# §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

Isobe, M., Tashima, S. (IGSES, Kyushu Univ.), Zushi, H. (RIAM, Kyushu Univ.), Okamura, S., LABCOM Group, QUEST Group (RIAM, Kyushu Univ.)

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 $R_{res1}$. Experiments have been carried out in the QUEST at $B_t$=0.29 T ($R_{res1}$=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 $1^{st}$-$3^{rd}$ 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 ~2.5 x $10^{17}$ $m^{-2}$. Plasma with MHD equilibrium characterized by the inboard poloidal field null and $\varepsilon\beta_p$ of 1.3 was achieved, where $\varepsilon$, $\beta_p$ 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 $\beta_p$. 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 Ip flattop phase. The ration of co- and counter-HX was $\sim 5^{+15}_{-2}$, which is much less than that of the theoretical Bremmsstrahlung emission from the mildly relativisitic 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, $\beta_p$ due to energetic electrons is consistent with that in MHD equilibrium [2].

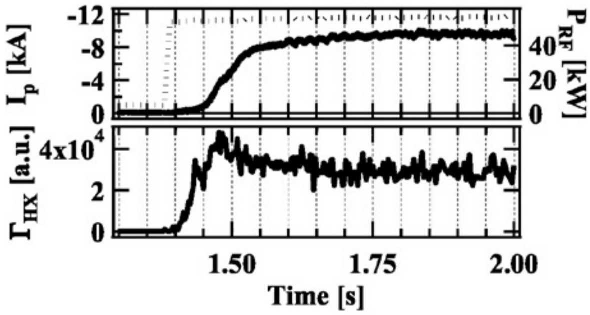


Fig. 1. Discharge waveforms of $I_p$, $P_{RF}$, and flux of hard X-rays in QUEST plasma with ECWs ($P_{RF}$=140 kW).

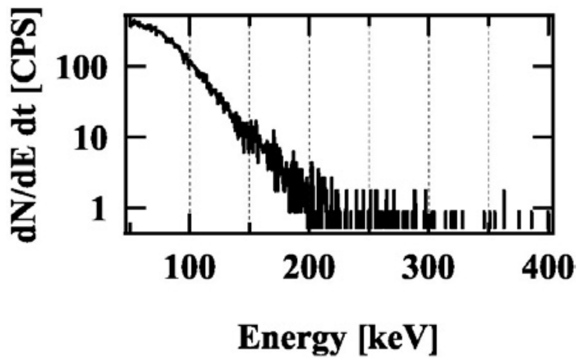


Fig. 2. Energy spectrum of hard X-rays in the steady state phase of QUEST plasma with ECWs ($P_{RF}$=140 kW).

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**.