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Calculation studies of a multi-layer decoupler system for a decoupled hydrogen moderator

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Abstract

We proposed a multi-layer decoupler as a method to improve pulse characteristics of emitted neutrons from a decoupled hydrogen moderator. Pulse shapes from a moderator with the multi layer-decoupler were compared with those with a traditional single layer decoupler. It was found that the multi-layer decoupler system gave better pulse characteristic with less decrease of peak intensity.

1. Introduction

Some neutron spectrometers need sharp pulse of the emitted neutrons from a moderator. We usually put a decoupler around moderator to improve pulse characteristics. By heterogeneous poisoning in a moderator, pulse width can be adjusted by changing a poison position in the moderator. On the other hand, at higher energy, deterioration of pulse shape will be caused by neutrons from outer side of a reflector. We can get a narrow and low-tail pulse by adopting a decoupler with high decoupling energy although the peak intensity of the pulse decreases largely.

One idea is to absorb higher energy neutrons which had distance from the moderator. So, we considered multi-layer decoupler system, namely, where decouplers are arranged in a way of a concentric circle. In this system, it is expected that the outer side decoupler absorb neutrons, which compose the tail of the pulse.

We studied the effect of the multi-layer decoupler on the pulse shapes of neutrons from a decoupled hydrogen moderator and the pulse characteristic were compared with those from a system with a traditional single layer decoupler. In a real target-moderator-reflector system, a coupled hydrogen moderator exists together. So, effect of the multi-layer decoupler on the intensity from a coupled moderator also studied.

2. Calculation

LCS were used for the calculations. ENDF/B-V was used for cross-section data. Two target-moderator-reflector system (TMRS) are shown in Fig.1. The reflector is lead. A B_4C is used for decoupler and thickness is changed to control decoupling energy.

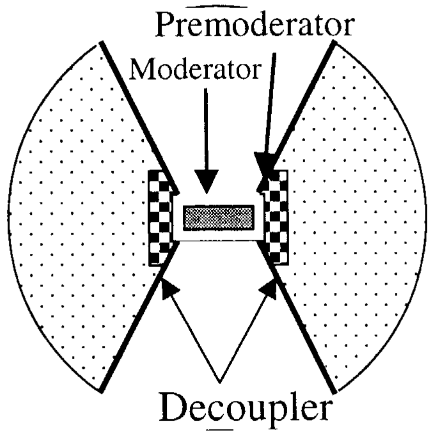

Fig.1-1. Traditional decoupler TMRS

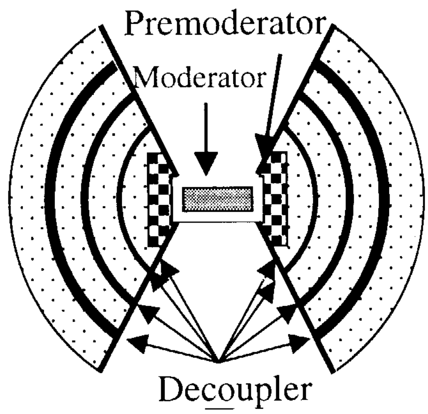

Fig.1-2. Multi-layer decoupled TMRS

Fig.1-1 indicates a reference TMRS, traditional single decoupler system, and Fig.1-2 the TMRS we proposed, in which the concentric cylinder system centering on a moderator is used as multi-layer decoupler. The target material used is mercury. A 12x12x5 cm^3 liquid hydrogen with a 5cm thick heavy water premoderator is viewed through 10x10 cm^2 collimator.

Reflector material is lead and it radius is 60cm and height is 120 cm. Decoupling energy of each layer of multi-layer decouplers are chosen so that the neutron flight time in vacuum space from center of moderator to each layer is kept constant. For example, 9eV neutron takes 5 μ sec to fly through 20cm, and in the same period (5 μsec) 20eV neutron fly through 30cm, 35eV neutron fly through 40cm and 50eV neutron fly through 50cm. We call this as 'Multi-5micro sec' or 'Multi-layer'. On the other hand, in traditional TMRS decoupling energy was 2.5eV, and it was distinguished by the notation like Ed=2.5eV.

3. Result

Making a comparison between standard model of Ed=2.5eV and Multi-5micro sec, neutron intensity was decreased by 16% in Multi-5 μsec system, and FWHM decreased by about 5% on average.

Decoupling energy is changed in the traditional type and the relation between decoupling energy and neutron intensity is shown in upper part of Fig. 2. From this figure, Multi-5μsec is equivalent to Ed=8.5eV in intensity. From under part of Fig.2 FWHM of Multi-5 μsec correspond to Ed=7eV.

However, the most important feature of multi-layered decoupler system is the fast decay of a pulse. We obtained first and second decay constants to evaluate the decay speed. First decay of the multi-5μsec is equivalent to Ed=19eV, which is shown in Fig. 3, and second

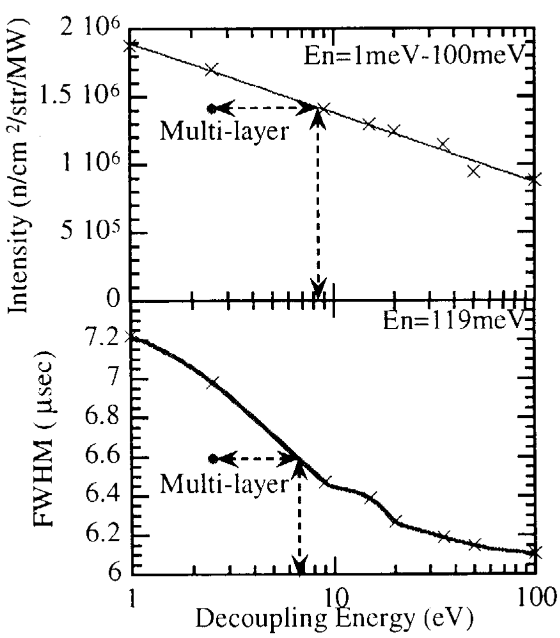

Fig.2. Relation of intensity and FWHM of multi-layered decoupler and traditional decoupler.

decay of the multi-5μsec is equivalent to Ed=20eV.

4. Discussion

From the above result, when only FWHM is considered, multi-layer Decoupler is not good selection since reflector structure becomes complex. In generally following methods, such as choice of thinner moderator, poisoning of the moderator etc. would be more effective, although intensity decreases rapidly with narrowing FWHM.

When aiming to improve the decay characteristic of pulse, as indicated before 2nd decay constant of multi-5micro sec corresponds to Ed=19eV and neutron intensity is equivalent to Ed=8.5eV. To evaluate this characteristics, we calculate Figure of Merit ratio (Flux/σ) as shown in Fig.4. Sigma is standard deviation of time distribution of neutron pulse. From this figure, when neutron energy is 40meV, Multi-layer decoupler shows good characteristics compared with a traditional type. About under 40meV, low decoupling energy (Ed=1eV) is better. Even in this region, multi-layer decoupler is comparable to Ed=9eV.

Furthermore, the adaptability of multi-layered decoupler to the case of three moderators (coupled x1 and decoupled x2) currently proposed in JSNS project[1] is described. 3 moderator TMRS with multi-layer decoupler is shown in Fig.5. In real calculation, multi-layer decouplers are four layers. A coupled moderator is placed over the target. Two decoupled moderators are under the target. Multi-layer decoupler was introduced only in the lower half in this calculation.

Checked here is influence of multi-layer decoupler on a coupled moderator, and effect on two decoupled moderators. Neutron intensity is shown in table 1. As a result, the influence on coupled moderator was not observed. The effect of multi-

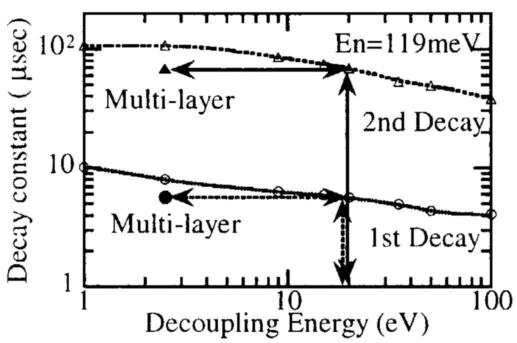

Fig.3. Relation of Decay constant of multi-layered decoupler and traditional.

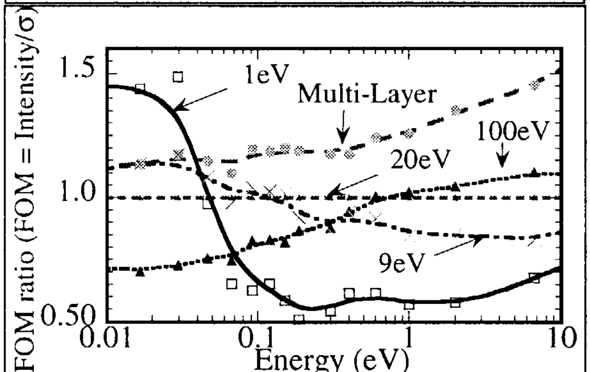

Fig.4. Figure of merit ratio of calculated pulse shapes.

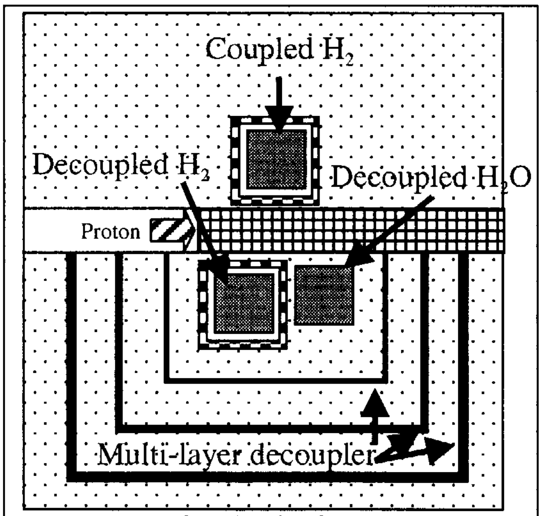

Fig.5. TMRS of JSNS project with multi-layer decoupler

Table 1. Effect of multi-layer decoupler on neutron intensity of 3 moderator system

	Coupled H_2	Decoupled H_2	Decoupled H_2O
Traditional	$7.86x10^6$	$9.68x10^5$	$6.44x10^5$
Multi-layered	$7.79x10^6$	$8.74x10^5$	$5.88x10^5$

En=1meV-100meV (n/cm²/str/MW)

layer decoupler appeared on both decoupled moderators. It is also shown in Fig. 6. As a method to improve the decay characteristic, multi-layer decoupler is effective. Pulse shapes of multi-layer decoupled moderator looks like the pulse shapes of a decoupled moderator with moderating type reflector, since slow neutrons travelling to part far from moderator can't go back to the moderator in both case.

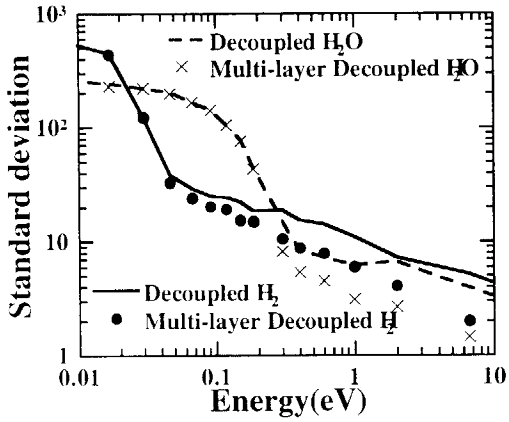

Fig.6. Standard deviation of decoupled moderators of JSNS model calculations

5. Conclusion

If reflector material is non moderating material, a multi-layer decoupler system is more effective to improve pulse decay than a traditional single decoupler system. However, it makes reflector system complex and affects other moderator near the moderator of multi-layer decoupler.

Reference

[1] JSNS neutronics meeting report 11.19.1999

Acknowledgement

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