Measurement of distorted oscillating magnetic fields using neutron spin interferometer

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Neutrons are electrically neutral and have magnetic moments. Their property enables non-destructive magnetic field imaging such as three-dimensional reconstruction. Recently, the measurements of oscillating magnetic fields have been studied for practical devices. In our previous study, we successfully demonstrated the measurement of high frequency oscillating magnetic fields using neutron interferometry, which is a simple system for polarized neutron measurements [1]. In this method, we utilize the deviation of spin direction over time induced by an oscillating field. We focused only on a sinusoidal oscillating magnetic field. However, a non-sinusoidal oscillating field is also important as they can cause the abnormal oscillation or energy loss in practical devices. In this study, we formulated an interference pattern when a non-sinusoidal oscillating magnetic field is measured and validated it through a measurement of a simple field which has a fundamental and double frequency oscillation.

The oscillating field is expressed as a Fourier series expansion based on the frequency f.

$$B(x,t) = B_0(x)\Sigma_{n=0}^{\infty} d_n \sin(-2\pi n f t + \phi_n)$$

Here, ϕ_n is phases of n times oscillation and d_n is relative amplitude to a fundamental oscillation. Introducing the $k = 2\pi f/v$ by the neutron velocity v and the Fourie transform of the field $|b(k)|e^{i\theta(k)} = \int_{-\infty}^{\infty} B_0(x)e^{-ikx}dx$, the interference patten will be expressed by using term of c,

$$c = \sum_{\substack{m_1+2m_2+\cdots=0 \\ n\in Z}} J_{m_1}\left(\frac{2|\mu_n|}{\hbar v} d_1 b(k)\right) J_{m_2}\left(\frac{2|\mu_n|}{\hbar v} d_2 b(2k)\right)\cdots$$
$$\times \exp\Big(i\big(m_1(\phi_1 + \theta(k)) + m_2(\phi_2 + \theta(2k)) + \cdots\big)\Big).$$

The absolute value $|c|$ will be the contrast of the interference pattern and argument $\arg(c)$ will be the phase.

In the experiment, we applied the oscillating field which has a fundamental and double frequency oscillation. Fig.1 shows the contrast of interference patterns under a condition of 1.5App amplitude for a fundamental oscillation. The contrast was measured while changing the phase of double oscillation. The plots are measurement result and the lines are calculated from the formulation. In the measurement, fixing absolute ϕ_2 value is difficult due to the inductance of a circuit therefore, the plots are fitted to the calculated one against ϕ_2. The result shows the great agreement between the experimental one and calculated one.

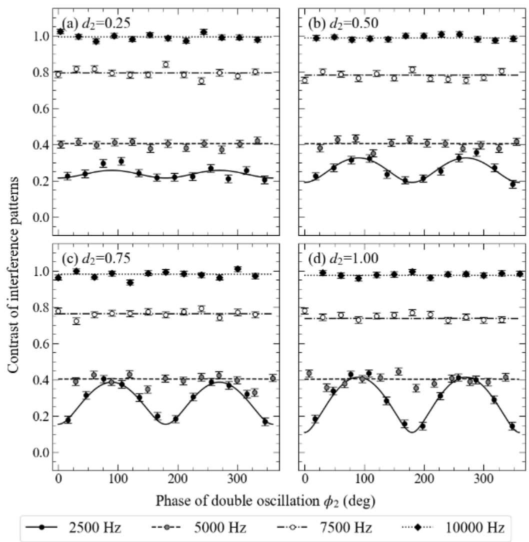

Fig.1 the contrast of interference patterns (a) the value of $d_2 = 0.25$ (b) the value of $d_2 = 0.5$ (c) the value of $d_2 = 0.75$ (d) the value of $d_2 = 1.0$

In this study, we formulated the interference pattern when a non-sinusoidal oscillating magnetic field is measured. This result shows the capability of identifying a non-sinusoidal magnetic field in practical devices with polarized neutrons.

[1] T. Suzuki, R. Fujitani *et al.*, *J. Phys. Soc. Japan.* 93, 091008(2024)