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An Accelerated Beam-Plasma Neutron/Proton Source and Early Application of a Fusion Plasma

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The inertial electrostatic confinement (IEC) fusion device employs a scheme for injecting energetic ions and electrons towards the spherical center of the IEC, trapping both species in the electrostatic self-field, giving rise to fusion reactions in the dense core. The IEC can be realized using a relatively simple device that employs a grid in a spherical vacuum vessel. The ions are produced with a glow discharge between the vacuum vessel (serving as the spherical anode) and the concentric-sphere inner grid cathode. The ions are accelerated and focused inwards the cathode. Some ions hit the mesh cathode producing secondary electrons, which are then accelerated towards the core region by the electric field generated by the ions. The electrons partially neutralize the space charge of the ions and play a role for increasing the ion density in the core. Under proper conditions (perveance > 0.4 mA $kV^{-3/2}$), a virtual anode/cathode structure develops in the high density center region, trapping energetic ions and further increasing fusion reaction rates.

The IEC offers an unique approach to a fusion, since it develops a possibility of the use of advanced fuels such as D-^3He, and yields intermediate products along the path to fusion power. The IEC is used as a portable, low-cost fusion neutron source with applications expected as follows[1]-[3]: (1) search for oil field, (2) therapeutic treatment of cancers, (3) testing drugs and explosive materials for safeguards, (4) identification of impurities in ores/coal, and (5) neutron source for benchmark testing.

Typical plots of measured neutron yield versus discharge current are shown in Fig.1 for different discharge voltages. The neutron yield increases linearly with current and scales strongly with voltage, in agreement with the theoretical estimation of fusion events between the beam ions and the background neutral particles. The scaling with voltage is fairly stronger than the variation of the fusion cross-section with energy. Figure 2 depicts the neutron generation rate divided by $n_0 n_i \sigma_{DD} v$, i.e. $S = \dot{N}_n / p I \sigma_{DD}$ versus discharge voltage V, where n_0 and n_i the densities of neutral gases and ions, σ_{DD} the fusion cross section, v the velocity of ions, $\dot{N}_n$ the neutron yield, p and I the neutral gas pressure and discharge current. It is revealed that the parameter S possesses the $V^{3/2}$ dependence. The excess dependence on voltage is interpreted as follows. The core ion density raised through the effects of potential structure produced by the ion space charge brings about a larger neutron yield than without any potential.

The key physics issues that must be understood in order to scale the IEC up to higher reaction rates involve the electric potential structure in the dense plasma core.[4] In order to identify the spatial profile of the fusion events and the electrostatic potential profile in the core of the spherical IEC, the fast proton source profile due to D-D fusion reactions has been measured using a well-collimated solid-state detector.[5] Collimated protons were detected by a silicon-surface barrier diode covered by a metal plate/channel configuration with a pin hole. This experiment has confirmed the development of a double-well potential structure, capable of trapping energetic ions, when the threshold perveance of 0.4 mA $kV^{-3/2}$ is exceeded.

Results for collimated proton measurements of the potential will be described in the presentation. Based on these results and on corresponding theoretical studies, underlying physics issues related to scale-up of the IEC to higher neutron levels or eventually, a power reactor, will be discussed. Technological issues related to scale-up such as grid design[6] will also be briefly covered.

References:

[1] M. Ohnishi, Y. Yamamoto, M. Hasegawa, and K. Yoshikawa, "Inertial Electrostatic Confinement Fusion Neutron Source R&D and Issues," American Nuclear Society Trans., Vol. 77, p. 503, Albuquerque, NM, Nov. 16-20, 1997.

[2] G. Miley, "Small Neutron Sources and Their Applications-I," American Nuclear Society Trans., Vol. 77, p. 305, Albuquerque, NM, Nov. 16-20, 1997.

[3] G. Miley and J. Sved, "The IEC Plasma Target-Based Neutron Source," App. Radiat. Isot., No. 48, No. 10-12, pp. 1557-1561, 1997.

[4] M. Ohnishi, K. Sato, Y. Yamamoto, and K. Yashikawa, "Correlation Between Potential Well Structure and Neutron Production in an Inertial Electrostatic Confinement Fusion," Nuclear Fusion, October 18, 1996.

[5] G. Miley, Y. Gu, M. Ohnishi, Y. Yamamoto, M. Hasegawa, and K. Yoshikawa, "Potential Well Structure and Scaling Studies for IEC," Int. Sherwood Fusion Theory Meeting, Madison, WI, April 23-26, 1997.

[6] L. Chacon, J. DeMora, G. Miley, "Engineering Issues of Gridded Inertial Electrostatic Confinement," Symposium of Fusion Energy, San Diego, Oct. 6-10, 1997.

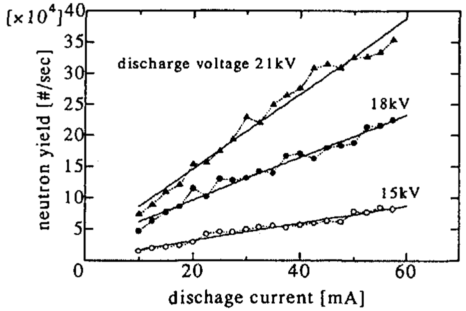

Fig.1 Neutron yield vs. discharge current.

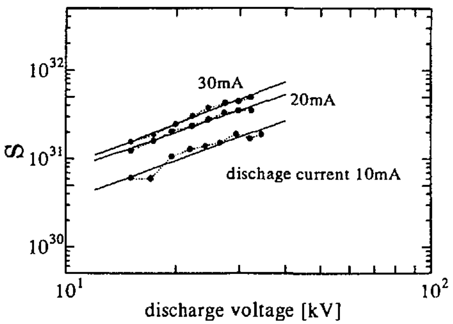

Fig.2 Excess V dependence of neutron yield.