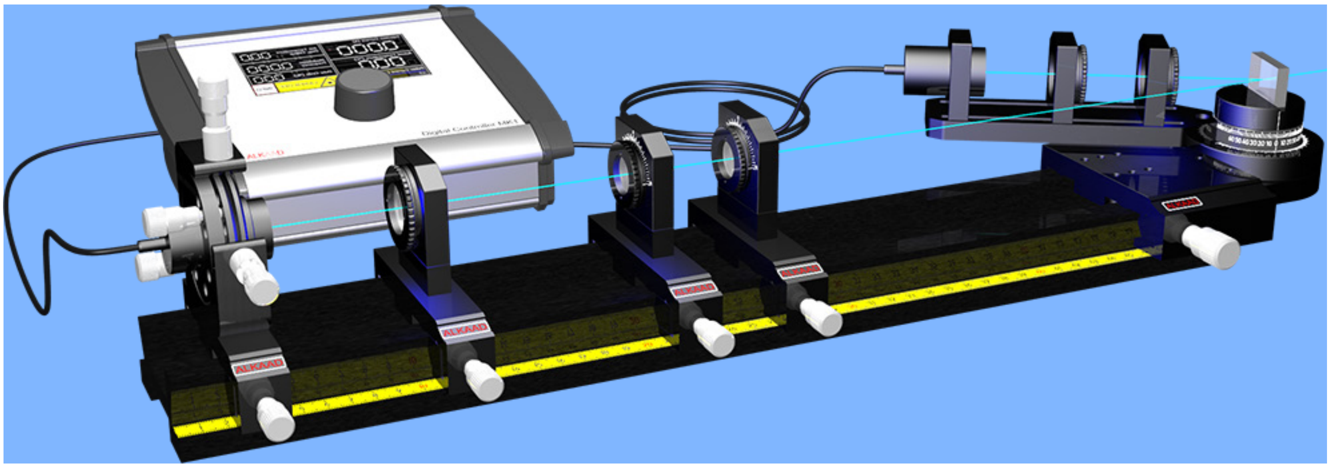
PE-0300 Reflection and Transmission



Keywords

Reflection Law
Transmittance
Brewster Angle
Fresnel Laws
Polarization
LED Characterization
Reflectance
Anti-Reflection Coating
Green Laser Properties

Introduction

Reflection of light on surfaces is a familiar phenomenon of daily life. Therefore it is no surprise that the reflection law is one of the well known optical laws and was first stated by Ibn Al Haitham in the beginning of the 10th century. Little was commonly known about polarization of light and its connection with reflection and refraction. This connection is formulated in the Fresnel Laws which are usually expressed as transmittance and reflectance as a function of the index of refraction and angle of reflection. The four formulas which were deduced by Augustin Fresnel in 1821 contain the complete theory of reflection, refraction and polarization of isotropic materials. The fundamental understanding of reflection and transmission is essential for the design of laser mirrors, sun glasses and a lot more. By dielectric coating, such components are made either to optimise or to suppress reflection. Within this experiment the reflection law is verified using a metal coated mirror. The next part covers the quantitative verification of the Fresnel Laws on a specially shaped glass plate using polarized light. Finally the spectral performance of a dielectric coated mirror is investigated using a white LED and a grating.

How it works

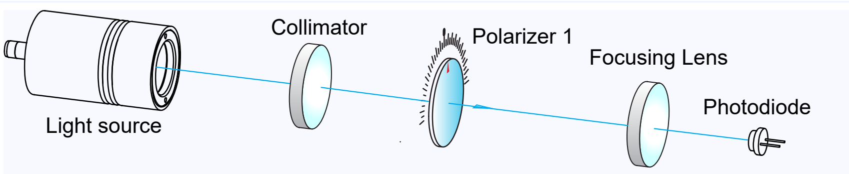


Fig. 4.13: Characterising the light source

As source a white light LED and a "green" laser are used. Both sources are characterised by measuring the optical power versus the injection current. In case of the LED, a collimator is used to obtain an almost parallel light beam. Furthermore, the spatial intensity distribution of the LED can be measured when using the provided goniometer.

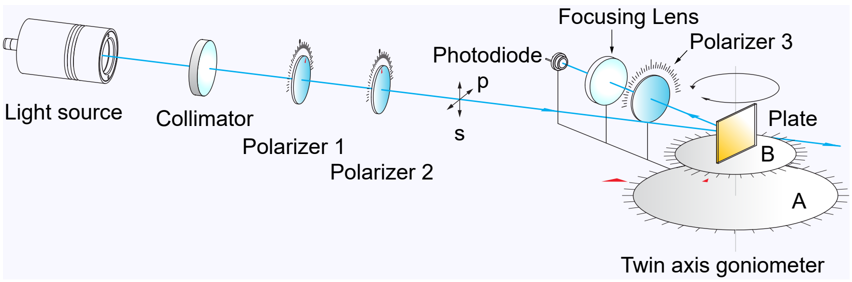


Fig. 4.14: Arrangement to measure reflected and transmitted light

The light of either a white light LED or "green" laser is strongly polarised by means of polarizer 1 and 2 and hits the probe plate. When using the LED, a collimator lens creates an almost parallel light beam. The optical plate is attached to the goniometer plate B and can be rotated by 360°. The photodiode along with a focussing lens and the polarizer 3 are attached to the arm of goniometer A. By turning of B a defined angle of incidence is set. The arm of goniometer A is turned in such a way that the signal detected by the photodiode becomes maximum. In this way the Snell's or reflection law is verified. To verify the Fresnel's equations, the polarisation state of the incident light is set to either "s" (perpendicular) or "p" (parallel) with respect to the plane of incidence which is spanned by the vector of the incoming and reflected beam.

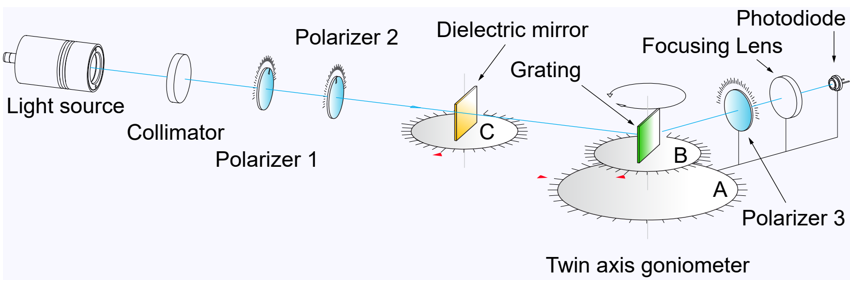


Fig. 4.15: Setup for measuring the spectral transmittance of a mirror

Optical components, especially mirrors are extremely important in photonics. Meanwhile a variety of technologies exist to tailor the spectral behaviour of optical surfaces like short pass, long pass or even ultra narrow band pass mirrors. The aim of this experiment is the spectral characterization of such a mirror. As light source a white light LED and for the spectral resolution a transmission grating is used. The dielectric mirror is attached to a turntable (C) to measure the spectral response also for different angle of incidence. The grating is attached to the goniometer B where it is kept at a angle of zero degrees with respect to the direction of the probe light beam. The arm of goniometer A is turned to the first or second order of the grating. The first measurement is carried out without the dielectric mirror to record the spectrum of the white light emitting LED. The second measurement is performed including the dielectric mirror. The spectral transmittance of the dielectric mirror is obtained by normalising the values of the second measurement to the first measurement.

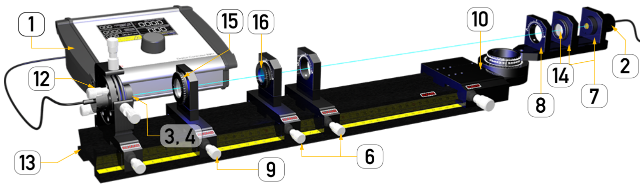


Fig. 4.16: Characterising the light source

The aim of this setup is the measurement of the optical power of the provided white light LED and the "green" laser versus the injection or operation current. By means of the LED and laser controller (1) the individual current can be set from zero to the maximal permissible value. The output power is measured by the photodiode (2) which is connected also to the controller (2). The built-in amplifier and microprocessor converts and displays the measured photo current. In a next measurement the polarisation of the LED and the green laser is measured by rotating the polarizer (16) in its holder whereby the optical power is measured.

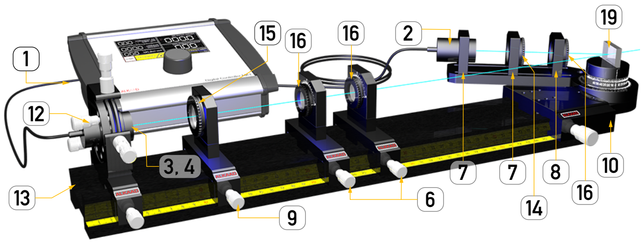
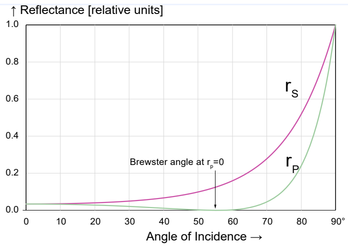


Fig. 4.17: Setup to verify the Snell's (reflection) and Fresnel's Law

With this setup the angle and polarisation dependent reflection or transmission of a probe (19) is measured. The probe which can be either a glass plate or a front face mirror is placed into the fixed arbor receptacle of the twin axis goniometer (10). The probe body has an index mark for reading its angle with respect to the scale of the arbor receptacle. The second goniometer provides an arm onto which the photodetector (2), a focussing



lens (14) and a polarizer (16) are mounted. As light source either the green laser or the whit light LED is used. When using the LED the additional collimator (15) is used to obtain an almost parallel LED light beam. By means of the pair of polarizers the desired polarisation *s* or *p* are adjusted. For different incident angles the reflected intensity is measured by the photodiode (2) and the control unit (1). The plot of the data as intensity against the angle of incidence verifies the Fresnel equations. For an index of refraction of 1.45 these values are calculated and shown in the figure above. The angle of incidence for which the reflected intensity I_p becomes zero is termed as Brewster angle which is highly important for all those applications where the losses due to reflection should be zero.

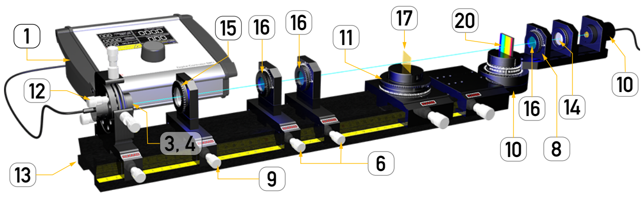
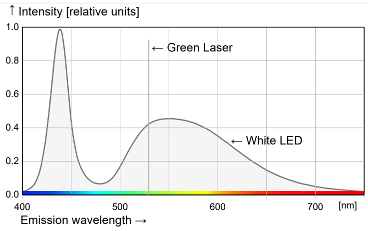
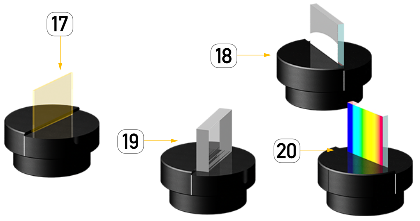


Fig. 4.18: Measuring the spectral transmittance

By placing a transmission grating (20) into the fixed arbor receptacle of the goniometer (10) the setup is converted into a simple spectrometer. To measure the spectral property of the dichroic mirror (17) it makes sense to use the white light emitting LED. The emission wavelength of the LED ranges from 400 - 700 nm. The mirror (17) is inserted into the



centre hole of the carrier with rotation stage (11). By turning the goniometer arm the photodetector measures the intensity as a function of the angle. The measurements can be performed in the first or second order of the transmission grating. A first measurement is performed without the mirror (17) to obtain the spectral curve of the LED. In a subsequent measurement with inserted mirror (17) the influence of the mirror becomes apparent. The spectral curve of the mirror (17) is obtained by dividing the data of the second measurement with the data of the first measurement.



The experiment comes with four different optical modules (OM). A dichroic mirror (17) reflects in the blue range and transmits in the red spectral range. The dichroism depends on the angle of incidence, which will be measured in the experiment. The front face mirror (18) has a metallic coating and is used as general purpose reflector. The mirror is used for the verification of Snell's law. For the measurement and verification of the Fresnel equations and Brewster's angle, an optical polished glass plate (19) is used. A transmission grating (20) with 600 lines per millimetre is used for the spectral analysis. All components are mounted to a solid base which fits either into the goniometer (10) or into the carrier with rotary stage (11). The index mark serves to measure the angle of incidence when inserted into the respective holder.

PE-0300 Reflection and Transmission consisting of:

Item	*Code*	*Qty.*	*Description*	*Details page*
1	DC-0020	1	LED and Photodiode Controller	121 (2)
2	DC-0120	1	Si-PIN Photodetector, BPX61 with connection leads	123 (14)
3	LQ-0020	1	Green (532 nm) DPSSL in ø25 housing	119 (10)
4	LQ-0200	1	White LED in ø 25 Housing	119 (6)
5	MM-0020	1	Mounting plate C25 on carrier MG20	93 (1)
6	MM-0024	2	Mounting plate C25-S on carrier MG20	93 (2)
7	MM-0026	2	Mounting plate 40, C25	
8	MM-0028	1	Mounting plate C25-S with angle gradation	93 (3)
9	MM-0030	1	Mounting plate C30 on carrier MG20	93 (4)
10	MM-0300	1	Carrier with 360° rotary arm	95 (20)
11	MM-0380	1	MG65 carrier with rotary stage	96 (22)
12	MM-0420	1	Four axes kinematic mount on carrier MG20	96 (24)
13	MP-0150	1	Optical Bench MG-65, 500 mm	93 (8)
14	OC-0060	1	Biconvex lens f=60 mm in C25 mount	99 (5)
15	OC-0140	1	Achromat f=40 mm in C30 mount	99 (9)
16	OC-0710	3	Polarizer in C25 mount	102 (34)
17	OM-0310	1	Dichroic mirror on rotary table	111 (11)
18	OM-0320	1	Front face mirror on rotary table	111 (12)
19	OM-0330	1	Glass plate on rotary table	111 (13)
20	OM-0340	1	Transmission grating on rotary table	112 (14)
21	UM-PE03	1	Manual Reflection & Transmission	

Highlights

Basic experiment

Intended institutions and users:
- Physics Laboratory
- Engineering department
- Electronic department
- Biophotonics department
- Physics education in Medicine