

§55. Role of Energetic Electrons on Non-inductive Current Start-up and Formation of an Inboard Poloidal Field Null Configuration in the Spherical Tokamak QUEST

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One of key subjects toward steady state operation in a tokamak is to establish a method of non-inductive current ramp up and sustainment. In particular, in a spherical tokamak (ST) such as QUEST, a space at the center column of the machine is fairly limited. For this reason, numerous efforts to develop non-inductive start up scenario by means of radiofrequency (RF) technology are being made intensively in STs [1]. In order to establish the method for non-inductive plasma current (I_p) start up and sustainment in STs, a new start-up scenario has been proposed using electron cyclotron waves (ECWs) at the high ratio of vertical to toroidal fields of 10% at the fundamental resonance layer position R_{res} . Experiments have been carried out in the QUEST at $B_t=0.29$ T ($R_{res}=0.3$ m). Up to 140 kW of RF power (P_{RF}) at 8.2 GHz was injected in the O-mode whose parallel refractive index $N_{||}$ along the magnetic field line is less than 0.4. Since the chamber aspect ratio is 1.33 and 1st-3rd harmonics coexist, electrons can interact with ECWs in the wide region. If $N_{||}$ has an inverse R dependence, the resonance interaction may also occur for $N_{||} \geq 1$.

Figure 1 shows the discharge waveforms of I_p , P_{RF} and flux of hard X-rays. I_p was increased up to 9.7 kA at the fast ramp-up of 84 kA/s and was sustained for several seconds. The line electron density was $\sim 2.5 \times 10^{17} \text{ m}^{-2}$. Plasma with MHD equilibrium characterized by the inboard poloidal field null and $\epsilon\beta_p$ of 1.3 was achieved, where ϵ , β_p are the inverse aspect ratio and poloidal beta value, respectively. Hard X-ray (HX) detectors having detectable energy range from 10 keV to 600 keV were used to investigate the role of energetic electrons on I_p , relativistic interaction with ECWs and contribution to β_p . Both horizontal and vertical distributions of the HX energy spectra are also measured with radial and time resolutions of ~ 80 mm and ~ 6 ms, respectively. HX of which energy is over 50 keV was observed within 10 ms after RF injection and then both HX flux and I_p increase simultaneously.

Figure 2 shows the energy spectrum of HX in steady state. After the phase of start-up, a steady spectrum with effective temperature T_{HX} of ~ 27 keV was observed during the I_p flattop phase. The ration of co- and counter-HX was $\sim 5_{-2}^{+15}$, which is much less than that of the theoretical Bremsstrahlung emission from the mildly relativistic electrons moving in the co-direction, where ‘‘co-’’ is defined as the direction anti-parallel to I_p . If we assume that the energetic-electron density is 10 % of bulk electron density,

β_p due to energetic electrons is consistent with that in MHD equilibrium [2].

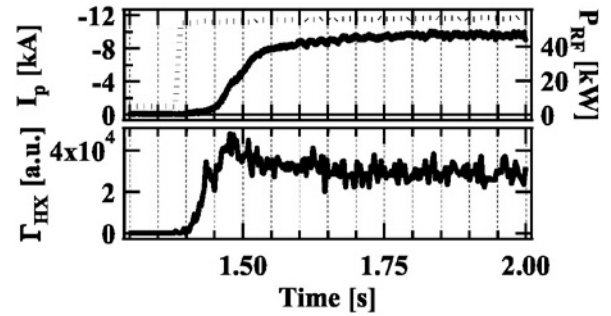


Fig. 1. Discharge waveforms of I_p , P_{RF} , and flux of hard X-rays in QUEST plasma with ECWs ($P_{RF}=140$ kW).

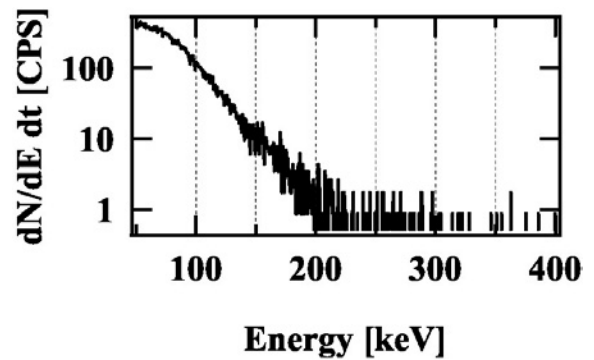


Fig. 2. Energy spectrum of hard X-rays in the steady state phase of QUEST plasma with ECWs ($P_{RF}=140$ kW).

- 1) Hanada, K. et al.: Plasma Science and Technology **13** (2011) 307.
- 2) Tashima, S. et al.: 39th European Physical Society Conference on Plasma Physics/16th International Congress on Plasma Physics, Stockholm, Sweden, 2-6, July 2012. **P1.051**.