Investigation of Possibilities for the Measurement of Parity Violation in Neutron Diffraction at the IBR-2M Reactor

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Abstract. The experiment was performed at the 30-meter flight path of the channel N1 of the IBR-2 reactor. During the experiment a data acquisition system was tested, the neutron beam parameters were defined and quality of KBr crystal was checked. Indication on the pendellösung effect was observed, that is evidence for good quality of the KBr single crystal as well as for the low divergence of neutron beam. Using these results we have estimated the time needed for detecting the effect of parity violation in neutron diffraction with statistical accuracy of 10^{-4}.
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INTRODUCTION

In papers [1–4] it was shown that in case of the Laue dynamical diffraction of neutrons, a significant increase of the parity violation effects can be seen. Amplification of the P-odd effects in neutron diffraction occurs from the oscillatory dependence of integrated intensity of reflected neutrons on the reduced thickness of crystal. An expression for the asymmetry in neutron diffraction as a function of reduced thickness of single crystal was obtained in [1]:

$$A_{dif} = (f_{sp}/2)\cdot(\pi\cdot t/\Delta_0)^{0.5}\cdot\cos((\pi\cdot t/\Delta_0) - \pi/4), \quad (1)$$

where $(f_{sp}/2)$ is a coherent amplitude of weak nuclear interaction of neutrons, $(\pi\cdot t/\Delta_0)$ is a reduced thickness of crystal, Δ_0 is an extinction length, and t is a thickness of the crystal. In [5] the expression for the integrated intensity of reflected neutron beam under conditions of dynamic diffraction was given:

$$R_{ref} = \pi/2\{1 - 0.798\cdot\cos(2\pi t/\Delta_0 + \pi/4)/(2\pi t/\Delta_0)^{1/2}\}. \quad (2)$$

If to compare expressions (1) and (2), it is obvious that the observation of the oscillations in the integrated intensity of the reflected neutron beam is a prerequisite for detection of the P-odd asymmetry in neutron diffraction.

During two days of power startup cycle of modernized IBR-2 reactor the test of prototype setup to search for spatial parity violation in neutron diffraction (PVND) was carried out at the 1-st channel of IBR-2. Objectives of study were following:

1. determination of neutron flux density vicinity of the p-resonance of bromide (E = 0.88 eV);
2. determination of the number of neutrons reflected from a single crystal of potassium bromide;
3. determination of the background conditions.

EXPERIMENT AND RESULTS

Neutron flux density was measured by means of a fission ionization chamber at the 12-m flight path. An ^{235}U target of 1 cm in diameter with mass of 35 μg was used. We obtained neutron flux density at energy near 1 eV of ~ $3\cdot10^6$ n/ ($cm^2\cdot s\cdot eV$).

A prototype of the PVND setup was installed at the 30 m flight path. It consisted of a goniometer and a neutron detector (assembly of four counters SNM-17) located at a distance of 2.4 m from the KBr single crystal. Efficiency of neutron registration was ~ 0.3. Detector was placed at the angle 2θ = 0.1 rad with respect to axis of the incident neutron beam direction. The axis of beam was determined with use of a coordinate-sensitive detector.

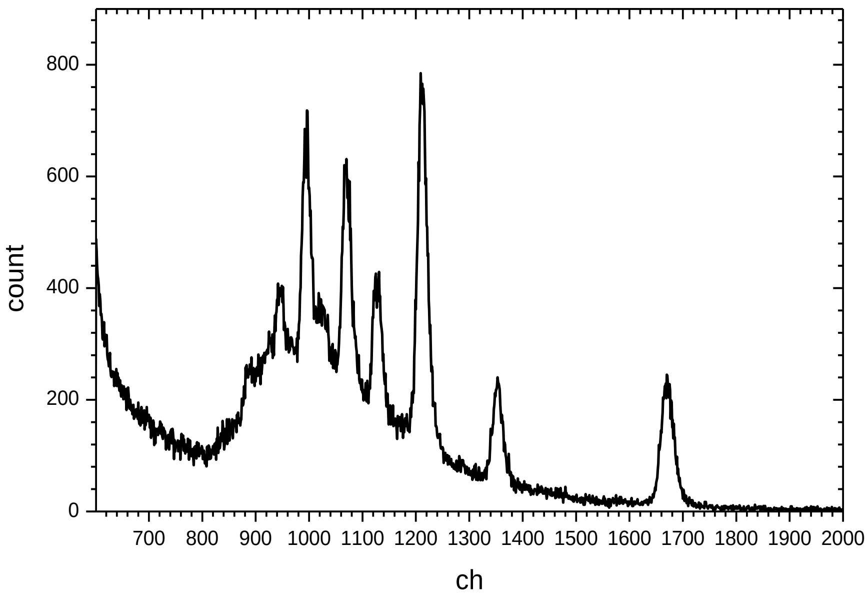

Fig. 1. TOF spectrum of diffracted neutrons on polycrystalline iron.

In order to determine flight path and time between signal “Start” from a synchronizer and reactor power pulse a measurement of neutron diffraction on a polycrystalline iron sample was carried out (see Figure 2). In this measurement a neutron detector was installed at the angle $2\theta_B = \pi/2$, i.e. a line between detector and sample was perpendicularly to the beam axes. Using known interplanar distances for iron crystal we obtained a flight path of 28.32 ± 0.09 m.

Figure 3 shows a spectrum of neutron diffraction from the reflection plane (200) of KBr single crystal in dependence on neutron wavelength. Measurement time consisted of 85 minutes. After subtraction of background the neutron count rate in first order of reflection is 28 neutrons per second.

According our analysis, oscillations of reflected beam intensity as well as P-odd effect value in diffraction depends on the mosaicism of single crystal and the angular divergence of incident neutron beam. We tried to find the oscillations of integrated intensity of reflected beam turning the crystal around axis, which was perpendicular to the reflecting planes. The thickness of crystal is a function of rotation angle: $t = t_0/\cos(\varphi)$ (in cm). Measurements were carried out at the angles φ = 0°, 3º25', 6º50'.

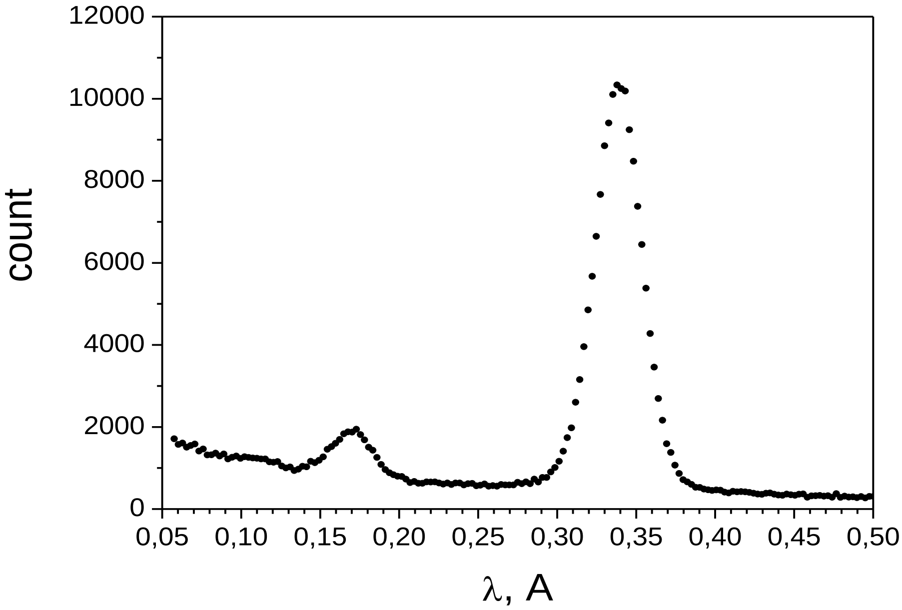

Fig.2. Spectrum of neutrons diffracted on KBr single crystal.

The experimental values J_n of the integrated intensity were linked to calculated curve in one point. The thickness of crystal is expressed in terms of the reduced thickness t / Δ_0, where Δ_0 is extinction length of neutrons in a single crystal of potassium bromide for reflection plane (200). A satisfactory agreement between calculated integral diffraction intensities and experimental those can be an indication on the existence of oscillation behavior. In turn it points to the low angular divergence of incident beam as well as to the good quality of single crystal.

Using quantity of neutrons, which meet diffraction condition and experience total reflection, we have estimated the time needed to detect parity violation effect in diffraction. With a double increase of detector efficiency it is required about 30 days of measurement time to identify the effect with statistical accuracy of $\sim 3{\cdot}10^{-4}$.

CONCLUSIONS

The result of our work is as follows:

1) we obtained the parameters of neutron beam;
2) we measured the amount of reflected neutrons;
3) we found out an evidence of pendulum behavior for reflected neutrons, thatpoints to the good quality of the single crystal and neutron beam;
4) we estimated the time needed to detect the effect of spatial parity violation in diffraction at the level of statistical accuracy of 10^{-4}.

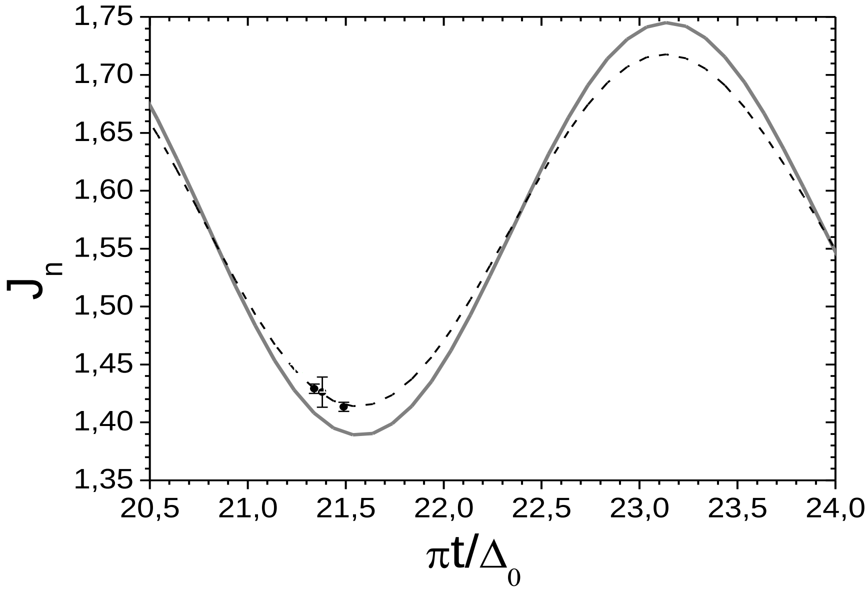

Fig.3. Integrated reflected beam intensity as a function of reduced thickness of the crystal. Black circles are experimental data, solid line is calculated intensity with an angular divergence of the incident beam $1\cdot10^{-3}$; dashed line is calculated intensity with an angular divergence of the incident beam $2\cdot10^{-3}$.

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