Possible Measurements of Reaction Cross Sections for Explosive Nucleosynthesis using Laser -Driven γ-ray Pulses

HAYAKAWA, Takehito, KOTAKI, Hideyuki, KANDO, Masaki
(National Institutes for Quantum and Radiological Science and Technology)

NAKAMURA, Tatsufumi
(Fukuoka Institute of Technology)

KAJINO, Toshitaka
(Beihang University/NAOJ/University of Tokyo)

Progress in laser physics enabled us to produce various quantum beams such as electrons, gamma-rays, and ion beams from high field plasma generated from the interaction between high peak power laser and materials. The energies of these radiations become higher than 10 MeV and thus they can interact with nuclei. The quantum beams generated by high peak power laser have a potential to be used for the study of nuclear physics. These laser driven quantum beams have the following features: high flux, ultra-short pulse in a range from femtosecond to nanosecond, and continuous energy distribution.

A pioneering nuclear experiment with high peak power laser for the Big-Bang nucleosynthesis was performed at University of Texas at Austin [1]; the astrophysical cross section of the $^{3}\mathrm{He}(\mathrm{d,p})^{4}\mathrm{He}$ reaction in the plasma generated by the Texas Petawatt Laser was measured. In the Extreme Light Infrastructure Nuclear Physics (ELI-NP), it was proposed to produce extremely neutron rich unstable isotopes using fusion reactions of neutron rich fission products on multi-targets including ^{232}Th with high peak power laser to study the r process [2]. It was also proposed to study the s process and photodisintegration reactions in supernova explosions (γ process) using highly intense neutron pulse provided from laser driven D-T nuclear fusion reactions at the Nuclear Ignition Facility (NIF) in LLNL [3].

We have proposed nuclear experiments using laser driven γ-ray pulses to simulate stellar nuclear photoreactions [4]. We have proposed new concepts of three types of experiments using laser driven γ pulses with stellar energy distribution. First, the direct measurement of the stellar (γ, n) reaction cross section on the ground state of atomic nuclei using γ-ray pulse with stellar distribution. Second, the direct measurement of the (γ, n) cross section on exited states. As shown in Fig. 1, the main target is irradiated by the first laser and the nuclei are exited in plasma generated by the laser; the second laser irradiate the target to generated γ-ray pulse with stellar energy distribution. Third, the direct measurement of the transition probability between the ground state and an isomer of astrophysical interest via (γ, γ') reactions using the γ-ray pulse generated by the high peak power laser. An important point to consider in these methods is the generation of γ-ray pulse with energy distribution approximately identical with stellar photon distribution. We have concluded that it is possible to generate Planckian γ-ray pulse by bremsstrahlung on the solid gold target with electron beams with continues energy distributions generated by the laser plasma.

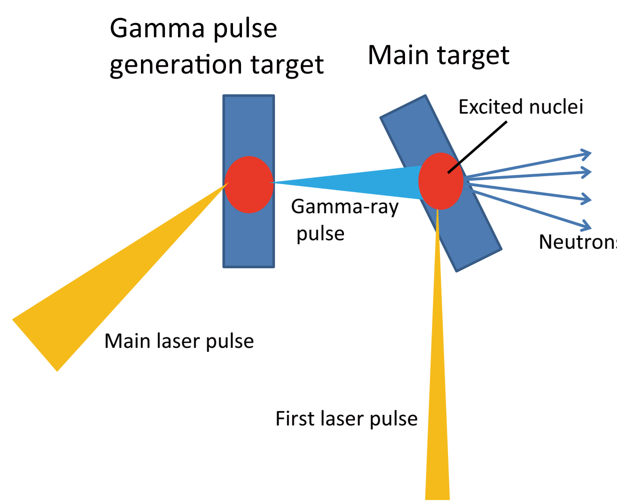

Figure 1: Schematic view of experiment.

References

[1] Barbui, M., et al.: 2013, *Phys. Rev. Lett.*, **111**, 082502.
[2] Habs, D., et al.: 2011, *Applied Physics B*, **103**, 471.
[3] Berstein, L., et al.: 2014, *Plasma and Fusion Research*, **9**, 4404101.
[4] Hayakawa, T., et al.: 2017, *Quantum Beam Science*, **1**(1), 3.