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ECR assisted ICRF plasma production in ADITYA-U tokamak

Kishore Mishra[1,2], J. Ghosh[1,2], K. M. Patel, K. A. Jadeja, S. Kumar, H M Jadav, R. Kumar, R. Tanna, K. Singh, H. Raj[1,2], B. Kadia, K. M. Parmar, M. Singh, N. Ramaiya, M. B. Chowdhuri, S. Aich, R. Joshi, D. Rathi, A. Varia, R. P. Yadav, G. Ashok, B. Hegde, A. Kumawat
[1] Institute for Plasma Research, [2]Homi Bhabha National Institute (HBNI)
e-mail (speaker): kmishra@ipr.res.in

Plasma start-up with assistance of preionized plasma has long been recognized as a fundamental requirement for a successful and controlled plasma current ramp up. Requirement of preionization is more prominent in superconducting continuous vessel machines, where available electric field (loop voltage) to initiate breakdown is severely limited. The Spherical Tokamak (ST) based concept also have limited central solenoid space, and hence available loop voltage is also small. While Gyrotron based Electron Cyclotron Resonance (ECR) breakdown is the most successful and utilized preionization method in fusion devices for low loop voltage start-up, alternative methods of preionization are also being developed for a long time. Ion Cyclotron Resonance Frequency (ICRF) plasma production is one such case, where successful plasma production in the vessel and its usefulness in wall conditioning and low loop voltage start-up has been demonstrated in several machines [1-3]. Though, ICRF system is present in almost every machine, achieving successful plasma production through ICRF alone is not guaranteed.

Unlike ECR, plasma production through ICRF antenna is not a resonant phenomenon. ICRF plasma is produced if the matched oscillation of stray electrons under the influence of high frequency electric field around the antenna and supported by ponderomotive potential created by it along with surrounding metallic components are met with favorable condition of neutral density, local error field, and RF electric field. For example, the ICRF antenna that was used to produce successful plasma in Aditya torus, could not form plasma when the vacuum vessel is upgraded to Aditya-U machine even under an expanded operational regime. A RF electric field modelling indicated that the revised antenna vessel wall distance in old and new machine, modified the RF electric field and thus prevented a successful breakdown. Considering the unalterable nature of the RF electric field structure without changing the antenna, one is prompted to ponder: 'Could the introduction of a few seed electrons potentially facilitate the avalanche?'

To investigate this aspect, a 2.45 GHz magnetron, 2kW is used to form plasma in the vessel. The toroidal field (Bt) ~ 876 G corresponding to the EC frequency is created by a programmable DC power supply before applying EC pulse. Hydrogen fill pressure is kept between $4x10^{-5}$ torr to $2x10^{-4}$ torr. No vertical field or error compensating field is applied in this set of experiments. After ECR plasma is formed, ICRF power 40-80kW, 36MHz is applied to the antenna and promptly plasma is formed near the antenna and filled the torus both toroidally and radially. Once it is formed, ICRF plasma continues to remain as long as ICRF power is applied independent of ECR plasma. The minimum required overlapping time period between EC and IC pulses is found to be ~30ms and minimum power required is 200W. The location of ECR is varied to investigate the effect on ICRF plasma formation at similar conditions. It is observed that, ECR should not be very near to the antenna as it detunes the RF source and leads to high reflection. The ICRF plasma could be produced by keeping ECR even at high field side wall.

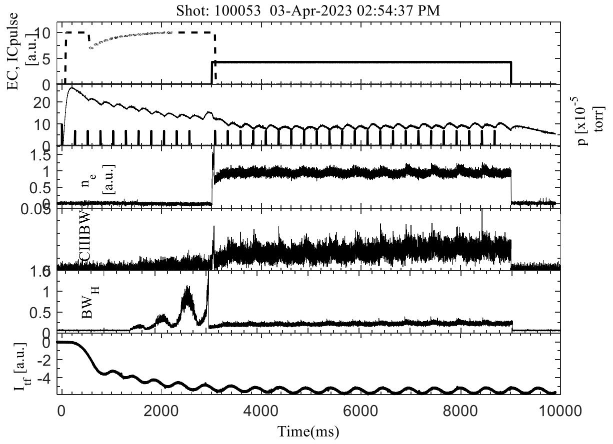

Figure-1: EC pulse is followed by IC pulse with 30ms overlapping. Density is measured near IC antenna, Visible light and Hα emission during EC and IC phase.

Since the operating Bt for 2.45GHz is one order lower than tokamak operation including the present machine, the next obvious objective is to produce and sustain ICRF plasma during the Bt ramp-up phase. This scheme could also be useful for ICRF wall conditioning utilizing both ramp-up and ramp down phases of Bt during each plasma discharge. This scheme may be developed and utilized, where EC cannot be used due to restriction of operating Bt.

References

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