Further Study on the Photoneutron Source for Bragg Edge Imaging

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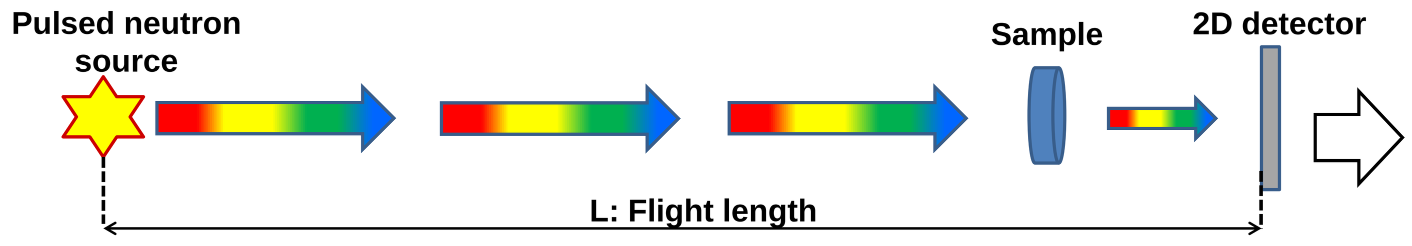
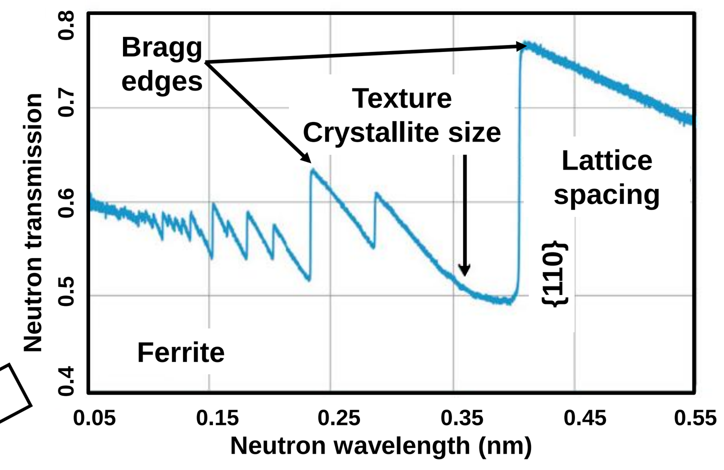
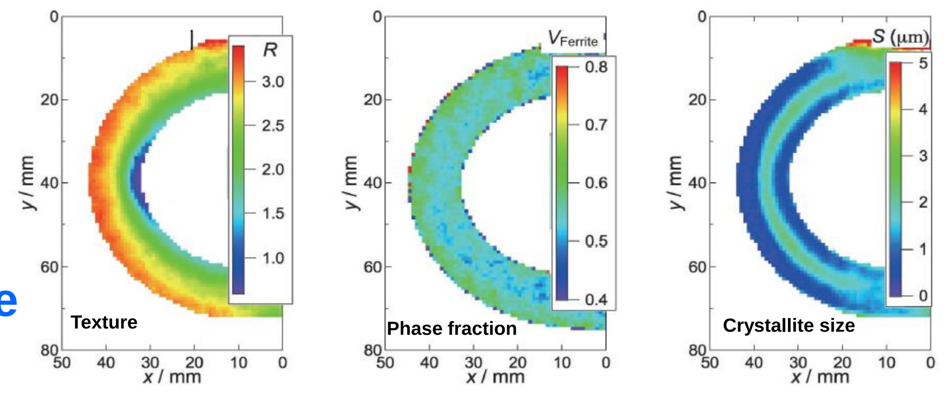
Introduction

- Bragg edge imaging is a non-destructive material testing method.
- A pulsed neutron source and a 2D detector are needed for Bragg edge imaging [1].
- Compact Accelerator Neutron Sources (CANS) have shown the ability of the Bragg edge imaging [2].
- Texture orientation, phase volume fraction and crystalline size of structural materials such as steel can be obtained [3].
- There is a lack of this novel technique in Korea.
- **A simple geometry was used to consider the FWHM* and FWTM** of the neutron pulse emitted from a rectangular polyethylene (PE) moderator.**
- **FWHM and FWTM determine the neutron wavelength resolution (Δλ/λ) which is important to obtain sharp Bragg edges [1].**







For neutrons with wavelength of λ>2d (d is the interatomic distance) the transmitted intensity increases significantly. This increase in neutron transmission is called Bragg edge.

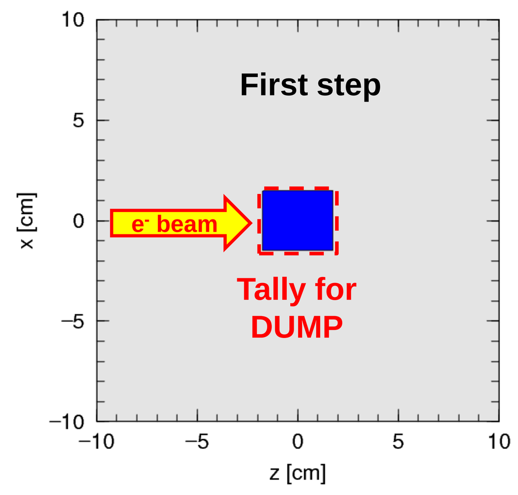
* Full Width at Half Maximum
** Full Width at Tenth Maximum

Methods

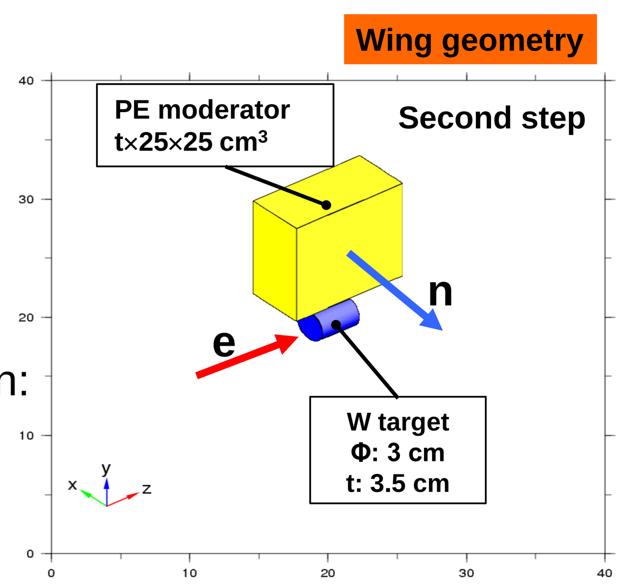
- **Neutron production yields for designing the cold neutron source were calculated using the PHITS-3.1 code [4].**

❑ **Simulations were performed in two steps:**

- **First step:**
  - A cylindrical W target: Φ = 3 cm, t = 3.5 cm [5]
  - Electron beam: R = 0.25 cm, E = 40 MeV
  - EGS5 mode was activated for electrons.
  - Generalized Evaporation Model (GEM) model for evaporation.
  - Neutrons were scored using DUMP option to improve the calculation time and statistics.



- **Second step:**
  - Moderator: Polyethylene @ 293 K with area of 25 × 25 cm^2 and different thicknesses
  - JENDL-4.0 [6] library was used for neuron interactions.
  - Neutrons scored in the first step were used as the source in the second step.
  - Moderated neutron flux were scored @ 100 cm from the target
  - Neutron emission time was scored at the moderator surface



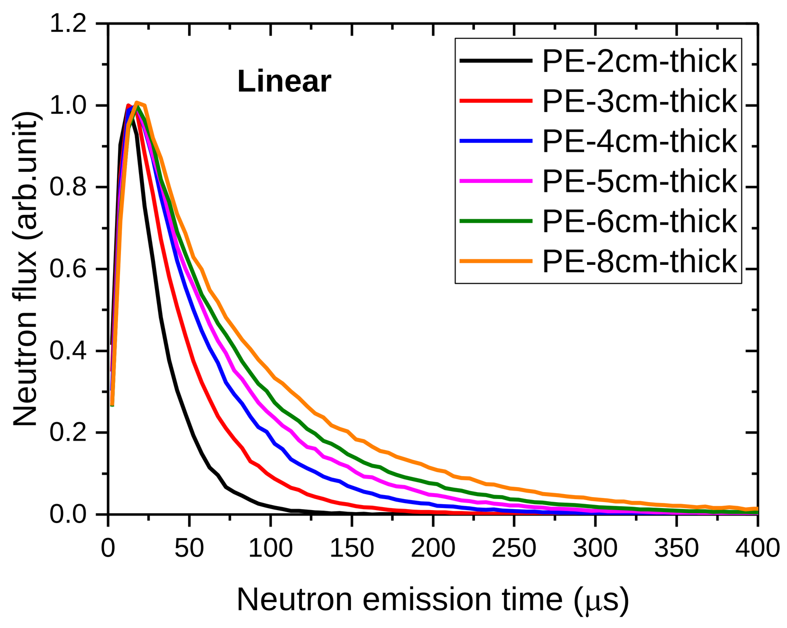
➢ **Purpose**

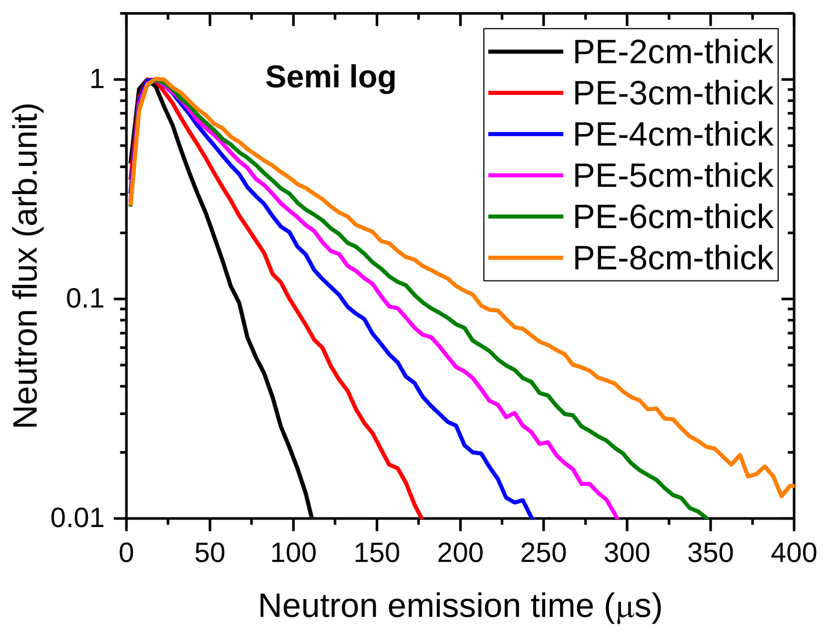
- To determine the optimum PE thickness based on:
  - Neutron flux maximization
  - Narrow neutron emission time
  - Interested neutron energy: 5 meV

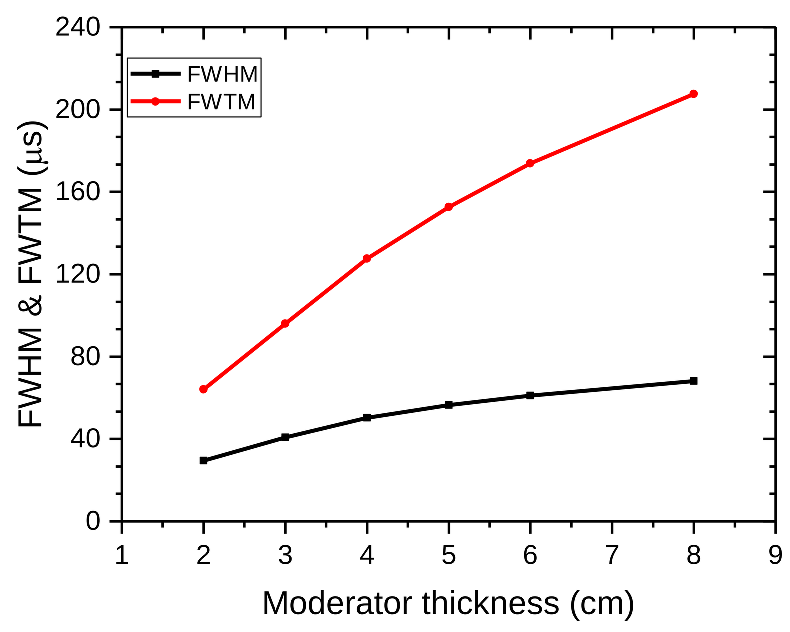
➢ **Final goal is to achieve a neutron intensity of ~ 10^4 n/cm²/s and wavelength resolution (Δλ/λ) of ~1 - 2 % @ 8 to 10 m.**

Results

- **Neutron emission time (E_n = 5 meV)**
  - Neutron flux is normalized to the peak value.
  - Neutron emission time at the PE surface increases with increasing the PE thickness.
  - The linear scale shows the FWHM of the neutron pulses.
  - The semi-log scale shows the pulse tail→ FWTM



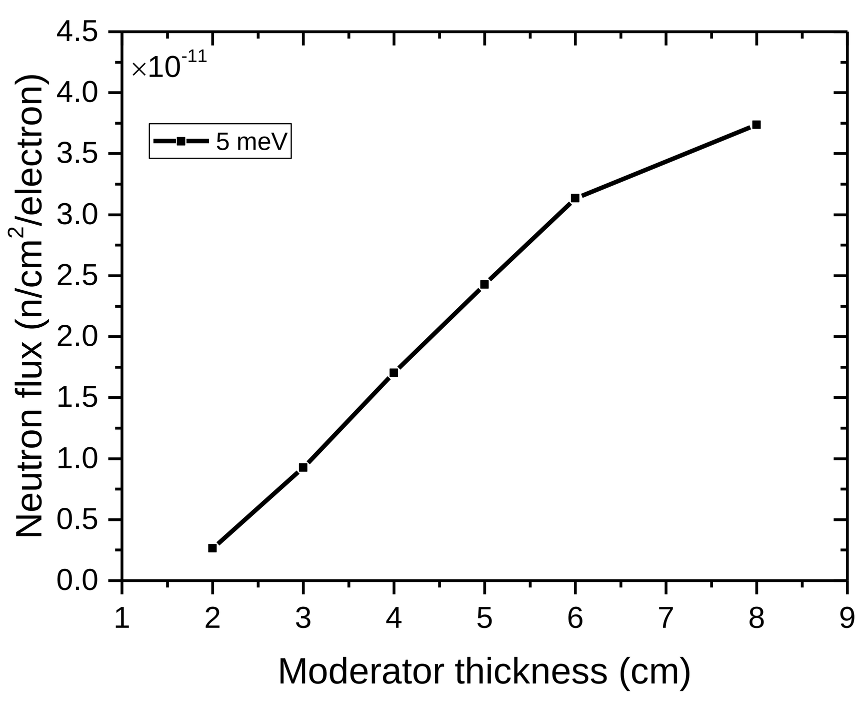


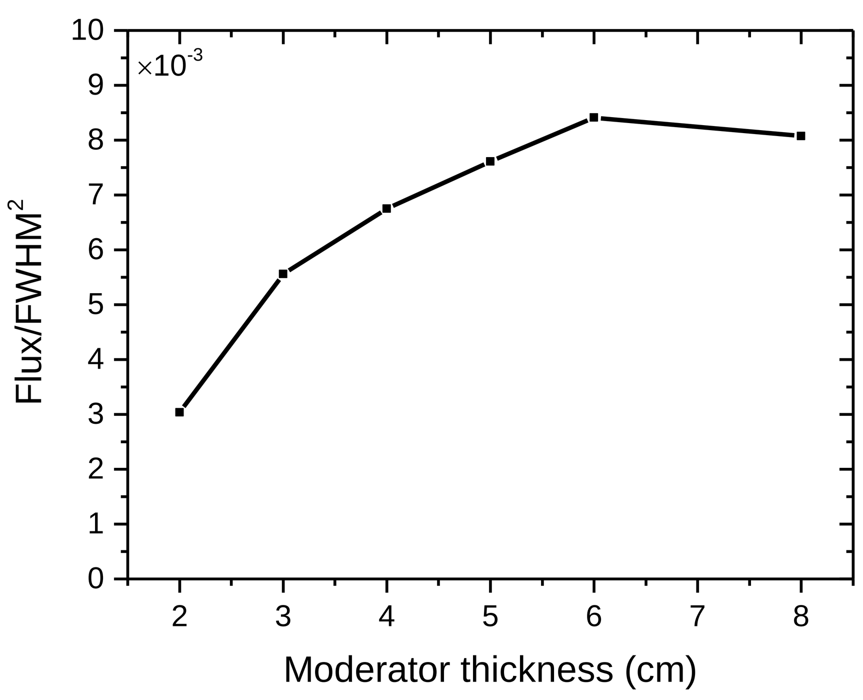


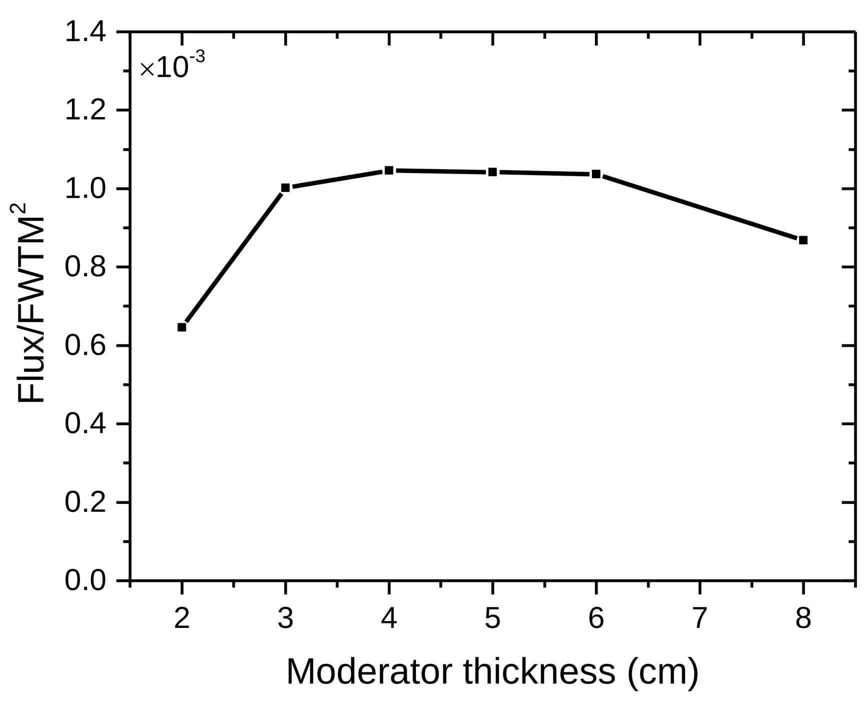
- FWHM increases with the PE thickness up to ~ 5 cm and its growth decreases after that.
- FWTM increases with the PE thickness constantly.

Results

- **PE optimum thickness for the wing geometry**
  - The cold neutron flux increases @ 100 cm from the target with PE thickness.
  - To determine the optimum thickness of PE, the Flux/FWHM² and Flux/FWTM² were also estimated.
  - The Flux/FWHM² growth is high up to the PE thickness of 6 cm and after that it decreases.
  - Flux/FWTM² reaches a maximum at 4 cm and after that it decreases
  - **The optimum thickness of the PE can be selected as 4 cm regarding the pulse shape as well as the maximum neutron flux.**







- For this simple wing geometry:
  - The neutron wavelength resolutions (Δλ/λ) @ 8 and 10 m are: 0.61%, 0.49% for 4 cm-thick PE
  - The cold neutron flux from this geometry is quite small for Bragg edge imaging→ Because only PE is used without any reflector material.

Summary and future plans

➢ A neutron source for performing Bragg edge imaging in under development using the PHITS code.
➢ Tungsten (W) target with size of Φ = 3 cm, t = 3.5 cm was irradiated with E_e = 40 MeV.
➢ Regarding the FWHM and FWTM of the neutron pulse, 4 cm-thick PE was set as the optimum thickness.
➢ The neutron pulse resolution is less than 1% @ 8 m.
➢ The geometry in this work is not the final case and was used only for checking the neutron pulse shape.

Future plans:

➢ A reflector such as graphite will be considered to increase the neutron flux.
➢ Other Target-Moderator-Reflector geometries and configurations will be studied to achieve the highest neutron flux.
➢ Heat deposition in the target will be considered.
➢ The designed cold neutron source will be developed.

References

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