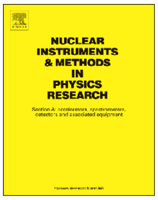
Nuclear Instruments and Methods in Physics Research A 759 (2014) 83–91

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima



Wide-angle mechanical velocity selection for scattered neutrons in inelastic neutron spectrometers

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ARTICLE INFO

Article history:
Received 17 March 2014
Received in revised form
13 May 2014
Accepted 13 May 2014
Available online 21 May 2014

Keywords:
Inelastic neutron scattering
Neutron chopper
Velocity selector

ABSTRACT

We have analyzed the performance of the proposed mechanical device suitable for wide-angle velocity selection of neutrons scattered at the sample position in inelastic neutron spectrometers. The proposed wide-angle velocity selector (WAVES) is essentially a collimator that rotates about the vertical axis passing through the sample position, whose blades are not radial, but instead shaped to optimize the transmission of neutrons of the targeted velocity. The rotation phase of the selector does not need to be synchronized with the incident beam pulses, as long as the incident neutrons can reach the sample position, which greatly simplifies the selector control and makes it suitable for neutron spectrometers at both pulsed and steady sources. We discuss applications of the proposed selector in various types of the inverted-geometry neutron spectrometers.

1. Introduction

We propose a rotating mechanical device that could be used as a wide-angle velocity selector for the neutrons scattered at the sample position at neutron spectrometers. Similar to neutron velocity selectors, the rotation phase of such a device does not need to be synchronized with the incident neutron pulses, provided that the incident neutrons could reach the sample. These devices could be used at both spallation and steady neutron sources in various types of inverted geometry neutron spectrometers, some of which we discuss.

Time-of-flight (TOF) inelastic neutron spectrometers can be distinguished as either direct- or inverted-geometry types, depending on whether it is the incident, initial neutron energy, E_i, or the detected, final neutron energy, E_f, that is fixed in the measurement. With the known neutron flight paths, the variable parameter, either the E_f for the direct-geometry spectrometer, or the E_i for the inverted-geometry spectrometer, is determined from the overall neutron TOF, thereby yielding the neutron energy transfer, $E=E_i-E_f$. The goal of a neutron scattering experiment is to measure the scattering intensity as a function of E and the scattering momentum transfer, $Q=k_i-k_f$, defined by the E_i, E_f, and the scattering angle.

Modern direct-geometry TOF neutron spectrometers utilize crystal monochromators or choppers to select the E_i, whereas inverted-geometry spectrometers employ crystal analyzers or filters to select the E_f. Mechanical neutron velocity selectors [1–3] do not provide the practical means to define the E_i precisely. However, they can be employed to merely restrict the range of the incident energies to a relatively narrow band, often in conjunction with low neutron velocity, long-wavelength techniques, such as small-angle neutron scattering, neutron backscattering, and neutron spin-echo. On the other hand, mechanical velocity selectors are not considered practical for filtering the velocities of the neutrons following scattering at the sample position. This is because of the practical difficulties in selecting narrow enough a range of the E_f by velocity selectors, but even more so due to the wide angular span of the scattered neutrons. The relatively small incident beam cross-section, typically in the 10–100 cm^2 range for inelastic spectrometers, is relatively amenable to velocity selection by a spinning mechanical device. On the other hand, a velocity selector for the scattered neutrons cannot be placed too close to the sample position because of the space requirement to accommodate sample environment equipment, and also needs to span a wide angular range to intercept the scattered neutrons. The solid angle detector coverage at the modern neutrons spectrometers can often exceed 10% of 4π. Thus, a velocity selector at a 50 cm distance from the sample position needs to span an area of several thousand cm^2, which is a formidable task.

We first considered a velocity selector for the scattered neutrons in conjunction with the proposed design of a mica analyzers-based neutron backscattering spectrometer [4] at the Spallation Neutron Source (SNS). In the view of the experience gained in the course of operation of the conceptually similar silicon analyzers-based backscattering spectrometer [5] at the SNS, it is desirable to allow only the 20 Å neutrons reflected from the (002) mica analyzer crystal planes to reach the detectors, while suppressing the higher order mica reflections, such as (004), (006), etc.

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http://dx.doi.org/10.1016/j.nima.2014.05.041
0168-9002/

This presents a significant challenge. Separation of the (002)-reflected neutrons from the higher order reflections using the difference in their TOF requires impractically long flight paths and severely restricts the accessible range of energy transfers. There is no suitable material to use as a polycrystalline filter to eliminate the (004) 10 Å neutrons and (006) 6.7 Å neutrons. Furthermore, suppression of the higher order reflections has to be applied to the scattered, not incident on the sample, neutrons in order to address the thermal up-scattering in the sample to the wavelengths of the higher order mica reflections. Hence there seems to be a compelling need for the wide-angle mechanical velocity selector for scattered neutron in the proposed backscattering spectrometer. Our analysis reveals that such a device can be practical at a backscattering spectrometer, and may also find applications in other types of the inverted-geometry spectrometers where the fixed E_f is needed.

2. Design and analysis

The starting point of our consideration was a typical background-suppressing collimator with vertically straight, radial blades (Figs. 1a and 2a). The performance of such a device, utilized to suppress the background scattering from the parts of the spectrometer that are not very close to the geometrical center of the collimator, has been analyzed in detail [6]. In our analysis, we consider both infinitely small samples and samples with finite lateral dimensions, but neglect the thickness of the collimator blades, since we envision a collimator with thin blades whose inner and outer radii far exceed the dimensions of the sample.

A static or slowly oscillating radial collimator does not exhibit selectivity to the velocity of neutrons scattered by the sample at the collimator center. Let us consider a radial collimator rotating about the vertical axis passing through its center (the center of the sample position) with a frequency f, angular frequency $\omega=2\pi f$. For a sample of infinitely small lateral dimensions at the collimator center position, this collimator will only allow transmission of the neutrons traveling from the collimator center with a velocity $v > n_b(R_2-R_1)f$, where R_1 and R_2 are the inner and outer radii of the collimator blades and n_b is the number of the equidistantly spaced blades per 360° of the collimator circumference (e.g., $n_b=360$ in the case of 1° separation between the collimator blades). The transmission function, $T(v)$, becomes non-zero at the neutron velocity just above $n_b(R_2-R_1)f$ and approaches unity for $v=\infty$. If the direction of the collimator rotation is clockwise, looking from the top, then every neutron traveling from the collimator center with a velocity below $n_b(R_2-R_1)f$ will be hit (intercepted) by the blade which is immediately to the left of the neutron at the time it reaches the distance R_1 before this neutron could emerge from the collimator blades at the distance R_2.

The maximum of the rotating collimator transmission could be shifted from the infinite velocity to the desired finite velocity if the collimator blades are tilted in the direction opposite to the rotation direction (Figs. 1b and 2b). Such geometry of the blades is not optimal, and not particularly amenable to analytical transmission calculation, especially for samples of a finite size. Nevertheless, we analyze this geometry first because such a collimator could be constructed easily within the realm of traditional technology, when the blades made of a thin neutron-absorbing material are put in tension to minimize their waviness and maximize the

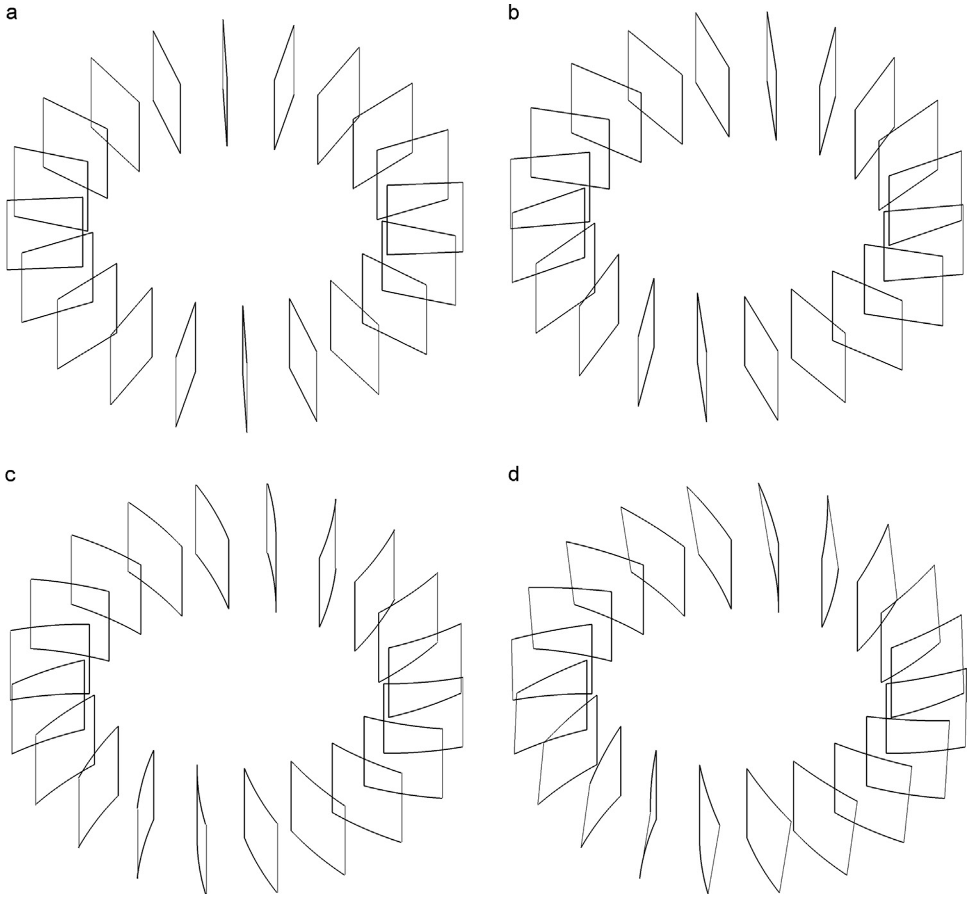

Fig. 1. Schematic illustration of various collimator blades. (a) Vertically straight, radial. (b) Vertically straight, tilted. (c) Vertically straight, curved. (d) Curved in all directions. See the text for explanation.