Discharge-Driven Neutron Generation: Exploration and Application

L. Saikia[1], S. R. Mohanty[1,2], N. Bharali[1], S. Kalita[1], and M. K. D. Sarma[1]
[1] Centre of Plasma Physics-Institute for Plasma Research, [2] Homi Bhaba National Institute
e-mail: lucky.saikia@cppipr.res.in

This study explores the enhancement of neutron generation in Inertial Electrostatic Confinement Fusion (IECF) devices through the development of a modified IECF configuration, with the generated neutrons being utilized for Neutron Activation Analysis (NAA). IECF devices operate by accelerating deuterium ions toward a central cathode grid, where ions oscillate and collide with each other or gas atoms, leading to fusion and neutron release [1]. Deuterium-deuterium fusion produces 2.45 MeV neutrons per reaction. Although single-grid IECF systems are compact and simple, they suffer from low neutron output and short ion confinement times, limiting their portability. Factors like ion density, gas pressure, and collisions influence confinement and neutron yield [1,2]. To address these limitations, a triple-grid configuration is introduced, supported by both simulations and experiments.

Simulations are conducted using the XOOPIC code (2D-3V) show that the triple-grid configuration creates narrow, focused ion beams, which reduces energy loss and results in more than a 50% improvement in ion confinement time [3]. The simulations also indicated that the triple-grid design produced a distinct electric field structure, resembling a "hill" around the cathode, in contrast to the broad "valley" seen in the single-grid configuration. This new setup effectively maintained the ions at the center of the device, thereby increasing the likelihood of fusion [3, 4].

Experiments are conducted to evaluate neutron production in a triple-grid IECF configuration and its potential applications. The new setup achieves a tenfold increase in neutron yield, producing approximately 10^8 ns^{-1} compared to 10^7 ns^{-1} from the traditional system, while operating below 1 kW. To assess its practical use, NAA is performed on a 100 g cement sample. After five minutes of neutron exposure, a gamma ray detector identifies elements such as calcium, magnesium, cesium, strontium, and trace amounts of hazardous elements like protactinium and antimony. These findings confirm that the device generates a sufficient neutron flux, making it suitable for material analysis and environmental monitoring. The results highlight the triple-grid IECF's promise as a compact neutron source for applications in medical isotope production, material testing, nuclear diagnostics, and fusion research. Future work focuses on optimizing grid design, increasing output, and integrating advanced diagnostics.

References

[1] G.H. Miley, S.K. Murali, Inertial electrostatic confinement (IEC) Fusion, Springer, 2014.

[2] N. Buzarbaruah, S.R. Mohanty, E. Hotta, A study on neutron emission from a cylindrical inertial elerostatic confinement device, Nucl. Instrum. Methodes Phys. Res. A 911 (2018) 66–73.

[3] L. Saikia, S. Adhikari, S.R. Mohanty, D. Bhattacharjee, Improvement in ion confinement time with multigrid configuration in an inertial electrostatic confinement fusion device, Phys. Rev. E 110 (2024) 1–10, 015203.

[4] C.C. Dietrich, "Improving particle confinement in inertial electrostatic fusion for spacecraft power and propulsion," Ph.D. thesis (Massachusetts Institute of Technology, Cambridge, MA, 2007).