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Polarized Electrons by Photoemission from Solid Alkalis

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We have observed spin polarization of photoelectrons emitted by solid alkali targets exposed to circularly polarized light. The polarization increases monotonically with increasing atomic number.

In earlier experiments[1-3] Fano's prediction[4] of a polarization effect in photoionization of the alkalis was verified: Photoelectrons emitted by free alkali atoms exposed to circularly polarized light are highly spin polarized if the wavelength of the light falls within a broad spectral band near the ionization threshold. This polarization is due to the influence of spin-orbit interaction on photoionization.

It is the purpose of the present paper to report the first measurements on spin polarization of photoelectrons emitted by solid alkali targets exposed to circularly polarized light.

The apparatus used has been fully described in an earlier paper,[3] the only major change being that the target was no longer an atomic beam. Instead, the alkali atoms were evaporated on a substrate in high vacuum at a rate of about 50 atomic layers per second.

The experimental results for cesium are given in Fig. 1. There are the following characteristic differences between these results and those for free cesium atoms: (1) The polarization maximum is shifted to longer wavelengths in the visible range, which makes the experiments very convenient. (2) The polarization is much lower. (3) The intensity obtained with the solid target is much higher.

Similar results were obtained for the other alkalis. For reasons of conciseness they are presented schematically in Fig. 2. The uncertainty of all the curves is given by the error bar in Fig.

2. It is the same for all targets. Within these error limits no polarization was found for Li and Na. For K a small polarization appeared. It increased as the atomic number became larger.

Whereas the earlier results for free alkali atoms were perfectly explained by Fano's theory, it is much more difficult to understand the present measurements. The similarity of the effect for free atoms and solid targets as well as the fact that the polarization increases with increasing atomic number, as does spin-orbit interaction, suggests that the polarization is caused by spin-orbit coupling. On the other hand, there is no appreciable spin-orbit interaction to be expected for the conduction electrons of the alkalis.
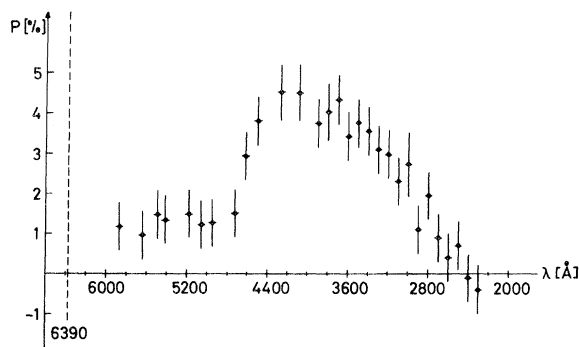

FIG. 1. Wavelength dependence of the polarization of photoelectrons produced by exposing solid cesium to circularly polarized light. Dashed line, ionization threshold.
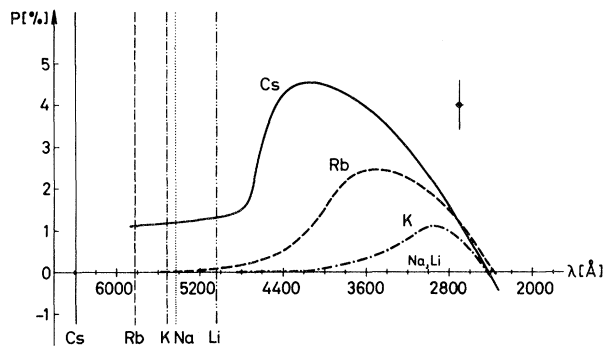
FIG. 2. Comparison of spin polarization obtained from solid Cs, Rb, K, Na, and Li targets. Dashed lines to the left, ionization thresholds. Error bar to the right applies to all curves.

It has been shown,[5,6] however, that the effective number of conduction electrons per atom decreases monotonically as one goes from sodium to potassium and rubidium to cesium.

A striking feature which will be displayed in a

more detailed[7] paper is a close correlation between the wavelengths for producing plasma oscillations and the wavelengths at which the polarization maxima appear. We believe this correlation to be fortuitous, since we do not see a mechanism for its explanation.

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Macroscopic Quantum Uncertainty Principle and Superfluid Hydrodynamics

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By application of a macroscopic quantum uncertainty principle to the flow of superfluid helium, one can understand the onset of third sound in thin helium films, and the large excess absorption of third sound in thick helium films.

Liquid helium below $T_\lambda = 2.2°K$ (He II) is a remarkable fluid because Planck's constant h enters directly into the description of its hydrodynamic properties. That this should be the case was first proposed by Onsager[1] who claimed that the circulation of the superfluid component of He II must be quantized:

$$\oint \vec{v}_s \cdot d\vec{r} = nh/m, \tag{1}$$

where m is the mass of a helium atom, n an integer, $\vec{v}_s$ the velocity of the superfluid component, and $d\vec{r}$ is an element of path length in the line integral. Equation (1) is clearly a macroscopic version of the Bohr-Sommerfeld quantization condition $\oint \vec{p} \cdot d\vec{q} = nh$ of the early quantum theory. In principle, the above quantization conditions are used to pick out a discrete set from the continuum of states obeying the classical dynamics.[2] At a higher level in the quantum theory, one must come to grips with the wave-particle duality and its consequence that the classical dynamics can

no longer give the fundamental description of the motion. In the basic quantum theory these facts are most simply reflected by the uncertainty principle, $\Delta p_i \Delta q_i = \hbar$. One is naturally led to expect that at a higher level our description of superfluids will include a macroscopic uncertainty principle,

$$\Delta v_{s,i} \Delta r_i = \hbar/m. \tag{2}$$

In this paper we propose to describe the onset of third sound in thin He II films and the large excess absorption of third sound in thick helium films by use of Eq. (2).

A solid surface immersed in helium vapor is coated by a film whose thickness is determined by the pressure of the vapor. The film is held to the substrate by the van der Waals force of attraction. Because of this force, surface waves (third sound), which are analogous to long gravity waves, can propagate through the film parallel to the substrate. The dynamical equation which de-