# ABERRATION-FREE DIFFRACTION-GRATING NEUTRON INTERFEROMETER

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Achievements of neutron interferometry in the thermal region of the spectrum make it feasible to develop interferometers for longer wavelength, including ultra cold neutron (UCN) interferometers that are expected to permit breakthroughs in problems of fundamental physics /1/. The analysis of the UN diffraction-grating interferometer design is the subject of this paper.

The addition of a third diffraction grating to an interferometer (fig. 1) permits a complete compensation of wave aberrations of the instrument. This is connected with the fact that here grating $G_1$ is «depicted» by grating $G_2$ in the plane of grating $G_3$ which in principle leads to the formation of an infinite-width interference band. Moreover, because this result holds true for any wavelength, the design under discussion is also achromatic.

At the same time, the use of UN results in considerable aberration distortions is due to interaction between the neutrons and the gravitational field. Indeed, the phase shift associated with the propagation of neutrons over parabolic trajectories is /2/

$$\Phi \sim V_u^2 V_y \left(1 + \frac{V_y^2}{3V_u^2}\right). \tag{1}$$

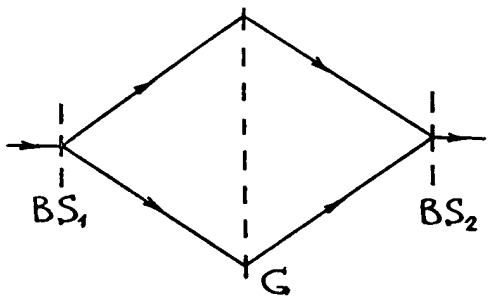


Fig. 1. Three-grating interferometer

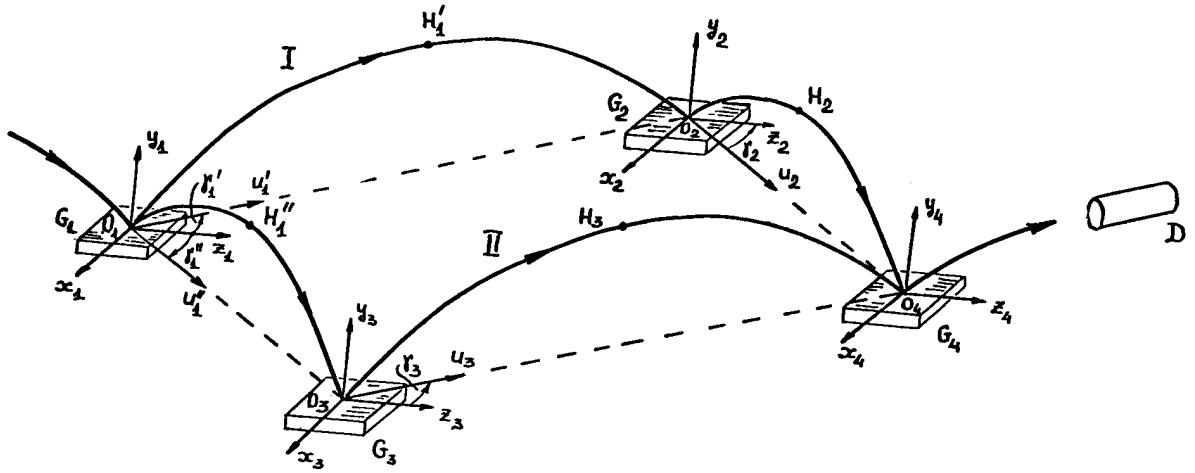


Fig. 2

Here $V_y$ and $V_z$ are projections of the initial velocity vector $V_0$ on the coordinate axes 0y and 0z, respectively (fig. 2). The nonparallelism between the horizontal component $V_z$ and the slits of the diffraction grating results in different velocities of $V_u$ in the plane of the neutron trajectory. Therefore, there emerges a phase difference for neutron waves propagating along different arms of the interferometer, which results in a poorer interference pattern and consequently in limitations on the permissible angular spread of the illuminating beam and in a lower output intensity.

It was shown /2/ that the initial velocity components on opposite sections of trajectories $O_1H_1'O_2$--$O_3H_3O_4$ and $O_1H_1''O_3$—$O_2H_2O_4$ coincide, which means that the trajectories and the phase shifts (eq.(1)) of the neutron wave thereon are identical. This result was obtained for the vector of the initial velocity of the neutron which is arbitrarily oriented in space, in general, without specifying the magnitude of this velocity. Consequently the phase difference of the neutron beams propagating in the interferometer is identically zero for an uncollimated and unmonochromatized illuminating neutron beam.

Thus the incorporation of the third diffraction grating likewise fully compensates the aberration distortions of the wavefronts caused by the interaction of neutrons with a gravitation field of the Earth, and the three-grating design of the neutron interferometer under discussion is completely aberration-free. This interferometer is not very sensitive to the mutual angular adjustment of the optical elements. The accuracy of the adjustment is close to 2′ and may be easily realized by a conventional optical technique.

REFERENCES

1. Proc. Workshop on The Investigations of Fundamental Interactions with Cold Neutrons, NBS Special Publ., 711. Washington. 1986.

2. *Ioffe A. I.* Nucl. Instrum. and Meth., A268. 1988. 169.