Reprinted from:

PHYSICS LETTERS

Volume 56A, No. 4, 5 April 1976

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G. BADUREK, H. RAUCH and A. ZEILINGER
Atominstitut der Österr. Hochschulen, A-1020 Wien, Austria

W. BAUSPIESS
Institut für Physik, Universität, D-46 Dortmund, Germany
and Institut Laue-Langevin, F-38042 Grenoble Cedex, France

and

U. BONSE
Institut für Physik, Universität, D-46 Dortmund, Germany

pp. 244–246

NORTH-HOLLAND PUBLISHING COMPANY
AMSTERDAM

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Institut für Physik, Universität, D-46 Dortmund, Germany

Received 26 January 1976

The effects of simultaneous phase shift and spin rotation on neutron waves were measured with the perfect crystal neutron interferometer. Using an unpolarized beam of slow neutrons characteristic "beat" effects of the interference pattern and a polarization of the neutrons behind the interferometer could be observed.

Using the perfect crystal neutron interferometer [1, 2], which splits an incident neutron beam into two coherent parts, phase changes of particle waves and the transformation properties of spinors can be studied. Thus the change of sign of a spinor wave function for rotations by angles of 2π and odd multiples thereof was clearly verified [3], an effect which was recently demonstrated by other authors [4, 5]. In the present work measurements were done on the more general case of simultaneous nuclear phase shifting and magnetic spin rotation [6, 7] which was recently treated in detail [8]. Besides a characteristic intensity modulation of the interference pattern polarization effects are expected in this case, even with unpolarized incident neutrons. The unitary operator

$$U = \exp(\mathrm{i}\chi)\cdot\exp(-\mathrm{i}\boldsymbol{\sigma}\cdot\boldsymbol{\alpha}/2) = \exp(\mathrm{i}\chi)\cdot(\cos\alpha/2 - \mathrm{i}\boldsymbol{\sigma}\cdot\boldsymbol{\alpha}\sin\alpha/2) \qquad (1)$$

describes the phase shift χ and a rotation of the spin around the direction of the unit vector $\hat{\boldsymbol{\alpha}}$ by an angle α in one of the partial beams within the neutron interferometer. The beams leaving the interferometer are obtained by coherent superposition of the two partial waves, one of them being unchanged and the other one being transformed according to eq. (1). The intensity of the forward diffracted (O) beam is then given as [8]

$$I_{\mathrm{of}} = \frac{I_{\mathrm{oi}}}{2}(1 + \cos\chi\cos\alpha/2 + \boldsymbol{\alpha}\cdot\boldsymbol{P}_{\mathrm{i}}\sin\chi\sin\alpha/2) \qquad (2)$$

where I_{oi} denotes the intensity of the forward beam for the empty interferometer and $\boldsymbol{P}_{\mathrm{i}}$ is the polarization of the incident beam. For unpolarized neutrons, which we used in our experiments, eq. (2) simply describes a "beat" of the intensity. The general expression of the final polarization is a rather complicated function [8], so we restrict ourselves again to the case of $\boldsymbol{P}_{\mathrm{i}} = 0$ and assume the rotation axis being parallel to the z-axis. The polarization of the forward diffracted beam then is

$$\boldsymbol{P} = \left(0, 0, \frac{\sin\chi\sin\alpha/2}{1 + \cos\chi\cos\alpha/2}\right). \qquad (3)$$

The intensity and the polarization of the deviated diffracted (H) beam have corresponding values according to the conservation of particle number.

The measurements were performed with the perfect crystal interferometer [1, 2] which is now placed

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☆ Work supported partially by Fonds zur Förderung der wissenschaftlichen Forschung in Österreich - project 1178.

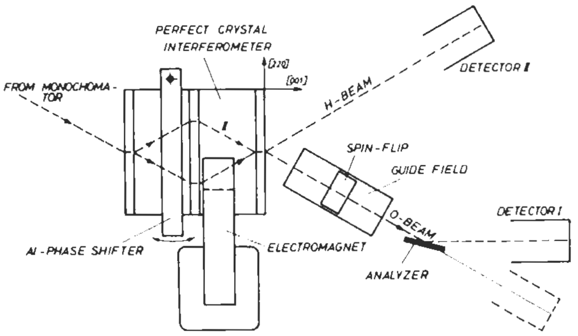

Fig. 1. Sketch of the experimental arrangement

at the HFR Grenoble. Unpolarized neutrons were used with the wavelength of 1.835 Å and a beam cross section of 5 × 2.5 mm^2. Fig. 1 shows a sketch of the arrangement. Rotation of a 10 mm thick Al-plate produced the nuclear phase shift $\chi = -N\lambda b_c\, \Delta D$ (N ... number of nuclei/cm^3, b_c ... coherent scattering length, ΔD ... path difference of the two partial beams within the phase shifter) and the field of an electromagnet with 10 mm gap [3] allowed to rotate the neutron spin by the angle $\alpha = -\gamma \int B dt = -(\gamma/v) \int B ds$ (γ ... neutron gyromagnetic ratio, v ... neutron velocity). By automatic recording of the field distribution inside the interferometer by means of a $x - y$ driven Hall probe the angle α_{eff} (the difference of the rotation angles along the two beam paths) was measured for several values of the magnet current. The polarization of the forward beam was analysed using Bragg-reflection at the (111)-plane of a saturated Heusler-alloy single crystal in combination with a d.c. operated spin-flip coil [9].

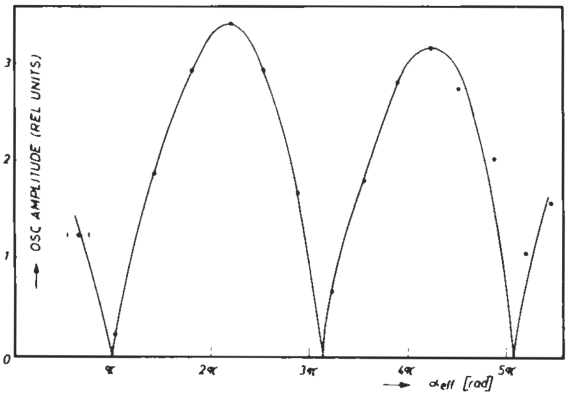

Fig. 2. Observed amplitude of the intensity oscillations of the O-beam due to variation of the nuclear phase shift as a function of the effective spin rotation angle α_{eff}.

For various rotation angles α_{eff} the intensity oscillations behind the interferometer due to variation of the nuclear phase shift were measured. In fig. 2 the amplitude of these oscillations is plotted as a function of the effective rotation angle. In accordance with eq. (2) the amplitude is modulated vanishing for $\alpha_{\text{eff}} = (2n + 1)\pi$ (n integer). Fig. 3 shows the intensity of the H-beam and the polarization of the O-beam as a function of the nuclear phase shift for $\alpha_{\text{eff}} = -115°$. Its clearly seen that the polarization oscillates with the same period as the intensity but with the phase shift of 90°. A more detailed analysis of the effects of simultaneous phase shift and spin rotation is in progress and will be reported in due course.

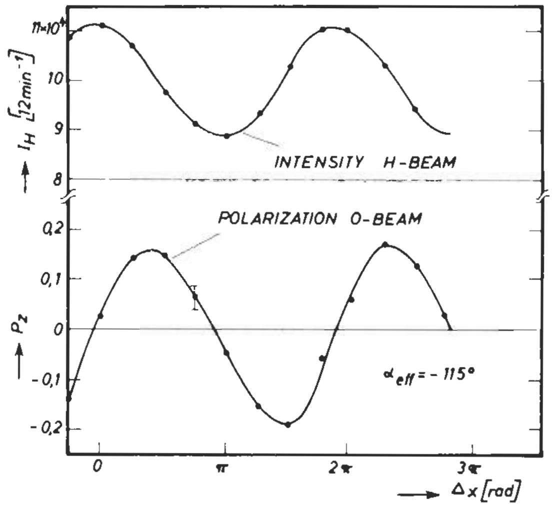

Fig. 3. Measured intensity of the H-beam and polarization of the O-beam as a function of the nuclear phase shift for $\alpha_{\text{eff}} = \text{const} = -115°$.

The authors wish to thank Prof. Rudolf Mössbauer for his continuous stimulating interest. We acknowledge the use of the analyzing crystal supplied by Dr. W. Just.

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