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ANOMALOUS TRANSMISSION OF NEUTRONS IN A PERFECT CdS CRYSTAL

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The theory of coherent phenomena accompanying the interaction of neutrons with an ideal crystal [1, 2] shows that the inelastic channels of the nuclear reaction can be partly or fully suppressed. This should lead to "anomalous transparency" of the crystal, if the Bragg conditions are satisfied. According to [1, 2], coherence should be retained also in resonant scattering, in spite of the large lifetime of the compound nucleus, the presence of spin and isotopic incoherence, and the thermal motion of the atoms in the crystal. Allowance for these factors leads only to a certain weakening of the effect of inelastic-channel suppression.

Anomalous transmission of neutrons was observed experimentally [3, 4] in predominantly potential scattering and weak absorption, under conditions when the neutron energy was far from resonant. A study of this phenomenon in the resonant region would yield an answer to the question of the conservation of coherence in resonant scattering. However, measurements near resonance entail certain difficulties: first, it is necessary to have sufficiently large and perfect crystals made up of nuclei with low-lying resonance levels; second, strong absorption leads to a sharp decrease of the intensity. We have investigated the reflection and transmission of neutrons by a perfect α-CdS crystal of intermediate thickness ($1 < \mu t < 10$), in a range of energies comparable with the resonance-excitation energy of Cd^{113} (0.178 eV). The coherence should become manifest already in the intermediate case, and the magnitudes of the effects should be appreciably larger than in the case of a thick crystal ($\mu t > 10$).

The measurements were performed with a universal automatized diffractometer of variable wavelength [5], on the IRTM reactor of the Kurchatov Atomic Energy Institute. To make the neutron beam monochromatic (primary collimation 20') we used the (111) reflection from a large (90 x 90 x 5 mm) ideal Ge crystal (Fig. 1), since its Bragg angles are close to the (0002) reflection angles of the CdS crystal, an important factor when it comes to decrease the dispersion of a two-crystal spectrometer [6]. The sample was a plate with orientation $(10\bar{1}0)$, of approximate area 5 cm^2 and thickness 1 mm ($\mu t = 14$ at 0.178 eV), cut from a CdS crystal obtained by the Bridgman-Stockbarger method and annealed at equilibrium pressures of sulfur and cadmium [7].

The widths of the reflection curves (Fig. 2) agree with the calculated ones and are determined by the dispersion of the two-crystal spectrometer at $\theta_1 \neq \theta_2$. The difference between the intensities of the (0002) and $(000\bar{2})$ reflections is due to violation of the Friedel law ($F_{HKL} \neq F_{\overline{HKL}}$) for the non-centrally-symmetrical CdS crystal under conditions when the imaginary part of the amplitude is comparable with the real one.

From the curves (Fig. 2) and from Table I we see that the Laue reflections (0002) and $(000\bar{2})$ are weaker than the Bragg ones $(10\bar{1}0)$ by only one order of magnitude, whereas in the

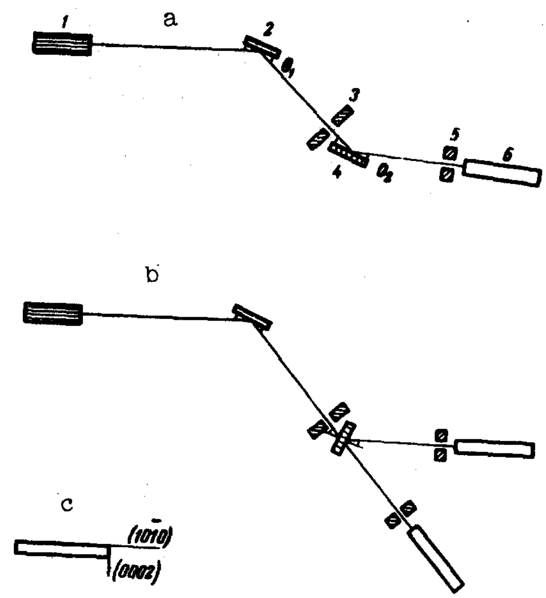

Fig. 1. Arrangement of crystals. a) Bragg reflection, b) Laue reflection, c) sample orientation: 1 - collimator, 2 - monochromator (Ge single crystal), 3, 5 - beam limiters, 4 - CdS single crystal, 6 - detector.

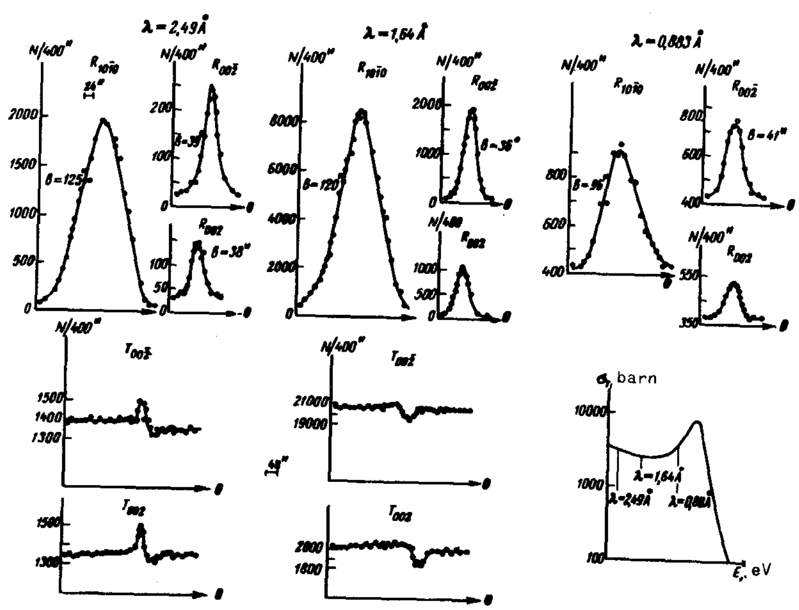

Fig. 2. Curves of Bragg (10$\bar{1}$0) and Laue [(0002) and (000$\bar{2}$)] reflections (R) and transmission (T). In the lower right corner is shown the energy dependence of the total cross section $\sigma_+(E)$ of cadmium in the thermal region.

Integral reflection coefficients

$$\rho = \frac{1}{I_0} \int R(\theta)\, d\theta$$

λ, Å	μt	ρ (000$\bar{2}$)	ρ (0002)	ρ (10$\bar{1}$0)
0,88	7,3	$0{,}68 \cdot 10^{-7}$	$0{,}29 \cdot 10^{-7}$	$1{,}80 \cdot 10^{-6}$
1,64	4,7	$3{,}47 \cdot 10^{-7}$	$1{,}68 \cdot 10^{-7}$	$3{,}85 \cdot 10^{-6}$
2,49	5,9	$1{,}63 \cdot 10^{-7}$	$0{,}72 \cdot 10^{-7}$	$3{,}65 \cdot 10^{-6}$

case of ordinary reflection the difference would amount to two or three orders. Consequently, when the crystal is in a reflecting position, the neutron absorption is noticeably decreased ($\mu_{eff} \approx 0.3\mu$). This effect is observed also in transmission curves, although here the measurements are made difficult by the incomplete absorption of the incident wave in a crystal of intermediate thickness. In addition, when resonance is approached, the background increases sharply, and the fraction of the monochromatic neutrons decreases in accord with the Maxwellian distribution in the reactor spectrum.

Single-crystal quartz filters were used to attenuate the fast-neutron background.

The anomalous-transmission effect could be observed most distinctly on the transmission curves at $\lambda = 2.49$ Å ($\mu t = 5.9$), which have a dispersion form due to the interference between the two wave fields ("transmitted" and "reflected"), a characteristic feature of a crystal of intermediate thickness. With decreasing μt at $\lambda = 1.64$ Å (see the plot of the cross section in Fig. 2), the "depth of the dip" increases, in accord with the theory, and the height of the transmission maximum decreases. At $\lambda = 0.88$ Å it was possible to observe only anomalous reflection of the neutrons, since the effect/background ratio is too small in this energy region on the transmission curve, owing to the weak effectiveness of the quartz filters at room temperature. It is interesting that the singularities on the T-curves for (0002) and $(000\bar{2})$ are practically of the same magnitude, whereas the intensities of the (0002) and $(000\bar{2})$ reflections differ strongly. This agrees with the formulas in [1, 2].

Our results confirm the conservation of coherence in resonant scattering, as manifest by the existence of anomalous transmission of neutrons near the resonance (effect of suppression of inelastic channels). To observe the effect directly in the resonance of Cd^{113} it is necessary to optimize the experiment to some degree. A quantitative comparison of the results with the theory will be reported separately.

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RADIATION OF Hg-He^3 GAS MIXTURE BOMBARDED BY A NEUTRON STREAM

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The idea of exciting a gas laser by nuclear-reaction products has already been advanced in the literature [1, 2]. Among the advantages of such a pumping method is, in particular, the possibility of exciting large volumes at high pressures of the working gas.

The authors have attempted to obtain lasing of an Hg-He^3 mixture bombarded by neutrons from a pulsed source with a thermal-neutron flux of about 5×10^{16} neut/cm^{2}sec.

The large cross section of the reaction $He^3(n, p) + 0.8$ meV ($\sim$5000 b for thermal neutrons) ensures a large per-unit energy input. The slowing down of the reaction products in the gas leads to formation of mainly unexcited ions. Charge exchange of the He^+(1s) ions with the Hg atoms excites selectively the upper level of the 7p - 7s transition of the Hg^+ ion ($\lambda = 6150$ Å) [3, 4]. An analysis of the relaxation mechanism has shown that the optimal mixture is one with a small partial pressure of mercury (on the order of several per cent) and that the lasing power should increase with increasing total gas pressure (the corresponding calculations will be published). The experimental setup is illustrated in Fig. 1.