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The Influence of the Absorption of the Pumping Light on the Degree of Polarization of an Optically Pumped He Target

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The influence of the absorption of the pumping light on the degree of polarization of an optically pumped He target*

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Abstract

In order to investigate the optical pumping of helium the mean free path λ of the pumping light in ^{4}He was measured. At a pressure of 7 Torr a value $\lambda = 10.8 \pm 0.4$ cm was obtained for a weak discharge. An exact calculation for ^{3}He resulted in $\lambda = 13.5$ cm. Therefore the approximation of weak absorption cannot be considered to be valid.

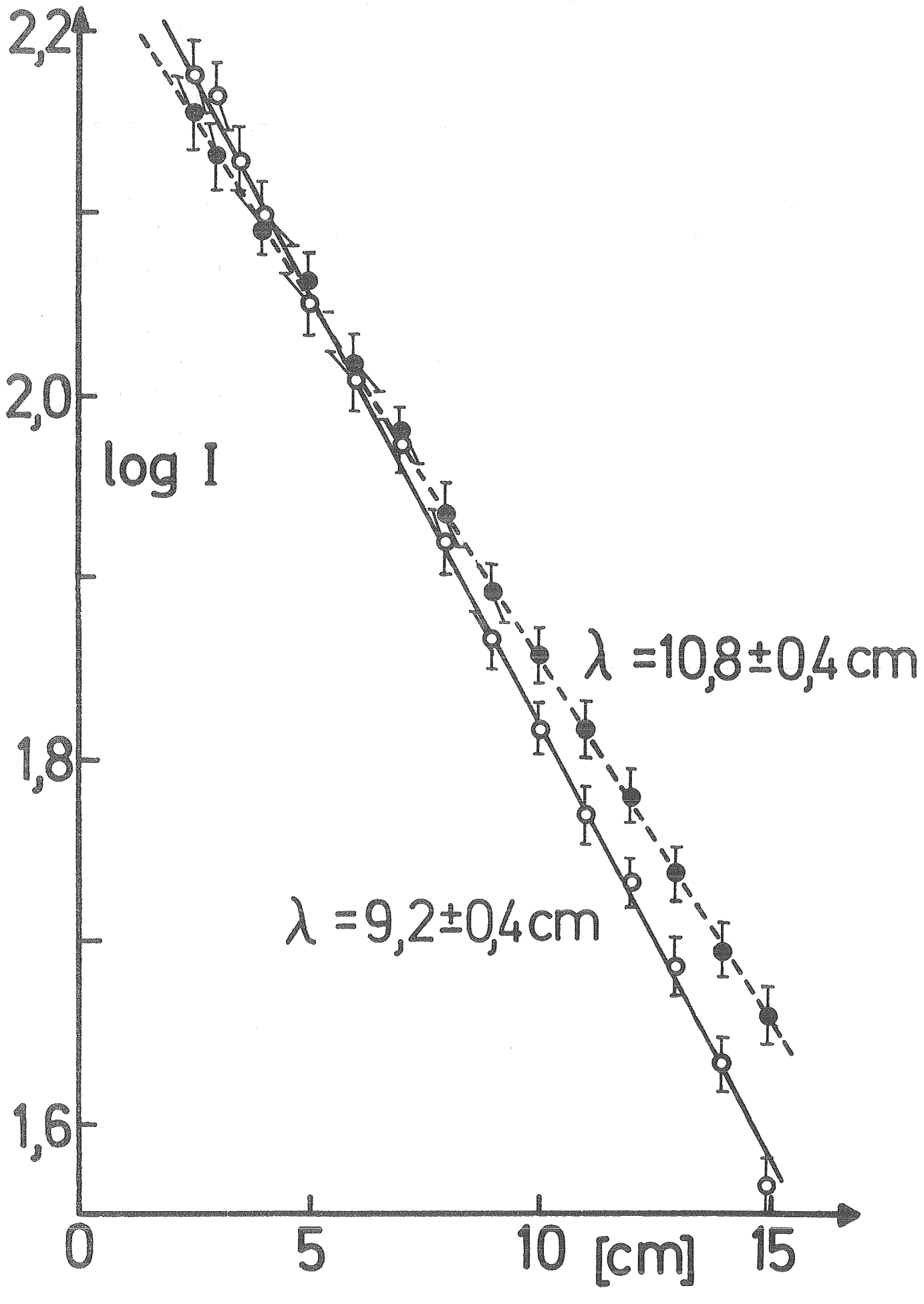
Zusammenfassung

Zur Untersuchung des optischen Pumpvorganges in Heliumgas wurde die mittlere freie Weglänge λ der Pumplichtphotonen in ^{4}He gemessen. Bei einem Druck von 7 Torr und schwächster, homogener Entladung im ^{4}He ergab sich $\lambda = 10{,}8 \pm 0{,}4$ cm. Durch eine exakte Umrechnung auf ^{3}He folgte für dieses $\lambda = 13{,}5$ cm. Damit ist die Voraussetzung der schwachen Absorption, die zum Erreichen eines hohen Polarisationsgrades notwendig ist, nicht mehr gültig.

The degree of polarization observed experimentally in an optically pumped ^{3}He target does not agree with the prediction derived by Colegrove et al. [1]) for its dependence on the intensity of the pumping light. Up to now the question of the influence of the pumping light intensity on the polarization is not yet answered and only one theoretical approach [1]) to this problem is published. This approach assumes a weak absorption. A high absorption of the pumping light by the metastable atoms might be able to explain the discrepancy between the experiments.

The dependence of the pumping light intensity on the range of the light in a He gas discharge was investigated experimentally. Light from a ^{4}He lamp was circularly polarized and sent along the axis through a cylindrical glass vessel. The vessel contained ^{4}He gas at a pressure of either 0.05 mm Hg or 7 mm Hg. The dimensions of the vessel were 20 cm in length and 7.0 cm in diameter. Metastable He atoms were produced by a weak rf gas discharge. The frequency and the geometry of the electrodes were adjusted carefully in order to obtain a constant density of metastable atoms along the axis of the cell. With exception of the regions close to the entrance and exit windows this condition has been fulfilled very properly. The intensity of the fluorescently scattered light was taken to be a measure of the local variation of the pumping light intensity. The fluorescent light emitted at 90 degrees with respect to the axis of the cell was observed by a movable phototube.

The figure shows the result of such a measurement. The intensity of the fluorescent light is plotted in a logarithmic scale versus the range coordinate scaled from the entrance window. The measured values of each of the two experiments shown are very well represented by straight lines. The two experiments differed only by the density of the metastable He atoms. The pressure of the ^{4}He gas was 7 mm Hg in both cases. The pure exponential decrease leads to the conclusion that the decay of only one of the two pumping light components are denoted by D_0 and D_3. By a separate measurement of the polarization of the fluorescent light it was assured that only the D_3 component was present. The mean free path λ of the photons was obtained from the slope of the decay


2,2
2,0
1,8
1,6
log I
λ =10,8±0,4 cm
λ =9,2±0,4 cm
0
5
10
[cm]
15

curve. At le lowest discharge level possible the mean free path is $\lambda = 10.8 \pm 0.4$ cm while at a slightly higher discharge level it turns out to be $\lambda = 9.2 \pm 0.4$ cm. The mean free path in ^{3}He gas is easily evaluable from the ^{4}He data measured. In this way for ^{3}He a value $\lambda = 13.5 \pm 0.5$ cm was obtained corresponding to the lowest discharge level.

The measurements discussed exhibit such a high photon absorption that the approximation of weak absorption cannot be considered to be valid. The mean free path of the photons is comparable to the dimensions of the absorption cell. Therefore reabsorption of fluorescently emitted photons has to be taken into account. This effect decreases the degree of polarization. In addition to the polarized pumping light a fraction of unpolarized fluorescent light acts in the pumping process. It can be shown, that this is equivalent to an additional relaxation mechanism which reduces the maximum obtainable target polarization.

1) F.D. Colegrove, L.D. Schearer, G.K. Walters
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