Improvement of Pulse Characteristics of a Composite Cold Moderator of Liquid-Hydrogen Surrounded by Water for Pulsed Spallation Neutron Sources

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Abstract

An efficient cold neutron moderator is required for future projects employing spallation neutron sources. The most promising candidate is a composite moderator consisting of a liquid-hydrogen main moderator with a water premoderator. This type of moderator produces the highest cold neutron intensity but with broad pulse-width. We studied two methods for improving the pulse characteristics: the methods by decoupling the premoderator from the reflector and by heterogeneously poisoning the reflector. It was found that the former is superior for improving the pulse characteristics. Dependence of neutronic characteristics on premoderator thickness was also studied for the decoupling method.

1. Introduction

A composite moderator system consisting of a liquid-hydrogen main moderator with a water premoderator at ambient temperature coupled to a reflector has been considered to be the most promising candidate for a high-efficiency pulsed cold neutron source[1],[2]. It has been shown that a 5 cm thick liquid-hydrogen moderator with a 2-3 cm thick light water premoderator can provide about 6 times higher cold neutron intensity than a conventional decoupled liquid-hydrogen moderator although the pulse width is about 3 times wider and the pulse peak is about 2 times higher. The majority of cold neutron scattering experiments such as small angle neutron scattering, etc, can accept the broader pulse since the figure-of-merits (FOM) of the cold neutron source is proportional to the time-integrated intensity of cold neutrons per pulse[3]. On the other hand for high resolution spectroscopy using a inverted geometry, the FOM of the source is proportional to the peak height of the pulse, independent of the pulse width and repetition rate of accelerator provided that a neutron guide of a required length is available[3]. However, a very long guide is not practical. Therefore, a moderator which can provide a narrower pulse without sacrificing the pulse peak height become preferable. We have found that the pulse width can be controlled by changing the premoderator material or thickness[2]. In the case of ZrH_2 premoderator, the pulse width reduced to about 70-80% at the cost of 10-15% of the pulse peak height, when compared with that from the same cryogenic moderator with a 2 cm thick water

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premoderator.

The long-time tail of the pulse shape is another characteristics to be tailored. The pulse shape of cold neutrons from a coupled cryogenic moderator with a premoderator have a long-time tail due to the slowing down time in the reflector. This is cumbersome in many neutron scattering experiments. In order to suppress the long tail, we found that the insertion of neutron absorbing plate (for example Cd) in the reflector as a control sheet (heterogeneous poisoning) is useful[4]. In this paper we study more detail the effects of the heterogeneous poisoning and compare the method with a method by decoupling the premoderator from the reflector. Premoderator thickness dependence of neutronic performance are also studied in the case of decoupled composite moderator.

2. Experimental

The target-moderator-reflector systems used in the present measurements are shown in Fig. 1. The moderator system consists of a liquid-hydrogen moderator ($12 \times 12 \times 5\ cm^3$) surrounded by a light-water premoderator at ambient temperature. The upper figure shows the decoupled composite moderator in which the premoderator is decoupled from the graphite reflector of about $1\ m^3$. On the other hand, in the lower figure the premoderator is coupled to the reflector while the control sheet was inserted in the reflector at the center horizontal plane just above the target. A 0.5 mm thick Cd plate was used for both the decoupler and the control sheet.

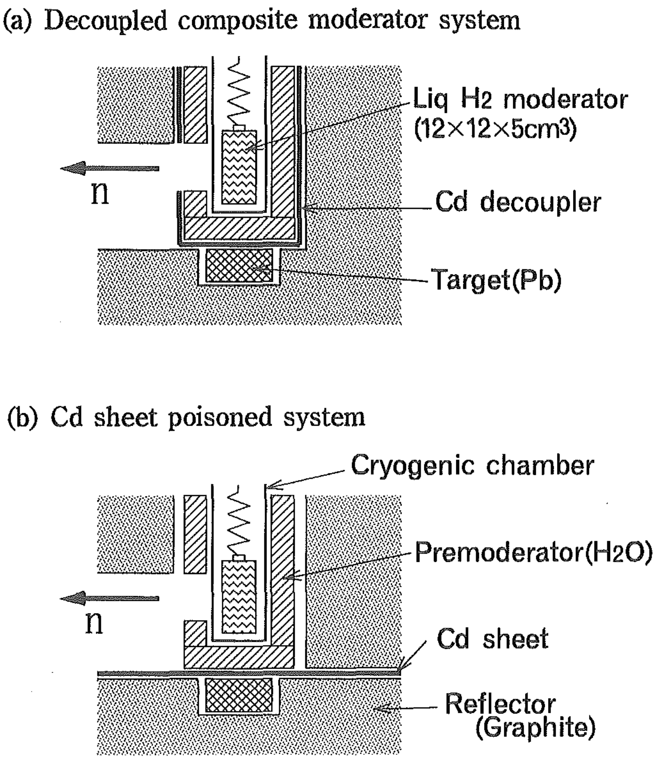

Fig. 1 Experimental set-up of target-moderator-reflector systems.

The measuring system is essentially the same as that used in the previous measurements[1]. As a pulsed neutron source, the electron linac at Hokkaido University was used with a lead target.

3. Comparison between decoupling and Cd sheet poisoning methods

Figure 2 shows the pulse shapes of cold neutrons from the decoupled system and Cd sheet poisoned one. The thickness indicated in the parentheses are for the water premoderator. For comparison the data from the coupled liquid-hydrogen moderators with a 3 cm thick water premoderator and without premoderator are plotted. Figure 3 shows the pulse widths (full width at half maximum, FWHM). The pulse width from the decoupled moderator system is reduced to about 73% at a cost of about 3% of the pulse height compared to the coupled one with a 3 cm premoderator. The corresponding value to the coupled one with Cd sheet is about 92% at a cost of 14% of the peak height.

The semi-logarithmic plots are also shown for the same data in Fig. 4 in order to look at long-time tail. In the case of 3 cm thick premoderator the decay of long-time tail is more quickly in the decoupled case than the Cd sheet poisoned one. In the moderator system without premoderator, improvement of the long-time tail is also observed by Cd sheet poisoning but the decrease of intensity is very large.

Figure 5 shows the relative time-integrated intensities of cold neutrons from these moderator systems to that from the reference coupled liquid-hydrogen moderator with a 3 cm thick premoderator. The intensity for the coupled moderator with Cd sheet is higher than that for the decoupled one by about 10% in the case of 3 cm thick premoderator. The difference is very small and the gain of intensity in the coupled moderator with Cd sheet comes mainly from the long-time tail. In the case of the moderator system without the premoderator the intensity from the moderator system poisoned by Cd sheet is almost the same as that from a conventional decoupled moderator system. Therefore, it is meaningless to use this system to improve the pulse shape.

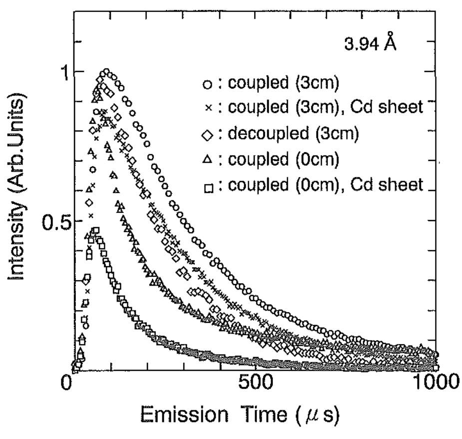

Fig. 2 Comparison of the Pulse shapes of cold neutrons.

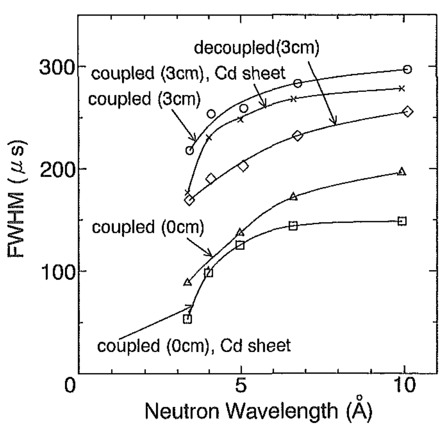

Fig. 3 Pulse widths from the two different systems.

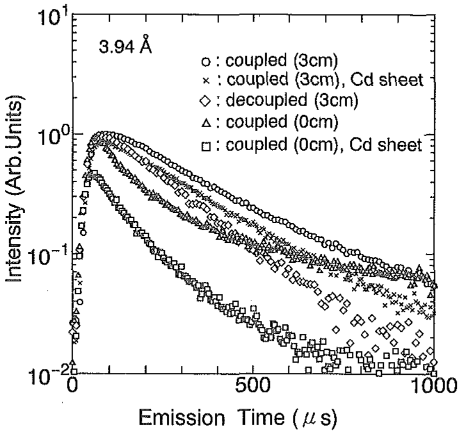

Fig. 4 Semi-logarithmic plots of the pulse shapes.

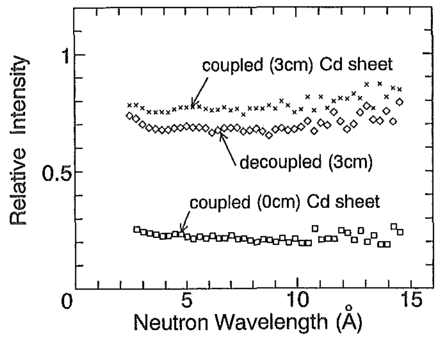

Fig. 5 Relative values of time-integrated intensities from the coupled composite moderator with Cd sheet and from the decoupled one.

4. Premoderator thickness dependence of the neutronic performance

In the previous chapter it was found that the decoupled composite moderator is superior to coupled one with Cd sheet for improving the pulse shape at the lowest cost of the pulse height. Here, we examine the premoderator thickness dependence of the neutronic performance of this system.

Figure 6 shows the cold neutron intensity as a function of the premoderator thickness. For reference the data of the coupled liquid-hydrogen are also indicated. The intensity increases almost proportionally with the premoderator thickness. The intensity at 3 cm thick premoderator is about 60% of maximum value of the coupled one. In Fig. 7 The intensity ratios defined as before are shown as a function of the neutron wavelength.

Figure 8 shows the premoderator thickness dependence of the pulse shapes. For reference the data from coupled moderator with 3 cm thick premoderator and the cou-

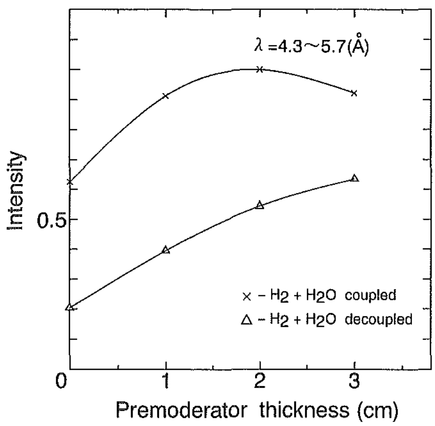

Fig. 6 Cold neutron intensity from the decoupled composite moderator as a function of the premoderator thickness.

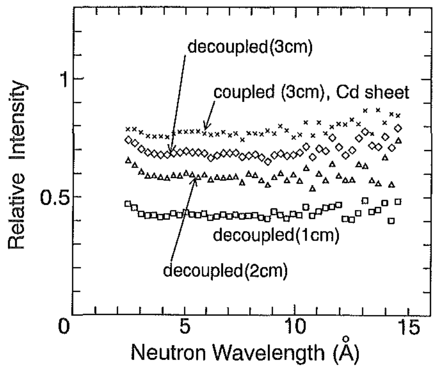

Fig. 7 Relative value of time-integrated intensities from the decoupled composite moderator with various premoderator thickness.

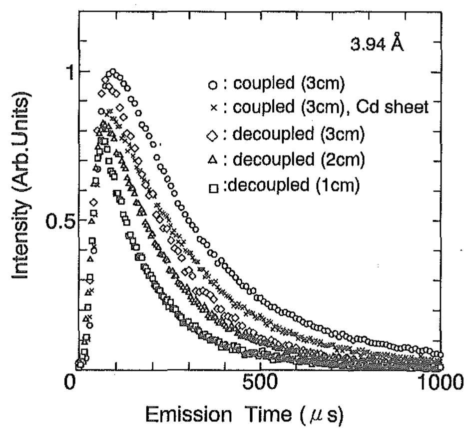

Fig. 8 Premoderator thickness dependence of the pulse shapes.

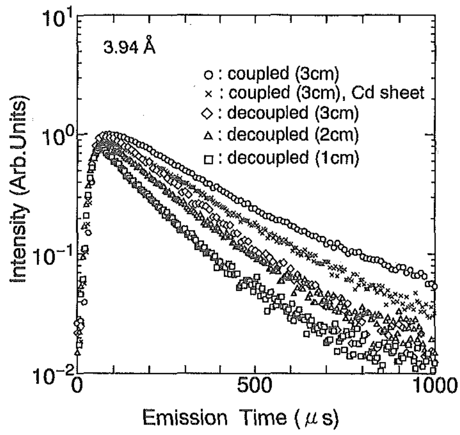

Fig. 9 Semi-logarithmic plot of premoderator thickness dependence of the pulse shapes.

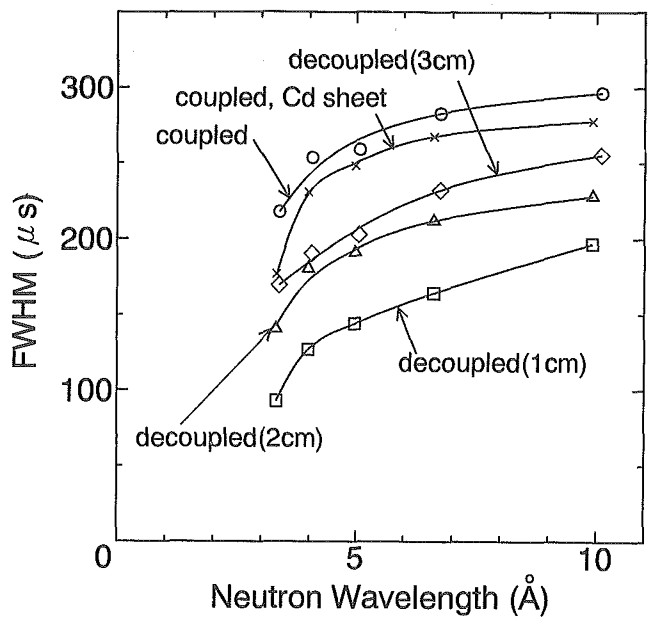

Fig. 10 Premoderator thickness dependence of the pulse widths.

pled one with Cd sheet are also shown. Both peak height and pulse width increase with premoderator thickness. Semi-logarithmic plots of the same data are shown in Fig. 9. The long-time tail also depends on the premoderator thickness. Figure 10 shows the pulse widths as a function of the neutron wavelength. The width also increase with premoderator thickness.

These results indicate that the premoderator thickness is important to control the neutronic performances of the decoupled composite moderator.

5. Conclusion

It has been found that the pulse shape (pulse width and long-time tail) can be improved effectively by decoupling a composite moderator from the reflector and that the performance of the decoupled composite moderator depends strongly on the premoderator thickness. Therefore, we have to choose the best premoderator thickness to achieve the highest performance of the neutron scattering experiments. Further study on the effects of the thickness of the cryogenic main moderator will be necessary

Acknowledgements

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