MEASUREMENT OF STRONG CRYSTAL ELECTRIC FIELD THROUGH SCHWINGER INTERACTION OF DIFFRACTED NEUTRONS

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The first experimental study of the Schwinger interaction of polarized neutrons with an electric field of a noncentrosymmetric perfect crystal (α-quartz) was made for a two wave dynamical diffraction [1].

The essence of the effect is as follows: in a noncentrosymmetric crystal for some planes the maxima of nuclear potential do not coincide with the maxima of electric potential. As a result the diffracting neutrons are affected with an interplanar electric field $\langle \Psi_n | E | \Psi_n \rangle \equiv E_g \approx 10^8$ V/cm.

The Schwinger interaction of the magnetic moment μ of the moving neutron with the magnetic field $\vec{H}_g = [\vec{E}_g \times \vec{V}_\parallel]/c$, in the coordinate system connected with the neutron, leads to spin dependence of the Pendellösung fringe ($\vec{V}_\parallel$ — component of neutron velocity which is parallel to the crystallographic planes). Omitting the quadratic term over the Schwinger interaction we can put down the Pendellösung phase shift $\Delta\varphi$ with a change of $\vec{\mu} \cdot \vec{H}_g$ sign. According to [1] we get:

$$\Delta\varphi = g_n \frac{eE_g L}{m_p c^2},$$

where g_n is a gyromagnetic ratio of the neutron, $g_n = 3.826$, e, m_p are the charge and the mass of the proton, L is the thickness of the crystal.

The value of E_g can be evaluated with the following formula [1]:

$$\vec{E}_g = \vec{g}\, v_g^E \sin(\Delta\Phi_g),$$

where v_g^E is the amplitude of the g-harmonic of the crystal's electric field; $\Delta\Phi_g$ is the phase shift between the g-harmonics of the electric and nuclear potentials (for centrosymmetric crystals $\Delta\Phi_g \equiv 0$): $g = 2\pi/d$ is the modulus of the reciprocal lattice vector $\vec{g}(hkl)$ ($g \sim 10^8$ cm^{-1}). Using the values of $v^E_{(11\bar{2}0)} = 1.89$ V; $\Delta\Phi_{(11\bar{2}0)} = 0.46$ rad; $g = 2.55 \cdot 10^8$ cm^{-1} evaluated with tabulated data for α-quartz, we find for the $(11\bar{2}0)$ plane:

$$E^{theor}_{11\bar{2}0} = 2.1 \cdot 10^8\,(10\%)\ V/cm.$$

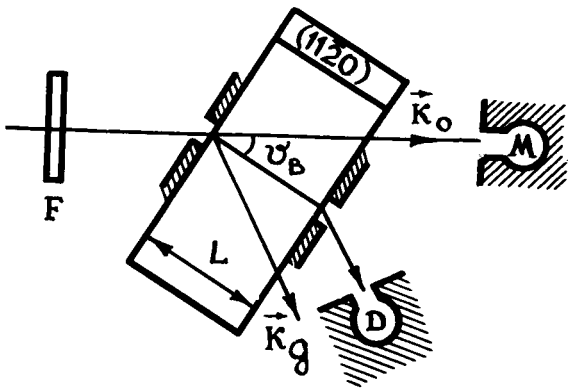

Fig. 1. Scheme of experiment. F is flipper coil, D is neutron detector, M is beam monitor. Neutron spin is normal to plane of drawing

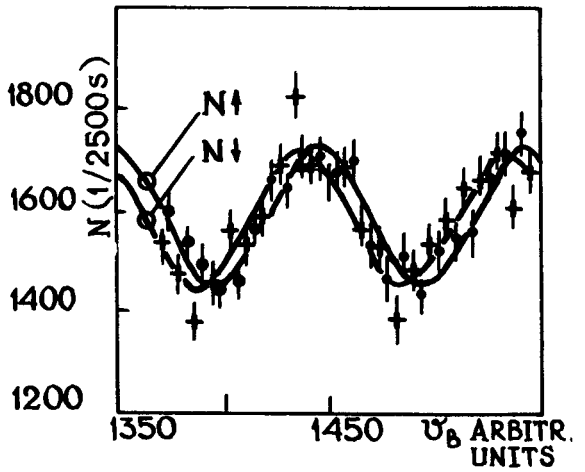

Fig. 2. Experimental Pendellösung fringes for polarization $N\uparrow$ $N\downarrow$. About 1/4 of whole accumulated statistics is represcnted

A schematic diagram of the device is shown in fig. 1. An incident neutron beam, polarized perpendicularly to the plane $\vec{k}_0$, $\vec{k}_g$ ($P = 0.75 - 0.8$ for $\lambda = 1.8 - 2.2$ Å), is in the Bragg condition. Two crystals were cut out from natural quartz. Reflecting planes (11$\bar{2}$0) are normal to the entrance and exit faces. The crystal thicknesses are $L_1 = 0.80$ cm and $L_2 = 1.14$ cm and the beam area is 0.06 x 1.6 cm^2. The exit slit (0.06 cm for L_1 and 0.08 cm for L_2) has been put right in the middle of the Borrmann fan. So the neutrons which are in the Bragg condition have been detected. The quality of the crystals was tested by the γ-diffraction method [2].

Table

Experimental values of Pendellösung phase shifts $\Delta\varphi$ for the (11$\bar{2}$0) quartz

L	$\Delta\varphi°$	Remarks
L_1	$+36.0 \pm 9.5$	
	-33.5 ± 6.9	Crystal turned upside-down
	$+34 \pm 12$	Crystal in upright position
	$+0.7 \pm 6.5$	Control run $P = 0$
L_2	$+35.3 \pm 7.8$	
	-57.0 ± 7.6	Crystal turned upside-down

The typical experimental Pendellösung fringes depending on Θ_B are shown in fig. 2 (1 angle unit is equal to 10″ for Θ_B). The full intensities (including background) are given. Two Pendellösung fringes correspond to opposite polarizations of $N^{\uparrow}$ and $N^{\downarrow}$ (the flipper coil F changed the sign of the polarization after each measured point).

The results of measurements are presented in the Table. Values of $\Delta\varphi$ are transformed to $P = 1$. Using these results and the universal constants we find the experimental value of the electric field affected on neutron $\langle \Psi_n | E | \Psi_n \rangle$:

$$E^{exp}_{11\bar{2}0} = (1.8 \pm 0.2) \cdot 10^8 V/cm .$$

This value is in good agreement with the theoretical one. The field is $10^3 - 10^4$ times stronger than the electric fields available in the laboratory. In principle, this field may be used for the study of electric properties of neutron.

REFERENCES

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2. *Alexeev V. L., Kurbakov A. I., Trunov V. A.* Preprint LNPI — 1345, Leningrad. 1987. 20 p.