Polarization analysis of oscillating field using static neutron spin interferometry

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The principle of neutron interferometry is that, as expressed in Fig.1, a polarized neutron is split into spin-parallel (to the quantum axis) and anti-parallel components, interacts with the sample magnetic field, and superposed to detect the phase introduced during the interaction.

The experiments were performed using MINE-2 beam line. The neutron beam of MINE-2 is well-collimated with the divergence of 1/1000 rad, and monochromatized with 0.88 nm (the velocity is about 445m/s) and its wavelength resolution of 3.5%.

In this study, oscillating magnetic field is adopted as the sample, and interference patterns were observed changing the frequency and the amplitude of the sample field [1].

Neutron counts N in the spin interferometer is expressed as

$$N = C_1 \sin(\chi - \chi_0) + C_2, \qquad (1)$$

where, C_1, C_2 are constants depending on the polarizing properties of the instruments, χ_0 is the phase factor given by the interaction with the sample magnetic field, and χ is control phase factor, equal to the phase difference between the two $\pi/2$-flippers in the present experiments.

In this study, since χ_0 is oscillatory changing, and a neutron flies with the velocity of about 445m/s, then the neutron feels position dependent magnetic field. Denoting the (space) Fourier transform of the oscillating magnetic field as $b_0(k)$, the resultant interfering pattern P_{osc} is expressed as follows

$$p_{\mathrm{osc}} = \frac{1}{2}\left\{1 - J_0\left(\frac{2|\mu_n|}{\hbar v}|b_0(k)|\right)\cos(\chi - \delta)\right\} \qquad (2)$$

Parameter δ is, as C_2 in eq. (1), the machine parameter. The function J_0 is 0 the order Bessel function. Since the parameter k is the `space frequency', it is proportional to the frequency of the oscillating field. Surprising feature of the eq. (2) is that depending on the argument of the Bessel function, the amplitude of the interference pattern can be minus.

This feature is examined experimentally and an example is shown in Figure 2 for the oscillating field amplitude is 1.25A. Horizontal and vertical axis in this figure are control phase χ and normalized neutron counts, respectively. The oscillating pattern without sample (red broken line) is changed as the frequency of the sample field of 10Hz (purple diamond), 100Hz (green diamond), 500Hz (sky blue diamond), and so on. For this example, the amplitude of the oscillating pattern is negative for the frequency under 7000Hz. This feature is explained quite well with the eq. (2).

[1] T.Suzuki et al., Journal of the Physical Society of Japan 93, 091008 (2024).

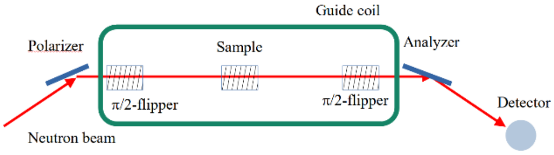

Figure 1 Experimental arrangement of spin interferometry

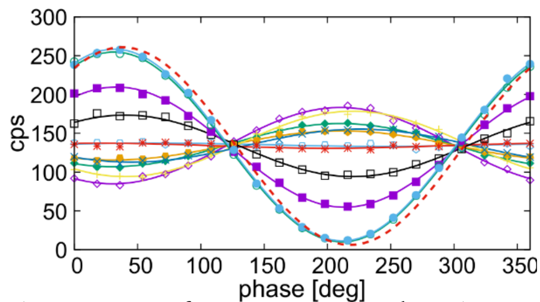

Figure 2. Interference patterns changing the frequency of the oscillating field.