Universität Regensburg - Department of Physics

Advanced Physics Laboratories

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Suitability of the Experiments:

F1:	Experiments as part of the compulsory module B-P5 (Bachelor in Physics) or PHY-LA-GYM-P8 (Teacher Training)
Na:	Experiments as part of the module NS-P8 (Bachelor in Nanoscience)
F2:	Experiments as part of the elective module B-WV3 (Bachelor in Physics) or PHY-LA-GYM-W5 (Teacher Training)
NF:	Experiments for students from other faculties, e.g. *Master in Mathematics*

A Short Description of All Experiments

af AFM *Suitable for F1 F2 NF*

The experiment "Atomic force microscopy" aims at teaching students how to use a modern measurement device of nanoscience, which is used routinely in laboratories today.

The experiment covers the physical basics of atomic force microscopy, the use of the device as well as visualization and evaluation procedures for the data sets obtained. In the first part of the experiment, the microscope will be calibrated and the sensor characterized. The second part includes measuring the surface of a CD and determining the capacity of the data carrier. Optionally, students can bring in samples to view under the microscope, for example samples that were created as part of another experiment.

b Fuel Cell *Suitable for F1 NF*

Hydrogen has been discussed as an alternative source of energy for decades. This experiment examines how hydrogen is produced by means of photovoltaics/solar cells and electrolysis as well as how hydrogen is used in a fuel cell.

d Diode-Pumped Solid-State Laser *Suitable for F1 Na F2 NF*

By using a semiconductor laser as pump light source, compact and efficient so-called *diode-pumped solid-state lasers* (DPSS lasers) of high beam quality can be achieved.

In this experiment, you will get to know the design of a diode-pumped Nd:YVO laser: You will at first explore the typical beam properties of diode lasers and their electrical characteristics. Then, you will set up the resonator of the Nd:YVO laser and induce laser action in various modes. After resonator-internal frequency doubling occurs by means of a KTP crystal, i.e. the infrared radiation of the Nd:YVO laser changes visibly to green, you will investigate the dynamic laser properties through relaxation oscillations.

e Ferromagnetic Resonance (ESR) *Suitable for F1 Na F2 NF*

The microwave absorption of ferromagnetic samples will be examined as a function of the applied magnetic field and microwave frequency. The results allow to determine the anisotropy, saturation magnetization, g-factor and damping constant of the samples. In addition, the experiment enables students to familiarize themselves with elements of microwave technology (Gunn oscillator, waveguides, Schottky detector, etc.).

f Fourier Spectroscopy *Suitable for F1 Na F2 NF*

This experiment allows you to get to know how a Fourier transformation infrared spectrometer works. The transmission and reflection spectra of various samples are obtained and examined. This allows to determine, for example, the OH content in quartz glass or the thickness of thin plane-parallel plates. In addition, you can broaden your knowledge of solid-state physics with this experiment and study the reststrahlenband of polar solid bodies as well as the plasma reflection of heavily doped semiconductors.

h Holography *Suitable for F1 Na NF*

By means of a spatially filtered He-Ne laser beam, Fresnel holograms of various objects are recorded and the virtual and real images are reconstructed. The optical Fourier transformation and the optical filtering of spatial frequencies will be investigated by means of existing signal functions and filters.

k Nuclear Spectroscopy *Suitable for F1 Na F2*

By means of a scintillation counter, the γ spectra of various radioactive elements are investigated. The measuring program comprises calibrating the detector by means of known samples as well as measuring various objects to identify the radioactive substances contained therein. Another part of the experiment is dedicated to the range of α particles in the air.

l Laser *Suitable for F1 Na F2 NF*

This experiment aims at demonstrating the fundamental properties of a He-Ne laser and at providing an outlook for applications. The individual steps of the experiment are: visualization of various transverse modes of the He-Ne laser, measuring the wavelength with a sliding caliper, measuring the gain factor by varying the resonator loss, determining the speed of light by superimposing longitudinal modes and modulating the laser beam, as well as signal transmission through fiber.

mo Magneto-Optics *Suitable for F1 Na F2 NF*

Magnetization curves of ferromagnetic thin layers are determined by using a magneto-optical measurement method and utilizing the longitudinal Kerr effect. The measurement data allow to make statements about anisotropies in the layers and shall be interpreted by means of a simple model.

mt Magnetotransport *Suitable for F2*

In this experiment, resistance measurements on As/AlGaAs heterostructures at helium temperature in relation to the magnetic field are conducted. With high fields (B > 1T), quantum effects play a big role while the resistance for small magnetic fields can accurately be described with classical models.

The small fields are of interest here: By imprinting periodic potentials (e.g. Antidot lattices), oscillations become visible in the otherwise constant longitudinal resistance whose maxima can be associated with specific cyclotron orbits of the electrons.

n NMR *Suitable for F1 Na F2 NF*

The magnetic moments of hydrogen nuclei are aligned in a static magnetic field B_0. In resonance, a high frequency pulse B perpendicular to B_0can turn the moments. After B is switched off, the moments relax with the characteristic times T_1 (spin-lattice relaxation) or T_2 (spin-spin relaxation). These will be identified for water and paraffin.

no Nonlinear Optics *Suitable for F2*

State of the art ultrashort pulse lasers enable the generation of high intensity light pulses as short as few femtoseconds. Together with the use of stroboscopic methods, this allows to observe the time dynamics of elementary processes in solids. In this experiment, you learn about methods from ultrafast optics as they are currently used in research. First, a nonlinear-optic crystal is used to double the frequency of high intensity light pulses. Subsequently, you apply a method to measure the duration of light pulses which are so short that no electronic device is able to capture their duration by direct methods. At the end, you apply these knowledge to measure the femtosecond carrier recombination dynamics in indium gallium arsenide with the help of a time resolved pump-probe experiment.

v Operational Amplifier *Suitable for F1 NF*

The operational amplifier is a versatile tool with respect to physical measurement techniques. This experiment will examine how operational amplifiers are used in measuring and control circuits. In addition, it will provide an introduction to computer-based measurement data acquisition.

a Optical Absorption *Suitable for F1 Na F2 NF*

By means of a transmission spectrometer, the rotation-vibration bands of Cl_2 and Br_2 will be recorded in the visible region. Knowing the electronic levels of simple molecules will allow for a quantitative evaluation of the results.

op Optical Phase Conjugation *Suitable for F1 Na NF*

With optical phase conjugations, a time-reversed beam is generated to a monochromatic beam of light, which counterpropagates the original beam and has at every point the same phase as the original beam *(phase conjugated)* . The phase conjugated beam is generated through four wave mixing (nonlinear optics) by using a He-Ne laser in the photorefractive bismuth silicon oxide (BSO) crystal. The photorefractive property of BSO is caused by the extremely long service time of free excess charge carriers. The temporal kinetics of the photorefractive effect can therefore be measured by very simple means and makes it possible to determine the service time of the charge carriers.

o Optical Pumping *Suitable for F1 Na F2 NF*

The Zeeman splitting of the hyperfine structure of the ground state of Rb atoms is explored by means of optical pumping. The experiment set-up allows working with "weak" and "strong" magnetic fields, which makes it possible to observe the Paschen-Back effect in addition.

p Pockels Effect *Suitable for F1 Na NF*

The linear electro-optic effect (Pockels effect) is explored by means of visible and infrared laser light in birefringent $KD^{*}P$ crystals. By using time-resolved measurements, the piezo-electrically induced additional contribution can be determined as well. Static measurements at various electric fields make it possible to determine the absolute value of the electro-optic constant.

q Quantum Hall Effect *Suitable for F2*

In this labs experiment, measurements are performed at semiconductor components at low temperatures and high magnetic fields. The quantization of the Hall resistance at values $R = [\ h/(e^2)]\cdot[\ 1/i](i=1,2,3...)$, for whose discovery Klaus von Klitzing was awarded the Nobel Prize in 1985, can be observed with various samples, a part of which will be created. This experiment does not only train handling low temperatures (liquid helium) and superconducting magnets, but at the same time makes it possible to gain insight into one of the current research topics of solid-state physics.

tm Scanning Tunnel Microscopy (STM) *Suitable for F2*

This experiment offers an insight into the world of scanning probe microscopy. Using a scanning tunnel microscope, surfaces of various samples are atomically resolved in the spatial domain and mapped. The device employed is an easyScan 2 of the company Nanosurf, which allows for easy access to use the microscope in the air at room temperature.

r X-Ray Diffraction *Suitable for F1 Na F2 NF*

Interference of continuous and monochromatic X-rays at the three-dimensional lattice of crystalline solids provides information on crystal symmetry, the lattice constants and the structure of crystals. In this experiment, cubic crystals are examined by means of a simple diffractometer using the Laue or the Debye-Scherrer method.

s Superconductivity *Suitable for F2*

The transition temperatures of a low-temperature superconductor (In) and of a high-temperature superconductor (YBaCuO) are determined as a function of the temperature by means of resistance measurements. By varying the external magnetic field, the critical magnetic field H_c of the Indium sample is determined in addition. The magnetic characteristics of high-temperature superconductors are illustrated by the levitation of a magnet.

x X-Band Radar *Suitable for F1 Na NF*

This experiment aims at providing a little insight into microwave technology. X-band refers to the frequency range between 8 GHz and 12.5 GHz of the electromagnetic spectrum. The wavelengths there are in the range of centimeters. By making use of transit time differences or the Doppler effect, it is possible in this experiment to determine distances and speeds, e.g. of cars passing by. In addition, various X-band components are to be examined, e.g. the radiation patterns of an antenna or the frequency response of a circulator.