

Another very interesting experiment is the measurement of the transit time of light through the fibre. The set-up is modified so that the detector is again next to the end of the fibre in holder E. The detector is connected to the signal conditioning box (module P) and the shunt is set to 50 Ω to reduce the rise time of the photodiode to the nano second range. The output of the signal conditioning box is connected to the first channel of the oscilloscope. The second channel is connected to the monitor exit of the modulation output at the control unit (module H). The difference in time of the rising edges of the start pulse and the photodetector signal corresponds to the speed of light and the length of the fibre

## P5873 Glass fibre optics consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Optical fibre cleaver and breaker S315 |
| 2 | 1 | Adjustable plastic cover stripper 103-S |
| 3 | 1 | IR converter screen 0.8 - 1.6 µm |
| 4 | 1 | BNC connection leads, set of 2 |
| 5 | 1 | Optical glass fibre, 1000 m, core 50 µm multi mode |
| 6 | 1 | Digital diode laser controller |
| 7 | 1 | Photodetector signal conditioning box |
| 8 | 1 | Optical rail MG 65, 500 mm |
| 9 | 1 | Module A - Diode laser head, adjustment holder |
| 10 | 1 | Module B - Collimating optics on carrier |

| Item | Qty | Description |
|------|-----|-------------|
| 11 | 1 | Coupling optics, with XY- adjustment holder |
| 12 | 1 | Bare fibre holder with translation stage |
| 13 | 1 | Module E, bare fibre holder on rotation stage |
| 14 | 1 | Module G, SiPIN photodetector, mounting plate C25 |

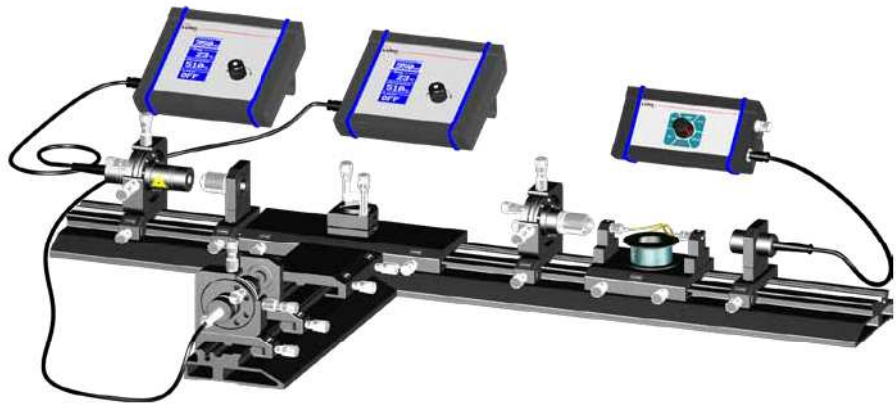**Required Option:**

| | | |
|---|---|---|
| | 1 | Oscilloscope 100 MHz digital, two channel |

**Options:**

| | | |
|---|---|---|
| | 1 | Optical glass fibre, 1000 m, core 9 µm mono mode |
| | 1 | Multimode optical fibre 5000 m, 50/125 µm |

**LEYBOLD®**

# P5874 Erbium doped fibre amplifier

✓ *Erbium doped optical fibre*

✓ *Pump laser diode*

✓ *Coupling light to fibre*

✓ *Optical Pumping*

✓ *Signal laser diode*

✓ *Optical amplification*

## Examples of investigation and measurements
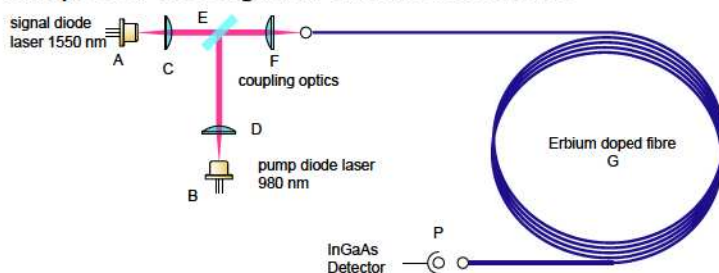
## Principle of operation

An Erbium doped fibre is optically pumped by a laser diode emitting at a wavelength of 980 nm. Due to the pump process a population inversion is created between two states with an energy difference corresponding to a wavelength around 1.5 µm. Signals having this wavelength will be amplified when passing the fibre. Such a signal is generated by a laser diode emitting a radiation of 1.5 µm which is also coupled into the fibre. For combining both emissions a dichroitic beam splitter plate (E) is used. The amplified or even fibre laser oscillation is detected by means of a InGaAs photodiode.

## General set-up

The EDFA fibre (15) is terminated with ceramic ferrules fixed to the assembly. The pump as well as the signal radiation is coupled with the module (13) into the Erbium doped fibre. The module (13) is provided with four fine pitch screws for XY and φϑ Adjustment. Turning the microscope objective results in a smooth translation to adjust the focus with respect to the entrance face of the fibre.

The module (14) combines the radiation of the signal as well as pump light by means of a dichroitic beam splitter plate. The plate is mounted into an adjustment holder for precise alignment of the reflected pump laser beam. The signal as well as the pump laser diode are mounted into precise 4 axes adjustment holder (17).

## Optical pumping and fibre laser

The experiment starts with the optical pumping of the erbium doped fibre. The pump laser radiation (D) is guided into the Erbium doped fibre. For simplification of the alignment process the modulation of the injection current is switched on and the oscilloscope is triggered with this signal. This allows the detection of even very small modulated signals when the oscilloscope is switched to AC mode. Once a transmission signal is detected the alignment can be improved and optimised. If this is done properly and the injection current of the pump laser diode set to the maximum laser oscillation at 1.5 µm can be observed since the gain is very high so that the Fresnel reflectivity of the fibre end surfaces is sufficient to form an optical cavity. Spiking as shown in the figure right will be observed.

## Optical amplification

Once the pump radiation has been launched to the fibre, the signal radiation needs to be fed through the fibre. The alignment strategy is the same as for the pump radiation. Once the signal radiation passes the fibre, the pump radiation (B) is modulated and the signal radiation not. As soon as amplification takes place the amplitude of the signal radiation is measured for different pump power and signal power levels and the maximum amplification determined.
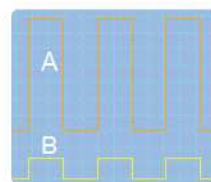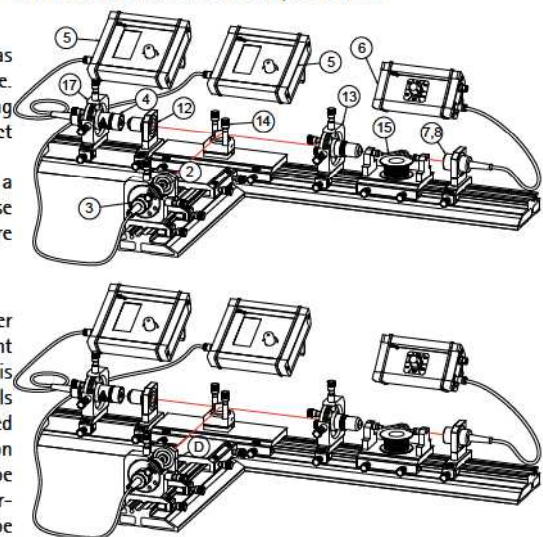
Optical amplification measured with an oscilloscope
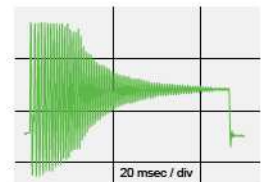
Spiking of the fibre laser operating at 1.5 µm

## P5874 Erbium doped Fibre Amplifier consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | BNC connection leads, set of 3 |
| 2 | 1 | Focusing optic, triplet, f=6 mm NA 0.6, click 25 mm |
| 3 | 1 | Dimo diode laser 980 (±10) nm, 80 mW |
| 4 | 1 | Dimo diode laser 1550 (±20) nm, 5 mW |
| 5 | 2 | Digital diode laser controller |
| 6 | 1 | Photodetector signal conditioning box |
| 7 | 1 | PIN Photodetector, BPX61 with connection leads |
| 8 | 1 | Photodetector, InGaAs in housing |
| 9 | 1 | Profile Rail MG-65, 300 mm |
| 10 | 1 | Optical rail MG 65, 500 mm |

| Item | Qty | Description |
|---|---|---|
| 11 | 1 | Infrared display card, spectral range 0.8 -1.6 µm |
| 12 | 1 | Collimating optics on carrier |
| 13 | 1 | Coupling optics, microscope objective x 20 |
| 14 | 1 | Dichroic beam combiner HR980, HT 1550 nm |
| 15 | 1 | Erbium doped fibre 17 m with holder |
| 16 | 2 | Mounting plate C25 with carrier 20 mm |
| 17 | 2 | Adjustment holder, 4 axes, carrier 20 mm |

Required Option:

|  |  |  |
|---|---|---|
|  | 1 | Oscilloscope 100 MHz digital, two channel |

# P5875 Optical time domain reflectometry OTDR

- ✓ *Short pulse laser diode*
- ✓ *Optical fibre*
- ✓ *Coupling light to fibre*
- ✓ *Si PIN fast photodetector*
- ✓ *Speed of Light*
- ✓ *Light echoes, fault detection*
- ✓ *Attenuation of optical fibre*
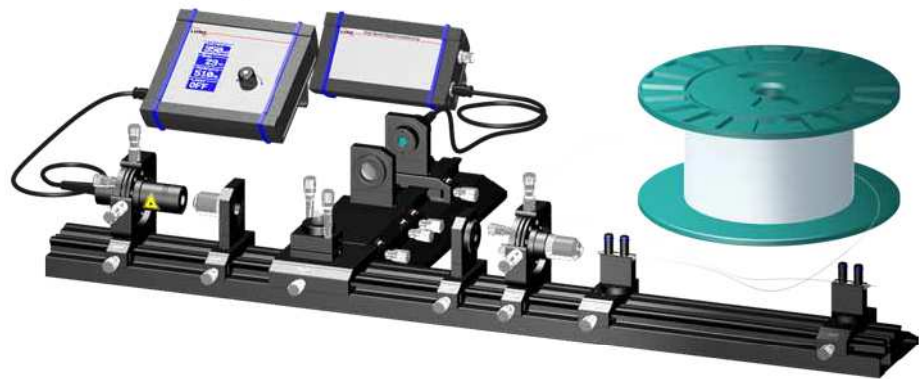


## Examples of investigation and measurement

### Principle of operation

The emission of a pulse laser diode (A) with a peak power of 70 W and a pulse width of 100 ns is collimated (B), passes the polarising beam splitter cube (PBSC) and is launched into the fibre (F) by the coupling optics (C). Micro structures which are more or less distributed homogeneously inside in every fibre are a result of the manufacturing process. Radiation which impinges on these structures disperses in such a way that the scattered light also reaches back to the entrance of the fibre. The back scattered light is diverted by the PBSC and focused to the photodetector (P). The quarter wave plate (Q) modifies the polarisation to obtain maximum signal at the detector.
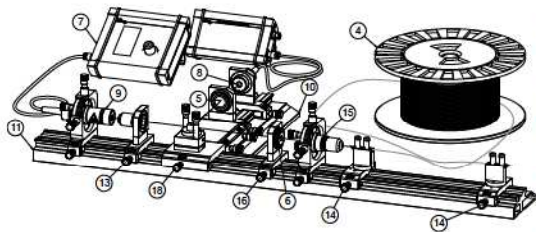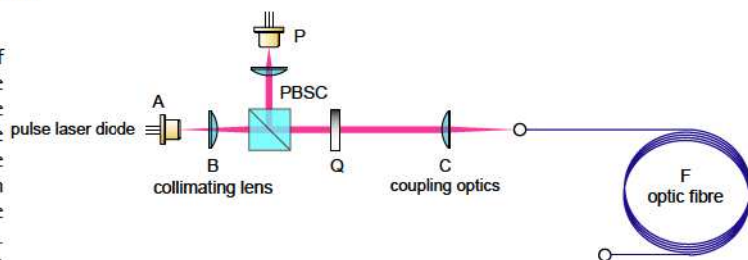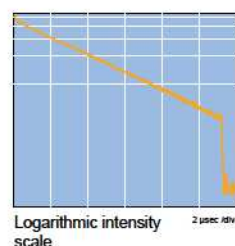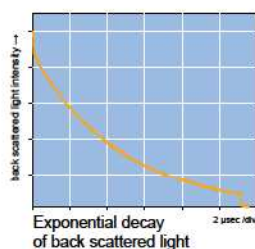


### General set-up

The pulse diode laser (4) is mounted into a 4 axes adjustment holder. The objective (13) collimates the strong divergent emission of the laser diode. The almost parallel light passes the polarising beam splitter cube (18) and is launched into the fibre by the objective (15). The fibre is placed into the groove of the holder (14) and fixed by magnets. The returning light has a different polarisation state and passes the rotary quarter wave plate (6) to achieve the highest degree of reflection at the beam splitter. The returning light is focused onto the fast photodetector (8). The signal is available at the BNC output of the signal conditioner box. The diode laser controller (7) allows the setting of the energy per pulse as well as the repetition rate up to 2.5 kHz.
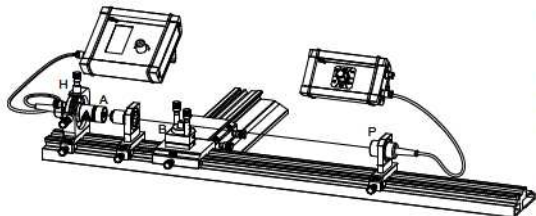
### Characterising the pulse diode laser

In a first task the properties of the pulsed diode laser are studied. For this purpose only the modules are shown in the figure left are required. The peak pulse is measured as function of the load voltage and repetition rate. By using the data of the laser diode the peak power can be determined.

The diode laser (A) can be rotated within the holder (H) and the polarisation recorded for different angle positions. For the OTDR measurements it is important that the diode laser is orientated in such a way that the maximum of intensity passes the polarising beam splitter (B).

### OTDR Measurements

With the completed setup as already shown in the general setup the OTDR measurements performed using the optical multimode fibre having a length of 1000 m. Thus approximate time of flight is 2 x 5 μsec which can be monitored with a 100 MHz oscilloscope. The figure on the left shows the exponential decay of the back scattered light. This is related to the losses along the fibre. Therefore exponential part of the curve contains the information about these losses. From the slope of the logarithmic intensity curve the absorption can be calculated.



Exponential decay of back scattered light

Logarithmic intensity scale

## P5875 Optical Time Domain Reflectometry (OTDR) consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Optical fibre cleaver and breaker |
| 2 | 1 | Adjustable plastic cover stripper |
| 3 | 2 | BNC cable, BNC connector both sides, 1,5 m |
| 4 | 1 | Optical glass fibre, 1000 m, core 50 μm multi mode |
| 5 | 1 | Biconvex lens, f=60 mm, C25 |
| 6 | 1 | Quarter wave plate, click 25 |
| 7 | 1 | Pulsed laser diode controller PLDC-01 |
| 8 | 1 | Photodetector, ultrafast with amplifier |
| 9 | 1 | Pulsed diode laser module |
| 10 | 1 | Profile rail MG-65, 300 mm |

| Item | Qty | Description |
|------|-----|-------------|
| 11 | 1 | Profile rail MG-65, 800 mm |
| 12 | 1 | Infrared display card, spectral range 0.8 -1.6 μm |
| 13 | 1 | Module B - Collimating optics on carrier |
| 14 | 2 | Bare fibre holder with carrier 30 mm |
| 15 | 1 | Coupling optics, microscope objective x 20 |
| 16 | 3 | Mounting plate C25 with carrier 20 mm |
| 17 | 1 | Adjustment holder, 4 axes, carrier 20 mm |
| 18 | 1 | Beam splitter module |

Required Option:

| | 1 | Oscilloscope 100 MHz digital, two channel |
|--|---|---|

# P5876 Signal transmission via optical fibre

- ✓ *Video Audio over optical glass fibre*
- ✓ *Fibre transmitter*
- ✓ *CCD Camera*
- ✓ *5000 m Optical multimode fibre*
- ✓ *Fibre receiver*

## Examples of investigation and measurements

### Setup of the sender site

An optical fibre (3) with a length of 5000 m is wound up on a spool with a patch panel for the connection with ST connectors. On the sender site a transmitter (1) for audio and video signal transfer is connected to the fibre (3). A CCD camera (5) and a CD player (6) are used as video and audio source respectively. Optionally the fibre coupling module (8) is used to demonstrate and train fibre coupling online.
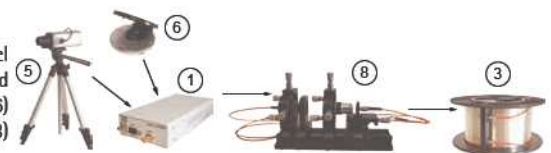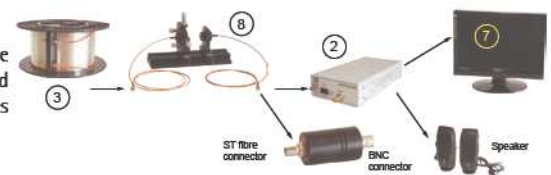
### Fibre coupling module

The unit is connected via a fibre patch cable (4) from module (K) to the transmitter (1) and from module (N) to the optical fibre line (3). The module L is used to collimate the from the fibre emerging light. The module (M) consists of a 4 axes adjustment holder with a microscope objective to focus the light back to the fibre of module N. The fibre of module N is mounted on top of a translation stage do adjust the distance between the objective and the fibre face in such a way that best coupling efficiency is achieved. The quality of the adjustment can be monitored by the photodetector which has a ST connector in the front and a BNC connection at the rear so that an oscilloscope can be connected and used as a monitor.
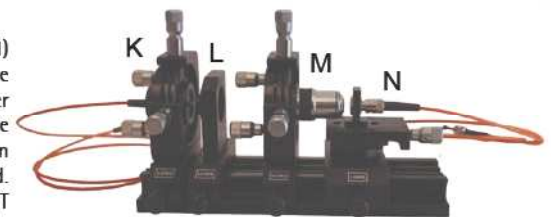
### Setup of the receiver site

If the optional fibre coupling module is not available the fibre is directly connected to the receiver module (2). The speaker as well as the TV monitor is connected to the unit and the image of the CCD camera becomes visible and the music of the CD player becomes audible.

### Fibre coupling module of the receiver site.

This module is useful for demonstrating the fibre to fibre coupling without intermediate optical treatment of the light. One fibre is mounted fix into its holder (P) whereby the other fibre is attached to a 4 axes adjustment holder.
Firstly the distance of the fibres is chosen as close as possible and the module (O) aligned for strongest signal. The quality of the signal is either monitored on the TV screen or by using the photodetector which is plugged to the module P using an oscilloscope.
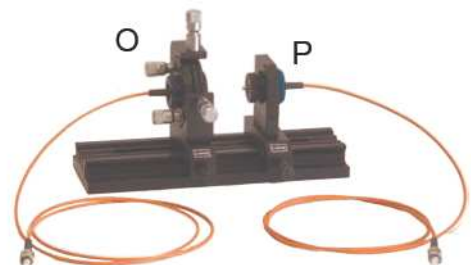
## P5876 Signal transmission via optical glass fibre consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Optical transmitter with ST fibre connection |
| 2 | 1 | Optical receiver with ST fibre connection |
| 3 | 1 | Optical glass fibre, 5000 m, core 50 µm multi mode |
| 4 | 2 | Fibre Patch cable ST connector, length 1 m |
| 5 | 1 | CCD Camera, coloured |
| 6 | 1 | CD player incl. music CD |

| Item | Qty | Description |
|------|-----|-------------|
| 7 | 1 | Flat panel TV 20 inch |

Options:

| Item | Qty | Description |
|------|-----|-------------|
| 8 | 1 | Fibre coupling module |
| 9 | 1 | Oscilloscope 100 MHz digital, two channel |

# P5877 Fibre optics workshop

✓ *Preparation of fibres*

✓ *Fibre stripping*

✓ *Fibre breaking*

✓ *Fusion splicing*

✓ *Fibre connectoring*

✓ *Fibre polishing*

✓ *Fibre inspection microscope*



## Fibre handling and connectorizing



ceramic ferrule

connector body

coated fibre

The main goal of this workshop is the connectoring of optical glass fibres with ST connectors. Although a variety of other fibre connectors exist the process of connectoring however remains the same.

Another major technology is the welded connection of bare fibres by means of the fusion splicing technology.

### Connectoring optical fibre



Fibre stripper (1)    Melting oven (6)    Cooling rack (9)

It starts with the preparation of the fibre by stripping the plastic cladding from the fibre for at least 3-4 cm. Within this workshop so called hot melt connectors (8) are used. The connectors are already filled with a hot melt adhesive. As the name suggests, these adhesives melt and flow when heated to wet the substrates and bond quickly upon cooling. A connector is placed by means of a special holder into the oven (6) and remains there for about 1 minute. After that the fibre (5) is inserted into the hot connector until 1 to 2 cm of fibre protruding the connector. The hot connector with the fibre is placed into the cooling rack (9) for a couple of minutes until it cooled down and the adhesive is solidified. The protruding fibre is scratched by means of the provided cleaver and subsequently broken.

### Polishing and inspection of the fibre connector



Fibre connector polishing (7)    Connector inspection (3)

The so prepared connector is polished with the polishing machine (7) . For this purpose the fibre is fixed to the swivel arm of the unit. A polishing film (2) is placed onto the rotating disk. After one minute of polishing the fibre is ready for inspection using the handheld fibre inspection microscope (3).

### Fusion splicing of optical fibres



Precision fibre cleaving and breaking (12)    Fibre fusion splicer (11)

Another important technology is the connection of two bare fibre ends. It is important that the splicing should affect the optical transmission to lowest possible degree. Fusion splicing is a well established technology for connecting bare fibres.

Before the fusion takes place the plastic cover of the fibre ends must be removed and precisely perpendicular cut. This is done by a precision fibre cleaving and breaking tool (12). The so prepared fibre ends are placed into the fusion splicer where the fibre faces are automatically orientated to each other. The fibre ends are moved to close contact of the faces and the fusion which is a kind of welding is started. Based on the resulting geometry of the "welded" fibre ends the unit calculates already the transmission losses. Actually before the splicing process a splicing tube and a hot shrinking protective plastic cover is attached to one side. After the fusion process the splice is covered and protected by this tube.

## P5877 Fibre optics workshop consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Adjustable plastic cover stripper 103-S |
| 2 | 1 | Polishing film  2 µm / set of 50 |
| 3 | 1 | Fibre inspection microscope, 200 x |
| 4 | 1 | Tungsten carbide fiber cleaver |
| 5 | 1 | Multimode glass fibre 1000 m, 50/250 µm |
| 6 | 1 | Hotmelt oven |
| 7 | 1 | HotMelt polishing unit |

| Item | Qty | Description |
|---|---|---|
| 8 | 1 | Hotmelt ST connector, set of 60 |
| 9 | 1 | Cooling rack |

Options:

| Item | Qty | Description |
|---|---|---|
| 10 | 1 | Splicing tubes set of 250 |
| 11 | 1 | Fusion splicer for SM and MM, model FSM-16A |
| 12 | 1 | High performance fibre cleaver and breaker |

**LEYBOLD®**

# P588 Technical Applications

www.ld-didactic.com

# P5881 Michelson's laser interferometer I

- ✓ *Coherence of laser radiation*
- ✓ *Two beam interference*
- ✓ *Index of refraction*
- ✓ *Speed of light*
- ✓ *Wave fronts*
- ✓ *Fringe contrast*
- ✓ *Coherence length*
- ✓ *Two mode HeNe laser*
- ✓ *Longitudinal mode spacing*



## Principle of operation

The beam of the probe laser is expanded (BE) and divided into two beams at the beam splitter plate (BSP). One beam is directed to the mirror M1 and the other to M2. The returning beams are superimposed by the beam splitter plate and expanded by means of the concave lens (EL). The resulting interference pattern is imaged on a white screen. Depending on the beam divergence circular or linear fringes are generated and observed.



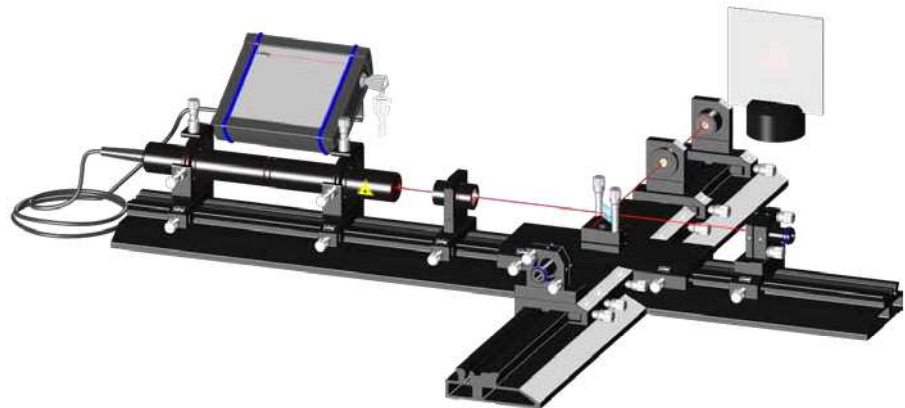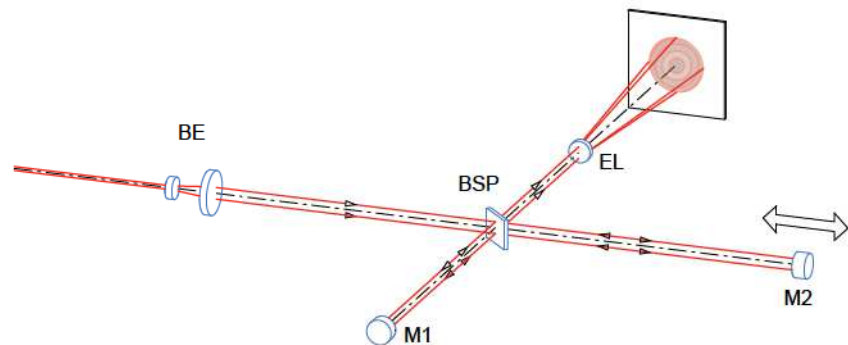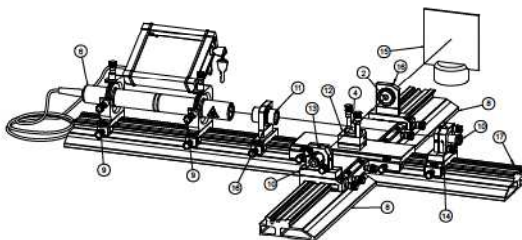## Examples of investigation and measurement



### Set-up a Michelson's interferometer

The beam of the HeNe probe laser (6) is expanded (11) and divided by the beam splitter plate (4) which is mounted into the adjustment holder (12). From here the beams are directed to the mirror (10) which are precisely adjustable (13) in such a way that the returning beams are exactly superimposed. A concave lens (2) expands the interference pattern of the superimposed beams on the white screen (15). By changing the divergence of the laser beam by adjusting the beam expander (11) the radius of curvature of the wave front is modified resulting in special interference pattern. For plane wave fronts linear and for curved ones circular interference pattern occur.
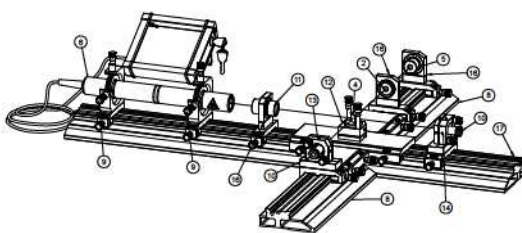


### Measuring the coherence length of the probe laser

The coherence length of a light source is determined by the bandwidth of its emission. To determine this important parameter one of the mirror holder (14) is provided with a gear and pinion drive allowing the mirror holder to be translated along the rail. By measuring the contrast at various position by means of the photo detector (5) and an oscilloscope the coherence length can be derived from the measured contrast function. Since the provided HeNe laser emits two orthogonal modes, the coherence length can be calculated ab initio and compared to the measured one.

## P5881 Michelson laser interferometer consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | BNC connection leads, set of 1 |
| 2 | 1 | Biconcave lens f=-10 mm, C25 mount |
| 3 | 1 | Optic cleaning set |
| 4 | 1 | Beam splitter plate 50/50 @ 632 nm, on holder |
| 5 | 1 | Photodetector Si PIN |
| 6 | 1 | HeNe Pilot laser Ø 30 mm |
| 7 | 1 | Target screen, click 25 |
| 8 | 2 | Profile Rail MG-65, 300 mm |
| 9 | 2 | Laser adjustment holder, soft ring 30 mm, C20 |
| 10 | 2 | Laser mirror 1/2", flat, HR @ 632 nm, click 30 mm |
| 11 | 1 | Beam expander 8x, click 25 mm |
| 12 | 1 | Carrier cross-piece with adjustable prism stage |
| 13 | 1 | Laser mirror adjustment holder C30 mount, carrier |

| Item | Qty | Description |
|------|-----|-------------|
| 14 | 1 | Laser mirror adjustment C30, carrier, pinion drive |
| 15 | 1 | Screen with carrier 20 mm |
| 16 | 3 | Mounting Plate, including carrier 20 mm, C 25 |
| 17 | 1 | Profile Rail, 500 mm with gear rack 200 mm |
| *Required* | | |
| *Option:* | | |
| | 1 | Oscilloscope 100 MHz digital, two channel |
| *Options:* | | |
| | 1 | Motorised translation unit with triple reflector, travel 50 mm |
| | 1 | Technical laser interferometer extension |
| | 1 | Set of spare parts |

## LEYBOLD®

# P5881 Michelson's laser interferometer II

✓ *Technical laser interferometer*

✓ *Definition of length*

✓ *Two mode HeNe-laser*

✓ *Two beam interference*

✓ *Optical homodyne detection*

✓ *Fringe detection, counting*

✓ *Interpolation of interference*

✓ *Calibration of µm dial gauge*
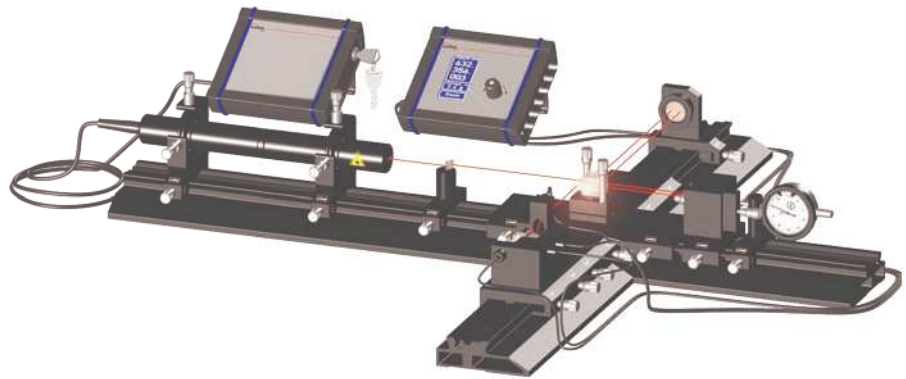


## Principle of operation

The beam of the laser is displaced by 5 mm by the rhomboid prism (BD). The polarising beam splitter (PBS) separates the two orthogonal modes of the laser. One mode travels to the triple reflector $T_1$ and the other one to $T_2$ which is attached to a translation stage. The measuring pin of the dial gauge touches the translation stage in such a way that when turning the micrometer screw the dial gauge displays the translation. The linear polarisation of the returning modes are converted to circular by means of the quarter wave plate (QWP) and are subsequently separated by the non polarising beam splitter (NBS) into two channels. Within these channels the modes are superimposed providing the necessary signals for counting and interpolating the fringes.
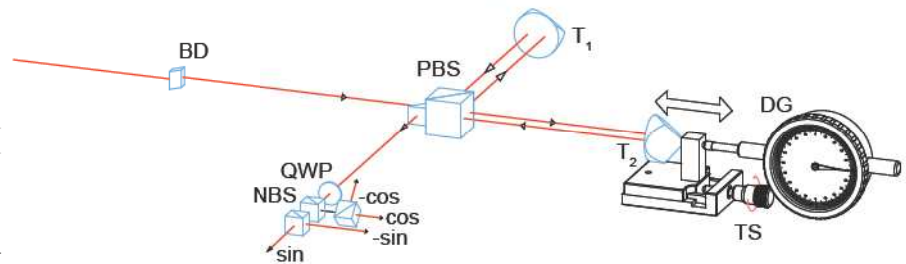


## Examples of investigation and measurement

### Set-up of a technical interferometer

The beam splitter is replaced by a polarising beam splitter cube (1). To avoid unwanted back reflections into the laser tube, the beam is displaced by 5 mm using the rhomboid prism (4). Furthermore the mirrors are exchanged against corner cube or also termed as triple reflectors. One of the triple reflectors is mounted onto a translation stage (7) allowing a precise translation of 5 mm. The interference signals are generated by the fringe detection unit (5). The photo detectors are connected to the up and down counter (2) providing the analogue signals to optimise the adjustment of the set-up. The goal of this part is to align the interferometer and by turning the micrometer screw of (7) up and down counting should occur.
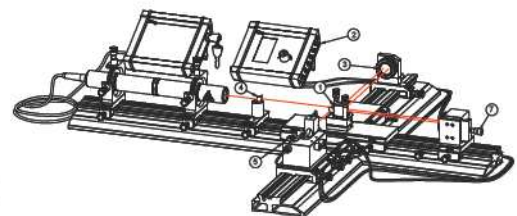


### Calibration of the µm dial gauge

Once the set-up has been properly set-up the calibration of the provided dial gauge takes place. It is placed into its holder (6) and positioned in such a way that the measuring pin touches the translation stage. The micrometer of the translation stage is turned and the read out of the dial gauge is monitored. In addition the counter reading is noted for each translation. The set value of the dial gauge and the interferometer reading are plotted and the calibration curve derived.
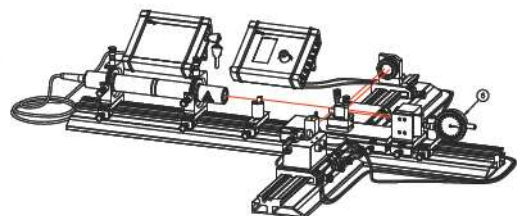


## Technical laser interferometer II consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Polarising beam splitter cube |
| 2 | 1 | Fringe up and down counter with quad input |
| 3 | 1 | Triple reflector in click 30 mm |
| 4 | 1 | Beam displacer |
| 5 | 1 | Detection unit with 4 quadrant photodiodes |
| 6 | 1 | Measuring gauge 5 mm / 1 µm with carrier 20 mm |
| 7 | 1 | Triple reflector, translation stage, counter bearer |

| Item | Qty | Description |
|------|-----|-------------|
| **Required Option:** | | |
| | 1 | Oscilloscope 100 MHz digital, two channel |
| **Option:** | | |
| | 1 | Motorised translation unit with triple reflector, travel 50 mm |

www.ld-didactic.com

# P5881 Michelson's laser interferometer III

✓ *CNC translation stage*

✓ *Definition of length*

✓ *Two mode HeNe-laser*

✓ *Two beam interference*

✓ *Optical homodyne detection*

✓ *Fringe detection, counting*

✓ *Interpolation of interference*

✓ *Calibration of CNC translation stage*
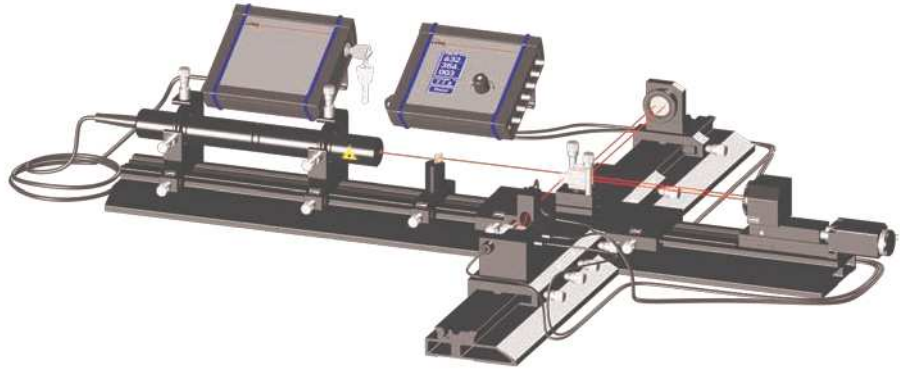


## Principle of operation

The measuring triple reflector $T_2$ is mounted on top of the movable slide of the translation stage. A stepper motor controlled by a computer drives the sled. The interferometer is counting the fringes which can be converted into the travelled distance. The up and down counter is connected to the computer and the respective data are stored and a plot is generated.



## Examples of investigation and measurement



### Set-up of a technical interferometer

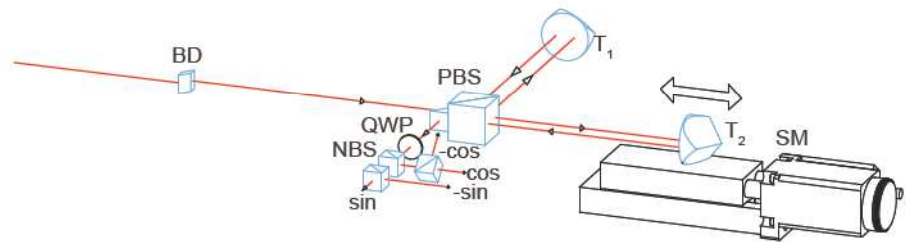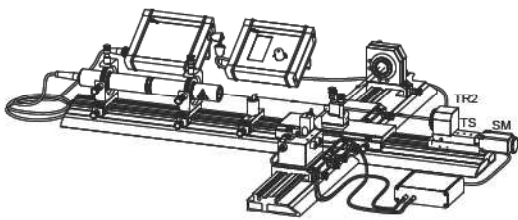The setup is done in the same way as the laser interferometer II. Instead of the manual translation stage a stepper motor driven translation stage (12) is used to obtain computer controlled displacements of the measuring triple reflector which is attached to the stage. The stepper motor is connected to its control box (4). The provided stepper motor controller with a wired remote control is used for the initial alignment. For the later measurements the control box is connected via its USB box to the computer. In the same way the up and down counter (3) is connected to the computer.
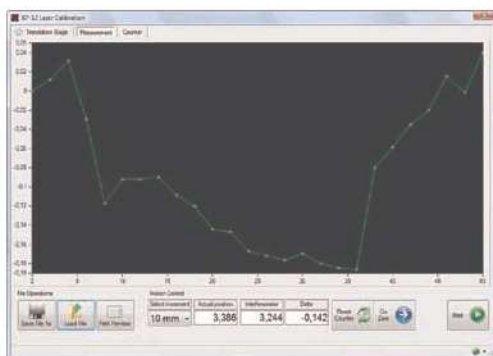


### Plotting the translation accuracy

By means of the provided software (17) the stepper motor is driven in such a way that a defined cycle of forward and backward motions are performed and the respective data of the up and down counter recorded.

Based on the set values of the positions and the measured position of the interferometer a deviation plot is created allowing the classification of the accuracy of the motorised translation stage. This way of calibration is the same as performed at CNC machines in industrial applications. Based on its natural fixed wavelength the HeNe laser provides an accuracy of $10^{-6}$ or in other words 1 m will be measured with an accuracy of 1 μm by using this set-up. Therefor the HeNe laser is suitable as secondary standard for the meter in a simple way.

## Technical laser interferometer III consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Stepper motor controller, 1 Axis, USB |
| 2 | 1 | Motorised translation unit with triple reflector, travel 50 mm |
| 3 | 1 | XP-12 Control and evaluation software |

**LEYBOLD®**

# P5882 Laser range finder

✓ *Short pulse laser diode*

✓ *Laser energy*

✓ *Peak pulse power*

✓ *Beam collimation*

✓ *Si PIN Photo Detector*

✓ *Light Echoes*

✓ *Time of Flight*

✓ *LIDAR*

**EYE SAFE !**
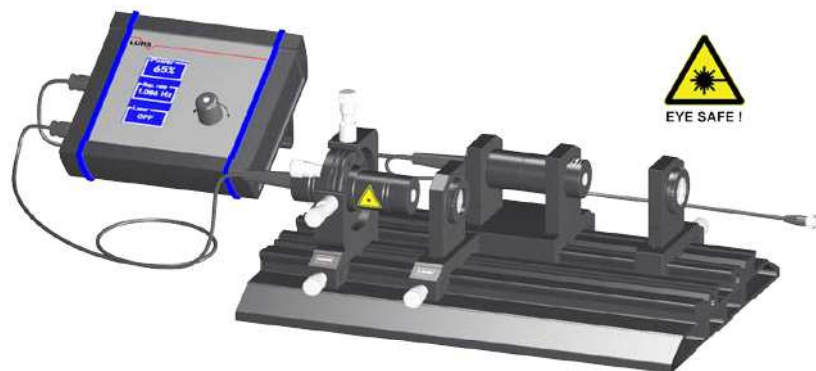
## Principle of operation

The emission of a pulsed laser diode is collimated and aimed to the target for which the distance shall be determined. The short laser pulse (100 ns) travels with the speed of light and hits the target. The scattered light is detected by the Si-PIN photodiode after passing the receiver lens. Based on the time of flight and the known speed of light the distance to the target is calculated.

Si-PIN photodiode — receiver lens — FOV — pulsed laser diode — collimated laser beam

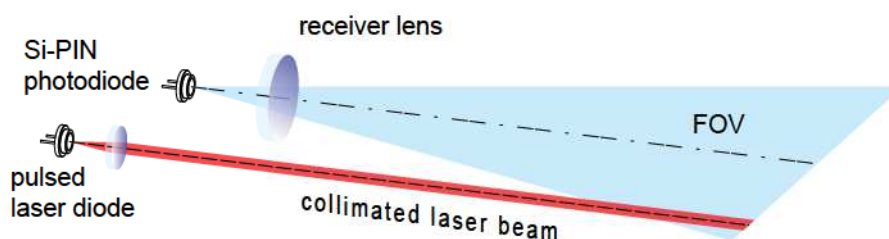## Examples of investigation and measurement

### Measuring the time of flight

The laser diode is mounted in a 4 axis adjustment holder (4). The divergent emission of the laser diode is collimated by means of the optics accommodated into the mounting plate (7). The electronic device (2) provides the trigger pulses and power for the laser diode. The device is fully controlled by a microprocessor and a clear display informs about the values. The control and settings of the parameters is done by a one knob control. The peak power is set by the discharge voltage and the average power is controlled by the repetition rate of the trigger pulses.

The scattered light is collected by the receiver lens (8) and imaged to the SiPIN photodetector. The amplifier is built into the same housing as the photodiode to achieve highest sensitivity and fast response. Via the coaxial cable terminated with a BNC connector the amplified signal can be connected to an oscilloscope. In the same way the trigger pulse of the laser diode is used to trigger the oscilloscope. This arrangement allows the determination of the time of flight by means of the oscilloscope.
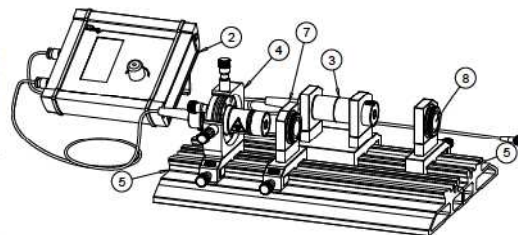
### Measuring the speed of light c

If the distance *ds* to a target is known the speed of light can be measured in this way. The distance should be chosen in such a way that a significant delay between the trigger and echoed pulse.

$$c = \frac{ds}{2 \times dt}$$

### Characterising the laser pulse

A laser pulse is characterised by its:

    Peak power
    Duration
    Rise time
    Pulse energy in Joule

These parameters are determined by means of the oscilloscope. In contrast to continuous operating lasers where the output power is given in W, here the energy per pulse is given in Ws or Joule.

pulse energy — Peak power — FWHM
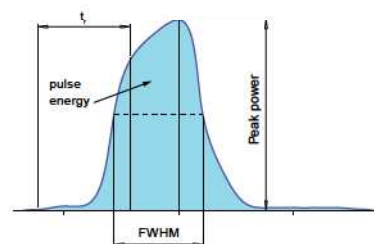
### P5882 Laser Range Finder consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | BNC connection leads, set of 2 |
| 2 | 1 | Pulsed laser diode controller PLDC-01 |
| 3 | 1 | Photodetector, ultrafast with amplifier |
| 4 | 1 | Pulsed diode laser module |
| 5 | 2 | Profile Rail MG-65, 300 mm |
| 6 | 1 | Infrared display card, spectral range 0.8 -1.6 µm |
| 7 | 1 | Module B - Collimating optics on carrier MG-65 |
| 8 | 1 | Module C - Focussing optics, f=60 mm |

Required Option:
    1    Oscilloscope 100 MHz digital, two channel

# P5883 Laser vibrometer

- ✓ *Dual Beam Interference*
- ✓ *Mach Zehnder Interferometer*
- ✓ *Acousto-optic light modulator*
- ✓ *Heterodyne optical detection*
- ✓ *Doppler Effect*
- ✓ *Vibration remote sensing*
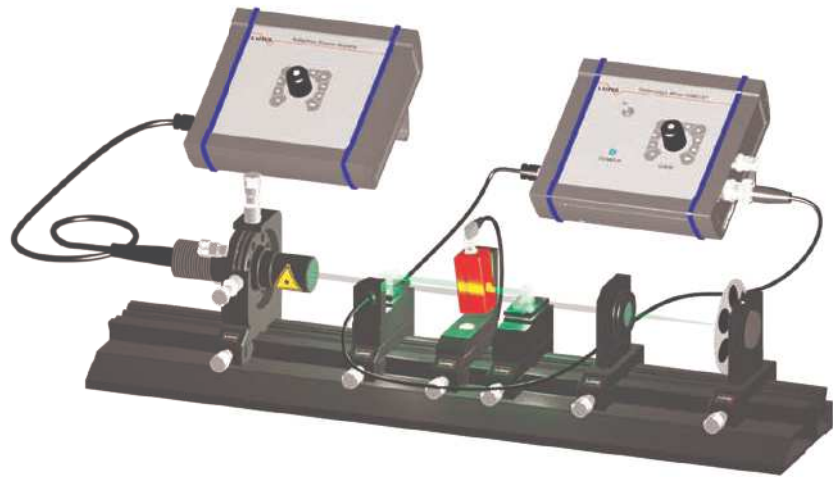


## Principle of operation

The vibrometer consists of a Mach Zehnder Interferometer formed by the beam splitter BS1, BS2 and the reflecting prisms DP1 and DP2.

The beam of the laser is separated into two beams by the beam splitter cube (BS1) The splitting ratio is chosen in such a way that the most powerful beam is used for the measuring arm.

The reference beam passes a Bragg cell (AOM) where its frequency is shifted by 40 MHz. The frequency shifted beam passes DP2, BS2 and reaches the photodetector after been deflected by the beam splitter (BS1). At the photodiode the signal containing the modulation frequency and the Doppler shift-ed measuring signal is present for further conditioning.
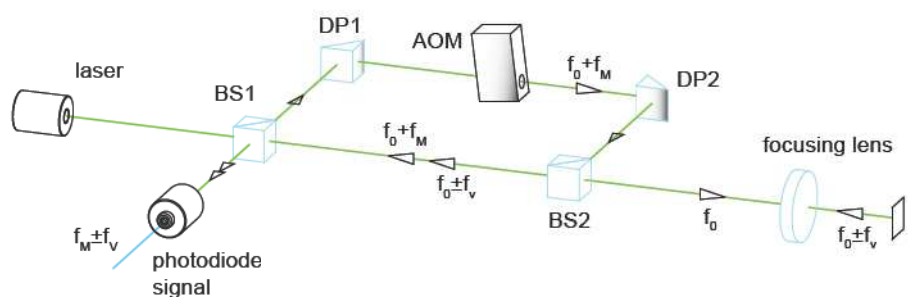


The laser vibrometer is a high precise and contactless working instrument for the measurement of vibrations of a target. In common laser interferometer at least one mirror must be attached to the target to reflect the light back. The remarkable property of the laser vibrometer is the fact that it does not need such a mirror. The back scattered and Doppler shifted light is coupled back to the interferometer and superimposed with the reference beam. The frequency of the reference beam is shifted by a Bragg cell to make use of the high sensitive heterodyne fringe detection technique. The subsequent signal amplifiers can be AC coupled allowing a much higher gain in a simpler way.

## Examples of investigation and measurement
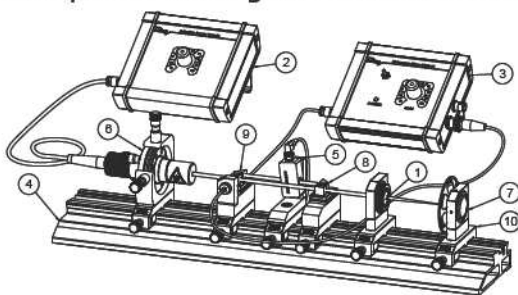


### General set-up

As light source a frequency doubled diode pumped Nd:YAG laser is used which emits a radiation with a wavelength of 532 nm and a power of 3 mW. The Mach Zehnder interferometer is formed by the beam recombiner (8) and the beam splitting assembly (9). The Bragg cell (5) is located inside the interferometer. The measuring beam is focussed by a lens (1) which is mounted into a mounting plate with carrier (10). As target a small speaker (7) is used with a reflective foil stuck to the membrane.

The signal of the photodetector which is part of the beam splitting assembly (9) is amplified and demodulated with the heterodyne mixer (3). It also contains the driver for the Brag cell.

The amplified detector signal as well as the demodulated signal are available at BNC connectors.

## P5883 Laser Vibrometer consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Biconvex lens, f=60 mm, C25 mount |
| 2 | 1 | Adaptive power supply APS-05 |
| 3 | 1 | Heterodyne mixer, AOM driver |
| 4 | 1 | Optical rail MG 65, 500 mm |
| 5 | 1 | Acoustic optic modulator AOM |
| 6 | 1 | Dimo diode laser module, 532 nm (green), HC |
| 7 | 1 | Speaker mounted on carrier 20 mm |

| Item | Qty | Description |
|---|---|---|
| 8 | 1 | Beam recombiner LV |
| 9 | 1 | Beam splitting assembly LV |
| 10 | 1 | Mounting plate C25 with carrier 20 mm |

Required Option:

| | | |
|---|---|---|
| | 1 | Oscilloscope 100 MHz digital, two channel |

## LEYBOLD®

# P5884 Laser Doppler anemometer

✓ *Dual Beam interference*

✓ *Interference pattern*

✓ *Doppler Effect*

✓ *Light Scattering*

✓ *Recording Particle Speed*

✓ *Fourier Transformation*
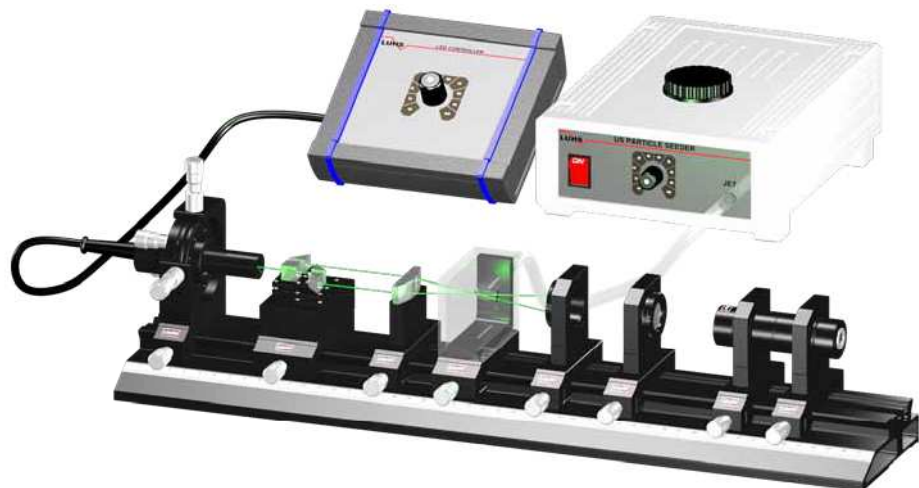


## Principle of operation

The emission of a DPSSL of 532 nm is divided into two beams. Both beams are recombined by means of a focussing lens producing a spatial interference pattern. Particles passing this zone creating timely modulated scattered light whereby the frequency depends on their speed as well as on the constant periodic pattern structure. A set of lenses focuses the scattered light onto a high sensitive and fast photodetector. The initial beams are blocked and do not reach the detector.
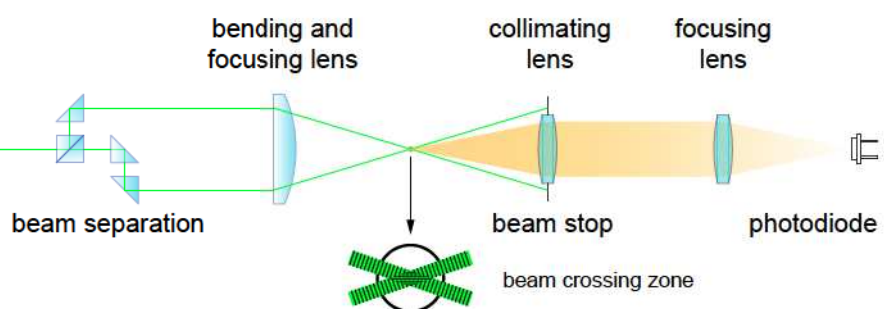


## Examples of investigation and measurement

Anemos is a word coming from Greek and means "wind". Consequently, a Laser Doppler Anemometer (LDA) may be termed as a "wind meter" using a laser based on the physical effect that Christian Doppler discovered in 1842. However, the LDA cannot just detect pure wind as a clean air stream; it needs to have particles moving with the wind. These particles are scattering the laser light and in fact their speed is measured. Due to the coherence of the laser light a spatial interference pattern can be generated within the crossing zone which look like interference pattern. When particles are moving through this pattern, they scatter the light resulting is specific bursts. Yeh and Cummins exploited the same principle in 1964 when they invented their Laser Doppler Anemometer.
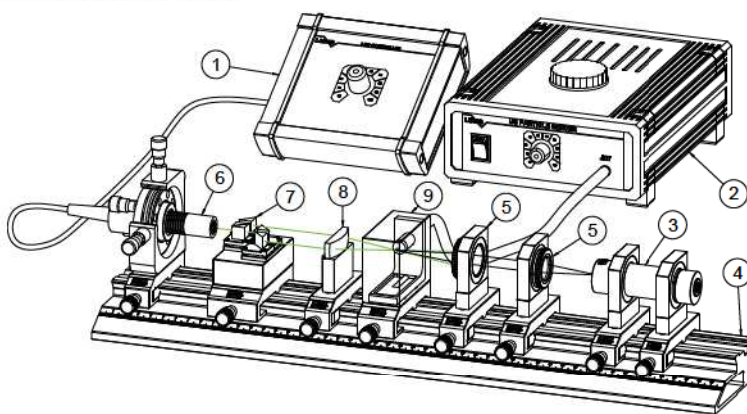


The set-up uses an ultra sonic particle seeder (2) and a nozzle (9) to create a stream of particles to be measured. The nozzle is covered by a transparent plastic cover to keep the moisture enclosed. The speed of the water vapour jet can be adjusted in such a way that a clear series of bursts are obtained. The scattered light is passed via the collimating (5) and focussing lens (5) to the extreme sensitive photodiode (3). The amplifier is built into its housing (3) and the signal as well as the operation voltage is connected via a multi pin connector. The laser beam is provided by a DPSSL (6) with an output power of 10 mW and a coherence length of 4 mm. By means of an arrangement of prisms (7) the beam is divided into two rays. The plano-convex lens (8) deviates and focuses the beam in one spot where the interference pattern is created. A digital oscilloscope is required to display and store the individual burst for subsequent analysis.

## P5884 Laser Doppler Anemometer (LDA) consisting of:

| Item | Qty | Description |
|---|---|---|
| 1 | 1 | Adaptive power supply APS-05 |
| 2 | 1 | Ultrasonic particle seeder controller USC-01 |
| 3 | 1 | Photodetector, ultrafast with amplifier |
| 4 | 1 | Optical rail MG 65, 500 mm |
| 5 | 1 | Module C - Focussing optics, f=60 mm |
| 6 | 1 | Dimo diode laser module, 532 nm (green), HC |
| 7 | 1 | LDA Beam splitting assembly |
| 8 | 1 | LDA beam divison and focussing lens module |
| 9 | 1 | Ultrasonic particle seeder |

| Item | Qty | Description |
|---|---|---|
| Required Option: | | |
| | 1 | Oscilloscope 100 MHz digital, two channel |

www.ld-didactic.com

# P5885 Laser gyroscope

✓ *Sagnac interference*

✓ *Helium Neon ring laser*

✓ *Ring laser modes*

✓ *Single mode operation*

✓ *Fringe detection*

✓ *Mode lock-in effect*

✓ *High precision angle measurement*
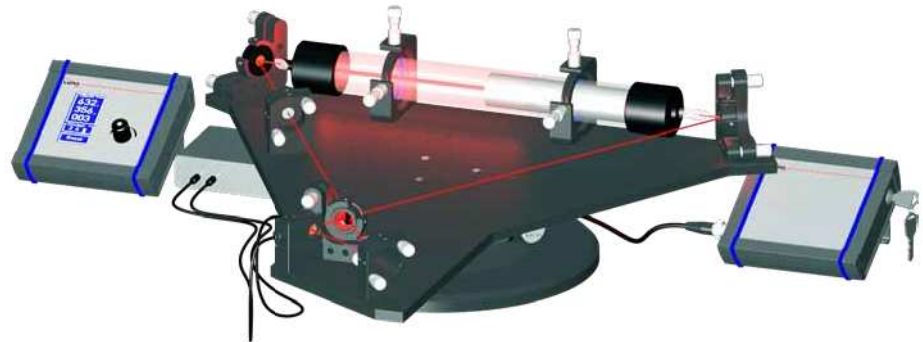
## Examples of investigation and measurement
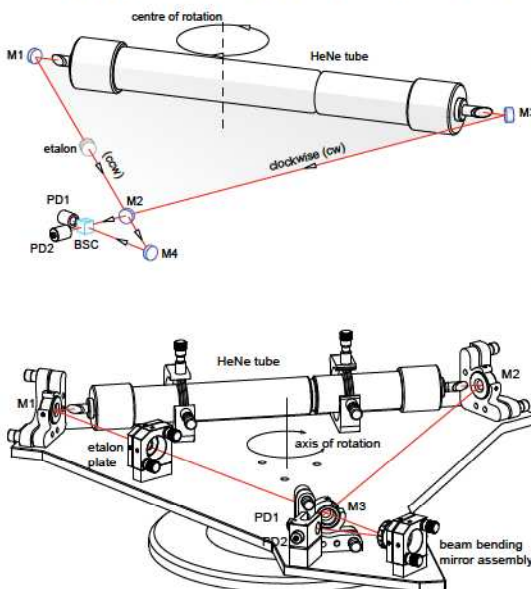
### Principle of operation

The ring laser is formed by three mirrors M1, M2 and M3 and the Helium Neon laser tube. In such a configuration the laser light is travelling in two directions, clockwise (cw) and counter clockwise (ccw). At mirror M2 a small fraction of both beams is coupled out. The cw beam passes the beam splitter cube BSC and is divided by 50/50 %. The ccw beam is deflected by the mirror M4 in such a way that the ccw beam also passes the beam splitter cube BSC and that they travel collinear to each other. At the photodetector PD1 and PD2 the beat frequency of both modes are measured.

The axis of rotation is chosen in such a way that the centre of rotation lies inside the centre of the equilateral triangle formed by the three mirrors or the propagating laser beams respectively.

### Set-up of the HeNe laser gyroscope

All three mirrors M1, M2 and M3 are mounted into high precision adjustment holder. The Helium Neon tube is placed into two XY adjustment holder enabling the centre adjustment of the tube with respect to the optical axis of the ring laser cavity. For the initial alignment a pilot laser is attached to the mirror holder of M2.

Once the ring laser is operating, the cw and ccw beams are aligned collinear to each other. The beam bending assembly is used to align the ccw beam collinear to the cw beam. The platform carrying the ring laser is mounted on top of a stepper motor driven rotary table. The stepper motor is controlled by a driver with USB computer connection.
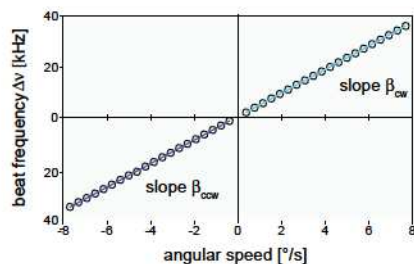
### Measurements, lock-in effect

The provided software allows the control of the angular speed in degrees per second. Furthermore the rotation angle (maximum 270 degrees) and the periodicity of the swing can be set. The beat frequency is displayed by the frequency counter (4) and can also be read from the software via the USB bus of the counter.

In such a way the beat frequency is measured for a set of angular speeds. From the plot of the data the slope is taken which is related to the scale factor of the gyroscope.

It will be noticed that in a certain region around the zero point no beat frequency will occur although the table is rotating slowly. This is due to the well known lock-in effect which will be investigated in more details with smaller steps of the angular speed around the zero point.

### Technical realisation

The advantage of a laser gyroscope is undoubtedly the fact that such systems do not contain any rotating mass, and hence are insensitive to linear accelerations as compared to the mechanical gyroscopes. Especially noteworthy is also the extended measurement range of 0.01°/h to 1000 °/s, so that these systems can also be used in fast flying objects. Today, laser gyroscopes are being used in commercial air crafts like the Airbus or in carrier missiles like the Ariane.

The figure on the left shows the technical realisation of such a laser gyroscope. To achieve a high thermal and mechanical stability the ring laser body including the Helium Neon tube is made from one zerodur glass block.
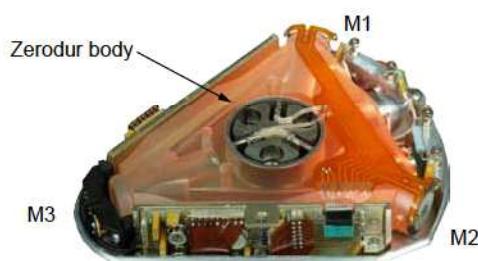
## P5885 HeNe Laser Gyroscope consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Manual HeNe laser gyroscope |
| 2 | 1 | HeNe Laser high voltage supply 6.5 mA |
| 3 | 1 | Photo diode amplifier 4 channel PDA-01 |
| 4 | 1 | Fringe up and down counter FC-01 with quad input |
| 5 | 1 | Stepper motor controller, 1 Axis, USB |
| 6 | 1 | Alignment laser 532 nm with power supply |

| Item | Qty | Description |
|------|-----|-------------|
| 7 | 1 | Fringe detection unit |
| 8 | 1 | Gyroscope base plate |
| 9 | 1 | Rotation unit |

Required Options:

| | | |
|------|-----|-------------|
| | 1 | Oscilloscope 100 MHz digital, two channel |
| | 1 | PC Pad |

## LEYBOLD®

# P5886 Laser beam analysis

✓ *Diode laser*

✓ *DPSS laser*

✓ *Gaussian beams*

✓ *Beam expanding*

✓ *Beam shaping*

✓ *Beam intensity distribution*

✓ *Computerised recording*

## Examples of investigation and measurement

### Principle of operation

A precise knife edge is moved through the cross-section of the laser beam. As the blade moves across the beam, it is cut from reaching the photodetector. The timely change of the signal is differentiated to obtain the beam profile. When the path to the detector is fully opened the entire intensity is measured and used as calibration value.

To increase the resolution of the measurement the number of knife edges is increased whereby the blades are differently orientated providing more information about the cross section. In this set-up a device with seven knife edges are used. The collection of the data is performed by a PC with the provided software. For this purpose an extra PCI board is built into the PC which controls the beam analyser, collects and stores the data on the hard disk. Based on the recorded data a 2D and 3D graphical presentation of the intensity profile is displayed on the monitor or can be printed out.
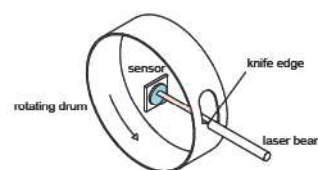
### Beam parameter of a visible (635 nm) laser diode

The laser diode (6) emits a divergent elliptical beam. By means of a spherical focusing lens (9) the beam is made almost parallel and the intensity distribution measured. In addition two cylindrical lenses are provided.

One has a focal length of 20 mm (2) and the other one 80 mm (3). The goal is to achieve an almost round diode laser beam which is controlled by the beam profiler (8). In this setup the objective (9) is used to focus the round beam and the smallest beam waist is measured.
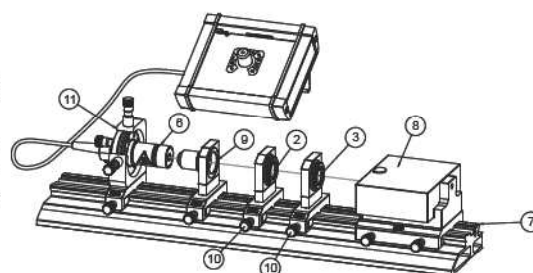
### Beam parameter of a DPSSL 532 nm

A diode pumped solid state laser (DPSSL) with second harmonic generation (5) emits an almost perfect round laser beam.

Firstly the intensity distribution of the beam without extra optics is measured.

In a next step the diameter of the beam is increased by means of the beam expander (1). The beam is focused with the objective (9) and the smallest beam waist is measured. This will be done with and without the beam expander to verify the Rayleighs law for the properties of Gaussian beams.
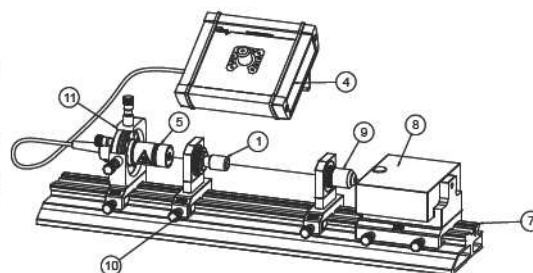
## P5886 Laser beam analysis consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Beam expander magnification 6x |
| 2 | 1 | Collimating cylindrical lens f = 20 mm |
| 3 | 1 | Collimating cylindrical lens f= 80 mm |
| 4 | 1 | Adaptive power supply APS-05 |
| 5 | 1 | DIMO diode laser module, 532 nm |
| 6 | 1 | Dimo diode laser module, 630 nm (red) |
| 7 | 1 | Profile rail MG-65, 500 mm |

| Item | Qty | Description |
|------|-----|-------------|
| 8 | 1 | Beammaster BM-7S, PC card and software |
| 9 | 1 | Module B – Collimating optics on carrier |
| 10 | 3 | Mounting plate C25 with carrier 20 mm |
| 11 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

Required Option:

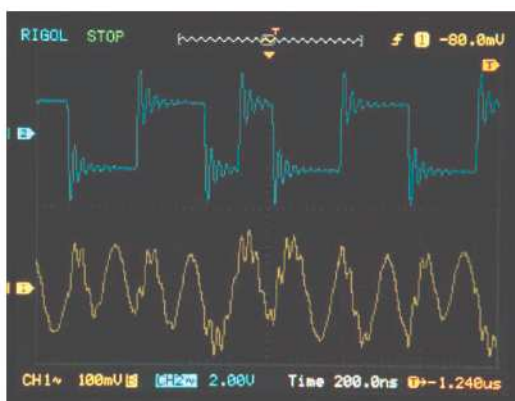| | 1 | Personal computer, X86 |
|---|---|---|

# P5887 Open frame CD/DVD reader

- ✓ *NIR and blue diode laser*
- ✓ *Beam bending and focusing*
- ✓ *CD Structure, pits and land*
- ✓ *Detection of light*
- ✓ *CD control system*
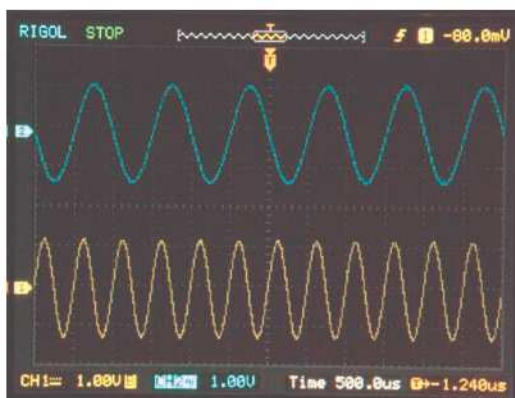- ✓ *CD signals*
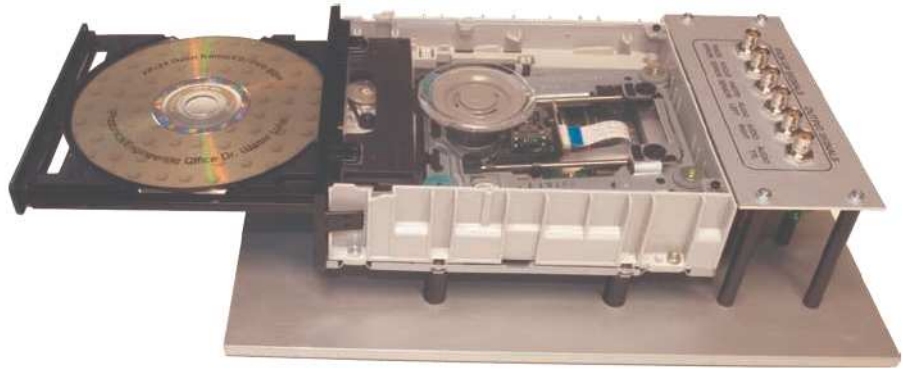


## Examples of investigation and measurement



### Optical detector signal

An open frame CD / DVD reader is prepared in such a way that the top has been exchanged by a translucent cover and the most important optical and electronic signals has been made accessible. For this purpose a buffer amplifier system for the individual signals is provided having mini BNC socket outlets to connect via the provided connection cable to the optional oscilloscope.

The oscilloscope track shown on the right side has been recorded with the test signals of the provided CD-ROM. The lower track shows the signal from "OPTICAL DETECTOR" and the upper track the "AUDIO TTL" signal also termed as S/PDIF.



### Analog outputs

On the provided test CD a stereo sinusoidal audio signal is stored with two different frequencies. Once the analogue signal output has been activated by the operating system of the attached computer these signals can be monitored via the output of the connection panel.

It can be seen, that two different frequencies are used and at a closer look the digitising steps become visible.

Any other combination of signals can be displayed depending on the aims of the experiment. Further signals available at the connection panel are the error signals of the focusing unit as well as for the track control.

## P5887 Open Frame CD-player consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 2 | BNC mini to BNC connection leads 1m |
| 2 | 1 | Manual CD/DVD ROM |
| 3 | 1 | Open frame CD-player on base plate |
| 4 | 1 | CD ROM with measuring signals |

Required Options:

| | |
|---|---|
| 1 | Oscilloscope 100 MHz digital, two channel |
| 1 | Personal computer, X86 |

**LEYBOLD**®

# P5888 Laser light show

✓ *DPSS Laser 532 nm*

✓ *Principle of light scanning*

✓ *Closed loop galvo scanner*

✓ *Creation of images*

✓ *Laser Light Show*
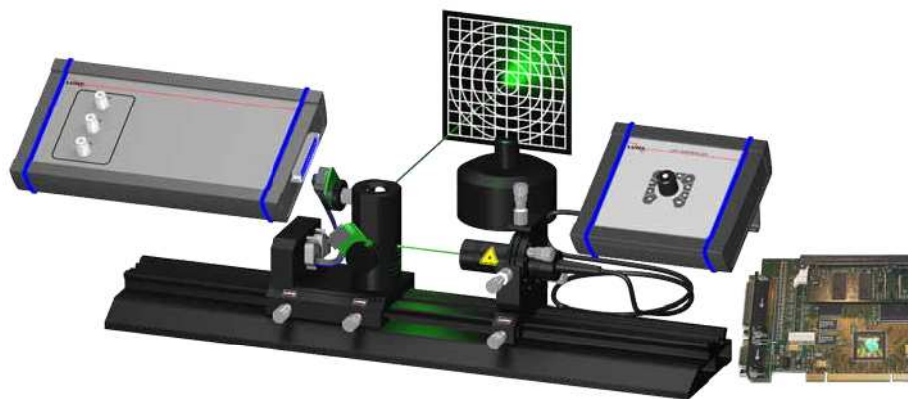
## Examples of investigation and measurement

### Galvo scanner

The key components of the setup are the so called galvo scanner (4, 5). Simply spoken the galvo scanner works like a galvanometer where an electrical current turns the axis into a position which linearly depends on the flowing current.

Small light weight mirrors (M1, M2) are attached to the rotary axis deflecting the laser beam (1) in such a way that the outgoing beam (3) is deflected in X and Y direction.

The area which is covered depends on the deflection range of the scanner as well as from the distance of the observation point or screen to the scanner.

By applying the coordinates of a structure in a timely sequence with a repetition rate equally or higher than the resolution of the human eye standing figures can be generated. This can be used either for entertainment purposes or for engraving structures with high power laser into different materials.

Within this setup the focus is on entertainment application. For the operation professional scanners including the software for creating fanciful pattern are provided.
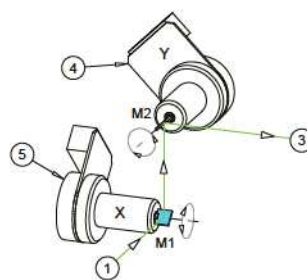
### General setup

The optical components are attached to the optical rail (4). The laser light source (3) is a frequency doubled solid state laser which is mounted into a 4 axes adjustment holder (6) to align the beam with respect to the optical axes of the galvo scanners. The laser is controlled by the adaptive power supply (1). The scanner (7) are connected to the XY scanner controller (2). It contains the power amplifier for the galvo scanner . Two outputs providing the X and Y analogue signal which can be connected to an oscilloscope. In XY mode of the oscilloscope the created structure can also be monitored in this way. A third output provides the blanking signal which is connected to the laser controller. This signal is required when the laser needs to be blanked when a next separate structure shall be written.

A black screen (8) with white target rings is used as observation screen. The beams can also be directed to a more afar screen or wall for public viewing, however the laser power is not that strong so that in such cases the room should be darkened.
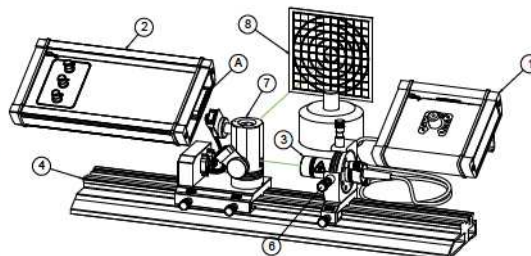
### Scanner control board

This board is required to transfer the structures created by the software to the scanner controller (2). It is inserted into the PC and connected to the port (A) of the scanner controller (2). This board calculates the required X and Y coordinates for the specific structure created by the software and sends it to the scanner.

Scanner control board (5)

### P5888 Laser light show consisting of:

| Item | Qty | Description |
|------|-----|-------------|
| 1 | 1 | Adaptive power supply APS-05 |
| 2 | 1 | XY Scanner controller |
| 3 | 1 | DIMO diode laser module, 532 nm |
| 4 | 1 | Profile rail MG-65, 500 mm |
| 5 | 1 | Scanner control board and laser light show software |
| 6 | 1 | Adjustment holder, 4 axes, carrier 20 mm |

| Item | Qty | Description |
|------|-----|-------------|
| 7 | 1 | XY scanner assembly |
| 8 | 1 | Target screen on base |
| Required Option: | | |
| | 1 | Personal computer, X86 |
| Option: | | |
| | 1 | Oscilloscope 100 MHz digital, two channel |

# P5889 Bar code reader

✓ *Types of bar codes*

✓ *Diode laser*

✓ *Rotating polygon mirror*

✓ *Detection of scattered light*

✓ *Bar code detection*

✓ *Bar code recognition*

## Examples of investigation and measurement
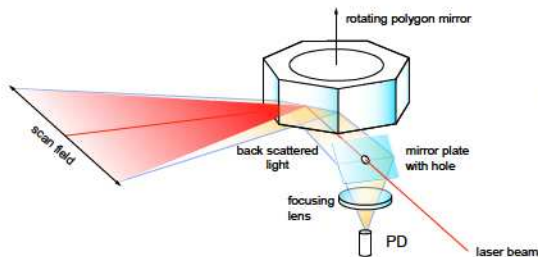
### Principle of operation

The key component of a bar code scanner is a rotating polygon mirror which deflects the laser beam. The beam passes a fixed mirror via a small hole. This mirror reflects the back scattered light from the target. A focussing lens is used to focus the back scattered light to the photodetector. If the laser beam hits a bright spot, the back scattered signal is high compared to the case when it hits a dark spot.

In this way the structure of a bar code is converted to a sequential electrical signal which is further processed.
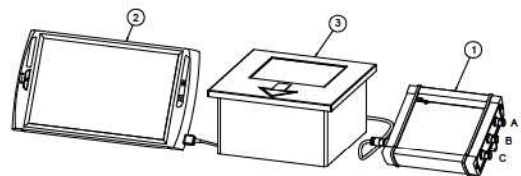
### General setup

A commercial bar code scanner (3) is modified in such a way that extra signals are brought to an external junction box (1). These signals are buffered by internal amplifiers and are available at BNC connectors:
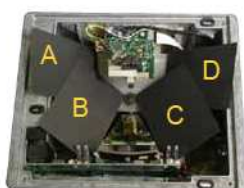
(A) The BNC connector, marked as "RAW", provides the direct analogue signals of the photodiode of the scanner.

(B) This signal represents the timely differentiation of the raw signal
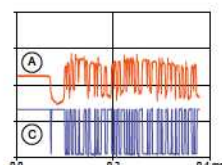
(C) TTL signal formed out of the signal A

To read and display the detected bar code a PC pad (2) is provided which is connected via USB to the scanner (3). The software reads the data from the scanner after a scanning process and displays the code on the screen. A integrated database allows to store items with a related bar code.

Different bar codes can be generated with the software and printed as samples. These samples can also be used as measurement samples.

Bar code software

### Measurements

The commercial scanner uses five extra mirrors to enhance the active area of the scanner. For the measurement however it is better to reduce it down to one for a clearer structure on the oscilloscope and for sake of easiness. For this purpose the provided black sheets (A, B, C, D) are placed as shown on the figure on the left.

A sample of the oscilloscope track is shown beside it. The raw photodetector signal (A) and the TTL signal (C) are shown. The signal (C) can directly be compared with the used bar code sample.

Number of active mirrors is reduced

Measurement sample

## P5889 Barcode reader consisting of:

| Item | Qty | Description |
| --- | --- | --- |
| 1 | 1 | Barcode scanner interface |
| 2 | 1 | PC Pad |
| 3 | 1 | Barcode scanner |
| 4 | 1 | Software Barcode Reader |

| Item | Qty | Description |
| --- | --- | --- |
| Required Option: | | |
| | 1 | Oscilloscope 100 MHz digital, two channel |

**LEYBOLD**®

# LD DIDACTIC

## LD DIDACTIC GmbH
Leyboldstr. 1
D-50354 Hürth
Tel.: +49 2233 604 0
Fax: +49 2233 604 222
E-Mail: info@ld-didactic.de

## WWW.LD-DIDACTIC.COM



LD DIDACTIC GmbH is a worldwide leading manufacturer of premium science and engineering equipment for academic education and vocational training.

LD DIDACTIC distributes its products and solutions under the brand LEYBOLD.

# LEYBOLD®