Exp 2 Photo-resistivity

Recording the current-voltage curve of a CdS photo-resistor at different illuminance values and constant wavelength (For example Green).

The behavior of the current flowing through the CdS photo-resistor will be investigated when a voltage is applied. During each measuring series, the luminous intensity acting on the photo-resistor from a light source will remain constant.

Each measurement series will then be used to produce a current-voltage curve for the respective irradiance.

Explore the relative sensitivity - wavelength curve of CdS by using different color of light.

The image of an illuminated slit is spectrally dispersed using a flint glass prism. A wavelength range will then be selected from the spectrum using a second slit and projected on to the photo-resistor. A combination of a polarizer and an analyzer enables a certain irradiance to be set. Further experiments are also possible with this setup, e.g. the spectral response of the photo-resistor to the radiation from the incandescent lamp can be measured by changing the angle between the optical benches.

Finally, a set up with simplified ray path will be demonstrated as an alternative to the first setup. Wavelength ranges will then be selected using different light filters.

Ohm's law usually applies to electricity conduction in a homogeneous solid. If two charge carries types are present, electrons and hole electrons, this law reads as follows in differential from:

$$\vec{J} = \sigma \cdot \vec{E} = \left(p \cdot e \cdot \mu_p + n \cdot e \cdot \mu_n\right) \cdot \vec{E}$$

$\vec{J}$ =Current density	σ =Conductivity
$\vec{E}$ =Electric field strength	e =Elementary charge
p =Concentration of the hole electrons	n =Electron concentration
μ_n or μ_p = Mobility of the electrons or hole electrons	

When a photo-conductor is illuminated, the current density increases by $\Delta\vec{J}$ due to the increase in charge carrier concentration by Δp and Δn as a result of light excitation:

$$\Delta\vec{J} = \left(\Delta p \cdot e \cdot \mu_p + \Delta n \cdot e \cdot \mu_n\right) \cdot \vec{E} \qquad (1)$$

Correspondingly, the increase in current is:

$$\Delta I \equiv I_F = \left(\Delta p \cdot e \cdot \mu_p + \Delta n \cdot e \cdot \mu_n\right) \cdot \frac{U}{d} \cdot q \qquad (2)$$

q = Cross section of the current flow path

d = Electrode spacing

I_F = Photo current

In the photo-resistor examined here $I_{ph} = I_{tot} - I_o \approx I_{tot}$, since I_0 = (= Dark current $\approx$ Background current) is insignificantly low in respect of I_{tot}.

Both Δp and Δn are stationary if irradiance is constant, and I_F is a linear function of U in accordance with equation (2), assuming that neither mobilities nor field strengths change. The first assumption is almost always fulfilled since the change due to charge reversal of impurity spots in the photoconductor when illuminated is usually extremely low compared with the change in p or n. However, the electric field does not remain homogeneous if the voltages become sufficiently large. The distribution of charge carriers then also becomes correspondingly unhomogeneous. This creats deviations from Ohm's law resulting in saturation of the photo current. This saturation is not reached in the measurement example.

Apparatus

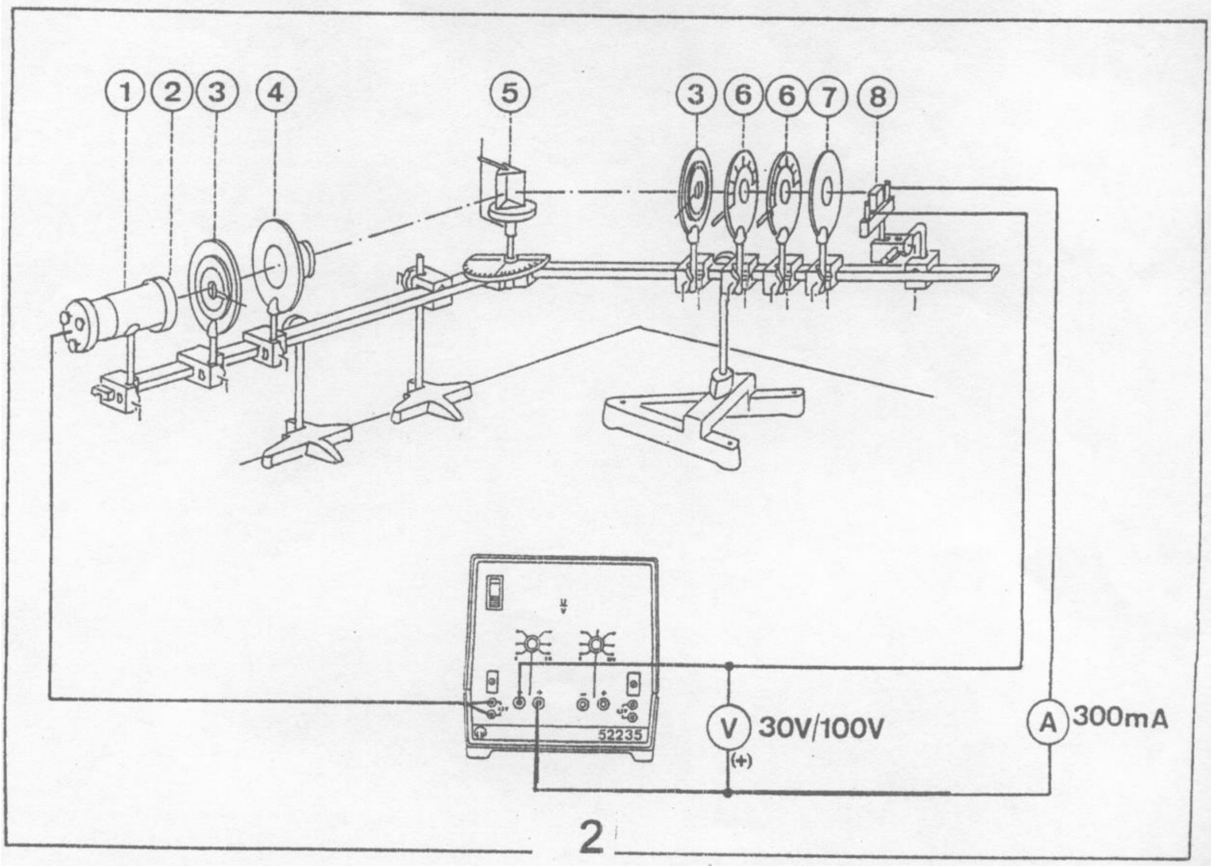
For the setup in accordance with Fig. 1:

1	Power supply unit for tube experiments
1	Lamp housing
1	Lamp, 6V/30W
1	Spherical condenser with diaphragm slider
1	Large stand base
2	Adjustable slits
1	Projection objective
1	Flint glass prism
1	Pair of polarizing filters
1	Lens, f=100mm

1	Small optical bench with long holder
1	Small optical bench with short holder
1	Stand rod, bent at right angles
1	Stand rod, 50cm long
2	Bench clamps, single
1	Large stand base
1	Swivel joint with protractor scale
1	Prism table
1	Holder for Plug-in units
11	Leybold multiclamps

Fig. 1: Experiment setup for recording the current-voltage curve of a photoresistor

(1) Light source
(2) Condenser
(3) Entrance or emergence slit
(4) Projection objective
(5) Flint glass prism
(6) Polarizer or analyzer
(7) Conversion lens f = 100 mm
(8) Photoresistor LDR 05



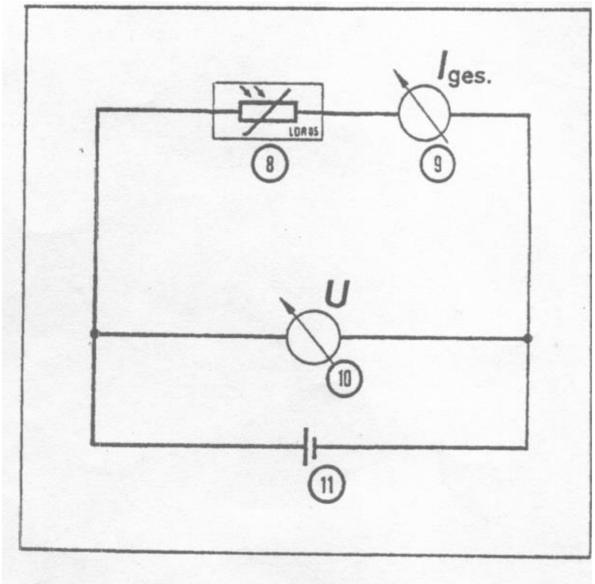


Fig. 1.1: Electrical connections
(8) Photoresistor LDR 05
(9) Multimeter 3E
(10) Multimeter M2LH
(11) Power supply unit for tube experiments

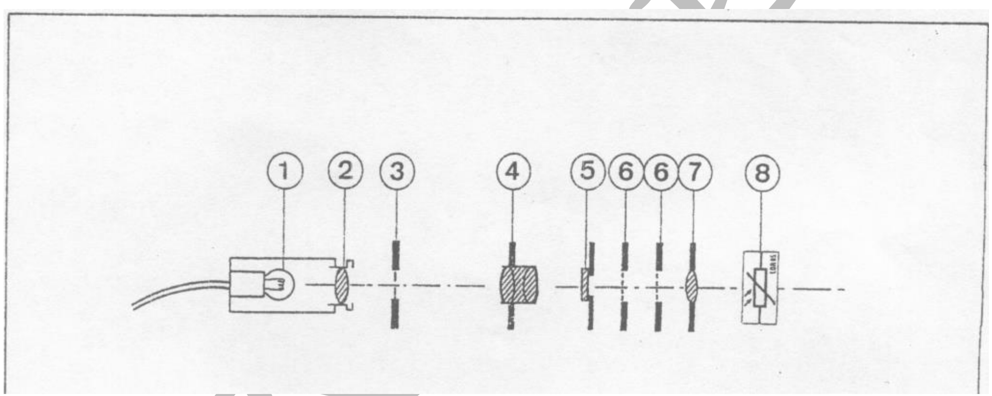


Fig. 2: Set up alternative:

① Light source
② Condenser
③ Adjustable slit
④ Projection objective
⑤ Light filter, yellow or green or other desired colors
⑥ Polarizer or analyzer
⑦ Conversion lens f = 100mm
⑧ Photo-resistor

Setting up

1. Set up the experiment as in Fig.1, making the electrical connection as shown in Fig. 1.1. (Measurements should be carried out with the room dark to suppress the influence of room light on the photocurrent (not a total black-out so that it is still possible to read off the instrument display). It is also recommended to place a black cover on the photo-resistor which is only open toward the ray path. In this way, the “dark photocurrent” can easily be kept negligibly small (see measurement results).
2. Set the entrance and emergence slits arbitrarily, but remember that **the smaller the gap width, the sharper the color separation**. It is advantageous to select the gap width of the entrance slit so that it is at least as large as the emergence slit.With slit widths of 0.3mm and less, the colors yellow, green, blue and violet, amongst others, can be separated at least as exactly as when using the filter set for these colors (cf. set alternative Fig.2).
3. Using lens ②, fully illuminate entrance slit ③. Form a sharp image of the entrance slit on the emergence slit using the projection objective (without prism).
4. Finally, place the prism in the ray path, adjusting for minimum deflection. Using the lens ⑦, focus the desired color on the receiver through the emergence slit by moving the mobile path of the optical setup.
5. Select Green light for operating the experiment **current-voltage curve of CdS.**
6. Select 5 different color of light at constant radiance for exploring **the characteristics of CdS, violet-blue-green-yellow-red is advised.** Before reading off each measurement value, it is recommended to allow a certain waiting period approx. 20 s, until the photocurrent has reached a stationary value.

Note: Fig. 2 shows a diagram of the setup with simplified ray path; electrical connections as in Fig. 1.1.

Carring out the experiment

Set the polarizer to the angle 0˚ and the analyzer to the desired α. The radiance J determined in this way is given by : $J = J_0 \cdot D \cdot \cos^2 \alpha$.

Irradiance J = radiation output / receiver area

J or J_0 = irradiation with or without polarizing filter.

D = permeability with the polarizing filters in parallel.

The photocurrent I_F is now measured step-by-step as a function of voltage U with fixed wavelength λ and irradiation J.

The background current I_0 is measured by sliding a black piece of paper into the ray path (preferably in front of the prism). I_{tot} is the total current.

Current-voltage curve of CdS

Select Green light for operating the experiment. Varying the voltage applied and measuring the current reading through receiver under the maximum radiance. Repeat the experiment for different irradiances, i.e. different angles for α and get the results as in Fig. 3.

Relative sensitivity V.S. wavelength of CdS

Select 5 different color of light, **violet-blue-green-yellow-red is advised,** with the same voltage applied and angle α between polarizer and analyzer for exploring **the characteristics of CdS** as in Fig 4.

Measurement examples

Slit width: entrance slit: a little over 0.3mm; emergence slit: a little below 0.3mm; $\lambda = 0.456\,\mu m$ (green); $I_F \approx I_{tot}$

$\frac{U}{V}$	α=0° $\frac{I_{Background}}{A}$	α=0° $\frac{I_{tot}}{A}$	α=30° $\frac{I_{tot}}{A}$	α=45° $\frac{I_{tot}}{A}$	α=60° $\frac{I_{tot}}{A}$	α=75° $\frac{I_{tot}}{A}$
0	$5x10^{-6}$	$5x10^{-6}$	$4\text{-}5x10^{-6}$	$4\text{-}5x10^{-6}$	$4\text{-}5x10^{-6}$	$4\text{-}5x10^{-6}$
2	$5x10^{-6}$	$1,5x10^{-5}$	$1,1x10^{-5}$	$1,0x10^{-6}$	$6,0x10^{-6}$	$4\text{-}5x10^{-6}$
4	$5x10^{-6}$	$2,5x10^{-5}$	$2,0x10^{-5}$	$1,7x10^{-5}$	$1,0x10^{-5}$	$4\text{-}5x10^{-6}$
6	$6\text{-}7x10^{-6}$	$4,0x10^{-5}$	$2,8x10^{-5}$	$2,7x10^{-5}$	$1,2x10^{-5}$	$6x10^{-6}$
8	$6\text{-}7x10^{-6}$	$5,3x10^{-5}$	$4,0x10^{-5}$	$3,6x10^{-5}$	$1,5x10^{-5}$	$6x10^{-6}$
10	$6\text{-}7x10^{-6}$	$7,2x10^{-5}$	$5,0x10^{-5}$	$4,8x10^{-5}$	$1,8x10^{-5}$	$8x10^{-6}$
15	$6\text{-}7x10^{-6}$	$1,18x10^{-4}$	$8,5x10^{-5}$	$7,9x10^{-5}$	$2,9x10^{-5}$	$8x10^{-6}$

Evaluation and results

As Fig. 3 shows, the photo-resistor clearly behaves ohmically for small voltages. This behavior is also guaranteed for the large irradiance values as long as the voltage U does not increase to excessive values.

Note:

1. The current-voltage curves display saturation for larger voltages and irradiance values in agreement with the theory of the internal photoeffect. The rise gradient of the curves then noticeably decreases (this cannot be seen in this experiment).
2. Error observation:
   The largest error occurs in the range of small currents, since here I_F is comparable with the background current. Otherwise, the background current is negligible. Other error sources might be fluctuations in the mains supply and the light yield of the lamp (particularly at the start when this has not yet reached operating temperature), heating up of the photo-resistor at excessive currents, and in particular unequal waiting periods before reading off the measurement values. The measurement curves show that the errors were kept to a minimum.

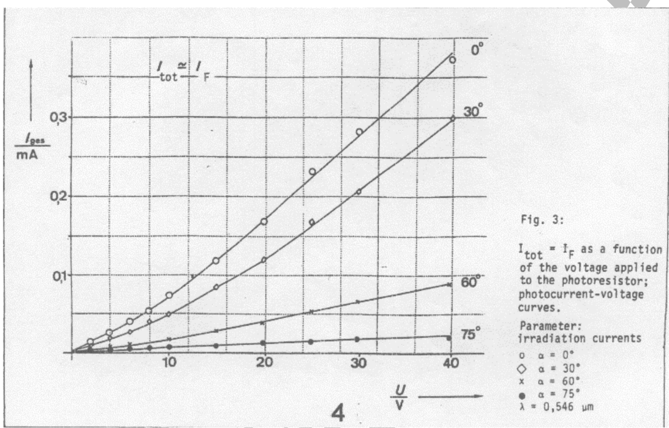


Fig 3

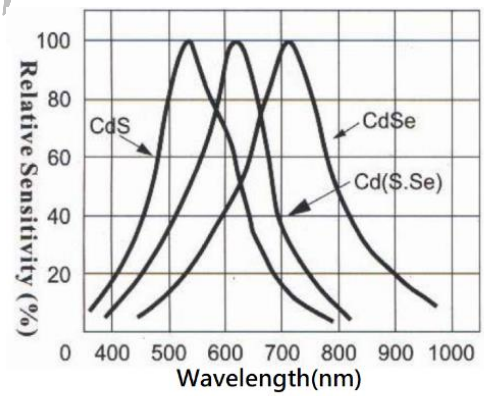


Fig 4