ANNIHILATION OF POLARIZED POSITRONS IN NICKEL

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IN experiments on the annihilation of positrons in ferromagnets, a system consisting of polarized positrons and unpolarized electrons is realized. This circumstance can be used to study the magnetic structure of a ferromagnet. To this end one investigates the variation of the angular distribution of annihilation gamma-quantum pairs as the direction of the magnetization vector relative to the direction of the positron polarization is varied [1]. Two-quantum annihilation is possible only if the annihilating electron-positron pair is an a spin singlet state [2], and therefore the polarization of various electron groups can be deduced from the variation of the angular distributions of the gamma quantum pairs.

We carried out such measurements with nickel. The measurement procedure was essentially that described by Lovas [3]. The geometry of the set-up, however, was such that we measured the integral distribution of the annihilation quanta, namely,

$$N\left(\theta=\frac{p_z}{mc}\right)=\int_{-\infty}^{\infty} dp_x\int_{-\infty}^{\infty} dp_y\int_{p_z}^{\infty} dp_z n(\mathbf{p}), \tag{1}$$

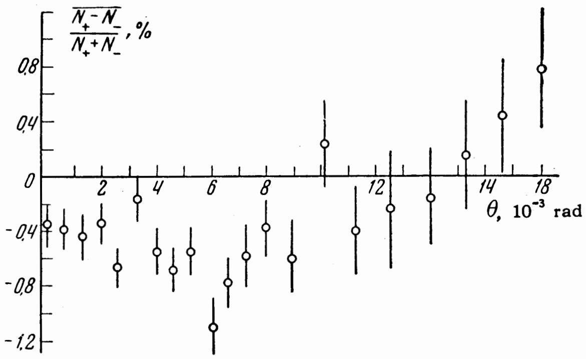
where n(p) is the electron momentum distribution function. This was accomplished by replacing the plane-parallel slits in front of each scintillator by lead bars.

The positron source was Na^{22}. In the beta decay of this isotope there are produced longitudinally polarized positrons with a degree of polarization $-\langle v/c\rangle$. The magnetic field was 13 kOe.

The figure shows the obtained values of the quantity

$$n(\theta) = [N_+(\theta) - N_-(\theta)] / [N_+(\theta) + N_-(\theta)].$$

The ± signs correspond to directions of the magnetic field along and against the direction of positron polarization; θ is the angle of inclination of the gamma-quantum pair to the direction corresponding to 180° travel.



In order to interpret the results, we assume that the valence electrons of nickel can be divided into localized (3d) and free (4s) electrons. The same form of $n(\theta)$ was obtained qualitatively by Mijnarends and Hambro [4] for iron. They concluded that positive values of $n(\theta)$ at large θ must be attributed to the fact that in this region the main contribution to the effect is made by polarized 3d electrons (their magnetic moments are antiparallel to the magnetic moment of the sample). A negative value of $n(\theta)$ in the region of small angles was interpreted as the result of opposite polarization of the 4s electrons. Berko and Zuckerman [5] noted that if one neglects the probability of three-quantum annihilation as compared with two-quantum annihilation, then, generally speaking, it cannot be concluded that the 4s electrons are polarized, for in this case the total probabilities of two-quantum annihilation are equal to each other, $p_{2\gamma}^{+} = p_{2\gamma}^{-}$.

In our case, as follows from (1), $p_{2\gamma} \sim N(0)$. We shall show that since $n(0) < 0$ for nickel, it does not follow at all that the 4s electrons are polarized antiparallel to the 3d electrons. In fact, since

$$p_{2\gamma}{}^{+} + p_{3\gamma}{}^{+} = p_{2\gamma}{}^{-} + p_{3\gamma}{}^{-} = 1,$$

we have

$$p_{2\gamma}{}^{+} - p_{2\gamma}{}^{-} = p_{2\gamma}{}^{-}/f_{-} - p_{2\gamma}{}^{+}/f_{+}, \tag{2}$$

where, according to [5],

$$f_{+-}=\left(\frac{\sigma_{2\gamma}}{\sigma_{3\gamma}}\right)\sum_{e}(1\mp P_eP_p)W_e\Big/\sum_{e}(3\pm P_eP_p)W_e;$$

$$W_e=\int|\psi_e(\mathbf{r})\psi_p(\mathbf{r})|^2dV, \tag{3}$$

$\sigma_{2\gamma}$ and $\sigma_{3\gamma}$ are the cross sections of two-quantum and three-quantum annihilation, while P_e and P_p are the values of the polarization.

In order to have $p_{2\gamma}^{+} - p_{2\gamma}^{-} < 0$ we must have

$$f_{-} > f_{+}. \tag{4}$$

If we assume that the direction of the total spin magnetic moment of the 3d electrons corresponds to the direction of the magnetic moment of the sample, then inequality (4) can hold only if the 4s electrons are polarized to some degree in a direction opposite that of the 3d electrons.

In conclusion we thank Prof. E. I. Kondorskiĭ for help during the performance of this work.

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THE THRESHOLD AND INTENSITY OF STIMULATED RAMAN RADIATION LINES IN LIQUIDS

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THE phenomenon of stimulated Raman radiation (SRR) in which coherent oscillations of molecules of the scattering medium are excited has, as is well known, a sharp threshold (cf., for example,[1]). An exponential growth of the amplitude of the field of the first Stokes component E_{s1} which plays a dominant role in the development of SRR occurs if the following condition is fulfilled (cf.[2])

$$\beta_{s1}E_0^2 \geqslant \delta_{s1}. \qquad (1)$$

Here E_0 is the intensity of the field of the incident wave (of frequency ω_0), β_{s1} is a quantity determined by the polarization of the molecule of the scattering medium at a frequency $\omega_0 - \Omega = \omega_{s1}$ (Ω is the characteristic frequency of the molecular oscillations) and δ_{s1} is the absorption coefficient of the medium at a frequency ω_{s1}. When (1) is satisfied the expression for the variation of the amplitude of the component E_{s1} in the medium is

$$E_{s1}(l) = E_{s1}(0)\exp\left\{\int_0^l [\beta_{s1}E_0^2(z) - \delta_{s1}(z)]\,dz\right\}. \qquad (2)$$

In the general case the amplitude of the pumping field depends on the coordinate; the dependence $\delta_{s1} = \delta_{s1}(z)$ can be related to the multiphoton absorption in the scattering medium [3]. It is important to emphasize that the intensity and the number of SRR lines depends not only on the "excess" over the threshold [cf., condition (1)], but also on the geometry of the experimental system.

In experiments described in [1,4], SRR was excited in a resonator tuned to the frequency ω_{s1}; on the other hand, as has been shown in [5,6], considerably broader possibilities of the study of SRR occur when the beam of the original radiation is focused into a volume of the substance under investigation. It is interesting that in the latter case not only does the number of SRR lines increase, but, as measurements show, their intensity increases also.

At the same time it should be noted that the factors which determine the value of the threshold and the intensity of the SRR lines cannot be considered as being fully understood at present. The restricted nature of the information obtained from the experimental papers quoted above is related largely to the circumstance that for the excitation of SRR the authors of these papers used only a ruby oscillator with $\lambda_0 \approx 0.69\mu$. In connection with these statements it appeared to us to be useful to carry out experiments on the excitation of SRR in other ranges, and in particular in those of shorter wavelength. Below we present some results of such experiments carried out with organic liquids. For the excitation of SRR we used the second harmonic of an oscillator utilizing glass activated by neodymium ($\lambda_0 = 0.53\mu$). The Q of the neodymium glass oscillator was modulated by means of a rotating prism; the frequency was doubled by a KDP crystal. The second harmonic radiation was focused on a cell with the liquid under investigation; in our experiments we utilized cells of length $l = 10$ cm, the cell windows were made of quartz. We observed the stimulated Raman scattering in benzene and in cyclohexane. The data of the experiments carried out under conditions optimal for our experimental arrangement are summarized in table I (the frequency ω_0 corresponds to the second harmonic of the oscillator utilizing glass activated by neodymium).

In liquids investigated by us we observed considerable lowering of the threshold of SRR compared to the corresponding value for $\lambda_0 \approx 0.7\mu$.