Development of wide-bandwidth half mirror for neutron interferometer

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Neutron interferometry is a powerful technique for studying fundamental physics. Numerous interesting experiments [1] have been performed since the first successful test of a single-crystal neutron interferometer [2]. However, the single-crystal interferometer is inherently not able to deal with a neutron that has a wavelength longer than twice its lattice constant. In order to investigate problems of fundamental physics, the interferometry with cold neutrons is extremely important, since the sensitivity of interferometer for small interaction increases with the neutron wavelength. One of the solutions is an interferometer using neutron multilayer mirrors [3]. We succeeded in developing a multilayer interferometer for cold neutrons in which two paths are completely separated for the first time using wide-gap etalons at MINE in JRR3 [4].

In the case of pulsed neutron beams, the intensity at each wavelength can be resolved with the arrival time on the detector. When the multilayer mirrors are applied to pulsed neutrons, the interference fringes at each wavelength can be observed simultaneously. The phase of interferogram depends on the wavelength of neutrons. We have already installed the interferometer into the beamline J-PARC MLF BL05 to demonstrate the interferometer with pulsed neutrons. Figure 1 shows the interference fringes according to time-of-flight. Because the mirrors had narrow bandwidth of the neutron reflectivity, the number of neutrons contributing to the interference was limited. When the neutron supermirrors whose lattice constants vary gradually are utilized in the interferometer, the effective range of neutron wavelength can be broadened.

In this study, we are continuing to fabricate the neutron half mirrors with wide band for the interferometer by using Ion Beam Sputtering facility in KURNS. The mirrors should have the wide and smooth top of the reflectivity with the range of momentum transfer from 0.4 nm^{-1} to 1.0 nm^{-1}. In 2022, we have been able to fabricate multilayer mirrors with stable performance. The reflectivity was measured with neutron reflectometer at MINE in JRR3. Figure 2 shows the reflectivity of the half mirrors on the fused silica substrates. Neutron wavelength was 0.88 nm and the bandwidth of the beam was 2.7% of the wavelength. We will try to create an interferometer with the mirrors shortly.

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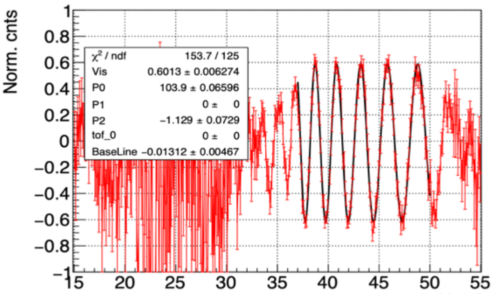

Fig. 1. Normalized interference fringes with multiplayer mirrors for pulsed neutrons.

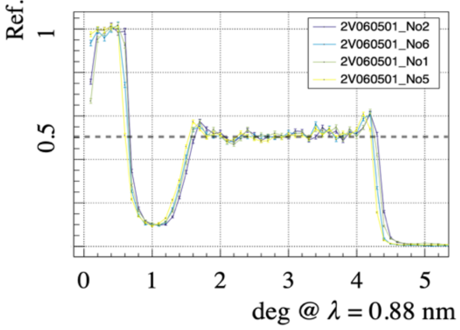

Fig. 2. Reflectivity of the half mirror with wide band of neutron wavelength. Colors represent the sample ID.