Design of a BSA for Producing Epithermal Neutron for BNCT

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High temperature plasma and nuclear fusion

- Magnetic Confinement Fusion (MCF)
  - Basic plasma, transport, MHD instabilities, plasma-wall interactions
  - Fusion reactors

- Dense Plasma Focus (DPF)
  - Radiation sources: X-ray, neutron, proton
  - Radioactive material
Low temperature & atmospheric pressure plasma

• Atmospheric pressure plasma for agriculture and health
  – Improvement of seed germination and production
  – Sterilization

• Dense Plasma Focus (DPF)
  – Radiation sources: X-ray, neutron, proton
Utilization of nuclear fission technology

• Nuclear reactor technology
  – Nuclear power plants: Conventional and innovative nuclear reactors
  – Siting in Thailand
  – Policy and Roadmap for nuclear development

• Nuclear for health
  – Neutron and proton technology for cancer treatment
• Boron Neutron Capture Therapy (BNCT)
• Beam Shaping Assembly (BSA)
• Simulation results with D–T neutrons
  ✓ Multiplier
  ✓ Moderator
  ✓ 2nd Moderator
• Conclusion
The existing treatment methods for brain cancer, such as surgery and chemotherapy, are found to be ineffective.

An ideal therapy for cancer should selectively destroy the cancer without damaging normal tissues.

Boron Neutron Capture Therapy (BNCT) is an indirect radiotherapy for destruction of cancer cells.

BNCT features:
- New treatment of refractory cancer
- Causes minimal stress to patients
- Pinpoint treatment at cell level
Background

- Treatment mechanism of BNCT

http://www.osakafu-u.ac.jp
Advantages and uses of BNCT

1. Only necessary for a small number of these particles to release their energy in order to be effective at killing malignant cells.

2. BNCT does not result in the destruction of surrounding, healthy tissue.

**Sources:** Clinical Cancer Research, 2005, 11:2, 3987; Radiation Research, 1999, 151, 1-18
Background

- Difficulties for BNCT applications

High intensity thermal–epithermal neutron beam
\(5 \cdot 10^8 \text{n/cm}^2 \text{s}^{-1}\)

< 10 keV energy range

Gamma contamination
< \(2 \cdot 10^{-13} \text{Gy cm}^2/\text{n}\)

Low toxicity
High specificity
Non-persistence in the bloodstream
Background

General beam properties

Comparison of flux–depth distributions for thermal and epithermal neutrons.
Beam characteristic

Intensity

determines treatment time

Quality

relates to the types, energies, and relative intensities of all the radiations present

Parameters for the quality:
1. The fast neutron component
2. The gamma ray component
3. The ratio between the thermal flux and the epithermal flux
4. The ratio between the total neutron current and the total neutron flux
To moderate high energy neutrons to the ones of lower energies and to remove fast and thermal neutrons and gamma contaminations, Beam Shaping Assembly (BSA) is used.
Simulation method: Monte Carlo
Code: Particle and Heavy Ion Transport code System (PHITS)

Neutron source:
• neutron yield = $1.45 \times 10^{14}$ n/s
  \cite{RasouliFS,MasoudiSF,KasesazY.2012}
• mono-energetic
• energy = 14 MeV
• $r_0 = 1.7$ cm
• Materials for multiplier must be able to effectively increase the number of neutron flux.

• Based on the graph, Pb of 4 cm thickness is the best choice for multiplier region.
Normalized neutron flux versus energy of Pb as neutron multiplier,
• Materials for moderator must be able to moderate the fast neutron into thermal and epithermal neutron

• It is shown that the best thickness for moderator is 24 cm TiF$_3$. Multiplication is done with 4 cm of Pb
Although the epithermal flux for 24 cm TiF₃ satisfy IAEA recommended value (1.58 × 10¹⁰ n/cm²s). its fast neutron flux is significantly high. As a result, the value of $\phi_{\text{epi}}/\phi_{\text{fast}}$ is very low and does not satisfy the IAEA recommended value (4.46 × 10⁻²).
• 2\textsuperscript{nd} moderator is adopted to increase the epithermal flux and decrease the fast neutron flux.

• the $\frac{\phi_{\text{epi}}}{\phi_{\text{fast}}}$ values are still very far from that recommended by the IAEA.
Adopting multiplier, first moderator, and second moderator still cannot satisfy one of the IAEA criteria; thus more BSA components are needed.

Materials selection and size optimization are required to obtain BSA design which is suitable for BNCT applications.
THANK YOU