Recovery of reduced fringe visibility due to finite crossing angle between two paths of a neutron interferometer

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To form a better understanding of quantum effects, many experiments have been performed using neutron interferometers. For example, the incompatibility of non-contextual hidden variable theories with quantum mechanics and the violation of Bell-like inequalities have been experimentally demonstrated. In these experiments, the visibility of interference fringes played an essential role. Moreover, fringe visibility is an important index of the particle- or wave-like behavior of neutrons inside the interferometer. Therefore, understanding the factors that influence interference fringe visibility is attracting attention.

One process that can reduce the visibility of fringes is the smearing out of fringes due to a dispersive phase shift. Although this process is in general irreversible, there are some methods by which the interference pattern can be restored. Here, a method for recovering the visibility of a fringe pattern that was degraded due to a finite crossing angle between the two paths of an interferometer is reported.

To produce a finite crossing angle between the two paths of an interferometer, a multilayer spin splitter (MSS) with a wedge-shaped gap layer was used [1]. Layers of the MSS were deposited on silicon substrates using the ion beam sputtering system at the Kyoto University Research Reactor Institute. The wedge-shaped gap layer was produced by tilting the substrate holder of the sputtering system so that the solid angle between the sputtering target and the substrate, and hence the deposition rate, became substrate-position-dependent. Using this method, we fabricated a MSS with a wedge-shaped gap layer whose wedge angle was 500 nrad.

To restore the visibility of interference fringes degraded by the finite crossing angle between the two paths of the interferometer, magnetic field gradients were used.To generate magnetic field gradients, two electro-quadrupole magnets with air-core coils were used. Both magnet apertures were 40 mm in width, 40 mm in height, and 50 mm in longitudinal length. The magnets generated field gradients of 0.64 G/cm along the vertical axis for a current of 0.4 A.

The experiment was performed using the MINE 2 beam line in the JRR-3M reactor at the Japan Atomic Energy Agency. The fringe visibility was 40% when no current was applied to the magnets. However, when a current of 0.4 A was applied to the magnets, the fringe visibility increased to 74%. Figure 1 shows the dependence of fringe visibility on the current to the magnets. The results clearly indicate that the visibility of the fringes can be restored and indicate the feasibility of enhancing fringe visibility in large neutron interferometers using multilayer mirrors [2].

References

[1] K. Taketani, M. Hino, and H. M. Shimizu: Physica B 406 (2011) 2377.
[2] K. Taketani: Appl. Opt. 48 (2009) 2027.

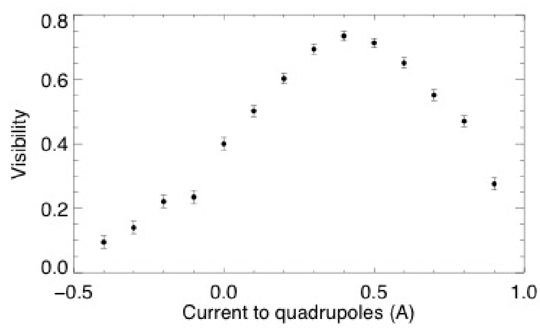

Fig. 1. Dependence of fringe visibility on magnet current.