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Drabkin Energy Filter for Pulse Shaping and Energy Analysis

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We have been developing Drabkin energy filters for pulse shaping and energy analysis at the J-PARC spallation neutron source. By installing two Drabkin energy filters in sequence (a double Drabkin filter), subsidiary peaks of the resonant spin-flip are suppressed and pulse shaping could be performed more effectively. In this contribution, simulation results of pulse shaping by a double Drabkin filter for the J-PARC moderators are presented.

Keywords: Spatial neutron spin resonance; Neutron pulse shaping; Spallation neutron source; Drabkin energy filter

Pulse shaping is essential in order to perform high-resolution experiments at a pulsed neutron source. Choppers are often used for pulse shaping but they extract only a small range of wavelength and stop most of the neutrons from the moderator. A Drabkin energy filter could reduce the pulse width without the expense of band width and with the small reduction of pulse peak height [1–5].

A Drabkin energy filter is composed of a neutron polarizer, a Drabkin resonator [6,7], a spin π-flipper and a polarization analyzer. It extracts polarized monochromatic neutrons: the Drabkin resonator flips the spin of neutrons with a particular wavelength by means of spatial neutron spin resonance and the polarization analyzer extracts the spin-flipped beam. Since the resonant wavelength depends on the strength of the periodical magnetic field in the Drabkin resonator, pulse shaping is achieved by varying the field strength in synchronization with the time-of-flight from the source [8]. The wavelength resolution of the resonant spin-flip is inversely proportional to the number of the period of magnetic field in the resonator, N, which could be controlled electronically.

The spin-flip probability as a function of wavelength has subsidiary maxima more than 0.1 near the resonant peak, which deteriorate the efficiency of pulse shaping. But, the subsidiary maxima could be reduced by modulated magnetic fields or by installing several Drabkin energy filters in sequence [7,9]. Here, we call a system with two Drabkin energy filters installed in sequence a “double Drabkin filter”. In this paper, simulation results of pulse shaping for JSNS by a double Drabkin filter are presented and discussed.

The shape of pulses from the JSNS moderators are presented in Ref. [10]. When varying the field in synchronization with the pulses, it should be noticed that peak emission time is

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not zero. The peak position at the JSNS moderator surface is given by $15.61\lambda + 16.00(\mu\text{s})$ for the coupled moderator [4] and $6.84\lambda + 13.03(\mu\text{s})$ for the decoupled moderator as a function of wavelength $\lambda(\text{Å})$. The field strength in a Drabkin resonator thus should be varied as B_{coup} (Gauss) for the coupled moderator and as B_{dec} (Gauss) for the decoupled moderator

$$B_{\text{coup}}(t) = \frac{678.2(15.61 + 1000L_1/3.956)}{(t - 16.00)d}, \quad B_{\text{dec}}(t) = \frac{678.2(6.84 + 1000L_1/3.956)}{(t - 13.03)d}, \quad (1)$$

in order to sharpen the pulse over a range from 3 to 9 Å, where L_1 (m) is the distance from the source to the entrance of Drabkin resonator and d (mm) is the width of a half period of the magnetic field in the resonator. The unit of time is μs.

A Drabkin energy filter could also be installed after the sample in order to extract elastically scattered components or inelastic components. It is the strong point of Drabkin energy filters that elastic or inelastic components are extracted over the wide range of incident wavelength λ_{in} by a run of measurement. Suppose that the distance from the source to the sample is $L_1^{'}$ and that from the sample to the entrance of a Drabkin resonator is $L_2^{'}$. Then the elastically scattered components can be extracted by varying the field strength as

$$B_{\text{el}}(t) \propto \frac{L_1^{'} + L_2^{'}}{t}, \quad (2)$$

where we neglected the peak-emission time for simplicity. Inelastic components with a wavelength transfer $\Delta\lambda$ can be extracted by replacing t with $t - L_1^{'}\Delta\lambda$ in this equation. Inelastic components with a relative wavelength transfer $\Delta\lambda/\lambda_{\text{in}} \equiv \alpha$ are extracted by replacing $L_1^{'}$ with $L_1^{'}/(1+\alpha)$.

Simulations on pulse shaping were performed with the following configuration shown in Fig. 1.

- The number of periods of magnetic fields are $N_1 = 54$ and $N_2 = 100$.
- $L_1 = 11$ m and $L_2 = 2$ m for the coupled moderator pulse shaping, and $L_1 = 7$ m and $L_2 = 1$ m for the decoupled moderator.
- The strength of the field is uniform in a resonator (only the direction is changed periodically).
- Both two spin π-flippers after the first and second resonators work perfectly.
- Transmissivity of each magnetic mirror is 93.8% for spin-up neutrons and 1.2% for spin-down neutrons.

The widths of each half period d is 2.5 mm and fluctuation of it is set at 0%. The two numbers of periods 54 and 100 are selected so that the subsidiary maxima of the resonance curve by one resonator match the minima of the other.

In the simulations, neutron wavefunctions in each half period are derived in sequence. Results are shown in Fig. 2(A) and (B) for the coupled moderator pulse. Sharpened pulses of 3.2091 and 5.7067 Å are displayed as examples though pulse shaping are performed over

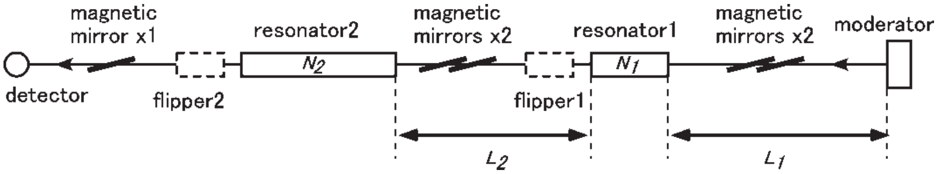

FIGURE 1 Set-up of a double Drabkin filter in our simulation.

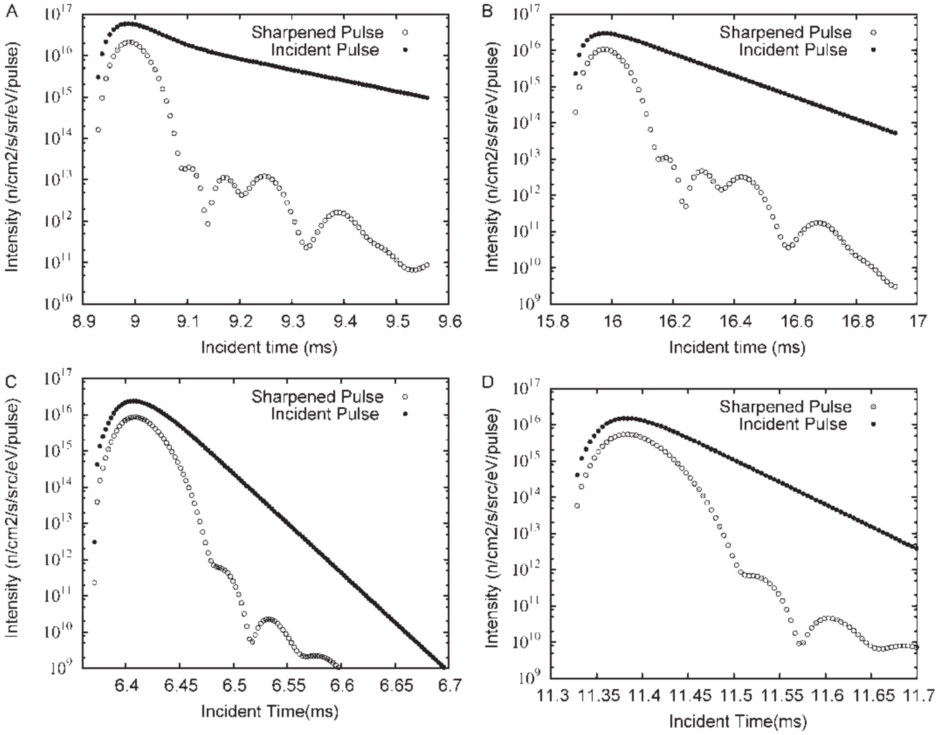

FIGURE 2 Simulation results of pulse shaping for JSNS. Sharpened coupled-moderator pulses of (A) 3.2091 Å and (B) 5.7067 Å, and decoupled-moderator pulse of (C) 3.6007 Å and (D) 6.4030 Å are shown as examples.

a range of 3 to 9 Å at a time. The results show that subsidiary maxima are reduced down to 10^{-3} of the resultant peaks. The pulse widths are reduced to be comparable to that of the decoupled moderator. The pulse heights are also reduced to about 1/3 of the incident one, but the results depend on the transmissivity of the magnetic supermirrors. The performance of magnetic mirrors is thus essential.

Figure 2(C) and (D) show results for the decoupled moderator pulse of 3.6007 and 6.4030 Å, respectively. The tails of the pulses are reduced down to $10^{-2} \sim 10^{-3}$ of the incident one and the subsidiary maximum is almost 10^{-4} of the peak. The pulse width is not reduced dramatically. To reduce the peak width, Drabkin resonators with a larger number of the period of magnetic fields are necessary.

The simulations with a modulated field strength and an experimental test of a Drabkin resonator with 100 periods of field will be presented elsewhere.

Drabkin energy filters could also be used as a high-resolution chopper for pulsed sources without the fast rise and fall of magnetic fields, which will be discussed elsewhere.

Drabkin energy filters could be installed at JSNS in the inelastic near-back-scattering spectrometer (DIANA) [11] in order to sharpen the pulse width for high-resolution measurements and also in a total scattering spectrometer to extract elastically scattered components.

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