

**TESS**  
expert

**PHYWE**

**Demo**  
expert

**PHYWE**

Eng  
&

Geo

JAN. 2013

# Engineering/Geo Science

University Experiments

# Materials Science and Engineering: Curricula Compliant Experiments – for your educational needs

PHYWE™ experiments have been matched to the curricula of more than 30 selected universities worldwide. The interaction between PHYWE's experiments and the supporting content of experimental lectures and lab courses has led to the creation of a teaching package that is highly relevant to the curriculum worldwide.



## Materials Science and Engineering Bachelor of Science Course – Reference Curriculum

Content	1. Sem.	2. Sem.	3. Sem.	4. Sem.	5. Sem.	6. Sem.
Laboratory Experiments	General Physics*		Electrical Engineering (Chapter 5)		Material Analysis and Testing (e.g. NDT) (Chapter 4)	
	General and Inorganic Chemistry**		Physical Chemistry**	Crystallography (Chapter 3)	Thermochemistry**	
		Materials Science 1 (Chapter 3)	Materials Science 2 (Chapter 3)			
Lecture, Tutorial, Experiments	General Physics*		Electrical Engineering (Chapter 5)		Solid State Physics*	
	Materials Science 1 (Chapter 3)		Materials Science 2 (Chapter 3)		Material Analysis and Testing (e.g. NDT) (Chapter 4)	
	General and Inorganic Chemistry**		Physical Chemistry**	Organic Chemistry**	Electrochemistry**	
			Crystallography (Chapter 3)		Thermochemistry**	
Elective Subject			e.g. Metals, Polymers, Ceramics, Biomaterials		e.g. Nanotech., Renew. Energy, Electr. Devices, Photonics (Chap. 5,6,7)	
Theoretical Courses	Mathematics		Computer Sciences and Engineering		Measurement Technology	
			Technical Mechanics		Design and Construction	Business Administration and Industrial Management
Interships			Industrial Internship		Research Internship	
Bachelor Thesis						Bachelor Thesis

**More than 80% of the experimental courses are covered by PHYWE experiments!**

PHYWE Experiments available in this catalogue

\* Please refer to TESS expert Physics catalogue

\*\* Please refer to TESS expert Chemistry catalogue

# Geo Science: Curricula Compliant Experiments – multidisciplinary education with PHYWE

Geo science is one of the most multidisciplinary subjects taught in natural sciences. The first semesters or introductory courses cover general topics in physics, chemistry and biology followed by classical topics of geo science such as: geology, petrology, palaeontology, mineralogy, environment (climate, soil, water), spectroscopy, or X-ray analyses. Find corresponding experiments in this catalogue or refer to our TESS expert and Demo expert catalogues Physics, Chemistry or Biology.

## Geo Science

### Bachelor of Science Course – Reference Curriculum

Content	1. Sem.	2. Sem.	3. Sem.	4. Sem.	5. Sem.	6. Sem.
Laboratory Experiments	General Chemistry**		Optics and Microscopy***	Water: Cycle and Quality (Chapter 8.1)	General Biology***	Ore Microscopy, Nanoimaging (Chapter 3)
	General Physics*		Geochemistry	Soil Science (Chapter 8.3)	Mineralogy and Crystallography (Chapter 4.1)	Elementary Analysis/ Spectroscopy (e.g. XRF) (Chapter 4.1, 8.4)
Lecture, Tutorial, Experiments		Introductory Geology	Mineralogy and Petrology	Geophysics	Geocology (Chapter 8)	Petrology / Petro-chemistry**
Elective Subject		Metallurgy**	Atmosphere: Science, Climate, and Change (Chapter 8.2)	Meteorology	Water: Hydrogeology, Hydrochemistry**	X-ray Powder Diffraction Laboratory (Chapter 8.9)
Theoretical Courses	Mathematics		Palaeontology	Sedimentation	Digital Mapping	
	Geology	Mineralogy	Sedimentary / Igneous	Petrology	Geomorphology	Meteorology, Climatology
Field Studies	e.g. Field Mapping		e.g. Landscape Evolution and Analysis		e.g. Environmental Geology	
Bachelor Thesis						Bachelor Thesis

More than 60% of the experimental courses are covered by PHYWE experiments!

PHYWE Experiments available in this catalogue.

\* Please refer to TESS expert Physics catalogue

\*\* Please refer to TESS expert Chemistry catalogue

\*\*\* Please refer to TESS expert Biology catalogue



TESS expert and Demo expert Physics



TESS expert and Demo expert Chemistry / Pharmacy



TESS expert and Demo expert Biology

## TESS expert Engineering and Geo Science

<b>1</b>	<b>Table of contents</b>	<b>2</b>
<b>2</b>	<b>Applied Mechanics</b>	<b>13</b>
<b>3</b>	<b>Materials Science</b>	<b>43</b>
<b>4</b>	<b>Non-destructive Testing (NDT)</b>	<b>79</b>
<b>5</b>	<b>Electrical Engineering</b>	<b>107</b>
<b>6</b>	<b>Renewable Energy</b>	<b>141</b>
<b>7</b>	<b>Photonics</b>	<b>165</b>
<b>8</b>	<b>Geo Science</b>	<b>193</b>
<b>9</b>	<b>About PHYWE</b>	<b>217</b>
<b>10</b>	<b>Indices</b>	<b>233</b>

## How to use

the table of contents

Use the curricula-based content on the next pages to find your topics and our corresponding experiments. The TESS expert catalogue is adapted to international university curricula making it easy for you to find experiments corresponding to your desired topic. On each page you find the detailed description of one of our university level experiments. More information including the complete experiment description is available on our website [www.phywe.com](http://www.phywe.com).

**Overview TESS expert**

**2 Applied Mechanics**

2.1 Statics		
P2120200	Modulus of elasticity	14
P2120300	Mechanical hysteresis	15
P2120100	Moments	16
P1253500	Torque	16
P2133000	Torsional vibrations and torsion modulus	17
P5160900	Shear waves in solid state materials	18
P2130160	Hooke's law (with Cobra4)	19
P2130101	Hooke's law	19
2.2 Dynamics		
P2131500	Moment and angular momentum	20
P2131305	Moment of inertia and angular acceleration with a precision pivot bearing	21
P2131301	Moment of inertia and angular acceleration and with an air bearing	21
P2131311	Moment of inertia and angular acceleration with Cobra3 and with an air bearing	21
P2131315	Moment of inertia and angular acceleration with Cobra3 and with an air bearing	21

Curricular topic = main chapter of the catalogue

Curricular subtopic = sub-chapter of the catalogue

Curricular fitting PHYWE experiments

Find the overview of all experiments fitting to the international reference curriculum on our homepage!  
Click [www.phywe.com](http://www.phywe.com)



## 2 Applied Mechanics

### 2.1 Statics

P2120200	Modulus of elasticity	14
P2120300	Mechanical hysteresis	15
P2120100	Moments	16
P1253500	Torque	16
P2133000	Torsional vibrations and torsion modulus	17
P5160900	Shear waves in solid state materials	18
P2130160	Hooke's law (with Cobra4)	19
P2130101	Hooke's law	19

### 2.2 Dynamics

P2131500	Moment and angular momentum	20
P2131305	Moment of inertia and angular acceleration with a precision pivot bearing	21
P2131301	Moment of inertia and angular acceleration and with an air bearing	21
P2131311	Moment of inertia and angular acceleration and with an air bearing (with Cobra3)	21
P2131315	Moment of inertia and angular acceleration and a precision pivot bearing (with Cobra3)	21
P2131360	Moment of inertia and angular acceleration (with Cobra4)	21
P2133100	Moments of inertia and torsional vibrations	22
P2132801	Moment of inertia / Steiner's theorem	22
P2132660	Harmonic oscillations of spiral springs - Spring linked in parallel and series (with Cobra4)	23
P2132701	Forced oscillations - Pohl's pendulum	24
P2132760	Forced oscillations - Pohl's pendulum (with Cobra4)	24
P2131900	Laws of gyroscopes / 3-axis gyroscope	25
P2132000	Laws of gyroscopes / cardanic gyroscope	26
14440-62	Software "Measure Dynamics", campus licence	27

### 2.3 Fluidynamics and Aerodynamics

P2140100	Density of liquids	28
P2140200	Surface of rotating liquids	29
P2140300	Viscosity of Newtonian and non-Newtonian liquids (rotary viscometer)	30
P2140400	Viscosity measurement with the falling ball viscometer	31
P2140500	Surface tension with the ring method (Du Nouy method)	32
P2140700	Barometric height formula	33

P2260511	LDA - laser Doppler anemometry with optical base plate (with Cobra3)	34
P2260560	LDA - Laser Doppler Anemometry (with Cobra4)	34
P5140100	Mechanics of flow	35
P5142100	Flow Measurement Ultrasonic Doppler effect	35
P5141100	Level measurement	36
P2151000	Optical determination of the velocity of sound in liquids	37
P2151100	Phase and group velocity of ultrasound in liquids	38
P2151200	Temperature dependence of the velocity of ultrasound in liquids	38
P2150305	Velocity of sound in air with Universal Counter	39
P2150605	Velocity of sound using Kundt's tube and digital function generator	40
P2150601	Velocity of sound using Kundt's tube	40
P2150405	Acoustic Doppler effect with universal counter	41
P2152415	Ultrasonic Doppler effect (with Cobra3)	42
P2152460	Ultrasonic Doppler effect (with Cobra4)	42

## 3 Materials Science

### 3.1 Mechanical Properties

P5160900	Shear waves in solid state materials	44
P2133000	Torsional vibrations and torsion modulus	45
P2120300	Mechanical hysteresis	45
P2120200	Modulus of elasticity	46
P2120100	Moments	46
P2130160	Hooke's law (with Cobra4)	46

### 3.2 Magnetic Properties

P2430760	Ferromagnetic hysteresis (with Cobra4)	47
P1221300	Ferromagnetism, paramagnetism and diamagnetism	47
P2430800	Magnetostriction with the Michelson interferometer	48
P2538500	Investigate in magnetic micro and nano structures by Magnetic Force Microscopy (MFM)	49

### 3.3 Thermal and Electrical Properties

P2310100	Thermal expansion in solids and liquids	50
P2310200	Thermal expansion in solids	50
P2310300	Thermal expansion in liquids	50
P2330101	Heat capacity of metals	51
P2330160	Heat capacity of metals (with Cobra4)	51

P2350200	Thermal and electrical conductivity of metals	52
P2410460	Temperature dependence of different resistors and diodes (with Cobra4)	53
P2410401	Temperature dependence of different resistors and diodes with a multimeter	53
P2530300	Hall effect in metals	54
P2530101	Hall effect in p-germanium	55
P2530160	Hall effect in p-germanium (with Cobra4)	55
P2530260	Hall effect in n-germanium (with Cobra4)	55
P2530201	Hall effect in n-germanium	55
P2260106	Faraday effect with optical base plate	56
P2260100	Faraday effect	56
P2420600	Dielectric constant of different materials	57
<b>3.4 X-ray Structural Analysis</b>		
P2541301	Examination of the structure of NaCl monocrystals with different orientations	61
P2541401	X-ray investigation of cubic crystal structures / Debye-Scherrer powder method	62
P2541501	X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method	62
P2541602	X-ray investigation of crystal structures / Laue method with digital X-ray image sensor (XRIS)	63
P2541601	X-ray investigation of crystal structures / Laue method	63
<b>3.5 X-ray Fluorescence Analysis</b>		
P2544701	Qualitative X-ray fluorescence analysis of powder samples	64
P2545001	Quantitative X-ray fluorescence analysis of alloyed materials	65
P2545101	Quantitative X-ray fluorescence analysis of solutions	66
P2544501	Qualitative X-ray fluorescence spectroscopy of metals - Moseley's law	66
P2544601	Qualitative X-ray fluorescence analysis of alloyed materials	66
<b>3.6 Nanotechnology</b>		
09600-99	Compact-Scanning Tunneling Microscope (STM)	67
P2532000	Atomic Resolution of the graphite surface by STM (Scanning Tunnelling Microscope)	68
P2532500	Investigate in surface atomic structures and defects of different samples by STM	68
P2535000	Quantum Mechanics by STM - Tunneling Effect and Charge Density Waves	68

P2536000	Imaging and characterization of carbon-nanoarticle by STM (and STS)	68
P2534500	Self-assembled molecular networks of TMA and hexadecanol by STM	69
P2534000	Self-assembled molecular networks of arachin acid by STM	69
P2537000	Roughness and nanomorphology of different metal samples by STM	70
09700-99	Compact-Atomic Force Microscope (AFM)	71
P2538000	Basic methods in imaging of micro and nanostructures with atomic force microscopy (AFM)	72
P2538400	Imaging of biological and medical micro and nanostructure with atomic force microscopy (AFM)	73
P2538100	Basic methods in force spectroscopy to investigate material characteristics with atomic force microscopy (AFM)	74
P2538200	Using the phase contrast mode to distinguish between different materials on the nano scale - Material contrast with AFM	75
P2538500	Investigate in magnetic micro and nanostructures by Magnetic Force Microscopy (MFM)	76
<b>3.7 Metallography</b>		
P5510100	Metallographic sample preparation - grinding and polishing	77
P5510200	Metallographic sample preparation - chemical etching	78

## 4 Non-destructive Testing (NDT)

### 4.1 X-ray Investigations

P2542001	Determination of length and position of an object which can not be seen	82
P2542701	Debye-Scherrer diffraction measurements for the examination of the texture of rolled sheets	83
P2540010	Counter tube characteristics	83
P2545001	Quantitative X-ray fluorescence analysis of alloyed materials	84
P2545101	Quantitative X-ray fluorescence analysis of solutions	84
P2545201	X-ray fluorescence spectroscopy / layer thickness determination	85
P2550100	Computed tomography	86
09110-88	XRE 4.0 X-ray expert set	87
09180-88	XRCT 4.0 X-ray Computed Tomography upgrade set	87
09057-40	XR 4.0 X-ray Direct Digital Image Sensor (XRIS) with USB cable	88

09057-42	XR 4.0 X-ray CT Z-rotation stage (XRstage)	88
14421-61	XR 4.0 Software measure CT	88
P2550300	Principles of beam intensity	89
<b>4.2 Ultrasonic Testing</b>		
P5160100	Velocity of ultrasound in solid state material	90
P5160200	Ultrasonic echography (A-Scan)	91
P5160300	Ultrasonic echography (B-Scan)	92
P5160400	Angle beam measurement	93
P5160500	Time of flight diffraction (TOFD)	94
P5160600	Detection of discontinuities	95
P5160700	Frequency dependence of resolution power	96
P5160800	Attenuation of ultrasound in solid state materials	97
P5160900	Shear waves in solid state materials	98
P5161000	Determination of the focus zone	99
P5161100	Mechanical scan methods	100
P5161200	Ultrasonic computertomography	101
<b>4.3 Other Methods of NDT</b>		
P2538000	Basic methods in imaging of micro and nanostructures with atomic force microscopy (AFM)	102
P2538100	Basic methods in force spectroscopy to investigate material characteristics with atomic force microscopy (AFM)	102
P2538200	Using the phase contrast mode to distinguish between different materials on the nano scale - Material contrast with AFM	102
P2538500	Investigate in magnetic micro and nanostructures by MagneticForce Microscopy (MFM)	102
P2532500	Investigate in surface atomic structures and defects of different samples by STM	103
P2537000	Roughness and nanomorphology of different metal samples using by STM	103
P2150501	Chladni figures	104
P2220900	Michelson interferometer - High Resolution	105
P2260305	Transfer hologram from a master hologram	106

## 5 Electrical Engineering

### 5.1 Preparatory Courses

15265-88	TESS advanced Physics Electricity / Electronics Building Block System, Basic Set Electricity	108
----------	--	-----

15266-88	TESS advanced Physics Electricity/Electronics Building Block System, supplementary set Electromagnetism and Induction	108
15267-88	TESS advanced Physics Electricity/Electronics Building Block System, supplementary set Electronics	108
13470-88	TESS advanced Electronics necessary accessories for 1 group	108
01006-02	TESS Physics manual Electric/Electronic Building Block System, Part 1 and 2	108
01054-00	Software interTESS Physics, Electrics / Electronics, DVD	108
15221-88	TESS advanced Physics set Electric motor/Generator	109
15250-88	TESS advanced Physics set Equipotential lines and electric fields	109
13411-88	TESS advanced Equipotential lines necessary accessories for 1 group	109
13029-02	TESS advanced Physics manual Equipotential lines and Electric field	109
01055-00	Software interTESS Physics, Electrostatics / Magnetism, Equipotential lines, DVD	109
07880-02	TESS advanced Physics manual Electric Motor / Generator	109
13412-88	TESS advanced Electric Motor / Generator EMG necessary accessories for 1 group	109
30505-77	Electrochemical measurement set	110
01194-02	TESS advanced manual Electrochemical measurement set	110
13230-77	TESS advanced Physics set Magnetism, MAG	110
01162-02	TESS advanced Physics manual Magnetism	110
01055-00	Software interTESS Physics, Electrostatics / Magnetism, Equipotential lines, DVD	110
13422-88	TESS advanced Chemistry Electrochemical measurement set EC necessary accessories for 1 group	110
<b>5.2 Properties of Electrical Devices</b>		
P2410960	Characteristic curves of semiconductors (with Cobra4)	111
P2410460	Temperature dependence of different resistors and diodes (with Cobra4)	112
P2410401	Temperature dependence of different resistors and diodes with a multimeter	112
P2420600	Dielectric constant of different materials	113
P2420100	Electric fields and potentials in the plate capacitor	113
P2420201	Charging curve of a capacitor / charging and discharging of a capacitor	114



P2420715	Switch-on behaviour of a capacitor and an inductance with the FG module (with Cobra3)	115
P2420760	Switch-on behaviour of a capacitor and an inductance with the FG module (with Cobra4)	115
P2440501	Capacitor in the AC circuit	116
P2440560	Capacitor in the AC circuit (with Cobra4)	116
P2440401	Coil in the AC circuit	117
P2440460	Coil in the AC circuit (with Cobra4)	117
P2430260	Magnetic field of single coils/ Biot-Savart's law (with Cobra4)	118
P2430201	Magnetic field of single coils/ Biot-Savart's law with a teslameter	118
P2441211	Induction impulse (with Cobra3)	119
P2441260	Induction impulse (with Cobra4)	119
P2440260	Magnetic Induction (with Cobra4)	120
P2440201	Magnetic induction	120
P2440301	Inductance of solenoids	121
P2440360	Inductance of solenoids (with Cobra4)	121
P2441101	Resistance, phase shift and power in AC circuits with digital function generator	122
P2440100	Transformer	123
P2530300	Hall effect in metals	124
P2530101	Hall effect in p-germanium	125
P2530201	Hall effect in n-germanium	125
P2530160	Hall effect in p-germanium (with Cobra4)	125
P2530260	Hall effect in n-germanium (with Cobra4)	125
P2530401	Band gap of germanium	126
P2530460	Band gap of germanium (with Cobra4)	126
P2530411	Band gap of germanium (with Cobra3)	126
P3060962	Nernst equation (with Cobra4)	127
P3061262	Temperature dependence of the electromotive force (with Cobra4)	128
P2411360	Second order conductors. Electrolysis (with Cobra4)	129
P2410700	Semiconductor thermogenerator - Seebeck effect	130
<b>5.3 Properties of Electrical Circuits</b>		
P2410160	Ohm's law (with Cobra4)	131
P2410560	Kirchhoff's laws (with Cobra4)	132
P2410500	Kirchhoff's laws	132
P2410101	4 Point Method / Measurement of low resistances / Ohm's Law	133
P2441005	RLC measuring bridge	134
P2410200	Wheatstone bridge	134
P2440601	RLC circuit	135

P2440660	RLC circuit (with Cobra4)	135
P2440700	Rectifier circuits	136
P2440801	RC filters	137
P2440905	High-pass and low-pass filters with digital function generator	138
P2440960	High-pass and low-pass filters (with Cobra4)	138
P2440915	High-pass and low-pass filters with the FG module (with Cobra3)	138
P2450201	Coupled resonant circuits	139
P2450301	Forced oscillations of a nonlinear electrical series resonant circuit - chaotic oscillation (with Cobra3)	140
P2450360	Forced oscillations of a nonlinear electrical series resonant circuit - chaotic oscillation (with Cobra4)	140

## 6 Renewable Energy

### 6.1 Preparatory Courses

09492-88	Demo Applied Sciences Set Renewable Energy ENT1	142
09493-88	Demo Applied Sciences Set Renewable Energy ENT2	142
01157-02	Demo advanced Applied Sciences manual Renewable Energy on the magnetic board	142
12608-88	Cobra4 wireless, extension set for renewable energy: electric parameters, temperature	142

### 6.2 Basic Principles

P2350200	Thermal and electrical conductivity of metals	143
P3010701	Thermal conductivity of gases	144
P2320201	Heat capacity of gases	145
P1043960	Specific heat capacity of water (with Cobra4)	145
P2330160	Heat capacity of metals (with Cobra4)	145
P2320260	Heat capacity of gases (with Cobra4)	145
P2330101	Heat capacity of metals	146
P2330160	Heat capacity of metals (with Cobra4)	146
P2330200	Mechanical equivalent of heat	147
P2330260	Mechanical equivalent of heat (with Cobra4)	147
P3011160	Gay-Lussac's law (with Cobra4)	148
P3011260	Amontons' law (with Cobra4)	148
P3011360	Boyle's law (with Cobra4)	148

P3021701	Determination of the heating value of fuel oil and of the calorific value of olive oil	149
P3021401	Determination of the enthalpy of combustion with a calorimetric bomb	150
P2410960	Characteristic curves of semiconductors (with Cobra4)	151
P2410460	Temperature dependance of different resistors and diodes (with Cobra4)	151
P2530111	Hall effect in p-germanium (with Cobra3)	151
P2440100	Transformer	152
P2420201	Charging curve of a capacitor / charging and discharging of a capacitor	152
P2420715	Switch-on behaviour of a capacitor and an inductance with the FG module (with Cobra3)	152
P2420600	Dielectric constant of different materials	153
P2420100	Electric fields and potentials in the plate capacitor	153
P3060962	Nernst equation (with Cobra4)	153
<b>6.3 Heat</b>		
P2360360	Heat insulation / heat conduction	154
P2360200	Electric compression heat pump	155
13715-93	Work and power meter	155
P2410800	Peltier heat pump	156
P2410700	Semiconductor thermogenerator - Seebeck effect	157
P2360401	Stirling engine with an oscilloscope	158
P2360460	Stirling engine (with Cobra4)	158
<b>6.4 Solar Energy</b>		
P2350101	Stefan-Boltzmann's law of radiation with an amplifier	159
P2350160	Stefan-Boltzmann's law of radiation (with Cobra4)	159
P2360100	Solar ray collector	160
P2410901	Characteristic curves of a solar cell	161
<b>6.5 Hydrogen Technology</b>		
P2411200	Faraday's law	162
P3021501	Determination of the heat of formation of water	163
P2411100	Characteristic curve and efficiency of a PEM fuel cell and a PEM electrolyser	164

## 7 Photonics

### 7.1 Basic Principles

P2240405	Lambert's law of radiation on optical base plate	166
P2240400	Lambert's law	166
P2250105	Polarisation through quarter-wave plates with optical base plate	167
P2250100	Polarisation through quarter-wave plates with optical profile bench	167
P2250305	Fresnel's law - theory of reflection with optical base plate	168
P2250300	Fresnel's equations - theory of reflection with optical profile bench	168
P2230105	Diffraction at a slit and Heisenberg's uncertainty principle with optical base plate	169
P2230100	Diffraction at a slit and Heisenberg's uncertainty principle with optical bench	169
P2230405	Diffraction of light through a double slit or by a grid with optical base plate	170
P2230400	Diffraction intensity due to multiple slits and grids with optical profile bench	170
P2230605	Diffraction intensity at a slit and at a wire - Babinet's theorem with optical base plate	171
P2230600	Diffraction intensity at a slit and at a wire - Babinet's theorem with optical profile bench	171
P2220205	Newton's rings with optical base plate	172
P2220200	Newton's rings with interference filters	172
P2250505	Polarimetry with optical base plate	173
P2250200	Polarimetry	173
P2260106	Faraday effect with optical base plate	174
P2260100	Faraday effect with optical profile bench	174
P2261100	Fourier optics - 2f arrangement	175
P2261200	Fourier optics - 4f arrangement - filtering and reconstruction	176
P2260511	LDA - laser Doppler anemometry with optical base plate (with Cobra3)	177
P2260560	LDA - laser Doppler anemometry (with Cobra4)	177
<b>7.2 Interferometry</b>		
P2220505	Michelson interferometer with optical base plate	178
P2220500	Michelson interferometer with optical profile bench	178
P2220705	Refraction index of CO2 with the Michelson interferometer with optical base plate	179

P2220700	Refraction index of air and CO <sub>2</sub> with the Michelson interferometer with optical profile bench	179
P2220900	Michelson interferometer - High Resolution with optical base plate	180
P2221305	Twyman-Green interferometer	180
P2430800	Magnetostriction with the Michelson interferometer	181
P2221000	Doppler effect with the Michelson interferometer with optical base plate	182
P2221100	Refraction index of air with the Mach-Zehnder interferometer with optical base plate	183
P2220800	Quantum eraser	184
P2221205	Fabry-Perot interferometer - determination of the wavelength of laser light on optical base plate	185
P2221206	Fabry-Perot interferometer - optical resonator modes	186
<b>7.3 Holography</b>		
P2260300	Recording and reconstruction of holograms with optical base plate	187
P2260305	Transfer hologram - master hologram	188
P2260306	Holography - Real time procedure	188
<b>7.4 Laser</b>		
P2260701	Helium neon laser, basic experiment	189
P2260705	Helium neon laser, advanced experiment	189
P2260800	Optical pumping	190
P2260900	Nd:YAG laser	191
<b>7.5 Fibre Optics</b>		
P2261000	Fibre optics	192

## 8 Geo Science

<b>8.1 Water</b>		
P4100160	Comparison of the heat capacities of water and soil (with Cobra4)	194
P4100560	Conductivity of various water samples (with Cobra4)	195
P4100760	The origin of acid rain (with Cobra4)	196
<b>8.2 Air</b>		
P2140700	Barometric height formula	200
<b>8.3 Soil</b>		
P1521163	Salinity of soils and plant substrates (with Cobra4)	201
P1521063	The pH value of various soils (with Cobra4)	202

## 8.4 X-ray Analysis

P2541301	Examination of the structure of NaCl monocrystals with different orientations	207
P2541401	X-ray investigation of cubic crystal structures / Debye-Scherrer powder method	208
P2541501	X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method	208
P2541602	X-ray investigation of crystal structures / Laue method with digital X-ray image sensor (XRIS)	209
P2541601	X-ray investigation of crystal structures / Laue method	209
P2544701	Qualitative X-ray fluorescence analysis of powder samples	210
P2545001	Quantitative X-ray fluorescence analysis of alloyed materials	211
P2544901	Qualitative X-ray fluorescence analysis of ore samples	212
P2544501	Qualitative X-ray fluorescence spectroscopy of metals - Moseley's law	213
P2545101	Quantitative X-ray fluorescence analysis of solutions	214
P2544601	Qualitative X-ray fluorescence analysis of alloyed materials	214
<b>8.5 Literature</b>		
12622-02	TESS advanced Applied Sciences manual Cobra4 environment and outdoors	215
01200-02	Handbook Physics X-Ray Experiments	216

## How to use


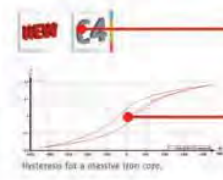
### Facts about the TESS expert catalogue

The TESS expert catalogue is adapted to the PHYWE reference curriculum. PHYWE's experiments fit to the content of experimental lectures and lab courses of schools, colleges and universities. The description of each experiment offers you a lot of information:

**3 Material Sciences**  
3.2 Magnetic Properties

**Article number**

**Ferromagnetic hysteresis (with Cobra4)** P2430760

**Pictograms for quick overview**

**Experimental setup**

**Principle**  
A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength  $H$  and the flux density  $B$  are measured and the hysteresis recorded. The remanence and the coercive field strength of two different iron cores can be compared.

**Task**  
Record the hysteresis curve for a massive iron core and for a laminated one.

**What you can learn about**


- Induction
- Magnetic flux
- Coil
- Magnetic field strength
- Magnetic field of coils
- Remanence
- Coercive field strength

**Exemplary measurement result**

**Description of main principle**

**Related Experiment**  
Ferromagnetism, paramagnetism and diamagnetism  
P1221300

**Cobra4 Sensor Tesla, magnetic field strength, resolution max.  $\pm 0.01$  mT**



**Function and Applications**  
Sensor out of the Cobra4 family to measure the magnetic field strength in DC and AC fields. This Sensor is suitable for the connection of the Hall probes.

**Benefits**

- Connection of two different Hall probes possible: tangential and axial
- Exceptionally good resolution
- Measurement of the earth's magnetic field possible

**Variations of the main experiment (e.g. the same experiment with PC-interface) and experiments with similar topics**

**Tasks for students**

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor Tesla, magnetic field strength, resolution max. $\pm 0.01$ mT	12657-00	1
Cobra4 Sensor-Link Electricity, Current $\pm 6$ A / Voltage $\pm 30$	12644-00	1
Software Cobra4 - multi-user monitor	14550-63	1
Power supply, universal	13500-93	1
Hall probe, tangential, protection cap	13610-02	1

**Devices suitable for the experiment**

**Related scientific topic**

**PHYWE Systeme GmbH & Co. KG - [www.phywe.com](http://www.phywe.com)**

**List of main articles**  
Complete list see: [www.phywe.com](http://www.phywe.com)

### Pictograms for a quick overview of categories, related films or information:

	Experiments with the Computer based measuring system Cobra4		Demonstration experiments		Experiments with laser
	Experiments which have received a Nobel Prize		Computer based measuring		Experiments with radioactivity
	Product movie available - click at <a href="http://www.phywe.com">www.phywe.com</a>		New and completely revised experiments		Training recommended

### Didactic literature –

### comprehensive guide for every experiment

Extensive experimental literature is available for all our university level experiments. Rely on the advantages of our TESS expert experiment descriptions:

- All experiments are uniformly built up
- Experiments cover the entire range of classical and modern chemistry
- Didactically adapted descriptions – enables direct preparation by the student
- Developed and proven by practitioners – comfortable and reliable performance
- Excellent measurement accuracy – results agree with theory
- Computer-assisted experiments – easy, rapid assessment of results
- Modular experimental set-up – multiple use of individual devices, cost effective and flexible

**TESS expert** | **Detection of discontinuities** | TEAS 1.6.06 -00

**Related topics:**  
Ultrasonic echography, discontinuity, A-Mode, straight beam probe, angle beam probe, angle, signal-to-noise ratio.

**Principle:**  
The experiment demonstrates the application and performance of various non-destructive detection methods. First, the test object is scanned in order to determine which is suitable for which type of defect. Then, the signal-to-noise-ratio is determined for a straight beam probe, angle beam probe, and a transmitter-receiver probe (TR probe) by a discussion of the results in view of the selection of the most suitable detector task.

**Equipment:**

1 Basic Set "Ultrasonic Echoscopes" consisting of: <ul style="list-style-type: none"><li>1x Ultrasonic echoscope</li><li>1x Ultrasonic probe 1 MHz</li><li>1x Ultrasonic probe 2 MHz</li><li>1x Ultrasonic test block</li><li>1x Ultrasonic cylinder set</li><li>1x Ultrasonic test plates</li><li>1x Ultrasonic gel</li></ul>	13921-99
1 Extension set: Non-destructive testing	13921-01
1 Ultrasonic probe 2 MHz	13921-05

**Additional equipment:**  
PC with a USB port, Windows XP or higher

**Fig. 1: Detection of discontinuities, experimental set-up**

**Fig. 5: Measurement of the noise amplitude at the vertical crack with the straight beam probe**

**Fig. 6: Sectional image of the test object with the angle beam probe (tip pointing in the scanning direction)**

**PHYWE** | **PHYSIKALISCHES WERKZEUGE**

Picture, Equipment list and Instruction for the execution of the experiment guarantee easy conduction of the experiment.

Theory and evaluation includes full theory of the experiment and shows graphical and numerical experimental results.

## Your solution with just one click!



Our comprehensive Internet site [www.phywe.com](http://www.phywe.com) provides you with all the information you need covering the full spectrum of solutions and products from PHYWE – in five languages! Whether your specific needs involve physics, chemistry, biology or applied sciences, and whether you are looking for information relating to school or university-level materials, you can always find just the right products there quickly and easily.

### Further highlights on our website include:

- More than 50 product videos
- Complete assembly instructions in video form
- Up-to-date software downloads
- Free-of-charge descriptions of the experiments
- Operating manuals and instruction sheets to download

- 1 Language
- 2 Subject area = Physics, Chemistry, Biology, Applied Sciences
- 3 Education level = School, University
- 4 Media e. g. product videos
- 5 Downloads e. g. experimental literature



Visit us today: [www.phywe.com](http://www.phywe.com)



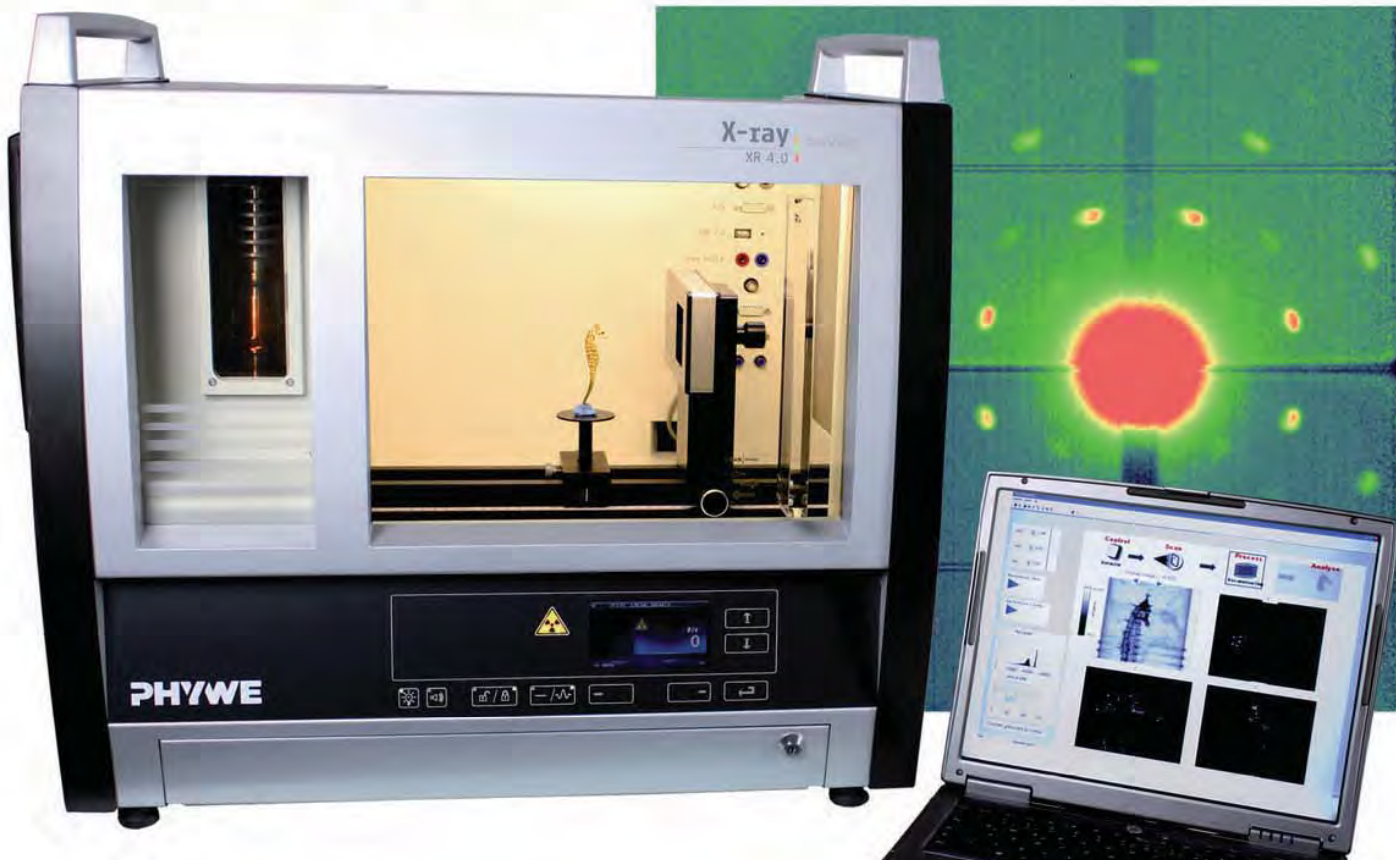
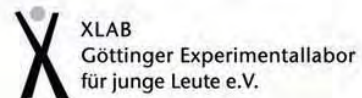
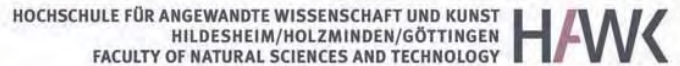
# Cooperations – Reliable partner for education

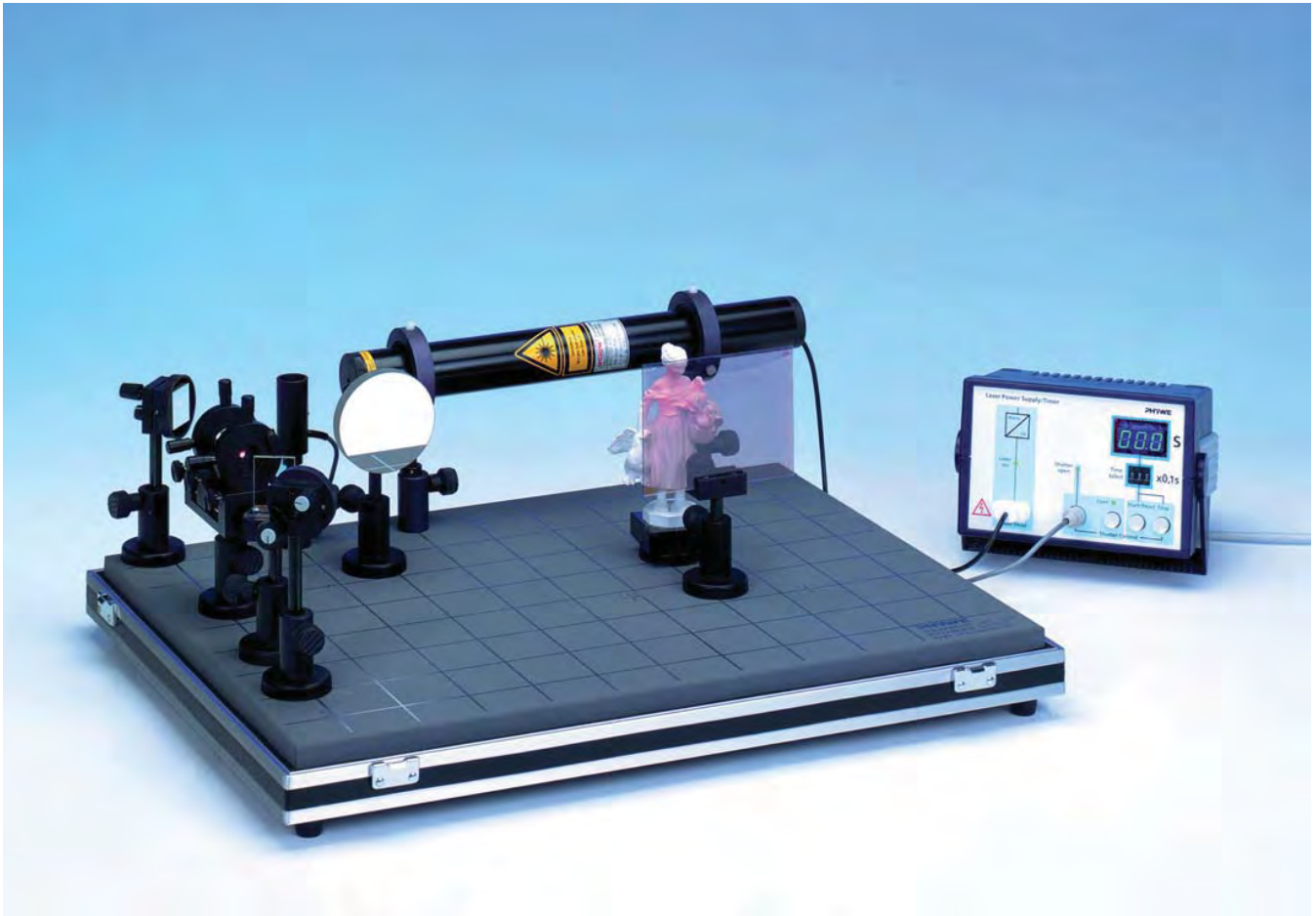
There's a way to do  
it better – find it.

Thomas Edison

The share of ideas and transfer of knowledge between academia and PHYWE is one of our major attempts in R&D. Our network is spread out worldwide and comprises cooperation projects, research assignments, and the education of expert staff.

Some breathtaking novelties of our new XR 4.0 platform are one by one the result of fruitful cooperation in this regard - thank you!





## Photonics

<b>7.1</b>	<b>Basic Principles</b>	<b>166</b>
<b>7.2</b>	<b>Interferometry</b>	<b>178</b>
<b>7.3</b>	<b>Holography</b>	<b>187</b>
<b>7.4</b>	<b>Laser</b>	<b>189</b>
<b>7.5</b>	<b>Fibre Optics</b>	<b>192</b>



**P2240405 Lambert's law of radiation on optical base plate**

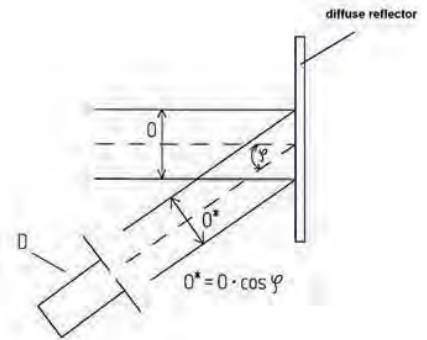


Diagram of the principle of measurements with the used magnitudes (with  $\theta$  as apparent magnitude of surface  $\theta$ ).

**Principle**

Visible light impinges on a diffusely reflecting surface. The luminance of this surface is determined as a function of the angle of observation.

**Tasks**

1. The luminous flux emitted reflected by a diffusely reflecting surface is to be determined as a function of the angle of observation.
2. Lambert's law (cos-law) is to be verified using the graph of the measurement values.

**What you can learn about**

- Luminous flux
- Light quantity
- Light intensity
- Illuminance
- Luminance

**Main articles**

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Rot. guide rail w. angular scale	08717-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	1

**Related Experiment**

**Lambert's law**

P2240400

**Laser, He-Ne, 0.2/1.0 mW, 230 V AC**

**Function and Applications**

Linearly polarised light source, very short design.

**Benefits**

- Welded glass tube assures a very long lifetime > 18 000 operating hours
- Key switch and integrated greyfilter to reduce radiation power to 0.2 mW. Screw-in release to activate the grey filter.
- Anodised aluminium casing with integrated mains power supply, screw in holding stem, signal light and required warnings printed on both sides. Fixed mains connecting cable 140 cm.

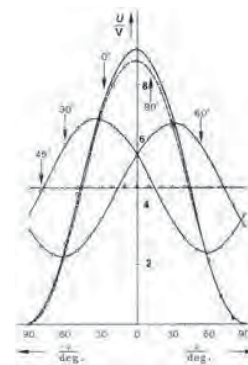
**Equipment and technical data**

- Wavelength 632.8 nm, optical output power without filter 1.0 mW, with filter 0.2 mW
- Beam diameter 0.5 mm, beam divergence < 2 mrad.
- Minimum polarisation 500:1, max drift over 8 hours ± 2.5%
- Oscillating mode TEM00, lifetime > 18000 h
- Power requirements 35 VA, connecting voltage 230 V, 50/60 Hz

08180-93

Polarisation through quarter-wave plates with optical base plate

P2250105



Intensity distribution of polarised light for different angles of the  $\lambda/4$  plate, as a function of the analyser position.

**Principle**

Monochromatic light impinges on amica plate, perpenicularly to its optical axis. If the thickness of the plate is adequate ( $\lambda/4$  plate), a phase shift of  $90^\circ$  occurs between the ordinary and the extraordinary beam when the latter leaves the crystal. The polarisation of exiting light is examined for different angles between the optical axis of the  $\lambda/4$  plate and the direction of polarisation of incident light.

**Tasks**

1. Measurement of the intensity of linearly polarised light as a function of the analyser's position (Malus' law).
2. Measurement of the light intensity behind the analyser as a function of the angle between the optical axis of the  $\lambda/4$  plate and the analyser.
3. Carrying out experiment (2) with two successive  $\lambda/4$  plates.

**What you can learn about**

- Linearly, circularly an elliptically polarised light
- Polarizer; Analyser; Malus' law; Plane of polarisation
- Double refraction; Optical axis; Ordinary and extraordinary beam

**Main articles**

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	2
Polarizing filter f.opt.base pl.	08730-00	2

**Related Experiment**

Polarisation through quarter-wave plates with optical profile bench

P2250100

**Universal measuring amplifier**

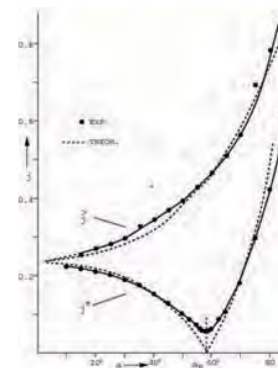


**Function and Applications**

Universal measuring amplifier for amplification of AC and DC voltages. Suitable for practical exercises.

13626-93

**P2250305 Fresnel's law - theory of reflection with optical base plate**



Measurement results.

**Principle**

Plane-polarized light is reflected at a glass surface. Both the rotation of the plane of polarization and the intensity of the reflected light are to be determined and compared with Fresnel's formulae for reflection.

**Tasks**

1. The reflection coefficients for light polarized perpendicular and parallel to the plane of incidence are to be determined as a function of the angle of incidence and plotted graphically.
2. The refractive index of the flint glass prism is to be found.
3. The reflection coefficients are to be calculated using Fresnel's formulae and compared with the measured curves.
4. The reflection factor for the flint glass prism is to be calculated.
5. The rotation of the polarization plane for plane polarized light when reflected is to be determined as a function of the angle of incidence and presented graphically. It is then to be compared with values calculated using Fresnel's formulae.

**What you can learn about**

- Electromagnetic theory of light
- Reflection coefficient; Reflection factor
- Brewster's law
- Law of refraction
- Polarisation; Polarisation level

**Main articles**

Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Prism, 60 degrees, h.36.4mm,flint	08237-00	1

Rot. guide rail w. angular scale	08717-00	1
Photoelement f. opt. base plt.	08734-00	1
Polarizing filter f.opt.base pl.	08730-00	2

**Related Experiment**

**Fresnel's equations - theory of reflection with optical profile bench**

**P2250300**

**Optical base plate with rubberfeet**

**Function and Applications**

For setting up magnetically adhering optical components.

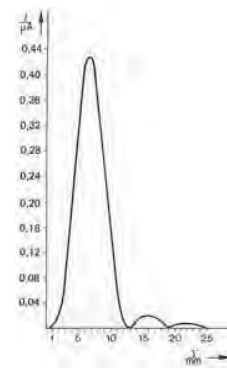
**Equipment and technical data**

- Rigid and vibration-damped working base made of steel plate
- With corrosion protection, NEXTEL® plastic coating and imprinted grid (5×5) cm
- Three fixed adapter sleeves for laser and laser shutter
- With rubber feet for non-slip working
- Base plate size (mm): 590 × 430 × 24
- Weight: 7 kg

**08700-00**

## Diffraction at a slit and Heisenberg's uncertainty principle with optical base plate

P2230105



Intensity distribution of the diffraction pattern of a 0.05 mm wide slit, at a distance of 490 mm.

### Principle

The intensity distribution in the Fraunhofer diffraction pattern of a slit is measured. Measurement results are evaluated both in the wave representation through comparison with Kirchhoff's diffraction formula and in the photon representation, in order to verify Heisenberg's uncertainty principle.

### Tasks

1. The intensity distribution of the Fraunhofer diffraction pattern due to a simple slit is measured. The amplitudes of the peaks and of the minima are calculated according to Kirchhoff's diffraction formula and compared to measured values.
2. Momentum uncertainty is calculated with the assistance of the diffraction patterns of simple slits of different widths, and Heisenberg's uncertainty relation is verified.

### What you can learn about

- Diffraction; Sharpness; Kirchhoff's diffraction
- Formula; Measurement precision
- Local uncertainty; Impulse uncertainty
- Wave-matter duality; De Broglie's relation

### Main articles

Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	1
Voltmeter,0.3-300VDC,10-300VAC /	07035-00	1

### Related Experiment

**Diffraction at a slit and Heisenberg's uncertainty principle with optical bench**

P2230100



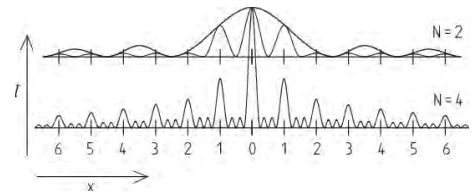
**Werner Heisenberg**

1932, Nobel Prize in Physics

## 7 Photonics

### 7.1 Basic Principles

#### P2230405 Diffraction of light through a double slit or by a grid with optical base plate



Qualitative intensity distribution of diffraction through 2 and 4 slits, the distance  $x$  being normalised to  $l/s$ . The intensity distribution of the simple slit has been represented with exaggerated height to give a clearer view.

#### Principle

The coherent monochromatic light of a laser is directed to a diaphragm with a varying number of slits. The resulting interference patterns are studied using a photoelement.

#### Tasks

- The intensity distribution of diffraction patterns formed by multiple slits is measured using a photoelement.
- The dependence of this distribution from the slit widths, the number of slits and the grid constant is investigated.
- The obtained curves are compared to the theoretical values.

#### What you can learn about

- Fraunhofer diffraction
- Huygens' principle
- Interference
- Coherence

#### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	1

#### Related Experiment

**Diffraction intensity due to multiple slits and grids with optical profile bench**

P2230400

#### Photoelement for optical base plate



#### Function and Applications

For determination of light intensities.

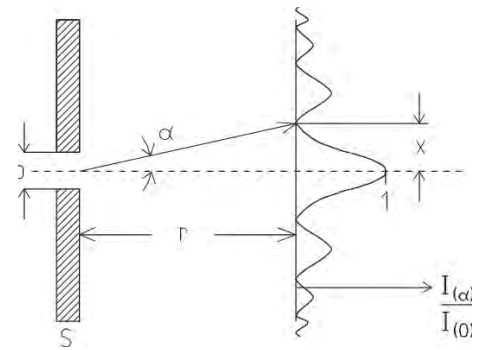
#### Equipment and technical data

- Spectral range: 400 nm...1100 nm.
- With changeable stem  $\varnothing = 10\text{mm}$  and  $l = 110\text{ mm}$  respectively  $l = 250\text{ mm}$ .
- Slit diaphragm  $d = 0.3\text{mm}$ .

08734-00

## Diffraction intensity at a slit and at a wire - Babinet's theorem with optical base plate

P2230605



Principle of set up for diffraction through a slit and qualitative distribution on intensities in the detector plane LD.

### Principle

Babinet's Principle states that the diffraction pattern for an aperture is the same as the pattern for an opaque object of the same shape illuminated in the same manner. That is the pattern produced by a diffracting opening of arbitrary shape is the same as a conjugate of the opening would produce.

### Tasks

Babinet's theorem is verified by the diffraction pattern of monochromatic light directed through a slit and an opaque stripe complementary to the latter. The experiment is also performed with a circular aperture and an opaque obstacle conjugate to this opening.

### What you can learn about

- Fraunhofer interference
- Huygens' principle
- Multiple beam interference
- Babinet's theorem
- Coherence

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Screen, with diffracting elements	08577-02	1
Photoelement f. opt. base plt.	08734-00	1

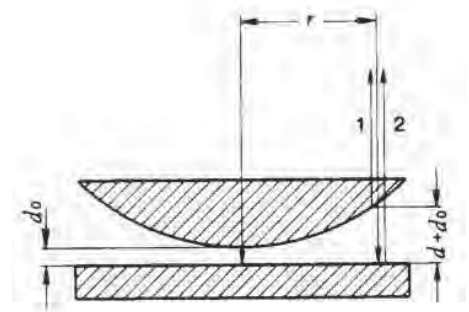
### Related Experiment

Diffraction intensity at a slit and at a wire - Babinet's theorem with optical profile bench

P2230600



**P2220205 Newton's rings with optical base plate**



Generation of Newton's rings.

**Principle**

The air wedge formed between slightly convex lens and a plane glass plate (Newton's colour glass) is used to cause interference of monochromatic light. The wavelength is determined from the radii of the interference rings.

**Tasks**

The diameters of interference rings produced by Newton's colour glass are measured and these are used to:

1. Determine the wavelength for a given radius of curvature of the lens.
2. Determine the radius of curvature for a given wavelength.

**What you can learn about**

- Coherent light
- Phase relation
- Path difference
- Interference at thin layers
- Newton's colour glass

**Main articles**

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate with rubberfeet	08700-00	1
Newton colourglass f.opt.b. pl.	08730-02	1
Sliding device, horizontal	08713-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

**Related Experiment**

**Newton's rings with interference filters**

**P2220200**

**He/Ne Laser, 5mW with holder**



**Function and Applications**

He/Ne laser with fixed connection cable with HV jack for laser power pack.

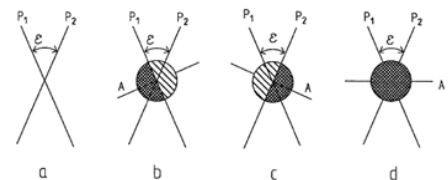
**Equipment and technical data**

- Wave length 632.8 nm
- Modes TEM00
- Degree of polarisation 1:500
- Beam diameter 0.81 mm
- Beam divergence 1 mrad
- Max. power drift max. 2.5%/ 8 h
- Service life ca. 15000 h
- Coaxial cylinder casing  $\varnothing = 44.2\text{mm}$ ,  $l = 400\text{ mm}$
- Incl. 2 holders with three-point bearing and 2 setting collars

**08701-00**

## Polarimetry with optical base plate

P2250505



Working principle of the half shadow polarimeter.

### Principle

Optically active substances cause very slight rotations of the light polarisation plan, which the method of crossed polarisation filters is not strong enough to measure. With this method, the direction of polarisation of the analyser is perpendicular to that of the polarizer. If an optically active substance is placed between them, the polarisation direction of the analyser must be corrected by the corresponding angle of rotation of the plane of polarisation in order to obtain an intensity minimum again. A stronger adjustment possibility for the determination of the angle is given with the half shadow polarimeter, used in this experiment to measure the angle of rotation of the plane of polarisation caused by glucose-water solutions of different concentrations.

### Task

Determine the angle of rotation for sugar solutions of different concentrations.

### What you can learn about

- Lippich polariser
- Malus' law

### Main articles

Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Optical base plate with rubberfeet	08700-00	0
Pol.filter halfshade f.opt.b.pl.	08730-01	1
Polarizing filter f.opt.base pl.	08730-00	2
Adjusting support 35 x 35 mm	08711-00	1
Surface mirror 30 x 30 mm	08711-01	1
Holder,dir.vis. prism,opt.b.pl.	08726-00	1

### Related Experiment

#### Polarimetry

P2250200

### Laser, He-Ne, 0.2/1.0 mW, 230 V AC



### Function and Applications

Linearly polarised light source, very short design.

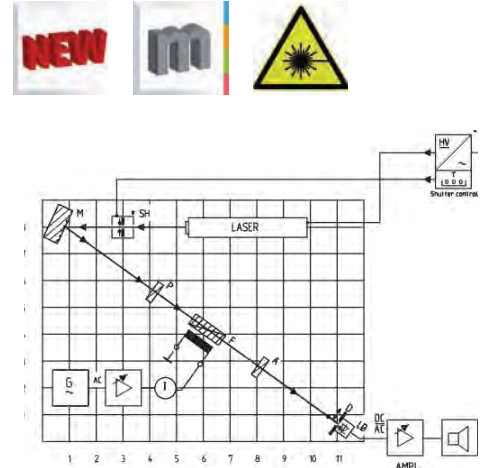
### Benefits

- Welded glass tube assures a very long lifetime > 18 000 operating hours; Key switch and integrated greyfilter to reduce radiation power to 0.2 mW. Screw-in release to activate the grey filter.
- Anodised aluminium casing with integrated mains power supply, screw in holding stem, signal light and required warnings printed on both sides. Fixed mains connecting cable 140 cm.

08180-93



**P2260106 Faraday effect with optical base plate**



Experimental setup.

**Principle**

When the Faraday effect was discovered in 1845 it was the first experiment that elucidated the relation of light and electromagnetism. If linearly polarised light passes through a region with magnetic field the angle of rotation of the plane of polarisation is altered. This alteration appears to be a linear function of both the average magnetic flow density and the distance that the wave covers in the magnetic field. The factor of proportionality is a medium-specific constant and is called Verdet's constant.

**Task**

Investigate the Faraday effect qualitatively through observation of the electro optical modulation of the polarised laser light with frequencies in the acoustic range.

**What you can learn about**

- Interaction of electromagnetic fields
- Electromagnetism
- Polarisation
- Verdet's constant
- Malus' law
- Electronic oscillation

**Main articles**

Digital Function Generator, USB, incl. Cobra4 Software	13654-99	1
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Faraday modulator f.opt.base pl.	08733-00	1
Loudspeaker, 8 Ohm/5 kOhm	13765-00	1
Photoelement f. opt. base pl.	08734-00	1

**Related Experiment**

**Faraday effect with optical profile bench**

**P2260100**

**Faraday modulator for optical base plate**



**Function and Applications**

Copper coil on temperature-stable aluminium winder with insert for holding glass rods (SF58) for Faraday effect.

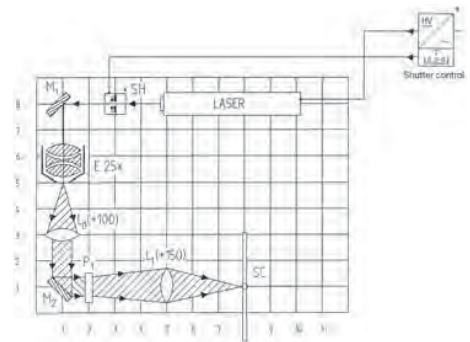
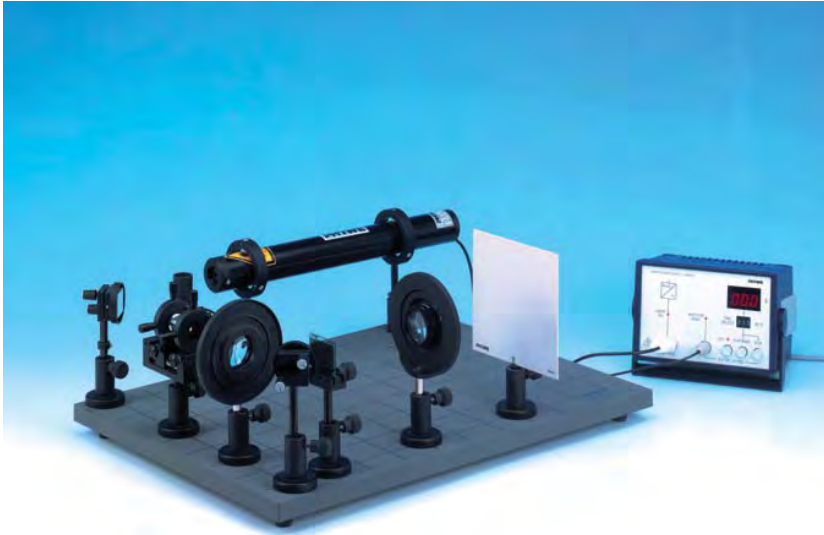
**Equipment and technical data**

- With round stem, clamp screws and fixed connection cable = 1m with 4-mm jacks
- Number of windings 1200
- Inductivity 6.3 mH
- Ohm's resistance 4 Ω
- Internal diameter 14 mm
- Max. current 5 A (1min)

**08733-00**

## Fourier optics - 2f arrangement

P2261100



Experimental setup for the fundamental principles of Fourier optic (2f setup).

### Principle

The electric field distribution of light in a specific plane (object plane) is Fourier transformed into the 2f configuration.

### Task

Investigation of the Fourier transform by a convex lens for different diffraction objects in a 2f set-up.

### What you can learn about

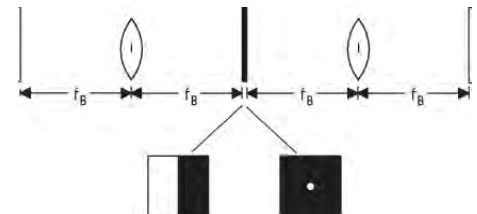
- Fourier transform
- Lenses
- Fraunhofer diffraction
- Index of refraction
- Huygens' principle

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Screen, with diffracting elements	08577-02	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1



**P2261200 Fourier optics - 4f arrangement - filtering and reconstruction**



Principle of the setup for coherent optical filtration.

**Principle**

The electric field distribution of light in a specific plane (object plane) is Fourier transformed into the 4f configuration by 2 lenses and optically filtered with appropriate diaphragms.

**Tasks**

1. Optical filtration of diffraction objects in 4 f setup.
2. Reconstruction of a filtered image.

**What you can learn about**

- Fourier transform
- Lenses
- Fraunhofer diffraction
- Index of refraction
- Huygens' principle
- Fog technique

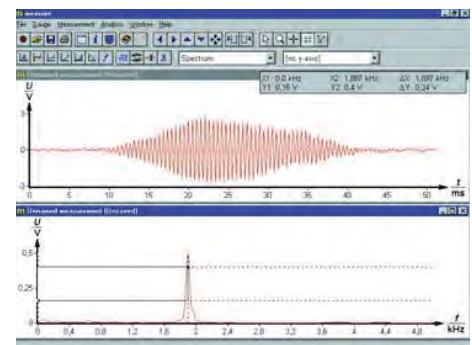
**Main articles**

Ultrasonic generator	13920-99	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Screen, with diffracting elements	08577-02	1
Glass cell, 150x55x100 mm	03504-00	1



## LDA - laser Doppler anemometry with optical base plate (with Cobra3)

P2260511



Measurement of the signal spectrum with a signal peak.

### Principle

Small particles in a current pass through the LDA measuring volume and scatter the light whose frequency is shifted by the Doppler effect due to the particle movement.

The frequency change of the scattered light is detected and converted into a particle or flow velocity.

### Task

Measurement of the light-frequency change of individual light beams which are reflected by moving particles.

### What you can learn about

- Interference
- Doppler effect
- Scattering of light by small particles (Mie scattering)
- High- and low-pass filters
- Sampling theorem
- Spectral power density
- Turbulence

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Cobra3 BASIC-UNIT, USB	12150-50	1
Si-Photodetector with Amplifier	08735-00	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Control Unit for Si-Photodetector	08735-99	1

### Cobra4 Experiment - available 2013

LDA - laser Doppler anemometry (with Cobra4)

P2260560

### Control Unit for Si-Photodetector

#### Function and Applications

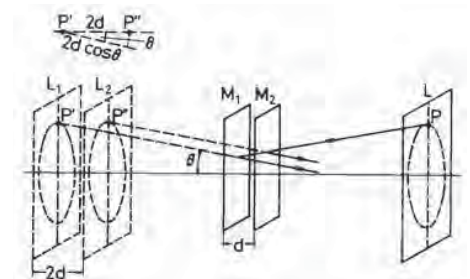
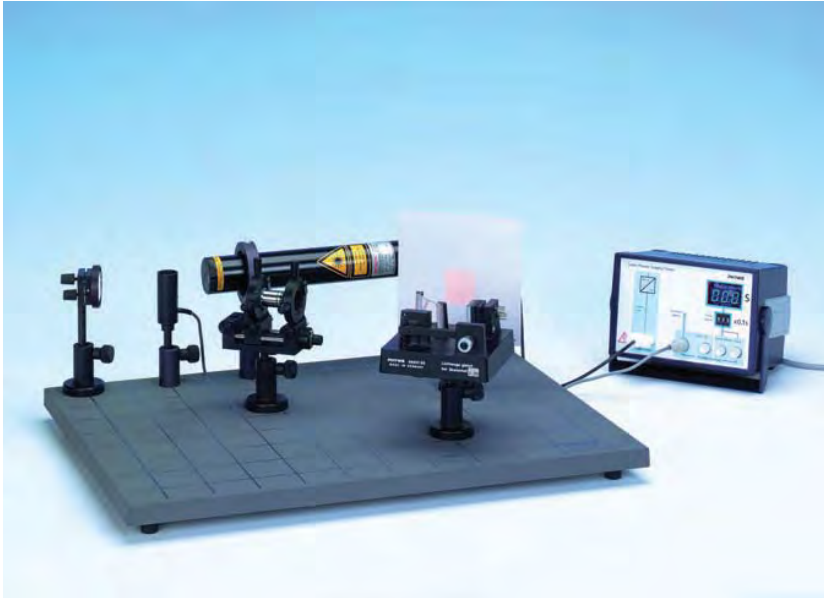
Amplifier for silicon photodetector.

#### Equipment and technical data

- 3 BNC outputs:
  - Output 1 (monitor output), gain 1, bandwidth for DC ... 60 kHz
  - Output 2, gain 1 ... 100, band width for AC 10 Hz ... 60 kHz
  - Output 3 (filter output), gain 1 ... 100, band width for AC 200 Hz ... 10 kHz
- Input: 5-pole diode socket for silicon photodetector
- Connections +9 V ... +12 V, Power consumption 1 W
- Impact-resistant plastic case (194 x 140 x 130) mm with carrying handle; Includes 110-V/240-V power supply

08735-99

P2220505 Michelson interferometer with optical base plate



Formation of interference rings.

**Principle**

In a Michelson interferometer, a lightbeam is split into two partial beams by a semi transparent glass plate (amplitude splitting). These beams are reflected by two mirrors and brought to interference after they passed through the glass plate a second time.

**Task**

The wavelength of the used laserlight is determined through the observation of the change in the interference pattern upon changing the length of one of the interferometer arms.

**What you can learn about**

- Interference
- Wavelength
- Refraction index
- Light velocity
- Phase
- Virtual light source
- Coherence

**Main articles**

Michelson interferometer	08557-00	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

**Related Experiment**

Michelson interferometer with optical profile bench

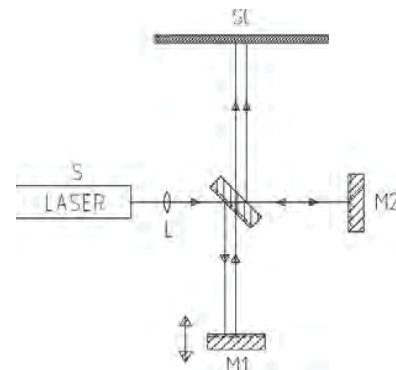
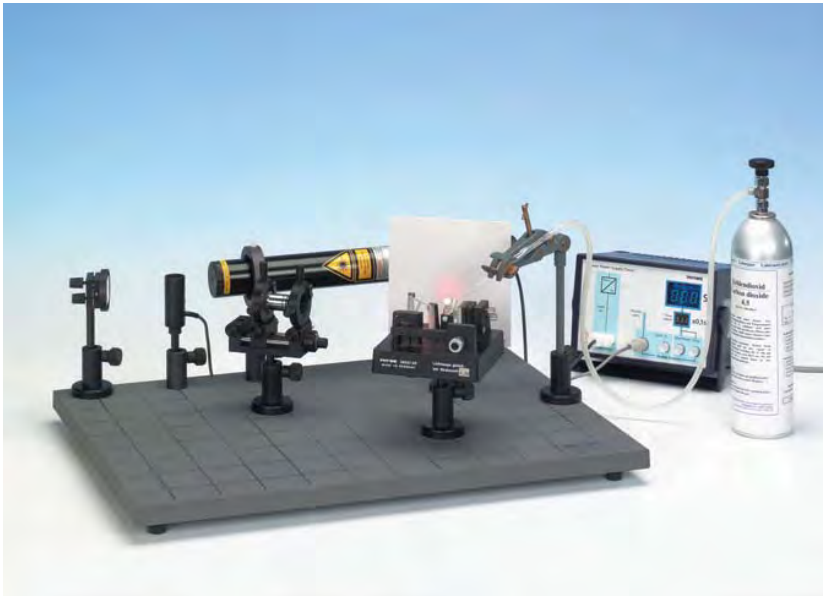
P2220500



Albert A. Michelson  
1907, Nobel Prize in Physics

## Refraction index of CO<sub>2</sub> with the Michelson interferometer with optical base plate

P2220705



Michelson's setup for interference.

### Principle

Light is caused to interfere by means of a beam splitter and two mirrors according to Michelson's set up. Substituting the air in a measurement cuvette located in one of the interferometer arms by CO<sub>2</sub> gas allows to determine the index of refraction of CO<sub>2</sub>.

### Task

Determine the difference of the refraction index between air and CO<sub>2</sub> from changes in the interference pattern.

### What you can learn about

- Interference
- Wavelength
- Index of refraction
- Light velocity
- Phase
- Virtual light source
- Coherence

### Main articles

Michelson interferometer	08557-00	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

### Related Experiment

Refraction index of air and CO<sub>2</sub> with the Michelson interferometer with optical profile bench

P2220700

### Michelson interferometer



### Function and Application

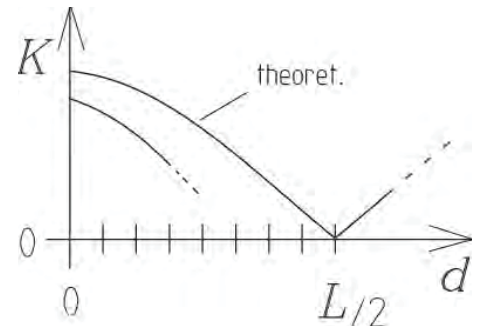
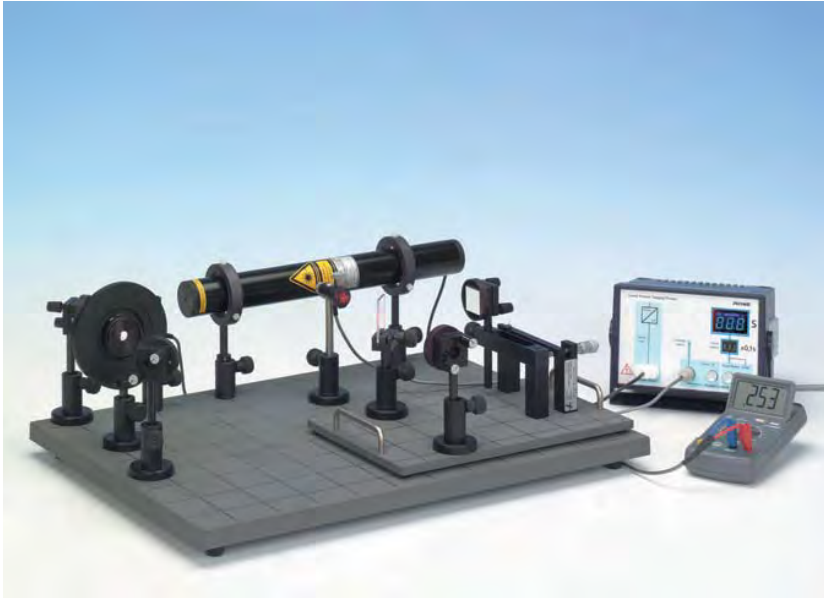
To measure light wavelengths and refractivity of liquids and gases.

### Equipment and technical data

- Metalbase-plate 120 x 120 mm with removable holding stem and with adjustable surface mirrors 30 x 30 mm
- Two polarising filters and micrometer
- Fine shoots to the tilt adjustment of fixed mirror
- Bracket for additional required cell for investigation of gases

08557-00

**P2220900    Michelson interferometer - High Resolution with optical base plate**



Experimentally determined contrast function in comparison to the theoretical contrast function  $K$  of a 2-mode laser.

**Principle**

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alteration in the interference pattern is observed and the wave length of the laser light determined.

**Tasks**

1. Construction of a Michelson interferometer using separate components.
2. The interferometer is used to determine the wavelength of the laser light.
3. The contrast function  $K$  is qualitatively recorded in order to determine the coherence length with it.

**What you can learn about**

- Interference; Wavelength; Diffraction index
- Speed of light; Phase; Virtual light source

**Main articles**

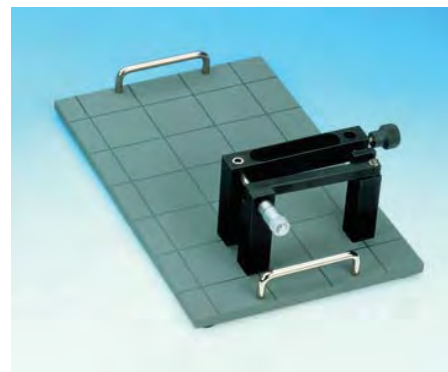
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Interferometerplate w prec.drive	08715-00	1
Optical base plate with rubberfeet	08700-00	1
Surface mirror 30 x 30 mm	08711-01	4

**Related Experiment**

**Twyman-Green interferometer**

**P2221305**

**Interferometerplate with precision drive**



**Function and Applications**

For precise and reproducible linear shift of optical components e.g. in interferometer setups.

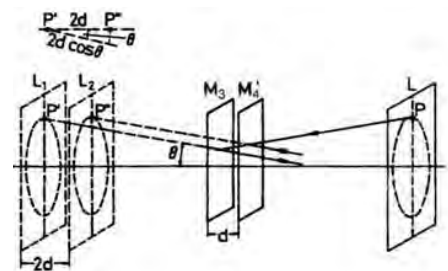
**Equipment and technical data**

- Suppression of tilting effects due to traverse construction.
- Wavelength adjustment through lever device with micrometer screw.
- Stiff steel base plate with NEXTEL®-Plastic coating.
- Set up on base plate.
- Shift path: max. 0.25 mm.
- Resolution: 500 nm.
- Dimensions (mm): 320 × 200 × 14.
- Mass: 5 kg.

**08715-00**

## Magnetostriction with the Michelson interferometer

P2430800



Formation of circular interference fringes.

### Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

### Tasks

1. Construction of a Michelson interferometer using separate optical components.
2. Testing various ferromagnetic materials (iron and nickel) as well as a non-ferromagnetic material (copper), with regard to their magnetostrictive properties.

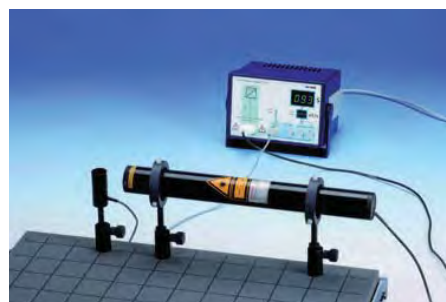
### What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Ferromagnetic material
- Weiss molecular magnetic fields
- Spin-orbit coupling

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Power supply, universal	13500-93	1
Optical base plate with rubberfeet	08700-00	1
Faraday modulator f.opt.base pl.	08733-00	1
Rods for magnetostriction, set	08733-01	1
Adjusting support 35 x 35 mm	08711-00	3

### Power supply for laser head 5 mW



### Function and Applications

High voltage power supply for lasers, e. g. the 5 mW laser (08701-00).

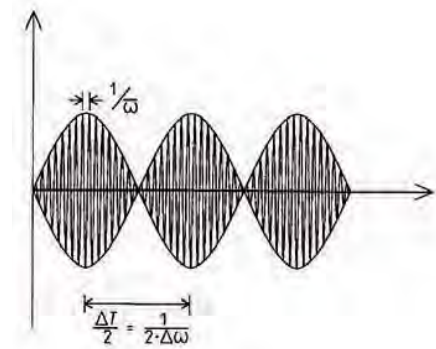
### Equipment and technical data

- With programmable timer for selection of exposure time of holograms between 0.1 ... 99 s.
- With acontrollable shutter.
- Digital display for preset shutter times as well as those which have already occurred.
- Shutter control via time select, new start, stop and shutter open (permanent open).
- Dimensions of plastic housing (mm): 184 x 140 x 130.
- Incl. shutter with fixed connection cord with unit plug on holding rod.
- Rod diameter: 10 mm.

08702-93



**P2221000 Doppler effect with the Michelson interferometer with optical base plate**



Resulting difference signal during interferometric measurement.

**Principle**

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alteration in the interference pattern is observed and the modulation frequency is measured using the Doppler effect.

**Tasks**

1. Construction of a Michelson interferometer using separate components.
2. Measurement of the Doppler effect via uniform displacement of one of the mirrors.

**What you can learn about**

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Temporal coherence
- Special relativity theory
- Lorentz transformation

**Main articles**

Recorder, tY, 2 channel	11415-95	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Interferometerplate w prec.drive	08715-00	1
Optical base plate with rubberfeet	08700-00	1
Light barrier with counter	11207-30	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1

**Light barrier with counter**



**Function and Applications**

With the function of an electronic time measuring and counting device.

**Benefits**

- 4 figure luminous display, selection switch for 4 operating modes
- RESET key, BNC jack for exterior starting and/ or stopping of time measurement, TTL output to control peripheral devices
- power supply connector (4 mm jacks)

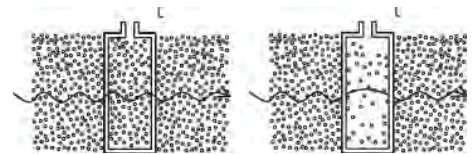
**Equipment and technical data**

- Fork width: 70 mm, Usable barrier depth: 65 mm
- Sensitivity adjustable, LED-Display: 4digits, 8 mm
- Time measurement: 0...9,999 s, Counting: 0...9999
- Supply voltage: 5 V DC, Max. working frequency: 25 kHz
- External dimensions (mm): 160 x 25 x 105M6
- Threaded holes in casing: 7, Stem included: 100 mm, M6 thread

11207-30

## Refraction index of air with the Mach-Zehnder interferometer with optical base plate

P2221100



Schematic representation of the cell with normal pressure (a) and nearly absolute vacuum (b).

### Principle

Light is brought to interference by two mirrors and two beam splitters in the Mach-Zehnder arrangement. By changing the pressure in a measuring cell located in the beam path, one can deduce the refraction index of air.

### Tasks

1. Construction of a Mach-Zehnder interferometer using individual optical components.
2. Measurement of the refraction index  $n$  of air by lowering the air pressure in a measuring cell.

### What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1
Adjusting support 35 x 35 mm	08711-00	4



**P2220800 Quantum eraser**



Pattern seen on the screen when blocking half of the beam.

**Principle**

A Mach-Zehnder-interferometer is illuminated with a laser beam. Circular interference fringes appear on the screens behind the interferometer. If polarisation filters with opposite polarisation planes are placed in the two interferometer paths the interference patterns disappear. Placing another polariser before one of the screens causes the pattern to reappear. Electromagnetic radiation can be described both in terms of propagating waves, as well as particles (photons). The experiment illustrates this duality by showing how interference patterns can be explained on the basis of both classical wave mechanics and quantum physics.

**Tasks**

1. Set up the experiment and observe the interference pattern on the screen.
2. Change the polarisation of the beams with the PF1 and PF2 polarisers and observe the influence on the interference pattern.
3. Use the third polariser PF3 to cancel the polarisation of the light in the two beams, and observe the reappearance of the interference pattern.

**What you can learn about**

- Wave-particle duality
- Wave interference
- Quantum mechanics

**Main articles**

Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Optical base plate in exp.case	08700-01	1
Diaphragm holder f.opt.base plt.	08724-00	1
Polarizing filter f.opt.base pl.	08730-00	3

Adjusting support 35 x 35 mm	08711-00	4
Polarization specimen, mica	08664-00	1
Surface mirror 30 x 30 mm	08711-01	4

**Diaphragm holder for optical base plate**



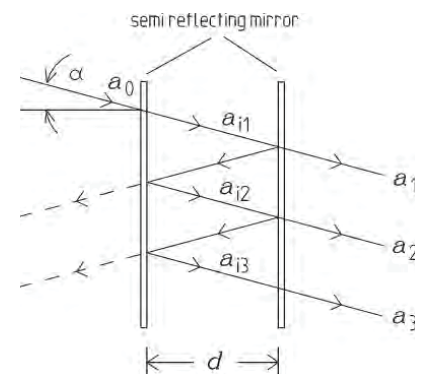
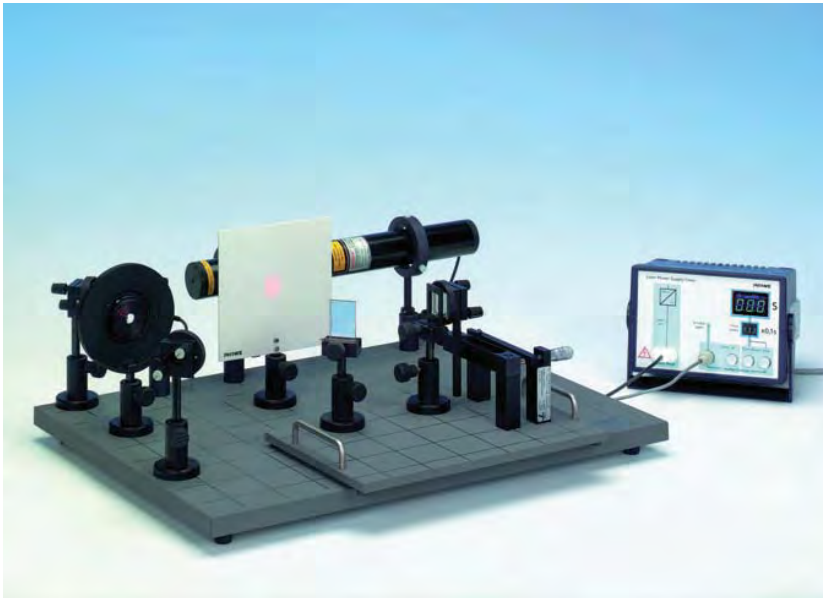
**Function and Applications**

Diaphragm holder for optical base plate with shortstem  $l = 35$  mm.

**08724-00**

## Fabry-Perot interferometer - determination of the wavelength of laser light on optical base plate

P2221205



Multibeam interferometer after Fabry and Perot. Illustration of the principle for deriving the individual amplitudes.

### Principle

Two mirrors are assembled to form a Fabry-Perot interferometer. Using them, the multibeam interference of a laser's light beam is investigated. By moving one of the mirrors, the change in the interference pattern is studied and the wavelength of the laser's light determined.

### Tasks

1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometer is used to determine the wavelength of the laser light.

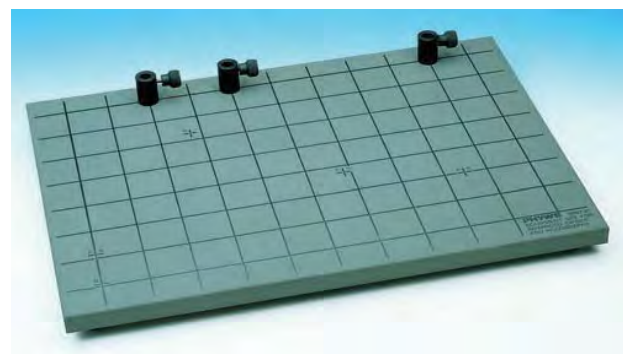
### What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Interferometerplate w prec.drive	08715-00	1
Beam splitter T=30,R=70, w.holder	08741-01	1
Optical base plate with rubberfeet	08700-00	1
Adjusting support 35 x 35 mm	08711-00	3
Surface mirror 30 x 30 mm	08711-01	3

### Optical base plate with rubberfeet



### Function and Applications

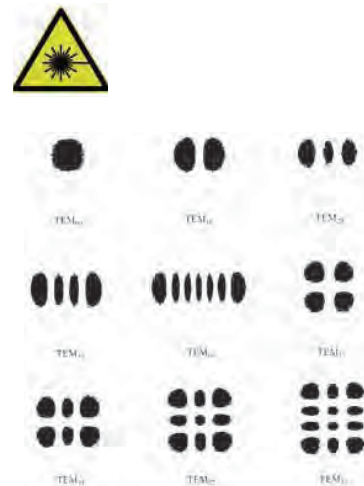
For setting up magnetically adhering optical components.

### Equipment and technical data

- Rigid and vibration-damped working base made of steel plate.
- With corrosion protection, NEXTEL® plastic coating and imprinted grid (5x5) cm.
- Three fixed adapter sleeves for laser and laser shutter.
- With rubber feet for non-slip working.
- Base plate size (mm): 590 x 430 x 24
- Mass: 7 kg

08700-00

**P2221206 Fabry-Perot interferometer - optical resonator modes**



Intensity distribution of the Hermitian-Gaussian resonator modes.

**Principle**

Two mirrors are assembled to form a Fabry-Perot Interferometer. Using them, the multibeam interference of a laser's light beam is investigated. On moving one of the mirrors, the change in the intensity distribution of the interference pattern is studied. This is a qualitative experiment, to study the shape of different laser modes and compare it with some photos given in the description.

**Tasks**

1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometer is used to observe different resonator modes within the interferometer.

**What you can learn about**

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Two-beam interferometer

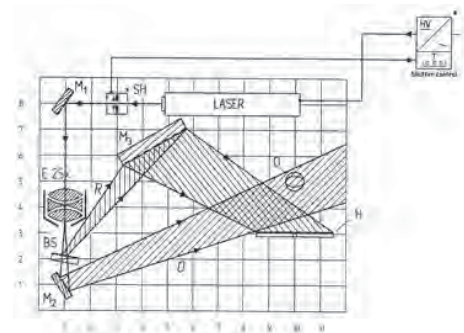
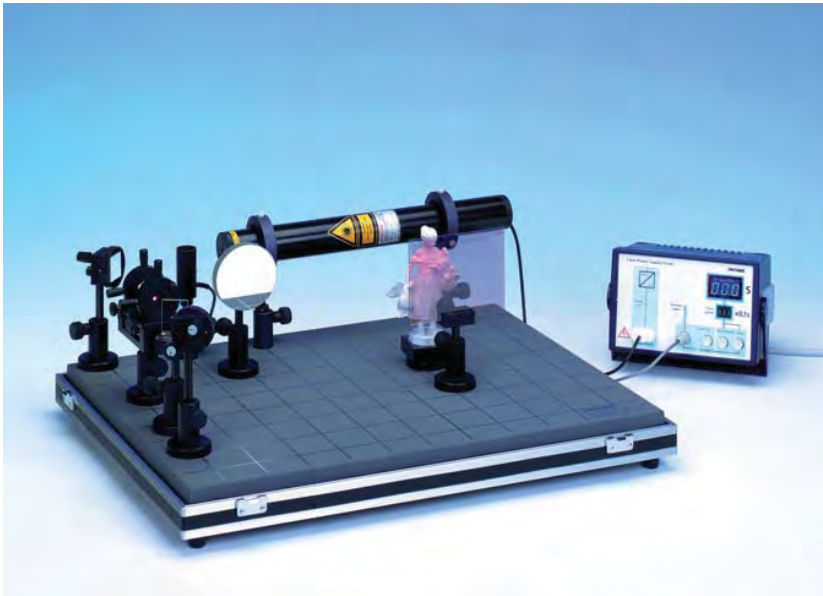
**Main articles**

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Concave mirror OC; $r=1.4m,T=1.7\%$	08711-03	1
Interferometerplate w prec.drive	08715-00	1
Plane mirror HR>99%,mounted	08711-02	1
Optical base plate with rubberfeet	08700-00	1
Adjusting support 35 x 35 mm	08711-00	4



## Recording and reconstruction of holograms with optical base plate

P2260300



Setup for recording and reconstruction of a transmission hologram.

### Principle

In contrast to normal photography a hologram can store information about the three-dimensionality of an object. To capture the three-dimensionality of an object, the film stores not only the amplitude but also the phase of the light rays. To achieve this, a coherent light beam (laser light) is split into an object and a reference beam by being passed through a beam splitter. These beams interfere in the plane of the holographic film. The hologram is reconstructed with the reference beam which was also used to record the hologram.

### Tasks

1. Record a laser light hologram and process it to get a phase hologram. Reconstruct it by verifying the virtual and the real image.
2. Record a white light reflection hologram and process it to get a phase hologram. Laminate it for reconstruction by a white light source.

### What you can learn about

- Object beam; Reference beam; Real and virtual image
- Phase holograms; Amplitude holograms; Interference
- Diffraction; Coherence; Developing of film

### Main articles

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate in exp.case	08700-01	1
Surface mirror, large, d=80 mm	08712-00	1
Holographic plates, 25 pieces	08746-00	1
Sliding device, horizontal	08713-00	1
Darkroom equipment for holography, 230 V	08747-88	1

### Optical base plate in exp.case



### Function and Applications

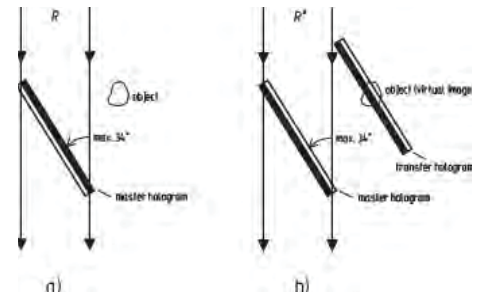
For vibration-damped storage of magnetic adherent optical components.

### Equipment and technical data

- Bottom clamp screws.
- When carrying out the experiments, the base plate remains in the bottom of the case.
- Separate case hood with lock.
- Case dimensions (mm): 620 × 460 × 280.
- Mass: 13 kg.

08700-01

P2260305 Transfer hologram - master hologram



Correct selection of the object position so that the image-capture of a transfer hologram is possible.

**Principle**

In contrast to normal photography a hologram can store information about the three-dimensionality of an object. To capture the three-dimensionality of an object, the film stores not only the amplitude but also the phase of the light rays. To achieve this, a coherent light beam (laser light) is split into an object and a reference beam by being passed through a beam splitter. These beams interfere in the plane of the holographic film. The hologram is reconstructed with the reference beam which was also used to record the hologram.

**Tasks**

1. Capture the holographic image of an object.
2. Perform the development and bleaching of this phase hologram.
3. Reconstruct the transmission hologram (reconstruction beam is the reference beam during image capture).

**What you can learn about**

- Object beam; Reference beam; Real and virtual image
- Phase holograms; Amplitude holograms
- Interference; Diffraction
- Coherence; Developing of film

**Main articles**

He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate in exp.case	08700-01	1
Surface mirror, large, d=80 mm	08712-00	1
Holographic plates, 25 pieces	08746-00	1
Sliding device, horizontal	08713-00	1
Darkroom equipment for holography, 230 V	08747-88	1

**Related Experiment**

Holography - Real time procedure

P2260306

**Advanced Optics, Holography package incl. manual, 230 V**

**Function and Applications**

A complete set to perform the following experiments using the experimental system "Advanced Optics" incl. handbook "Holography" with 11 described experiments:

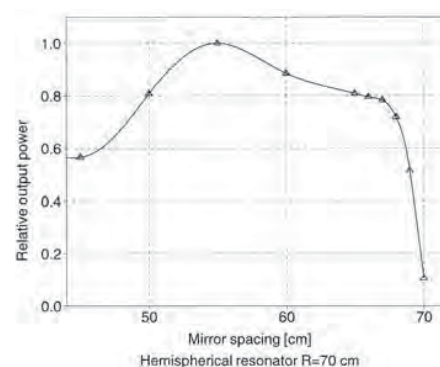
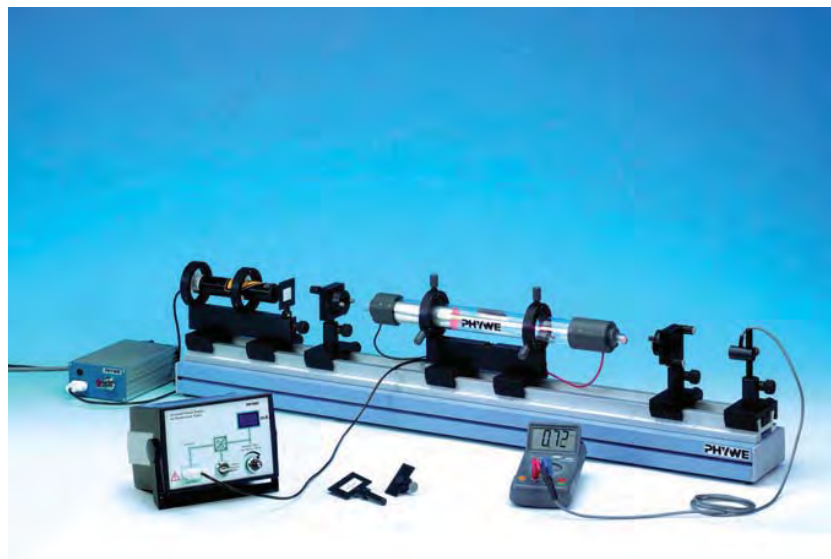
- white light holography
- transmission holography
- transfer a hologram from a master hologram

With the aid of a base plate and magnetic adhering holders, which can be positioned jolt-free, 1- and 2-dimensional setups can be quickly and reliably realised. By folding the lightpaths experiments with larger focal distances can be carried out on the working base. The high stiffness and vibration damping of the base plate allows sensitive holography arrangement to be set up.

08700-55

## Helium neon laser, basic experiment

P2260701



Relative output power as a function of mirror spacing.

## Principle

The difference between spontaneous and stimulated emission of light is demonstrated. The beam propagation within the resonator cavity of a He-Ne laser and its divergence are determined, its stability criterion is checked and the relative output power of the laser is measured as a function of the tube's position inside the resonator and of the tube current. The following items can be realised with advanced set 08656-02. By means of a birefringent tuner and a Littrow prism different wavelengths can be selected and quantitatively determined if a monochromator is available. Finally you can demonstrate the existence of longitudinal modes and the gain profile of the He-Ne laser provided an analysing Fabry Perot system is at your disposal.

## Tasks

1. Set up the He-Ne laser. Adjust the resonator mirrors by use of the pilot laser (left mirror: VIS, HR, plane; right mirror: VIS, HR,  $R = 700$  mm).
2. Check on the stability condition of a hemispherical resonator.
3. Measure the integral relative output power as a function of the laser tube's position within the hemispherical resonator.
4. Measure the beam diameter within the hemispherical resonator right and left of the laser tube.
5. Determine the divergence of the laser beam.
6. Measure the integral relative output power as a function of the tube current.

## What you can learn about

- Spontaneous and stimulated light emission; Inversion
- Collision of second type; Gas discharge tube; Resonator cavity
- Transverse and longitudinal resonator modes
- Birefringence; Brewster angle
- Littrow prism; Fabry Perot Etalon

## Main articles

Exp.Set-Helium-Neon Laser	08656-93	1
Sliding device, horizontal	08713-00	1
Protection glasses HeNe-laser	08581-10	1
Photoelement f. opt. base plt.	08734-00	1
Cleaning set for laser	08582-00	1
Diffraction grating, 600 lines/mm	08546-00	1
DMM, auto range, NiCr-Ni thermocouple	07123-00	1

## Related Experiment

## Helium neon laser, advanced experiment

P2260705

## Training recommended

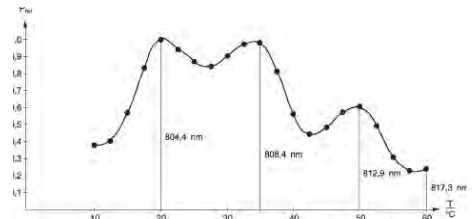
Service | PHYWE

For this experiment we recommend a seminar on equipment technology, handling and information of equipment-specific characteristics on site.

03333-02



### P2260800 Optical pumping



Relative fluorescent power of the Nd-YAG rod as a function of the diode temperature (wavelength) for  $I = 450$  mA.

#### Principle

The visible light of a semiconductor diode laser is used to excite the neodymium atoms within a Nd-YAG (Neodymium Yttrium Aluminium Garnet) rod. The power output of the semiconductor diode laser is first recorded as a function of the injection current. The fluorescent spectrum of the Nd-YAG rod is then determined and the main absorption lines of the Nd-atoms are verified. Conclusively, the mean life-time of the  $4F3/2$ -level of the Nd-atoms is measured in approximation.

#### Tasks

1. To determine the power output of the semiconductor diode laser as a function of the injection current.
2. To trace the fluorescent spectrum of the Nd-YAG rod pumped by the diode laser and to verify the main absorption lines of neodymium.
3. To measure the mean life-time of the  $4F3/2$ -level of the Nd-atoms.
4. For further applications see experiment "Nd-YAG laser".

#### What you can learn about

- Spontaneous emission
- Induced emission
- Mean lifetime of a metastable state
- Relaxation; Inversion; Diode laser

#### Main articles

Basic set optical pumping	08590-93	1
Sensor f. measurem. of beam power	08595-00	1
30 MHz digital storage oscilloscope with colour display, 2 x BNC cables l = 75 cm incl.	11462-99	1
Protection glasses for Nd:Yag laser	08581-20	1
Digital multimeter 2010	07128-00	1

### Basic set optical pumping

#### Function and Applications

The light from a lasersiode is used to excite neodymium atoms in a Nd:YAG crystal.

#### Benefits

- The power emitted by the laser diode can be measured as a function of the supply current.
- The fluorescence spectrum of the Nd:YAG crystal is analysed and the main absorption lines of the Nd-Atoms are verified.
- Finally the half-life of the  $4F3/2$ -level is estimated.
- With only a small number of additional components it is possible to build a Nd:YAG laser with this system.

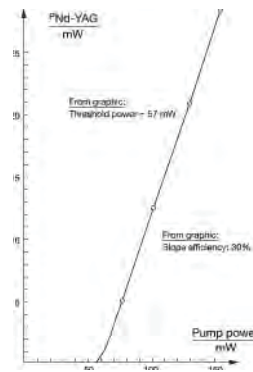
#### Equipment and technical data

- 1 Flat rail 500 mm with scale
- 1 Laser diode 450 mW in X-Y adjustment holder on carrier
- 1 Control electronics LDS 1200
- 1 Beam shaping optics in holder on carrier
- 1 Beam Focusing in holder on carrier
- 1 Nd:YAG crystal in holder adjustable on carrier
- 1 Filter holder on carrier with filter RG 1000
- 1 Photo detector in holder on carrier and adjustment target
- 3 BNC cables
- 1 IR detector converter screen 800-1200 nm
- 1 Set for optics cleaning
- 1 User manual

08590-93

## Nd:YAG laser

P2260900



Nd-YAG laser power output as a function of the pump power = 808.4 nm.

### Principle

The rate equation model for an optically pumped four-level laser system is determined. As lasing medium, a Nd:YAG (Neodymium-Yttrium Aluminium Garnet) rod has been selected which is pumped by means of a semiconductor diode laser. The IR-power output of the Nd:YAG laser is measured as a function of the optical power input and the slope efficiency as well as the threshold power are determined. Finally, a KTP-crystal is inserted into the laser cavity and frequency doubling is demonstrated. The quadratic relationship between the power of the fundamental wave and the beam power for the second harmonic is then evident.

### Tasks

1. Set up the Nd:YAG laser and optimise its power output.
2. The IR-power output of the Nd:YAG laser is to be measured as a function of the pump power. The slope efficiency and the threshold power are to be determined.
3. Verify the quadratic relationship between the power of the fundamental wave, with  $\lambda = 1064 \text{ nm}$ , and the beam power of the second harmonic with  $\lambda = 532 \text{ nm}$ .

### What you can learn about

- Optical pumping
- Spontaneous emission
- Induced emission
- Inversion
- Relaxation
- Optical resonator
- Resonator modes
- Polarization
- Frequency doubling

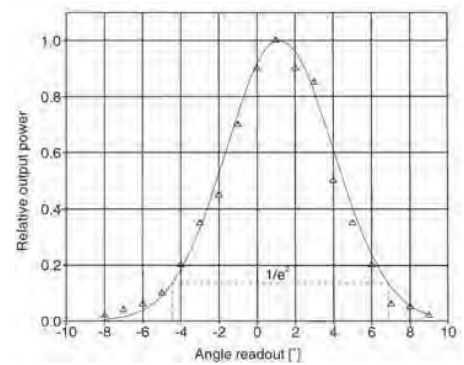
### Main articles

Basic set optical pumping	08590-93	1
---------------------------	----------	---

Frequ. doubling crystal in holder	08593-00	1
Nd-YAG laser cavity mirror/holder	08591-01	1
Laser cav.mirror frequ. doubling	08591-02	1
Sensor f. measur. of beam power	08595-00	1
30 MHz digital storage oscilloscope with colour display, 2 x BNC cables l = 75 cm incl.	11462-99	1
Protection glasses for Nd:Yag laser	08581-20	1



**P2261000 Fibre optics**



Relative output power at the fibre end versus angle readout.

**Principle**

The beam of a laser diode is treated in a way that it can be coupled into a monomode fibre. The problems related to coupling the beam into the fibre are evaluated and verified. In consequence a low frequency signal is transmitted through the fibre. The numerical aperture of the fibre is recorded. The transit time of light through the fibre is measured and the velocity of light within the fibre is determined. Finally the measurement of the relative output power of the diode laser as a function of the supply current leads to the characteristics of the diode laser such as "threshold energy" and "slope efficiency".

**Tasks**

1. Couple the laser beam into the fibre and adjust the setting-up in a way that a maximum of output power is achieved at the exit of the fibre.
2. Demonstrate the transmission of a LF-signal through the fibre.
3. Measure the numerical aperture of the fibre.
4. Measure the transit time of light through the fibre and determine the velocity of light within the fibre.
5. Determine the relative output power of the diode laser as a function of the supply current.

**What you can learn about**

- Total reflection; Diode laser
- Gaussian beam
- Monomode and multimode fibre
- Numerical aperture
- Transverse and longitudinal modes
- Transit time; Threshold energy
- Slope efficiency; Velocity of light

**Main articles**

Experimental set Fibre optics	08662-93	1
Digital Storage Oszilloscope 200 MHz, 2-Kanal, 2 GSa/s	11453-99	1
Screened cable, BNC, l 750 mm	07542-11	2



**Charles K. Kao**  
2009, Nobel Prize in Physics



## About PHYWE

<b>9.1</b>	<b>Company profile</b>	<b>218</b>
<b>9.2</b>	<b>Nobel Prize Experiments</b>	<b>220</b>
<b>9.3</b>	<b>Computer Assisted Measurement</b>	<b>222</b>
<b>9.4</b>	<b>Lucas-Nülle Group</b>	<b>226</b>
<b>9.5</b>	<b>Safety Instructions</b>	<b>228</b>
<b>9.6</b>	<b>General terms and conditions</b>	<b>231</b>

## Traditional yet modern 100 years of quality

Those who know nothing must believe everything.

Marie von Ebner-Eschenbach

With a 100-year tradition of excellence, PHYWE Systeme GmbH & Co. KG stands for technical capability, innovation, quality and customer satisfaction. As a leading supplier of premium quality teaching and learning materials, PHYWE is one of the world's largest providers of system solutions for the instruction of the natural sciences.

The product range comprises scientific equipment, experiments and solution systems along with modern blended learning systems, literature and software for the areas of physics, chemistry, biology, medicine, material science and earth science. A broad spectrum of services such as training programmes, installation and comprehensive consulting services completes the portfolio.

PHYWE solutions can be individually adapted to the specific curricula in each country and provide ideal coverage for the full spectrum of performance specifications and requirements. Ask us to prepare a customised equipment offering to suit your special needs!





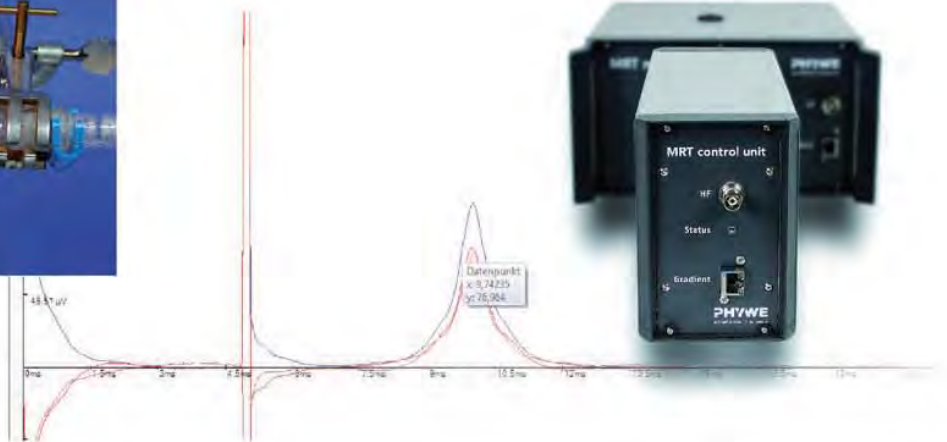
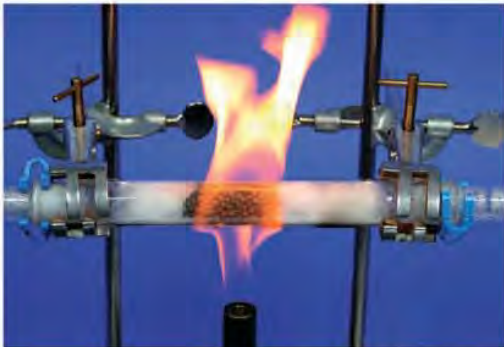
## 9 About PHYWE

### 9.2 Nobel Prize Experiments

## PHYWE supplies more than 50 Nobel Prize awarded experiments

The Nobel Prize is awarded annually in the disciplines of physics, chemistry, physiology or medicine, literature and peace. For scientists and researchers, it is the highest award.

PHYWE supplies more than 50 Nobel Prize awarded experiments. From Conrad Röntgen to Max Planck or Albert Einstein. Experiments in the footsteps of Nobel Prize winners. PHYWE made Nobel Prize experiments understandable.



### Nobel Prize awarded experiments (Selection)

#### 1900 ...

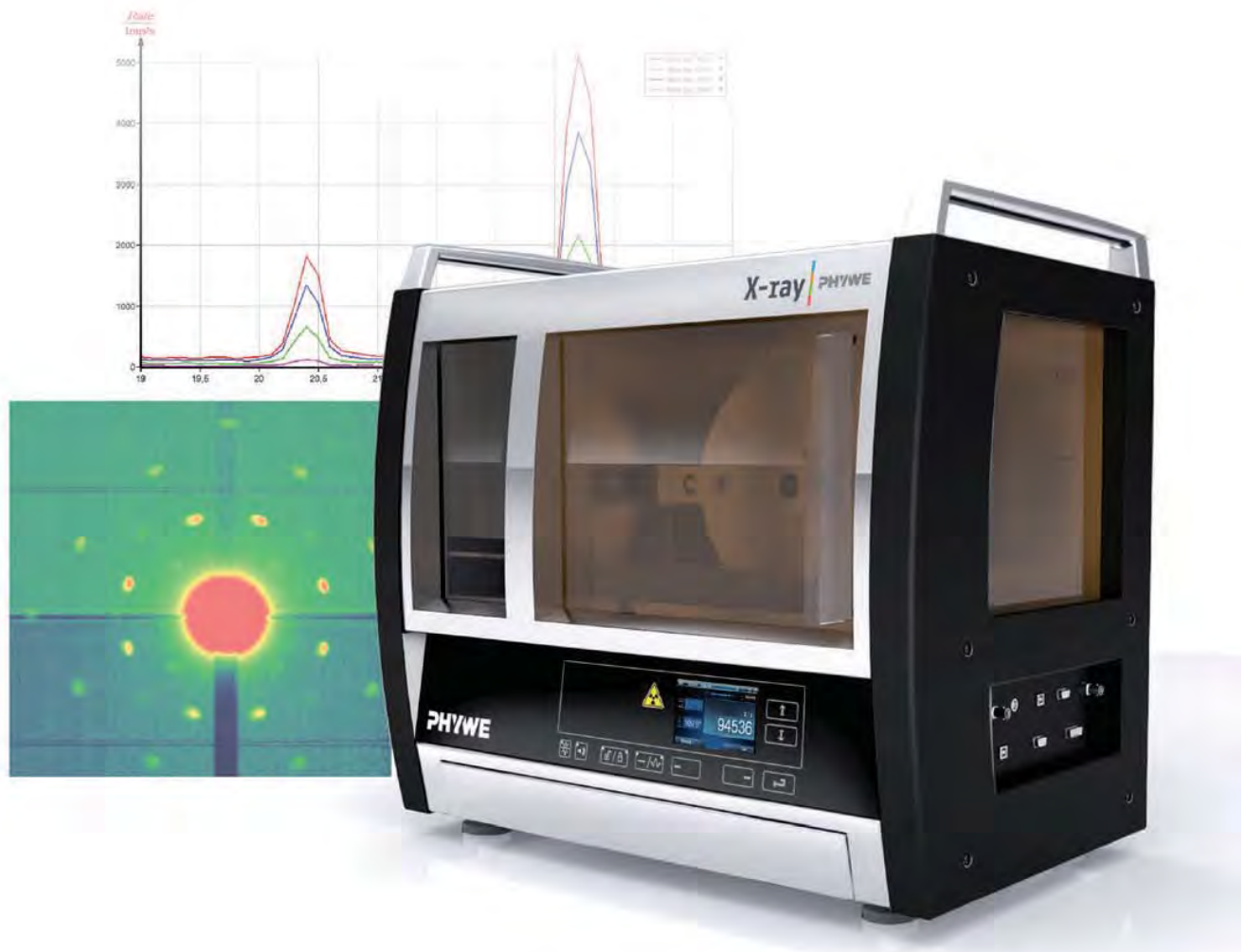
- 1901 – Wilhelm Conrad Röntgen
- 1901 – Jacobus Henricus van 't Hoff
- 1902 – Hendrik A. Lorentz,  
Pieter Zeeman
- 1903 – Henri Becquerel, Pierre Curie,  
Marie Curie
- 1908 – Ernest Rutherford
- 1909 – Wilhelm Ostwald

#### 1910 ...

- 1910 – Johannes Diderik van der Wals
- 1914 – Max von Laue
- 1915 – Sir William Henry Bragg,  
Sir William Lawrence Bragg
- 1912 – F. A. Victor Grignard
- 1918 – Fritz Haber

#### 1920 ...

- 1921 – Albert Einstein
- 1922 – Niels Bohr, Henrik David
- 1924 – Manne Siegbahn
- 1924 – Willem Einthoven
- 1925 – James Franck, Gustav Hertz



### 1930 ...

- 1931 – Carl Bosch, Friedrich Bergius
- 1932 – Irving Langmuir
- 1936 – Victor Franz Hess,  
Carl David Anderson
- 1936 – Peter Joseph W. Debye

### 1940 ...

- 1943 – Otto Stern
- 1952 – Felix Bloch, Edward M. Purcell
- 1952 – Archer John P. Martin,  
Richard Laurence M. Synge
- 1954 – Max Born, Walther Bothe

### 1970 until today

- 1971 – Dennis Gabor
- 1979 – Allan M. Cormack,  
Godfrey N. Hounsfield
- 1986 – Heinrich Rohrer, Gerd Binnig
- 2003 – Paul C. Lauterbur,  
Sir Peter Mansfield



## Computer assisted measurement – for your science experiments



With computer-assisted experiments from PHYWE you rely on a system that perfectly matches the demands of modern scientific education. Approximately 50% of the total number of TESS expert university experiments are computer-based. PHYWE offers the unique Cobra4 system with completely new experimentation possibilities. Be inspired by more than 200 described experiments with Cobra4.

The corresponding software measure stands for simple and reliable data recording, analysis and further processing – and it is available in 24 languages. Get more information about our Cobra4 program in the brochure "Experiments with Cobra4"

### Benefits

- wireless measurements – comfortable and modern
- more than 30 sensors for more than 50 measurands
- time-saving: settings can be saved
- fully automatic sensor identification
- up to 99 sensors can be addressed simultaneously
- can be used as a hand-held measuring instrument



Cobra4 Interface System

### The Cobra4 interfaces



Wireless measurement with  
Wireless-Link + Wireless  
Manager + Remote-Link



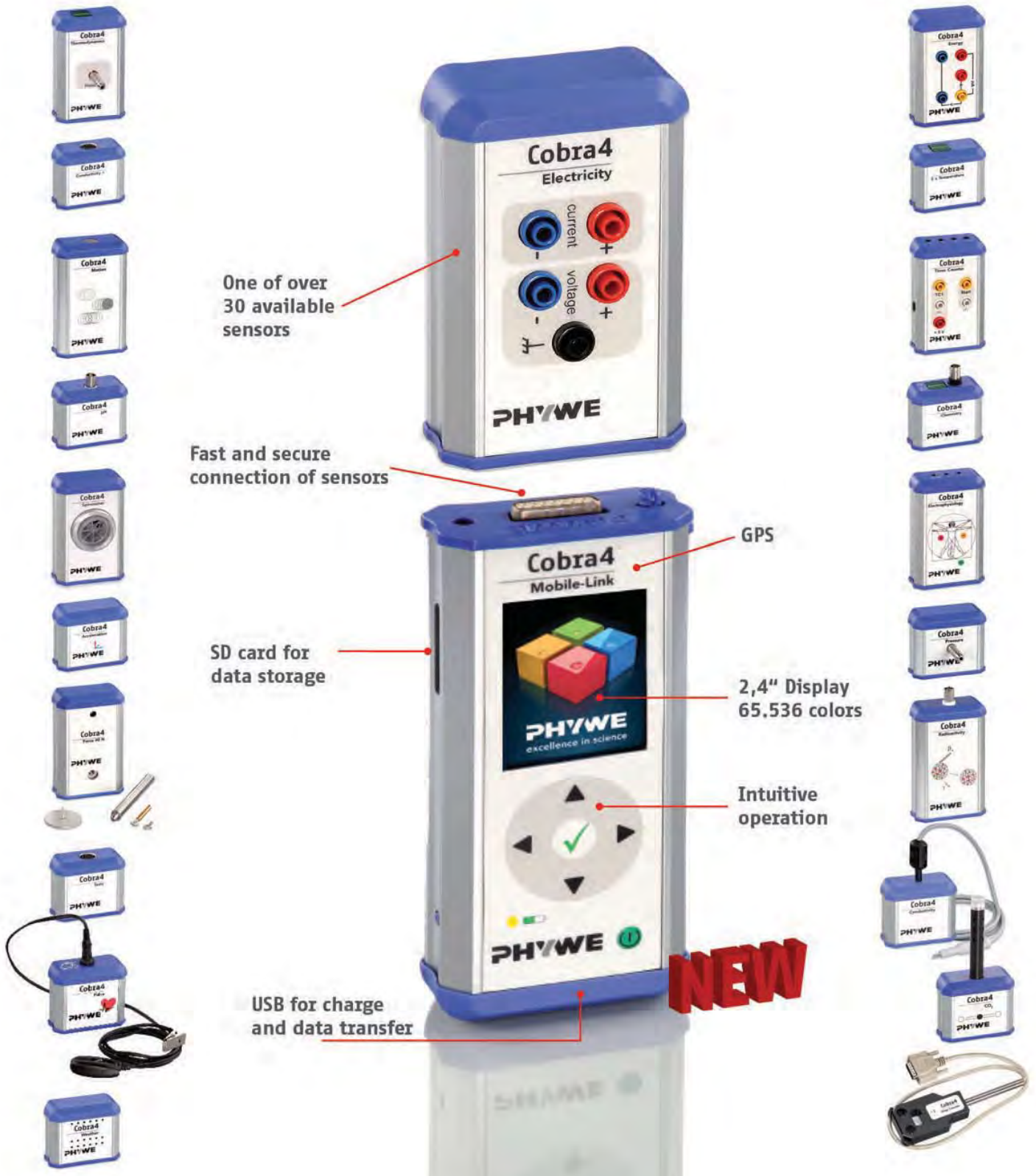
For high data rates  
with the USB-Link



Mobile-Link - even more  
functions included as of 2013 -  
no computer necessary

## The Cobra4 sensor family

# Cobra4



One of over 30 available sensors

Fast and secure connection of sensors

SD card for data storage

USB for charge and data transfer

Cobra4 Electricity

Cobra4 Mobile-Link

GPS

2,4" Display  
65.536 colors

Intuitive operation

**NEW**

## 9 About PHYWE

### 9.3 Computer Assisted Measurement

**Our roadmap for future products –**  
Coming up 2013

**Cobra4** | PHYWE

#### Cobra4 Sensors



Sound level  
(12669-00)

Skin resistance  
(12677-00)

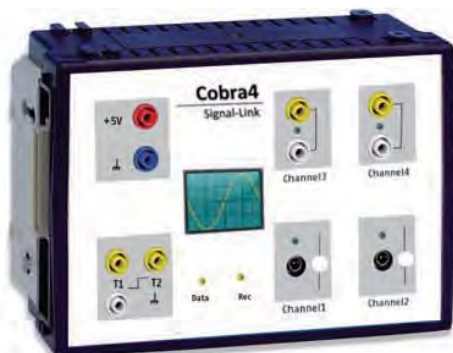
Oxygen  
(12676-00)

Forceplate  
(12661-00)

Colorimeter  
(12634-00)

#### Cobra4 Signal-Link –

The integrated and high accuracy interface for high speed experiments



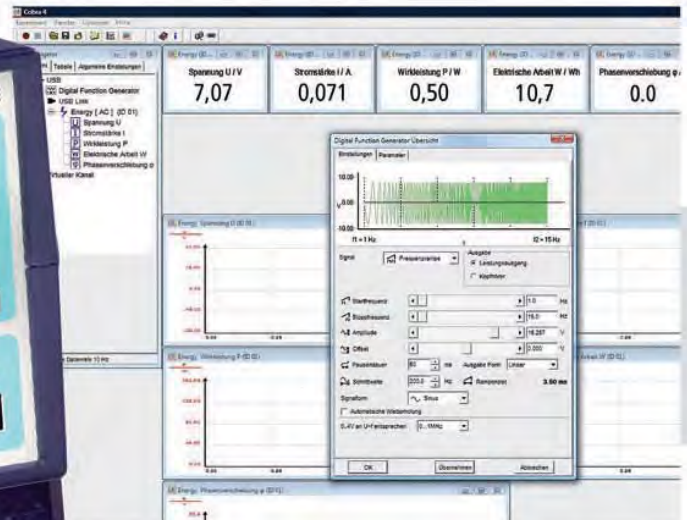
#### Features

- Integrated unit of voltage & current sensors + USB interface
- 4 channels (2x current, 2x voltage), electrically isolated
- True RMS converter for all channels
- High resolution: up to 5 microvolts, up to 1 microampere
- Sampling rate: > 1 MHz for current channels and >5 MHz for voltage channels
- Compatible to all Cobra4 equipment

Digital function generator –  
universal and intuitive

**Cobra4**  
compatible

**NEW**



**Features**

- Universal, programmable voltage source with a bandwidth of 1 MHz and an output current of 1 A
- Can be used with Cobra4 or as a stand-alone device
- Intuitive operation via function keys and a rotary control knob
- Illuminated display for optimum visibility
- Low distortion factor and high signal-to-noise ratio for brilliant signals (acoustics/hearing)
- $U = U(f)$  output for a particularly easy pick-up of the frequency – ideal for analysing circuits with frequency ramps
- Part of more than 25 TESS experiments



Faraday effect (P2260106)



Chladni's figures (P2150702)