ON NEUTRON EDM SEARCH BY DIFFRACTION METHOD

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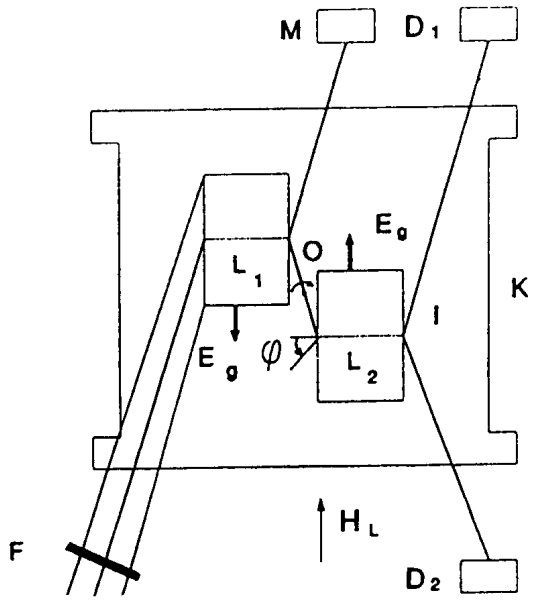
A new method of the neutron EDM search based on the spin dependence of a neutron pendulum phase for Laue diffraction in the noncentrosymmetric crystal is proposed [1]. The dependence is due to the interaction of the EDM with the strong electric crystal field. It leads to the change of the detector counting rate, resulting in the neutron spin reverse. Now the most precise method of the EDM measurement is the magnetic resonance method, using the ultracold neutrons (UCN method). It is being developed in LNPI (Gatchina, Russia) and in ILL (Grenoble, France). The following results are obtained $D = (0 \pm 0.4) \cdot 10^{-25}$ $e \cdot cm$ (LNPI [2]) and $D = (0.3 \pm 0.5) \cdot 10^{-25}$ $e \cdot cm$ (ILL [3]).

The absolute error of the EDM measurement, that characterizes sensitivity of the method, is determined with:

$$\delta(D) \alpha \frac{1}{E\tau\sqrt{N}} \tag{8}$$

where E is the value of the electric field applied to the neutron, τ is the mean time of a neutron presence in this field. The value $E\tau$ describes the experimental effect (the change of the counting rate, for example). N is the total number of the accumulated events. The possibility of its increasing is limited by the set up luminosity. For the UCN method the electric fields can reach the values $E \approx 10 - 15$ kV/cm. They are limited with the properties of isolating materials. For two variants of the UCN method (the flow through type ($\tau = 5$ s) and the storage type ($\tau = 70$ s)) the values of $E\tau$ are equal to 75 and 1050 $kV \cdot s/cm$, respectively [2].

The following ideas and properties of the proposed method (see refs. [1,4,5]) give us, in principle, the possibility to exceed the sensitivity of the UCN method.



1. The existence of a strong electric field in the noncentrosymmetric crystals ($E_g \approx 10^8$ V/cm), that affects the neutrons during the whole time of their diffraction (on the way of about some centimetres). Such a field is more than 10^4 times greater than the fields used in the UCN method. It was measured in experiment [4] for $(11\bar{2}0)$-plane of α-quartz crystal as a pendulum phase shift caused by the spin flip (due to the Schwinger interaction of diffracted neutrons). The experimental value of the electric field had coincided with the calculated one and turned out to be equal to $E_{11\bar{2}0} = (1.8 \pm 0.2) \cdot 10^8$ V/cm.

Fig. Principal scheme of set up. F is flipper, D are detectors, M is beam monitor, K is coil of leading magnetic field $\vec{H}_L$, φ is angle between two crystals, O is whole device rotation axis

2. There is a real possibility to increase essentially the time of a neutron passage through the crystal using a sufficiently thick crystal (up to 10 cm) and Bragg angles Θ_B close to $\pi/2$ ($\pi/2 - \Theta_B = \tilde{\Theta}_B < 1$), because the diffracted neutrons are moving along the crystallographic planes in the average with the corresponding velocity $v_{||} = v \cdot \cos\Theta_B$, under the condition $v_{||} \approx v \cdot \tilde{\Theta}_B << v$ [1].

3. The two crystal set up is proposed to get a sufficient luminosity, which makes possible to exceed the counting rate achieved with the UCN method more than by an order of the value (see fig.) [1].

4. There are some ways to eliminate the effect due to the Schwinger interaction of a neutron.

The characteristics of the storage type UCN and proposed diffraction methods are given in the table.

Table

Comparison of UCN and diffraction methods. Neutrons of vertical channel of LNPI reactor. Crystal dimensions are $(5\times10\times12)$ cm^3. $(11\bar{2}1)$ plane of α-quartz crystal ($\lambda = 4.4$ Å); $\tilde{\Theta}_B$=1/30

	UCN	Cold Neutrons Diffraction
	(storage type)	$\lambda = 4.4$Å SiO_2; $(11\bar{2}1)$ – plane
E, kV/cm	10 — 15	$2.3\cdot10^5$
τ, s	70 ($v=5-6$ m/s)	$11.8\cdot10^{-3}$ ($v_{||} = 27.5$ m/s)
$E\cdot\tau$, $kV\cdot s/cm$	1050	830
N, $neutrons/s$	40 — 50	440

We should note, that the electric fields in experiment [6] of Shull and Nathans (they used the Bragg reflection by the centrosymmetric crystal of Cd S for EDM search) have the same order as in our case and are due to the neutron absorbtion in the Cd, but the path is determined by the penetration depth into the crystal of a reflected neutron and has the value $\approx 7\cdot10^{-2}$ cm. The neutron velocity was $3.6\cdot10^5$ cm/s in that experiment, so if the field were equal even to 10^9 V/cm one would get $E\cdot\tau \approx 0.2$ $kV\cdot s/cm$. The upper limit for EDM $D < 5\cdot10^{-22}$ $e\cdot cm$ was obtained in that work.

We note also that one can consider the zero pendulum phase shift measured [5] for spin reverse along the direction of the electric field as a preliminary rough EDM measurement, showing the absence of EDM at the level $\approx 10^{-20}$ $e\cdot cm$. The proposal [7] of an experiment on the EDM search with a new method is founded on the results of works [1,4,5].

1) UCN method uses all 4 sections of the vertical channel. In diffraction case the crystal "sees" half one section, therefore the value 440 for N corresponds to 1/8 of the total available intensity.

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