EDUCATIONAL LASER AND PHYSICS SYSTEMS
THE COMPANY

**PI miCos** GmbH specialize in the development, manufacture and marketing of high precision positioning systems and components and a comprehensive range of laser optics and physics teaching systems. Founded in 1990 PI miCos is a well established company employing around 60 people ranging from physicists, engineers and staff members highly specialized in the fields of laser technology, optics and electronics. Development and production of PI miCos products are both consolidated in one facility. Additionally, as a service provider to research and industry PI miCos prides itself on its ability to work closely with its customers and has over the years shown itself to be a worthy and reliable partner. PI miCos markets its products and services all around the world through a global network of carefully selected representatives and subsidiary companies.
THE PRODUCTS

The use of lasers in a variety of research fields and industry, medicine and finally in many products of daily life demands a qualified education and training of students in laser technology from universities, technical high schools and vocational schools. These institutions are addressed by campus, the series of educational kits developed from PI miCos to support and improve practical laser and physics training. Within campus more than 30 laser training systems of the topics optics fundamentals, laser basics, laser metrology, fiber optics and telecommunications, laser material processing, and laser applications are presented by PI miCos. Besides the educational laser systems new kits for other fields in physics are developed, suited for secondary schools up to courses at universities.

Additionally to these products PI miCos offers support for elaboration of suited curriculums for laser courses, design of the laboratories and advice in equipment selection with concepts for complete laser training facilities. Last but not least, training courses for all experimental systems are held at PI miCos’ place as well as at your site.
# THE CONTENT

<table>
<thead>
<tr>
<th>Laser Basics</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-1210 CO₂ Laser</td>
<td>6</td>
</tr>
<tr>
<td>CA-1200 HeNe Laser</td>
<td>7</td>
</tr>
<tr>
<td>CA-1220 Diode Laser</td>
<td>8</td>
</tr>
<tr>
<td>CA-1230 Nd:YAG Laser</td>
<td>9</td>
</tr>
<tr>
<td>CA-1231 - 32 Options Nd:YAG Laser</td>
<td>10</td>
</tr>
<tr>
<td>CA-1233 - 34 Options Nd:YAG Laser</td>
<td>11</td>
</tr>
<tr>
<td>CA-1240 Fiber Ring Laser/EDFA</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Particles and Waves</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-1600 Wave-Particle Duality</td>
<td>14</td>
</tr>
<tr>
<td>CA-1620 Holography</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Optics Fundamentals</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-2100 Optics Kit Reflection/ Refraction</td>
<td>17</td>
</tr>
<tr>
<td>CA-2110 Extension for Optics Kit</td>
<td>18</td>
</tr>
<tr>
<td>CA-1100 Detection and Measuring of Light</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laser Metrology</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-1300 Laser Interferometer</td>
<td>26</td>
</tr>
<tr>
<td>CA-1301 Technical Interferometer</td>
<td>27</td>
</tr>
<tr>
<td>CA-1302 Motorized Extension</td>
<td>27</td>
</tr>
<tr>
<td>CA-1310 Laser Gyroscope</td>
<td>28</td>
</tr>
<tr>
<td>CA-1320 Laser Triangulation</td>
<td>29</td>
</tr>
<tr>
<td>CA-1340 Laser Range Finder</td>
<td>30</td>
</tr>
<tr>
<td>CA-1345 Velocity of Light &amp; LIDAR</td>
<td>31</td>
</tr>
<tr>
<td>CA-1350 Laser Doppler Anemometer</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fiber Optics &amp; Telecommunication</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-1400 Plastic Fiber Optics</td>
<td>34</td>
</tr>
<tr>
<td>CA-1410 Glass Fiber Optics</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material Processing</th>
<th>38</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-1500 CO₂ Laser Workstation</td>
<td>39</td>
</tr>
<tr>
<td>CA-1510 Nd:YAG Laser Workstation</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laser Spectroscopy</th>
<th>41</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-1710 Fourier Transform Spectroscopy</td>
<td>42</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Challenging Physics</th>
<th>43</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA-3100 Vibrating String</td>
<td>44</td>
</tr>
<tr>
<td>CA-3200 Adiabatic Exponent</td>
<td>45</td>
</tr>
<tr>
<td>CA-3210 Stirling Engine</td>
<td>46</td>
</tr>
<tr>
<td>CA-3300 Magnetic Moment and Gravity Acceleration</td>
<td>47</td>
</tr>
</tbody>
</table>
CA-1210 CO₂ LASER

Educational Objectives

- Gas Lasers
- Open Frame Resonator
- Infrared Optics
- Influence of Discharge Current
- Influence of Gas Pressure
- Gas Handling & Gas Flow
- Thermal Interaction of Radiation
- Laser Material Processing

The two main topics covered by this 10-15 Watt power gas laser are: 1. the alignment of the open frame resonator and the subsequent influence of parameters such as laser gas flow and discharge current on the output power are determined. 2. The laser is used for evaluation of thermal interaction of radiation with matter, resulting in heating, drilling, engraving or cutting of different materials. The test workpieces are mounted on an XY-translation stage and controlled by a CAD program. The workstation is equipped with a closed cooling system, a fume exhaust system, and a control PC.

Order No. 4900-9-1210
CA-1200 HeNe LASER

Educational Objectives

- Energy Levels of He-Ne
- Emission Spectrum of He-Ne
- Gain
- Longitudinal & Transversal Modes
- Mode & Line Selection
- Birefringent Filter
- Littrow Prism
- Single Mode Etalon

An open frame gas laser composed of a He-Ne tube with Brewster windows and separate resonator mirrors is used to demonstrate and teach the basics of gas lasers such as: resonator stability, coherence and mode behavior. By variation of the resonator mirrors (the set comprises five mirrors) the resonator properties and its influences on the laser power and stability are evaluated. Wavelength selection with optical components like birefringent filter and Littrow prism is performed. Using an optical grating different laser lines can be spatially separated. Mode selection is investigated using a single mode etalon. In a new extension set further challenging experiments for polarization, laser modes, or laser spectroscopy are possible. Order No. 4900-9-1200
CA-1220 DIODE LASER

Educational Objectives

- Types of Laser Diodes
- Beam Profile
- Fast and Slow Axis
- Spectral Properties
- Laser Threshold
- Slope Efficiency
- Beam Shaping
- Polarization State

Mounted on a rotational unit the spatial distribution of laser diode emission is measured. Beam shaping optics allows to collimate the laser beam and to modify its profile. To determine threshold current and slope efficiency, the relative output power of the diode is measured as a function of the injection current. By means of absorption in an Nd:YAG crystal the dependency on the laser wavelength from the chip temperature and injection current is evaluated. The state of polarization in dependence on the diode current is probed by a polarizer. Current, temperature and modulation of the diode are adjusted on the versatile controller with integrated photo diode amplifier.

Order No. 4900-9-1220
Based on a fully functional diode pumped solid state laser an experimental Nd:YAG laser is presented. Optically pumped at 808 nm absorption, spontaneous emission, lifetime of excited state, and absorption wavelengths of the Nd:YAG crystal are investigated. The relative output power of the solid state laser is measured as a function of the pump diode power to determine parameters such as threshold power and slope efficiency. Properties and stability of a hemispherical resonator are examined, and resonator modes are visualized. Furthermore, a multitude of measurements for diode characterization (compare CA-1220) can be performed. Optional extensions for non-linear optics are available (CA-1231-1234).
CA-1231/1232 OPTIONS FOR Nd:YAG LASER

CA-1231 Frequency Doubling
- Behavior of Nonlinear Optics
- Second Harmonic Generation
- Power of SHG-Radiation

A KTP crystal converts the Nd:YAG emission intra-cavity to green light. For green emission above 5 mW an output coupler mirror highly transmissive at 532 nm is provided. Using an IR-absorbing filter the quadratic response of the SHG process is measured. Transverse cavity modes of the Nd:YAG laser are visualized by SHG impressively.

Order No. 4900-9-1231

CA-1232 Active Q-Switching
- Active Q-Switch Technique
- Electro-Optical Modulator
- Q-Switching Behavior

A LiNbO₃-Pockels cell changes the polarization state of the Nd:YAG emission. A Brewster plate introduces losses and laser operation is suppressed. When switching the cell, the losses are minimized and a laser pulse builds up. Switching voltage and frequency are adjusted by a controller. In combination with CA-1231 intra- and extra-cavity SHG are shown.

Order No. 4900-9-1232
CA-1233/1234 OPTIONS FOR Nd:YAG LASER

**CA-1233 Passive Q-Switching**
- Passive Q-Switch Technique
- Saturable Absorption
- Q-Switched Radiation

A Cr:YAG crystal acts as a saturable absorber within the resonator. A train of needle-like pulses are observed. The pulse frequency is influenced by the pump power and the cavity alignment. When oscillating at higher transversal modes two or more pulse trains appear. In combination with CA-1231 intra- and extra-cavity SHG are shown.

Order No. 4900-9-1233

**CA-1234 Mirror Extension Set**
- Minimum Laser Threshold
- Slope Efficiency
- Laser Losses

A set of four laser mirrors with reflectivities between 80% and 99% at 1064 nm are provided. The influence of the reflectivity on the laser threshold and on the slope efficiency is shown. The maximum laser power as a function of the reflectivity is measured. The laser thresholds for different mirrors are plotted and extrapolated for a minimum threshold value.

Order No. 4900-9-1234
CA-1240/1241 FIBER RING LASER/EXTENSION EDFA

Educational Objectives

- Absorption/Emission of Gain Medium
- Optical Pumping
- Fluorescence Lifetime
- Laser Threshold and Slope Efficiency
- Laser Spiking
- Introduction of Losses
- Dynamic Laser Behavior
- Extension: Erbium Doped Fiber Amplifier

This fiber laser set offers a multitude of experimental performances. Laser threshold and slope efficiency of the 980 nm pump laser can be examined. Coupling the pump light in the erbium fibers, absorption and fluorescence properties are to investigate.

With help of a resonator mirror a linear erbium fiber laser is realized. Closing the resonator for a ring the fiber ring laser is built. Both types can be investigated with respect to parameters like the active fiber length, the amount of losses, the pump power, and so on. The ring laser operates bidirectional. An optical diode allows an unidirectional operation. Optionally a 1,55 µm laser for EDFA investigations is offered (CA-1241).

Order No. 4900-9-1240
CA-1600 WAVE-PARTICLE DUALITY

Educational Objectives

- Complementarity
- Quantum Nature of Light
- Mach-Zehnder Interferometer
- Coherence
- Single Event
- Michelson Interferometer
- Interference Pattern

Usually, in common classroom experiments either the wave or the particle nature of light is presented, never both aspects together. In contrary, the system presented here allows the demonstration of both aspects side by side: The beam of a laser is split in an intense and a weak beam. Both beams are sent in parallel through a Mach-Zehnder or alternatively Michelson interferometer. The weak beam is strongly attenuated, so a photo multiplier detects discrete, seemingly uncorrelated photon events. At the same time the interference of the intense beam shows the wave nature of light. Summing up all photon signals allows a transition of the particle aspect to the wave aspect and results in a signal equal to the strong beam interference.

ORDER NO. 4900-9-1600
CA-1620 HOLOGRAPHY

Educational Objectives

- Transmission Hologram
- Reflection Hologram
- Interference
- Assembling of a Holographic Setup
- Signal and Reference Beam
- Photo Plate Development

With the holography experimental set-up the principles of holographic recording is taught. Reflection as well as transmission holograms of objects can be taken. A beam is split into signal and reference beam and sent to the object and photo plate, respectively. The interference of reference beam and light scattered from the object is detected by the photo plate. Besides a set of photo plates all necessary developer agents and materials as well as a sample object and a sample hologram are included in the set. Using green laser light the holograms impress by their brilliance and high contrast.

Order No. 4900-9-1620
OPTICS FUNDAMENTALS
Photronics is the science of generating, controlling, and detecting photons. While the 20th century was the century of the electron, the 21st century seems to become the century of the photon. To be well prepared for this new era PI miCos offers an optics kit for the basics in refraction and reflection.

Developed and thoroughly tested at the University of Marburg, this kit is addressed to first year physics courses as well as classes of optics in colleges. Using a laser as light ray source and transparent materials in combination with well elaborated templates a new didactic approach to the classical optics laws of reflection and refraction is given. Besides the templates a comprehensive manual is provided.

Order No. 4900-9-2100
CA-2110 EXTENSION FOR OPTICS KIT

Educational Objectives

- Reflection of Metals
- Dispersion of Prisms
- Brewster Angle
- Diffraction of Gratings
- Absorption and Filters
- Polarization
- Crystal Optics
- Optical Activity

To allow the performance of more experiments in classical optics PI miCos has prepared an extension system for the Optics kit Reflection/Refraction. Additional materials as well as templates for investigation of several topics of absorption, refraction, diffraction, polarization and optical activity are provided. These extensions are built up on the transparent base plate of the CA-2100 kit. Besides the green laser source a red laser is used to demonstrate and test wavelength dependent properties of prisms, gratings and optically active plates. The kit comes with a fully elaborated manual and protocol template for teachers and students.

Order No. 4900-9-2110
CA-1100 DETECTION AND MEASURING OF LIGHT

Educational Objectives

- White Light Source
- Monochromator
- Spectral Sensitivity
- Semiconductor Photo-detectors
- Thermoelectric Photo-detector
- Response Time
- Electronic Circuits
- Optical Filters

Different properties such as spectral sensitivity or response time of a set of photo-detectors are characterized. A white light source in combination with a monochromator and a fast modulated laser diode are used for simulation of cw- and pulsed light sources. An electronic controller for the photo-detectors allows the evaluation of the effect of different types of electronic supplies and detection circuits of detectors. For a calibration measurement of the light source - monochromator pair a thermopile detector with a constant response between 200 nm and 20 µm is provided. Transmission curves of optical filters can be measured and are used for suppression of higher diffraction orders of the monochromator.

Order No. 4900-9-1100

<table>
<thead>
<tr>
<th>White Light Source</th>
<th>Monochromator</th>
<th>Spectral Sensitivity</th>
<th>Semiconductor Photo-detectors</th>
<th>Thermoelectric Photo-detector</th>
<th>Response Time</th>
<th>Electronic Circuits</th>
<th>Optical Filters</th>
</tr>
</thead>
</table>

**Educational Objectives**
- CA-1100
- White Light Source
- Monochromator
- Spectral Sensitivity
- Semiconductor Photo-detectors
- Thermoelectric Photo-detector
- Response Time
- Electronic Circuits
- Optical Filters
CA-1110 LASER SAFETY AND CLASSIFICATION

Educational Objectives

- Laser Power and Intensity
- Divergence of a Laser Beam
- Pulsed Laser
- Laser Classification
- Maximum Permissible Emission
- NOHD
- Eye Damaging
- Safety Goggles and Filters

This experimental set is equipped with four laser and one LED sources, their wavelengths range from blue to NIR with different powers and functions (cw- and pulsed lasers). These sources are to be classified in safety classes by power and energy measurement. Optical elements like beam expanders, filters, scattering discs, and an iris aperture are used to modify the laser beams and hence change their safety classes. Direct laser light as well as its scattering cone profiles are measured. Handling of standards like EN60825, EN207 and EN208 will be introduced and discussed. The effects of laser power on the human eye are simulated and MPE and MSD values are calculated and demonstrated. For laser power measurements a power meter is included.

Order No. 4900-9-1110
CA-1120 RADIO- AND PHOTOMETRY

Educational Objectives

- Black Body Radiator
- Thermal Light
- Cold Light
- Sensitivity of Human Eye
- $1/r^2$ relation
- Radiometric Units
- Photometric Units

While in Radiometry the units for optical radiation are related to physical units like Joule or Watt, in Photometry all measurements are based on the physiological sensitivity of the human eye. With this educational set the basics of light and the transformation from radiometric to photometric values and vice versa are taught. Calibration with a lamp standard is performed. The lamp's behavior with respect to a black body radiator and the discrepancy are discussed. A light chopper is used to determine the lamp signal for measuring photometric values. The $1/r^2$ relation of several radiometric and photometric units is examined.

Order No. 4900-9-1120
Optical pumping of an Nd:YAG crystal by the IR emission of a laser diode shows the absorption behavior of a laser medium. At a laser diode controller parameters like temperature and current of the pumping diode are set and hence its emission wavelength is defined. Therefore the spectral absorption profile of the crystal can be traced. The fluorescence of the crystal is selected with a narrow band interference filter. The lifetime of the excited \(^4\text{F}_{3/2}\) state is measured by a fast PIN photodiode. Varying the diode current the laser threshold and slope efficiency of the diode laser are determined. The temperature dependency on the diode current is measured at constant wavelength.
CA-1140 FABRY PEROT RESONATOR

Educational Objectives

- Two Beam Interference
- Multiple Beam Interference
- Free Spectral Range
- Finesse
- Types of Fabry Perot Resonators
- Stability Criterion
- Spectral Analysis of HeNe Laser
- Polarization

Aim of this experimental Fabry Perot resonator is the determination of characteristics like free spectral range and the finesse of a Fabry Perot, and the mode spectrum of a test laser (HeNe laser). One mirror of the resonator is mounted on a piezo translator resulting in a scanning Fabry Perot used as a spectrum analyzer. By variation of the resonator mirrors (the set comprises 6 mirrors) and the resonator length different types of optical resonators (confocal, concentric, hemispherical, etc.) are set up and can be evaluated. In case of a plane-parallel resonator a beam expander is used for enlarging the laser beam diameter. For distinction of the two laser modes a polarization filter is provided.

Order No. 4900-9-1140
CA-1150 LASER BEAM ANALYZER

Educational Objectives

- Beam Profile
- Beam Waist
- Beam Shaping Optics
- Transversal Modes
- Beam Intensity
- Gaussian Distribution

This Laser Beam Analyzer is designed as an add-on and is particularly suited to several of the Campus laser sets: Nd:YAG (CA-1230), He-Ne (CA-1200) and Diode Laser (CA-1220) are ideal candidates for demonstration of beam profiles, transversal mode structures or influence of beam shaping optics and telescopes on laser beams – all of them easily visualized by the Beam Analyzer. But also beam profiles after travelling through glass fibers (CA-1410, CA-1420) or interference patterns (CA-1300) are interesting objects for observation. The measured data is stored on a PC and with the software provided the intensity distribution of the laser beams can be visualized and presented.

Order No. 4900-9-1150
CA-1300 LASER INTERFEROMETER

Educational Objectives

- HeNe Laser
- Contrast Function
- Coherence Length
- Two Beam Interference
- Homodyne Interferometer
- Fringe Detection, Counting and Interpolation
- Definition of Length

The basic version of a Michelson interferometer is used to teach handling, alignment, and measurement of a homodyne interferometer system. By interfering two laser beams, fundamental properties of Gaussian beams as well as wave fronts and interference patterns are demonstrated and investigated. With one interferometer mirror on a mechanical rack and pinion drive the beam path difference can be changed and hence the interferometer contrast function can be probed. The measurement of coherence length of the He-Ne laser introduces the student to the spectral emission bandwidth of the laser source.

Order No. 4900-9-1300
CA-1301/1302 EXTENSIONS FOR LASER INTERFEROMETER

CA-1301 Extension Technical Interferometer
- Technical Distance Measurement
- Signal Conditioning of Sin / Cos
- Fringe Detection, Resolution, Limits
- Lissajous Curves

The basic Michelson interferometer is upgraded to a technical interferometer. Length measurement with this homodyne laser interferometer is based on electronic fringe counting. The quadrature detection technique is used to determine the direction and step numbers of movement of one interferometer mirror. A comparator digitalizes the measured signals. An event counter registers the fringe numbers which are converted into real length.

Order No. 4900-9-1301

CA-1302 Motorized Extension
- Industrial Application
- Calibration of a Translation Stage
- Calibration Record
- Environmental Conditions

The Technical Interferometer is extended by a motorized translation stage and a controller to demonstrate the calibration of an unknown length. Via a PC a travel range is set, encoded by the controller and forwarded to the translation stage. The value measured by the interferometer is compared to the travelling distance and hence to the set value. Corrected for environmental conditions the interferometer value builds the calibration standard.

Order No. 4900-9-1302
CA-1310 LASER GYROSCOPE

Educational Objectives

- He-Ne Ring Laser
- Ring Laser Modes
- Interference
- Single Mode Etalon
- Sagnac Effect
- Mode Lock-in
- Measurement of Rotation
- Dynamic Range

This active laser gyroscope contains a ring laser consisting of an open frame He-Ne tube and a triangular resonator. The whole ring laser is set up on a motorized rotational platform. The rotational velocity can be varied allowing to the dynamic range of the Gyroscope to be investigated. Counter-rotating modes of the ring laser are coupled out and are superimposed for demonstration and measurement of the Sagnac effect. The resulting interference is detected and electronically converted to a frequency proportional to the rotational velocity. The lock-in threshold is determined by variation of the rotation frequency. Single mode operation is achieved by an etalon mounted in the ring resonator.

Order No. 4900-9-1310
CA-1320 LASER TRIANGULATION

Educational Objectives

- Laser Diode
- Position Sensitive Detector (PSD)
- Distance Measurement
- Optical Detection of Presence
- Scattering on Surfaces
- Accuracy of Measurement

One application of triangulation in laser metrology is contactless distance measurement. Teaching and evaluation of the principles, abilities and limits of laser triangulation is the aim of this set. A laser diode and a position sensitive detector PSD are provided in an accessible housing. Together with control electronics and a translation stage for the object plates a triangulation set-up is assembled. With the translation stage displacements with 10 µm resolution are performed. Two samples with different scattering behavior simulate different surface properties. All measured and computed detector signals of the PSD are displayed on four digital multimeters in parallel.

Order No. 4900-9-1320
CA-1340 LASER RANGE FINDER (LIDAR)

Educational Objectives

- Pulsed Laser Module
- Optical Diode
- Polarization
- InGaAs Photo Detector
- Light Echoes
- Time of Flight
- Velocity of Light
- Light Scattering

The aim of this experimental pulsed laser range finder is to demonstrate the properties of a LIDAR (Light Detection and Ranging). Short and intensive pulses are sent to a corner cube reflector. A trigger signal generated by reference pulses starts the measurement. An optical diode guides the back scattered laser pulses towards the signal detector. The time of flight determines the distance of the measured object. The pulse width reaches less than 5 ns and distances of less than 40 cm can still be measured in the laboratory environment. High peak power and low beam divergence allow distance measurements of more than 100 m, still with a standard InGaAs detector. With a known target distance the kit can be used for demonstration and measurement of the velocity of light.

Order No. 4900-9-1340
CA-1345 VELOCITY OF LIGHT & LIDAR

Educational Objectives

- Velocity of Light
- Nanosecond Laser Pulses
- Light Echoes
- Time of Flight
- LIDAR
- InGaAs Photo Detector
- Light Scattering

The pulsed laser module sends short pulses to an object of interest. An optical trigger signal starts the measurement and synchronizes one channel of an oscilloscope (optionally available). The time of flight of the back scattered laser pulses determine the distance of the measured object. The pulse temporal width reaches below 5 ns and distances of less than 40 cm can still be measured in the laboratory environment. Low laser beam divergence allows the measurement of targets in distances of several tens of meters, still with a standard InGaAs detector. With a known target distance the kit can be used for demonstration and measurement of the velocity of light. Since the laser module emits at 1535 nm, the laser radiation lays in the eye safe wavelength range (Laser Class 1).

Order No. 4900-9-1345
CA-1350 LASER DOPPLER ANEMOMETER

Educational Objectives

- Doppler Shift
- Beam Interference
- Scattering of Light
- Velocimetry
- Particle Size
- Fourier Transformation
- Modulation Depth
- Beam Intersection Angle

The working principle of a Laser Doppler Anemometer (LDA) is demonstrated. Two coherent laser beams cross at the measuring spot at which a rotating acrylic disc with small distortions is placed. Distortions passing the beams' cross point generate scattered light. The frequency of this scattered light is up- and downward Doppler shifted causing a low frequency signal beating. This beating is proportional to the velocity of the distortions in the measuring spot. Scattered light is collected by a lens and focused onto a photo detector. By electronically filtering and fast Fourier transformation the frequency is extracted and the velocity of the particles can be deduced. This velocity can be compared to the rotation velocity of the disc. 

Order No. 4900-9-1350
CA-1400 PLASTIC FIBER OPTICS

Educational Objectives

- LED Transmitter
- LED Signal Modulation
- Si Photo Detector Receiver
- Dichroic Beam Splitter
- Dual Wavelength Data Transmission
- Plastic Fiber Handling and Preparation
- Plastic Fiber Attenuation
- Signal Beating and Cross Talk

The student starts with the preparation of a plastic fiber (POF): stripping, assembling a connector and polishing of the connector surface. The losses of different lengths of POFs in a transmission line are measured. The setup of a complete two channel low frequency data transmission system is investigated. An optical signal separation on the receiver’s side is performed. All necessary components, fibers and control electronics like modulator, transmitter, receiver, demodulator and an audio amplifier with two speakers are included. Features like signal cross talk and signal beating can be demonstrated. Additional signal sources like an MP3 player can be connected to the setup.

Order No. 4900-9-1400
CA-1410 GLASS FIBER OPTICS

Educational Objectives

- Stripping and Cleaving of Fibers
- Guiding of Light in Fibers
- Single & Multimode Fibers
- Coupling Optics
- Signal Transmission
- Numerical Aperture
- Laser Diodes
- Threshold and Slope Efficiency

This set is designed to introduce the theory and handling of glass fibers. The preparation of glass fiber ends by stripping and cleaving with appropriate tools is taught as well as the coupling of laser light in a bare fiber. This set is supplied with one kilometer of single- and multimode fiber, respectively. Fiber parameters like acceptance angle and numerical aperture, transmission speed and transmission losses are measured. The light coupled in the fiber is provided by a single mode laser diode. The power and state of modulation of the diode can be controlled through the control unit. Furthermore, the threshold and slope efficiency of the diode laser can be determined. A signal amplifier is integrated in the laser control unit.

Order No. 4900-9-1410
CA-1420 OPTICAL TIME DOMAIN REFLECTOMETRY (OTDR)

Educational Objectives

- Pulsed Laser Module
- Optical Fiber
- InGaAs Photodetector
- Fiber Handling and Preparation
- Coupling Light to Fiber
- Reflected Light Echoes
- Properties of Glass Fibers
- Speed of Light

After assembling the complete OTDR set reflectometry measurements can be performed. Short pulses (<5ns) are coupled in a 1 km multimode fiber. The fiber ends are prepared by Miller pliers and a fiber cleaver. A trigger signal generated by reference pulses starts the measurement. The time of flight of the light backscattered by the fiber determines the length of the fiber. A fiber-fiber coupling module introduces an air gap between two fibers and simulates a distortion of the fiber. Furthermore, measurements for pulsed laser characterization and most of the measurements of the Glass Fiber Optics kit (CA-1410) can be performed.

Order No. 4900-9-1420
CA-1440 DATA TRANSMISSION VIA OPTICAL FIBER

Educational Objectives

- Laser Diodes
- Optical Glass Fibers
- Photo Detector
- Handling of Fiber Optical Cable
- Modulation of Laser Diodes
- Video Cameras
- Video Signal Transmission
- Optical Signal Detection

The educational set for data transmission demonstrates digital signal transmission on a 5 km optical line. A video source consisting of a colour CCD camera and a stereo audio source consisting of an MP3 player are connected to the optical transmitter. Via the provided fiber the audio as well as video signals are transmitted simultaneously to the optical receiver. At the receiver’s side the optical signal is transformed to an electrical signal which passes on to a monitor which displays the picture detected by the CCD camera. The transmitted audio signal is played by a pair of active speakers. Furthermore, an air gap consisting of fiber coupling out and coupling in modules allow the introduction of signal losses.

Order No. 4900-9-1440
MATERIAL PROCESSING
Educational Objectives

- Sealed-Off CO$_2$ Laser
- Pulse Width Modulation
- RF Excitation
- Laser Cutting
- Laser Welding
- Laser Engraving
- Laser Drilling

Using a dedicated CO$_2$ laser system with power output of 100W this workstation is designed to teach material processing basics and techniques. It enables students to investigate welding, cutting, engraving and soldering using different materials. The system allows variation and control of laser power, repetition rates, transverse velocity, process gases and focal lengths. The laser head is a sealed-off CO$_2$ Laser, the laser gas is RF excited. The testing sample is mounted on an XY-translation stage controlled by a CAD program. The whole system is PC controlled. Laser protection and safety are achieved by housing the system in a secure cabinet - the whole workstation represents a Class 1 laser system.

Order No. 4900-9-1500
CA-1510 Nd:YAG LASER WORKSTATION

Educational Objectives

- Nd:YAG Laser
- Cw and pulsed Mode
- Active Q-Switch
- Laser Cutting
- Laser Welding
- Laser Engraving
- Laser Drilling
- Lamp Pumping

Different material processing techniques like soldering, drilling, engraving, cutting or welding can be studied with this Nd:YAG workstation. Laser power, process gas or focal length can be optimized depending on the test material and the process. Equipped with a Q-switch system the laser pulses are able to evaporate material, and laser drilling of very small holes can be studied in detail. In the workspace the testing sample is mounted on an XY-translation stage controlled by a CAD program. The whole system is PC controlled. Laser safety and protection are achieved by housing the laser in a secure cabinet - the whole workstation represents a Class 1 laser system.

Order No. 4900-9-1510
LASER SPECTROSCOPY
CA-1710 FOURIER TRANSFORM SPECTROSCOPY

Educational Objectives

- Interferometer
- Coherence
- Time-Bandwidth Relation
- Line / Band Spectrum
- Signal Beating
- Fourier Transformation
- Apodisation
- Zerofilling

The basic setup of a Fourier transform spectrometer is a Michelson interferometer with a movable mirror. Scanning this mirror generates a temporal interference pattern of the light beams which carries the spectral information of the light source or a sample placed in the beam path. Three light sources of different spectral properties are provided in this experimental set. The mirror of the measurement arm is mounted on a high precision translation stage driven by a controller, both from PI miCos. Different motion sequences within a broad velocity range can be programmed. The interference signals are recorded, evaluated and Fourier transformed in a PC (optionally available).

Order No. 4900-9-1710
CA-3100 VIBRATING STRING

Educational Objectives

- Waves and standing waves
- Resonance Condition of Forced Oscillation
- Phase Shift at Resonance
- Fundamental and higher Harmonics
- Lorentz Force
- Lissajous Figures

Topic of this musical experiment, developed and tested in the physics courses of the University of Bremen, are the basics of stringed instruments and the physical concept of resonant standing waves. Standing waves play an important role in acoustic and laser resonators, atomic models and quantum mechanics, in antennae or even in the microwave oven. In this experiment the harmonics of a Lorentz force driven vibrating string will be investigated e.g. in dependence on the tensile strength and the exciting force. The case of resonance can be impressively visualized by the Lissajous figures of the exciting and detected oscillation. Spectral analysis can determine the fundamental and harmonics, as well as overtones of these oscillations.

Order No. 4900-9-3100
An adiabatic change of state shows no heat exchange with the environment. Therefore a rapidly expanding gas is cooling down, a quickly compressed gas is heating up. The energy change in relation to the temperature change gives the specific molecular heat at constant volume or pressure. These variables depend on the possible degrees of freedom of the gas particles. In this experiment, developed and tested in the physics courses of the University of Bremen, the adiabatic exponents of different gases can be determined. An appropriate gas filled in a syringe is compressed by pressing the piston. Due to the repelling force, the gas and the piston are made to oscillate. From the oscillation period the adiabatic exponent is determined. The signal is detected by magnetic induction.

Order No. 4900-9-3200

Educational Objectives

- Molecular Heat $C_v$ and $C_p$
- Damped Oscillation
- Freedom Degrees of Gases
- Adiabatic Exponent
Besides the Otto- and Diesel engine, the Stirling engine has regained importance in special applications, e.g. in space research. This fully functional model of a Stirling engine is optimized for the classroom to demonstrate the conversion of thermal energy into mechanical and electrical energy, as well as to study the Stirling cycle. In this experiment the student will learn the operation of the Stirling engine, a periodically operating heat engine. After calibration of the apparatus, pV diagrams are recorded at different loads of the Stirling engine and are evaluated. The effective work and the power of the Stirling engine as well as various levels of efficiency can be determined and compared.

Order No. 4900-9-3210
A magnet moving in a copper coil changes the magnetic flux of the coil, and therefore a voltage is induced. The time integral over this voltage is proportional to the magnetic moment which can be determined by measurement of the temporal course of the voltage. Alternatively, coils in an equidistant arrangement can be regarded as sensors which allow the determination of the gravity acceleration of a falling magnet. In this experimental kit, developed and tested in the physics courses of the University of Bremen, several coils of equal length are arranged on a tube. Through the tube capsules with magnets are dropped. When passing through the coils voltage peaks are induced which can be displayed on an oscilloscope or read in a PC.

**Educational Objectives**

- Magnetic Moment
- Induced Voltage
- Magnetic Flow
- Gravitational Acceleration
Development, manufacture and marketing of laser and physics teaching systems for high schools, training colleges and universities.

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