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Neutronic Analysis of Pulse Core and Laser Module Coupled System for Nuclear Pumped Laser

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1. Introduction

Nuclear-pumped laser is produced by pumping laser active medium with kinetic energy of fission fragments. In this pumping process, the kinetic energy of fission fragments is transferred to laser active medium by collisions of fission fragments with laser active medium. The energy is converted to optical energy with the transition of energy levels of the laser active medium.

Experimental and theoretical study on nuclear-pumped laser has been performed in IPPE using a coupled reactor [1]. The coupled reactor consists of a twin-core pulse reactor with highly enriched metallic uranium and a subcritical laser module with highly enriched metallic uranium.

The purpose of study is to design a low enriched uranium coupled reactor for nuclear-pumped laser which consists of pulse reactors and a subcritical laser module. Neutronic calculations were performed for a coupled reactor with highly enriched metallic uranium and low enriched metallic uranium to show the possibility of low enriched uranium coupled reactor for nuclear pumped laser.

2. Neutronic Analysis of a Coupled Reactor with Highly Enriched Metallic Uranium

Effective multiplication factor and power distribution of a coupled reactor with 90% enriched metallic uranium were analyzed. Mote Carlo calculation was performed using continuous energy Monte Carlo code MVP2.0 [2] and nuclear data library JENDL-3.3. Figure 1 shows the schematic diagram of the highly enriched metallic uranium coupled reactor. This reactor consists of pulse cores with 90% enriched metallic uranium and a subcritical laser module with 90% enriched metallic uranium. Each pulse core is a cylinder which has the radius of 11cm and a height of 22cm. The subcritical laser module has the diameter of 1700mm and the axial length of 2500mm. It consists of laser cell region, reflector region and structural material region. The laser cell region is filled with laser cells. The cell is a stainless steel tube with the inner and outer diameter of 49mm and 50mm respectively and the axial length of 2500mm (see Figure 2); the gap between laser cells is filled with polyethylene moderator. On the inner wall of each laser cells, metallic uranium with the thickness of 5μm is coated, and laser active medium (Ar and Xe) is filled with the tubes.

The effective multiplication factor of the coupled reactor with 90% enriched metallic uranium was 1.3827 with σ of 0.04%. Obtained axial power distributions from 17CAcell to 33CAcell (see Figure 1) are shown in Figure 3. These axial power distributions have two main features. Firstly, axial power distributions of inner cells such as 17CAcell and 21CAcell have peaks at the positions of two pulse cores (±50cm). Secondly, the axial power distributions of outer cells such as 25CAcell, 29CAcell and 33CAcell have little contribution to the power of the coupled reactor. From these features, uniform gas pumping in axial and radial directions is difficult in the highly enriched metallic uranium coupled reactor.

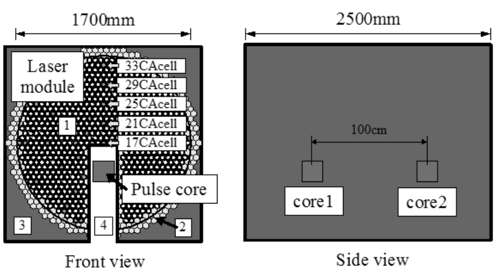

Figure 1. Schematic diagram of highly enriched metallic uranium coupled reactor (1: laser cell region, 2: polyethylene reflector region, 3: structural material region, and 4: void region.)

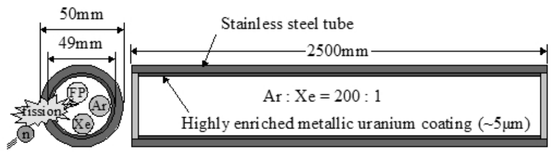

Figure 2. Schematic diagram of laser cell

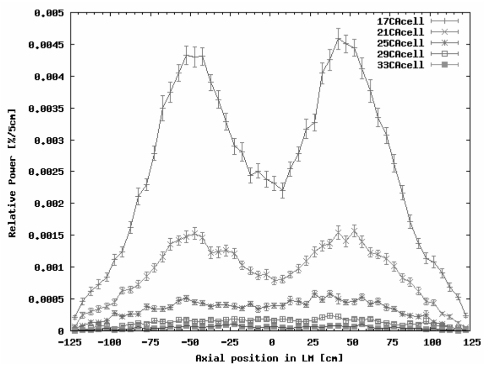

Figure 3. Axial power distributions in a coupled reactor with 90% enriched metallic uranium

3. Neutronic Analysis of a Coupled Reactor with Low Enriched Metallic Uranium

Figure 4 shows the calculation geometry in low enriched uranium coupled reactor. In this case, each pulse core has the radius of 13cm and the height of 30cm. Eight pulse cores are positioned properly in axial direction. The calculation condition and calculated effective multiplication factor are shown in Table 1. The axial power distributions are shown in Figure 5. These axial power distributions have two features. Firstly, axial power distributions of inner cells such as 17CAcell and 21CAcell are more flattened than that of the coupled reactor with 90% enriched metallic uranium. Flattened axial power distribution can provide uniform gas pumping in axial direction inside laser cells. Secondly, the axial power distributions of outer cells such as 25CAcell, 29CAcell, and 33CAcell have little contribution to total power.

More detail analysis showed that less than 20% of energy released from fissions can be released to the medium in laser module. This is one of the problems to be solved so as to improve conversion efficiency from nuclear to optical energy in designing a practical or commercial reactor for nuclear-pumped laser.

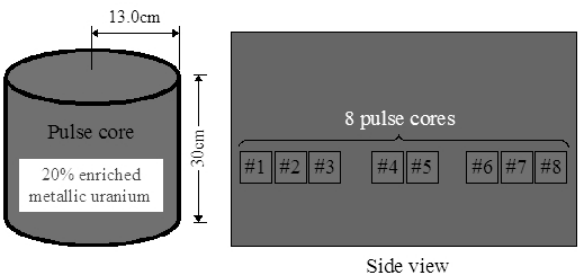

Figure 4. Coupled reactor with 20% enriched metallic uranium

Table 1. Calculation condition and k_{eff}

Position of pulse core #1 and #8	±100.1cm
Position of pulse core #2 and #7	±74.0cm
Position of pulse core #3 and #6	±47.9cm
Position of pulse core #4 and #5	±13.05cm
Keff	1.0067
σ[%]	0.04

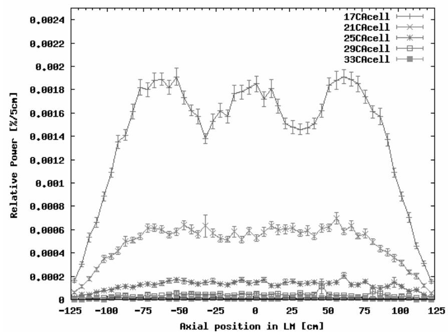

Figure 5. Axial power distributions in a coupled reactor with 20% enriched metallic uranium

4. Conclusions

Criticality analysis was performed for a coupled reactor with 20% enriched metallic uranium. The neutronic characteristics were compared with that of a coupled reactor with 90% enriched metallic uranium. The results showed that even in the case of the coupled reactor with 20% enriched metallic uranium, the reactor could be critical. In addition to that, flattened axial power distribution in the 20% enriched uranium coupled reactor was likely to enable to pump laser active medium uniformly in axial direction; on the other hand, uniform gas pumping in both axial and radial direction might be difficult in the coupled reactor with 90% enriched metallic uranium. The results of detail analysis showed that less than 20% of energy by fissions could be released to the medium in laser module.

REFERENCES

[1] A. Gulevich, et al., Status of the research for nuclear-pumped lasers in IPPE. Proceedings of the ISTC-TITech Japan Workshop on Nuclear Reactor Technologies in Russia/CIS, pp.19-29, Tokyo, 9 July, 2001.

[2] Y. Nagaya, MVP/GMVP II: General Purpose Monte Carlo Codes for Neutron and Photon Transport Calculations based on Continuous Energy and Multigroup Methods, JAERI 1348, 2005.