§21. Development of Compact Neutron Camera with Nuclear Emulsion for Energetic-ion Profile Diagnostics

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During neutral beam injection heating of magnetically confined deuterium plasma, DD fusion reaction is caused by energetic deuterium ions. The emission profile of fusion neutrons, 2.5 MeV neutron from DD reaction (DD neutron) is dominated by energetic ion in fusion plasma. Based on state-of-the-art nuclear emulsion technique, we have proposed a compact neutron pinhole camera using the nuclear emulsion as a complemental neutron profile monitor for deuterium plasma experiment planned in LHD. Toward an experimental demonstration of fusion neutron imaging using the neutron pinhole collimator, we investigated point-spread function of the neutron pinhole camera consists of a pinhole collimator made of tungsten alloy and stacked nuclear emulsions.

We evaluated the point spread function of the pinhole imaging system using accelerator based 14 MeV DT neutron point source at Fusion Neutron Source (FNS), Japan Atomic Energy Agency. Figure 1 shows the experimental setup at FNS. The pinhole camera was set up at 1150 mm far from a water-cooled tritium-storage target of 80 degree beam line of the "First Target Room". 400 kV deuterium ion beam was injected into the tritium-storage target and generate DT neutron with neutron yield of 10^{11} n/s. In this experiment, we used a nuclear emulsion, OPERA film. The stacked nuclear emulsions with 10 layers were irradiated for 3 minutes behind of the pinhole collimator made of tungsten alloy. After irradiation, the emulsions were developed to make visible image of tracks.The tracks of recoiled proton in the nuclear emulsion were then analyzed by a nuclear emulsion analyzing system, which is called "S-UTS". Note that we only analyze central 4×4 cm region of the emulsion in this experiment. Reconstructed image at the source position was obtained by the back projection method in which the incident angle of neutron was estimated by the starting point of the tracks of recoiled proton in the nuclear emulsion and the center of the pinhole. Figure 2 shows the reconstructed image of DT neutron at the source position. Here, volume of the DT neutron source was negligible compared with its spatial resolution. The FWHM in the profile as a spatial resolution was estimated to be 17 cm. The effective pinhole size for DT neutron d_e was evaluate to be 17×5/(5+115) = 7.0 mm, which was by a factor three larger than that for DD neutron.

Using the pinhole camera, we intend to demonstrate the DD neutron imaging using the accelerator based 2.5 MeV DD neutron point source at FNS to investigate its applicability for planned deuterium experiment at LHD and also DD neutron measurement at Korea Superconducting Tokamak Advanced Research (KSTAR) at National Fusion Research Institute, Republic of Korea.

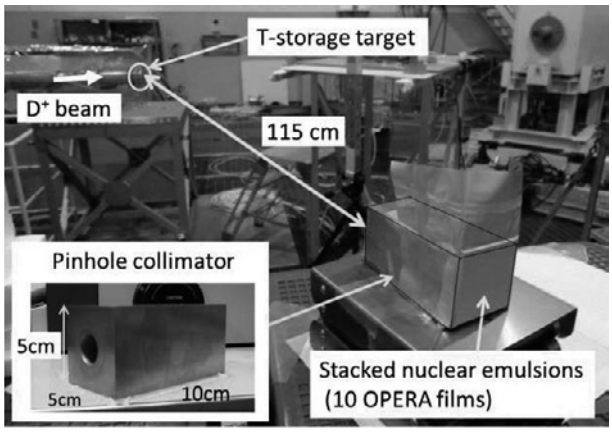

Fig. 1 Experimental setup at FNS

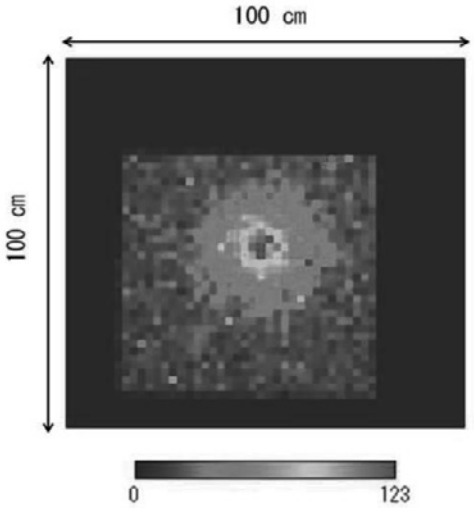

Fig.2 Reconstructed image of DT neutron at the source position

[List of Publications]

1) H. Minato, Y. Sakai, H. Tomita, K. Morishima, M. Isobe, Y. Yamamoto, F. Yamashita, K. Ogawa, J. Kawarabayashi, T. Nakano, M. Nakamura, and T. Iguchi, "Development of fusion neutron imaging by neutron pinhole camera with stacked nuclear emulsions", 6th Japan-Korea Seminar on Advanced Diagnostics for Steady-State Fusion Plasmas, **J-02**, Seogwipo Training Center of Jeju National University, Korea, Aug. 22 – 25, 2012.
2) H. Minato, Y. Sakai, H. Tomita, K. Morishima, M. Isobe, Y. Yamamoto, F. Yamashita, K. Ogawa, T. Nakano, M. Nakamura, Jun Kawarabayashi, T. Iguchi, and MunSeong Cheon, "Development of 2.5 MeV Neutron Imaging using Stacked Nuclear Emulsions for Energetic Ion Diagnostics", 22nd International Toki Conference **P1-43**, Ceratopia Toki, Toki-city, Gifu, Japan, Nov. 19-22, 2012.
3) H. Tomita, F. Yamashita, Y. Yamamoto, H. Minato, K. Morishima, Y. Sakai, M. Isobe, K. Ogawa, T. Nakano, M. Nakamura, J. Kawarabayashi, T. Iguchi, K. Ochiai, MunSeong Cheon, "Development of Fusion Neutron Pinhole Imaging using Nuclear Emulsions for Energetic Ion Diagnostics" Plasma Fusion Res. (*accepted*).