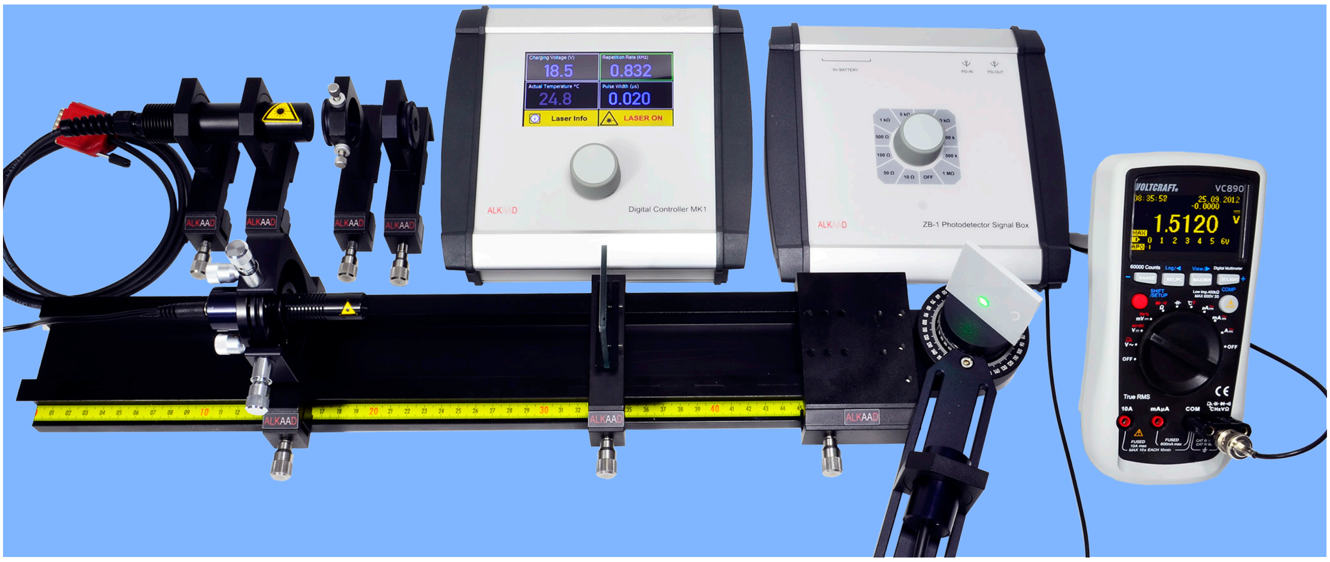
LM-0700 Laser Safety



IEC 60825 or ANSI Z136
Laser Intensity
Damaging Effects
Pulsed Laser
Laser Safety Regulations
Max. Permissible Radiation
Laser Classification
Laser Beam Divergence
Safety Distance
Safety Goggles

In this experiment the students are encouraged to convert the essential theoretical contents regarding „Laser Safety“ into practice. The application and use of the basics in calculation defined within the standards is submitted and trained by means of practical examples. The major measurement task is to determine the intensity of a laser beam which is defined as power per cross section typically given in W/m². The power is measured by using a calibrated power meter. The cross section and the divergence is determined by a set of imaging lenses with known focal lengths. In addition to the direct exposure also the danger of scattered light is classified by using a scatter probe mounted on a pivot arm.

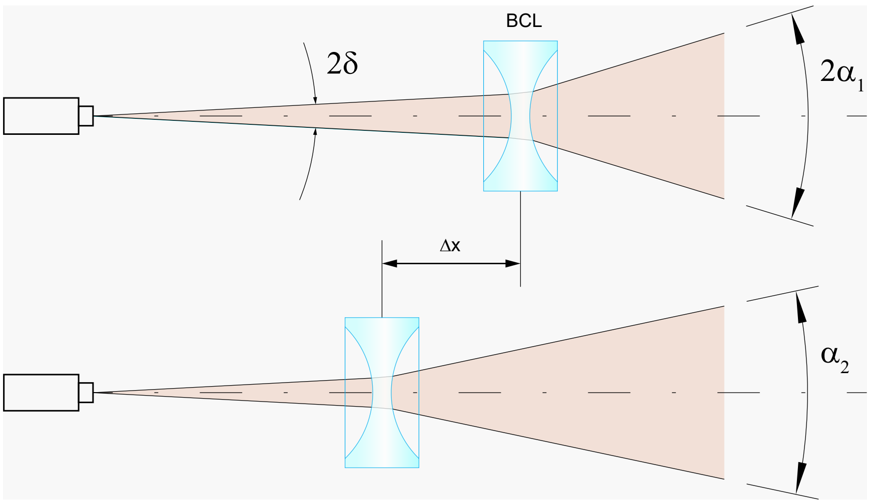
The experiment is divided into of several segments. Aspects such as the following ones have been considered:

1. Determination of the maximum permissible radiation (MPR) for skin and eyes
2. Minimum safety distance from a radiation source for direct and indirect irradiation of the skin and the eyes, (MSD)
3. Characterization of a pulsed laser systems
4. Requirements for laser safety goggles, transmission of optical filter

The fundamentals of IEC 60825 or ANSI Z136 or corresponding literature of laser safety should be known. The danger of lasers are understood by the characteristic properties of the laser radiation. In comparison with other light sources, a high energy and power density can be attained, because of the generally small beam divergence the radiation density can be very high even at large distances from the laser (potential danger of lasers used in metrology).

Not only the direct radiation also reflected and scattered radiation can cause damage at a large distance from the radiation source. Laser radiation can be generated within a broad spectral range. It extends from a few nanometre up to some hundred micrometers and is, in many cases, outside of the visible spectrum.

The damage of the biological tissue (skin, eye) depends strongly on the wavelength and on the duration of the exposure. This is of great importance under safety aspects when classifying the lasers and fixing radiation limits which is also subject of this experiment. By means of two different laser sources all parameters are measured in order to classify each laser and to determine the limits for which the laser can be considered as safe. This includes also the characterization of laser safety goggles.

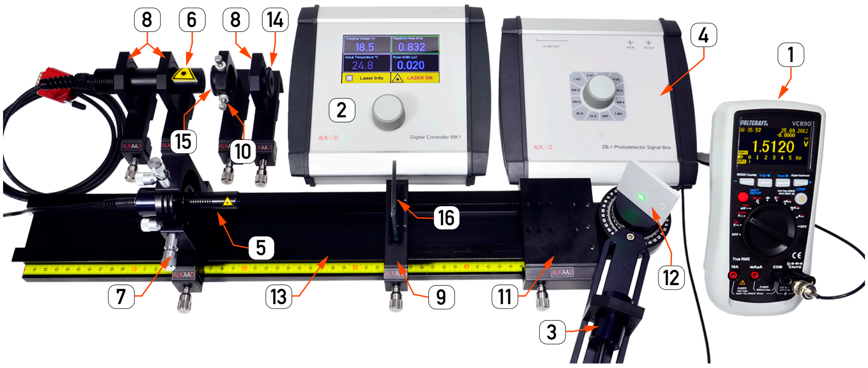


An easy way to measure the important value of divergence of the laser beam is to measure the diameter on a distant wall the enlarged diameter of the laser. However, this is not suitable in all cases. Thus we have introduced a diverging lens (BCL) to simulate the same effect. By using the goniometer the divergence angle is measured for a known distance from the laser. Applying the ABCD matrix formalism with the known transfer matrix [T] of the diverging lens (BCL)and related data and distances the unknown angle δ is determined:

$$\begin{pmatrix} T_1 & T_2 \\ T_3 & T_4 \end{pmatrix} \cdot \begin{pmatrix} r_1 \\ \delta \end{pmatrix} = \begin{pmatrix} r_2 \\ \alpha_2 \end{pmatrix}$$

In a more refined way the laser divergence is determined by carrying two or more measurements.

Description of the components



The experiment comes with two laser sources. One is a green emitting DPSSL (5) with an output power of 5 mW and the other is a pulsed diode laser with an output energy of 4 µJ. The green laser is operated with a wall plug power supply, whereby the pulsed laser (6) is powered by the digital controller (2). For the collimation of the divergent radiation of the pulsed diode laser a collimator (15) is provided, which is used in conjunction with the precision XY adjustment holder (19). The green laser is mounted into a 4 axes adjustment holder (7) by which the direction of the laser radiation is aligned with respect to the optical axes of the optical bench. The goniometer (11) is attached to the optical bench (13) and allows to measure the angle resolved emission of a laser source. The laser power is detected by a photodetector (3) which is attached to the rotary arm. The photodetector is connected to the junction box (4) where the detected photocurrent is converted into a voltage and displayed on the digital voltmeter (1). Furthermore, a filter (16) is provided. Its transmission is measured by using both laser sources and determined for which laser the filter is a suitable safety goggle material.

Measurements

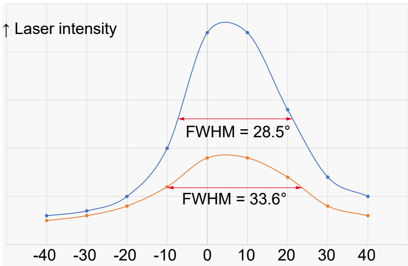


Fig. 2.45: Measurement of the divergence

To determine the maximum permissible radiation (MPR) the laser safety officer needs to know the wavelength, the beam diameter, laser power and finally the mode of operation, if pulsed or continuous mode. To get the MPR from the tables of the laser safety regulations one needs to know the laser intensity in W/m^2. The continuous laser power in watt or milliwatt is measured by a calibrated power meter (like 19,21). Dividing the measured value by the beam cross section we get the intensity. In order to determine the MPR in a defined distance, the officer needs to know in addition the divergence of the laser. Due to the large divergence of the pulsed laser it can be measured straight forward by using the goniometer. For the green laser with a much smaller divergence this method fails. That is why we need to increase the divergence first by using a lense (14) with known parameter. By using the ABCD parameter, the divergence of the laser source can be calculated backwards based on the measured divergence behind the lens. Such a measurement example is shown in Fig. 2.45.

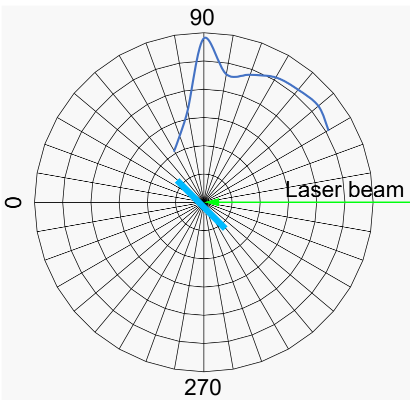


Fig. 2.46: Scattered intensity versus emission angle

The previous considerations targeted the safety of the human eye. In this section the irradiation of the human skin by scattered laser light is treated. Wearing laser safety goggles only protects the eyes, but what is about the scattered light from surfaces hit by the laser beam. To study this phenomenon a scattering surface is placed into the centre of the goniometer and illuminated by the green laser beam. The scattering surface is oriented under 45° with respect to the incident laser beam (see Fig. 2.46). The photodetector is turned around the probe and lets say for each 5 or 10 ° the value detected by the photodetector is taken. It makes sense to transfer the values into a chart with polar coordinates (Fig. 2.46). The curve shows a peak at 90° which indicates that the surface has also a slight directed reflectivity compared to a standard cosine scattering material. The absolute scattered power can be measured using the calibrated instrument (19, 21) or the provided photodetector. As already mentioned the junction box converts the photocurrent I_p into a voltage by measuring the voltage drop across the series resistor of the photodiode. This resistor R can be set via the knob on the front panel and the supply voltage is 9 VDC. From the voltage drop, the known resistor R and voltage we can determine the photocurrent. From the provided spectral sensitivity curve of the used photodiode we calculate the incident power.

LM-0700 Laser safety consisting of:

Item	Code	Qty.	Description	Details page
1	CA-0220	1	Multimeter 3 1/2 digits	129 (21)
2	DC-0050	1	Pulsed laser diode controller MK1	122 (9)
3	DC-0120	1	Si-PIN Photodetector, BPX61 with connection leads	123 (14)
4	DC-0380	1	Photodetector Junction Box ZB1	125 (30)
5	LQ-0020	1	Green (532 nm) DPSSL in ø25 housing	118 (1)
6	LQ-0350	1	Pulsed diode laser in housing	120 (15)
7	MM-0420	1	4 axes adjustment holder	96 (24)
8	MM-0020	3	Mounting plate C25 on carrier MG20	93 (1)
9	MM-0060	1	Filter plate holder on MG20	94 (7)
10	MM-0090	1	XY adjuster on MG20	94 (8)
11	MM-0300	1	Carrier with 360° rotary arm	95 (20)
12	MM-0340	1	Scatter probe on rotary table	95 (21)
13	MP-0150	1	Optical Bench MG-65, 500 mm	93 (8)
14	OC-0010	1	Biconcave lens f=-10 mm, C25 mount	98 (2)
15	OC-0170	1	Collimator 808 nm in C25 mount	99 (13)
16	OC-0939	1	Filter BG39, 50 x 50 x 3 mm	104 (53)
17	UM-LM07	1	Manual Laser Safety	
	Option (order separately)			
18	CA-0200	1	Oscilloscope 100 MHz digital, two channel	128 (19)
19	CA-0260	1	Laser power meter LabMax-TO	129 (22)
20	CA-0262	1	Energy sensor head 300 nJ - 600 µJ	129 (23)
21	CA-0264	1	Power sensor LM2 VIS 50 mW / 1 nW	129 (24)

Highlights

Premium class ★★ experiment

Intended institutions and users:

Laser safety officers
Physics Laboratory
Engineering department
Electronic department