Lambert´s law of radiation (Item No.: P2240405)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
ILIAS	Physik	Hochschule	Licht und Optik	Ausbreitung von Licht

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	1 Student

Additional Requirements:

Experiment Variations:

Keywords:

Specific irradiance, beam density, diffuse emission and reflection

Introduction

Overview

The diffuse reflection of a sheet of paper is examined according to Lambert’s law of radiation in relation to characteristic emission of radiation.

Fig. 1: Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	He/Ne Laser, 5mW with holder	08701-00	1
2	Power supply for laser head 5 mW	08702-93	1
3	PHYWE Universal measuring amplifier	13626-93	1
4	Rot. guide rail w. angular scale	08717-00	1
5	Optical base plate with rubber feet	08700-00	1
6	Photoelement f. opt. base plt.	08734-00	1
7	Diaphragm holder for optical base plate	08724-00	1
8	Voltmeter,0.3-300VDC,10-300VAC /	07035-00	1
9	Adjusting support 35 x 35 mm	08711-00	2
10	Surface mirror 30 x 30 mm	08711-01	2
11	Lensholder f. optical base plate	08723-00	2
12	Magnetic foot for optical base plate	08710-00	5
13	Lens, mounted, f +100 mm	08021-01	1
14	Connecting cord, 32 A, 500 mm, red	07361-01	2

Set-up and procedure

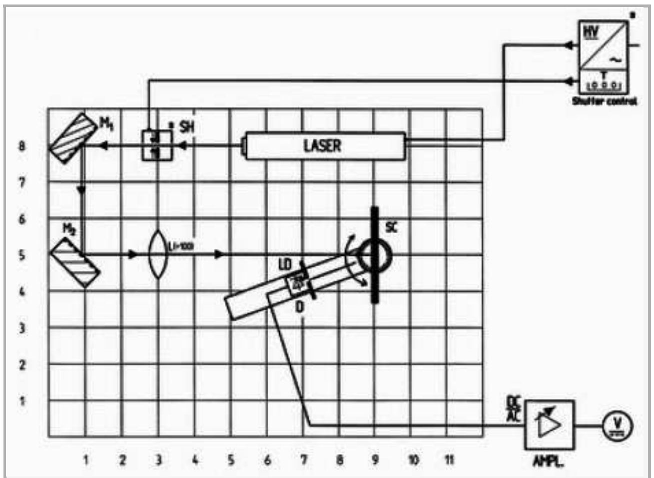

Fig. 2: Experimental set up for the qualitative Co. KG © All rights reserved P2240405 and 2. The recommended set up height (height of beam support. M1 and M2 in such a way that it impinges perpendicularly rotation axis of the rotating guide rail. angle by means of photocell LD face direc-) 15°. kened adethe univeramplifier adis meaand 80° in corres- : verification of Lambert’s law of radiation (* only required for 5 mW laser)

- The experimental set up is shown in fig. 1 and 2. The recommended set up height (height of beam path) should be 130 mm.
- A sheet of paper is inserted in the diaphragm support
- The laser beam is adjusted with the mirrors **M1** and **M2** in such a way that it impinges perpendicularly on the surface of the paper and on the rotation axis of the rotating guide rail.
- Light intensity is measured as a function of the angle by means of photocell LD on the rotating guide rail
- The smallest adjustable angle φ which can be comprehended between the perpendicular to the surface of the paper (that is, the direction of incidence of the laser beam) and the direction of the detector (cf. fig. 3) is 15°.

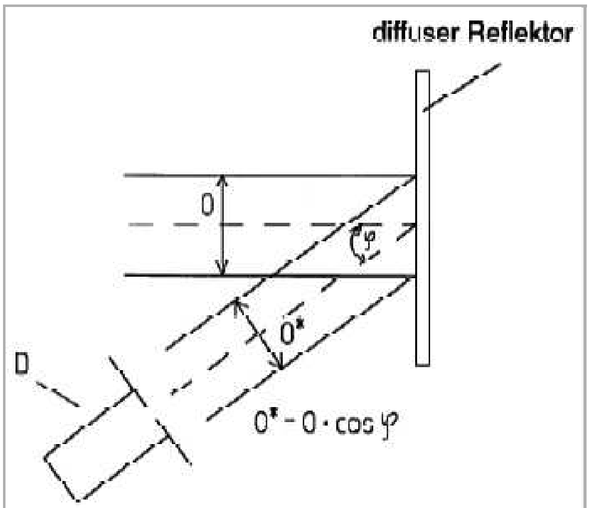

Fig. 3: Diagram of the principle of measurements with the used magnitudes (with O* as apparent magnitude of surface O)

- After the laser has warmed up for about half an hour, the experiment should be carried out in a darkened room, in order to keep luminous intensity constant.
- At the beginning of measurement, an adequate amplification is selected on the universal measurement amplifier (voltage should not be higher than the maximum output voltage of 10 V).
- The laser beam is interrupted and zero adjustment is carried out on the universal measurement amplifier.
- Angle ϕ is adjusted between 15° and 80° in steps of 5° with the assistance of the rotating guide rail and the angular scale. The corresponding intensities (or respectively voltages $U(\phi)$) are measured.

- For the sake of precision, the measurement should be repeated several times under the same conditions and voltages $U(\phi)$ should be averaged.
- Set up of the rotating unit: to begin with, the stop screw of a magnet foot is removed. The circular orifice of the rotating guide rail is pushed over the foot. Furthermore, the angular scale is set over the magnet foot, above the rotating guide rail. The magnet foot is fastened to the optical base plate, the rotating guide rail being sufficiently mobile. Photocell **LD** can then be set at the centre of the rotating guide rail by means of a magnet foot. Angular distribution should be sensible when set up is made on the optical base plate, that is, the 0° scale line should point in the direction of the incident laser beam.

Theory and evaluation

The emission characteristic of a diffusely reflecting surface O is determined by the fact that every surface element dO scatters incident light uniformly in all directions. This is the case, e. g., for a sheet of paper consisting of a large number of thin and transparent cellulose fibres. As the beam density L of a diffusely reflecting surface is constant, to the observer, the total surface O appears to have the same luminosity whatever direction it is being looked at from. In fig. 3 it can however be seen, that the apparent surface which is seen by the observer varies with the angle of observation φ. In the boundary case, $\varphi = 90^\circ$ the apparent surface vanishes and thus also the *irradiation E* perceived by the observer. As photocell LD only can "see" a small angle with its slit orifice, and as the receiving surface remains constantly at the same distance and perpendicular to the direction of observation during the whole measurement, influences due to the used reception surface may be neglected in the present case (that is, the radiation intensity E of the photocell is proportional to beam intensity I of the reflecting surface). In general, Lambert's cosine law is valid for the reflecting surface:

$$I = L \cos\phi \cdot O \tag{1}$$

where I : beam intensity and L : beam density (=constant)

Under the given circumstances, one then obtains the following relation of proportionality:

$$E(\phi) \propto \cos\phi \tag{2}$$

Irradiance intensity E is proportional to the measured voltage U of the photocell (cf. table 1).

Table 1: Voltage $U(\varphi)$ as a function of angle at the photocell, with corresponding angular adjustments φ

$U(\phi)$ /V	2.75	2.58	2.43	2.30	2.10	1.80	1.65	1.47	1.33	1.05	0.88	0.62	0.62	0.33	0.12
ϕ /°	15	20	25	30	35	40	45	50	55	60	65	70	75	75	80

The following relation is used for evaluation:
the smallest adjustable angle ϕ is 15°. According to equation (2), the smallest angle and an arbitrary angle ϕ are related by the fact that $E(15^\circ) \propto \cos(15^\circ)$ and $E(\phi) \propto \cos(\phi)$. This leads to

$$\frac{E(\phi)}{E(15^\circ)} = \frac{\cos\phi}{\cos(15^\circ)}) \tag{3}$$

When plotting

$$\frac{E(\phi)}{E(15^\circ)} \text{ or } \frac{U(\phi)}{U(15^\circ)} \text{ to } \frac{\cos(\phi)}{\cos(15^\circ)}$$

one should obtain a straight line of slope 1 (cf. fig. 4). The plot shows that this is true for the largest angular area. It also is shown that luminous intensity is too high for small angles. In this area, one receives a directly reflecting proportion which is not radiated diffusely. This shows that a smooth sheet of paper is no ideal Lambert radiator (the result improves with increasing roughness).

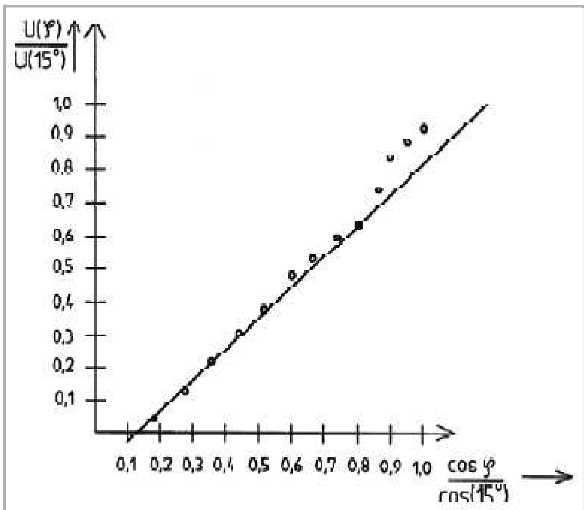

Fig. 4: Plot for the confirmation of Lambert's law. For this, voltages U(φ) were normalised with the value of U(15°) and cos(φ) with cos (15°)