

Experimental report

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Title: A time-of-flight Fourier chopper for very cold neutrons

Research area: Methods and instrumentation

This proposal is a new proposal

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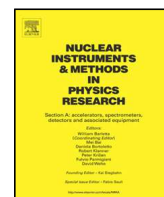
Hanno FILTER

Samples:

Instrument	Requested days	Allocated days	From	To
PF2 VCN	10	10	22/08/2023	05/09/2023

Abstract:

We propose to demonstrate the viability of a novel time-of-flight (TOF) Fourier chopper system for very cold neutrons. Two developments on the Fourier TOF technique will be implemented: (1) a chopper stator design to produce an exact sinusoidal beam modulation, and (2) a general method to determine the chopper phase offset.



Full Length Article

Demonstration with very-cold neutrons of developments in Fourier time-of-flight

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ABSTRACT

We demonstrate recent developments in neutron Fourier time-of-flight in an experiment using very-cold neutrons. The implementation of a novel sinusoidal stator design eliminates a systematic effect associated with triangular modulation in existing Fourier choppers. Although transmission is inherently higher for triangular modulation, it is demonstrated that only about 3% additional measurement time is needed with sinusoidal modulation to achieve the same statistical uncertainty. In addition, a new neutron-based technique that does not require additional instrumentation is employed to determine the chopper phase offset.

1. Introduction

The neutron time-of-flight (TOF) method enables the determination of the distribution of neutron beam velocities parallel to the axis between a chopper and a detector. In the standard TOF approach, the chopper admits short pulses of neutrons so that the event rate at the detector varies in time roughly as the TOF spectrum plus background. In this case, the TOF resolution is proportional to the opening time of the chopper t_{open} , as is the rate at which measurement statistics are accumulated. To avoid frame overlap, measurements are repeated with period no shorter than t_{max} , the maximum TOF in the experiment. In standard TOF therefore, the duty cycle is limited to $t_{\text{open}}/t_{\text{max}}$, which can result in long measurement times when high TOF resolution is required.

In an alternative approach, known as Fourier TOF, the beam is periodically modulated at angular frequency ω , resulting in an oscillating beam intensity with amplitude and phase that depend on $S(\omega)$, the Fourier transform of the TOF spectrum $s(t)$. By performing measurements over a grid of discrete frequencies, $s(t)$ can be reconstructed by inverse discrete Fourier transform. The resolution in Fourier TOF is inversely proportional to the maximum modulation frequency, which can be arbitrarily large within technical limits.

The original papers on experimental studies with Fourier TOF, published in 1969 and 1970 [1,2], implemented a chopper design that periodically modulated the beam with triangular intensity. Such modulation is associated with a systematic error, known as harmonic

distortion, in which measurements of $S(\omega)$ are contaminated by higher-frequency artifacts. One publication in 1974 reported a significant reduction in harmonic distortion using a chopper design that produced approximately sinusoidal modulation [3]. Despite this success, the prevailing opinion appears to have been that the size of the harmonic distortion is negligible in many cases of experimental interest [4,5], and that the associated reduction in beam intensity with sinusoidal modulation is undesirable [5], presumably because it should necessitate longer measurement times in order to reach the same statistical uncertainty. In any case, triangular modulation is employed at present by two of the most prominent Fourier TOF instruments, the High-Resolution Fourier Diffractometer (HRFD) [6] and the Neutron Fourier Stress Diffractometer (FSS) [7], both at the IBR-2 pulsed reactor at the Frank Laboratory of Neutron Physics in Dubna, Russia.

In a recent work by T.N. [8], the theoretical analysis of harmonic distortion is revisited, and a family of chopper stator hole shapes are introduced to produce exact sinusoidal modulation. It is predicted that, despite a 36% reduction in beam intensity compared to triangular modulation, only about 3% additional measurement time should be needed with sinusoidal modulation to achieve equal statistical uncertainty on measurements of $S(\omega)$, and consequently $s(t)$, when there is good signal-to-background. Ref. [8] also introduces a technique, taking advantage of sinusoidal modulation, by which the Fourier chopper phase offset ϕ can be determined by modulating the beam at low frequencies. This phase offset, which is a necessary input in the reconstruction of

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