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EX/P2-11: Non-inductive Plasma Initiation and Plasma Current Ramp-up on the TST-2 Spherical Tokamak

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To realize a compact spherical tokamak (ST) reactor, operation without the central solenoid must be demonstrated. In particular plasma current ramp-up from zero to a level required for fusion burn is crucial. Plasma initiation and current ramp-up in ST by waves in the lower-hybrid (LH) frequency range were demonstrated for the first time on TST-2. A combline antenna was used to inject RF power of ~ 100 kW at 200 MHz. Formation of a low current (~ 1kA, mainly driven by pressure gradient) ST configuration can be accomplished by waves in a broad frequency range (21 MHz to 8.2 GHz in TST-2). However, further current ramp-up (to ~ 10 kA, mainly driven by RF) is most efficient with a uni-directional traveling wave in the LH frequency range. Sufficient RF power must be supplied and the vertical field must be ramped up to maintain equilibrium. Plasma current ramp-up to 15 kA was achieved with 60 kW of net RF power. Soft X-ray emission in the direction of electron acceleration by RF wave was enhanced more strongly in the co-drive case (acceleration in the direction to increase the plasma current) compared to the counter-drive case. Hard X-ray spectral measurements showed that the photon flux is an order of magnitude higher and the photon temperature is higher in the co-current-drive direction than in the counter-current-drive direction (60 keV vs. 40 keV). These observations are consistent with acceleration of electrons by a uni-directional RF wave. The combline antenna excites vertical electric fields which match the polarization of the fast wave. There is evidence that the LH wave is excited nonlinearly, based on the frequency spectra measured by magnetic probes in the plasma edge region. While the pump wave at 200 MHz has a stronger toroidal component (fast wave polarization), the lower sideband has a stronger poloidal component (LH wave polarization). The time evolution indicates the tendency of the pump wave toroidal component to weaken when both sideband poloidal and toroidal components intensify. It is expected that the effectiveness of current drive would improve if the LH wave could be excited directly by the antenna. Two types of traveling-wave LH wave antennas will be tested on TST-2, a dielectric-loaded waveguide array, and an array of mutually coupled structure with the electric field polarized in the toroidal direction.

Country or International Organization of Primary Author

Japan

Primary author: Mr TAKASE, Yuichi (Japan)

Co-authors: Prof. EJIRI, Akira (University of Tokyo); Dr MOELLER, Charles (General Atomics); Mr KAKUDA, Hidetoshi (University of Tokyo); Mr FURUI, Hirokazu (University of Tokyo); Dr KASAHARA, Hiroshi (National Institute for Fusion Science); Mr HIRATSUKA, Junichi (University of Tokyo); Dr SAITO, Kenji (National Institute for Fusion Science); Mr KATO, Kunihiko (University of Tokyo); Mr SONEHARA, Masateru (University of Tokyo); Dr WATANABE, Osamu (University of Tokyo); Mr SHINO, Ryota (University of Tokyo); Prof. KUMAZAWA, Ryuhei (National Institute for Fusion Science); Mr HASHIMOTO, Takahiro (University of Tokyo); Mr SHINYA, Takahiro

(University of Tokyo); Mr AMBO, Takanori (University of Tokyo); Prof. MUTOH, Takashi (National Institute for Fusion Science); Mr YAMAGUCHI, Takashi (University of Tokyo); Mr WAKATSUKI, Takuma (University of Tokyo); Dr OOSAKO, Takuya (University of Tokyo); Mr SAKAMOTO, Takuya (University of Tokyo); Prof. SEKI, Tetsuo (National Institute for Fusion Science); Prof. NAGASHIMA, Yoshihiko (Kyushu University)

Presenter: Mr TAKASE, Yuichi (Japan)

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