# §18. Study of RF Generated Fast Electrons and their Behavior in the Low Collisionality Regime

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The purpose of this research is to advance the physics understanding of high energy particles by creating high energy collisionless electrons with large displacements of drift surfaces from magnetic surfaces. Such electrons have large poloidal gyroradii and play important roles in affecting the equilibrium and forming the radial electric field, similarly to alpha particles created in burning plasmas. It is easier to develop understanding of physical mechanisms by studying the behavior of energetic electrons in a simple axisymmetric geometry rather than in a complicated helical geometry.

In the TST-2 spherical tokamak at the University of Tokyo, the tokamak configuration is formed and maintained by the lower hybrid wave (LHW). In such plasmas, high energy electrons dominate the plasma current and plasma equilibrium, and are believed to play an essential role in forming the radial electric field. TST-2 is an ideal device to study this subject and to train the future generation of scientists by advancing this line of research efficiently in collaboration with the LHD group.

TST-2 has an RF generator system at a frequency of 200 MHz capable of producing up to 400 kW of RF power. Experiments are being conducted using a capacitively-coupled combline (CCC) antenna which can excite a traveling LHW with sharp and uni-directional wavenumber spectrum. Up to now, ST plasmas have been successfully formed and maintained at densities of order $10^{17}$ $m^{-3}$ and plasma currents of up to18 kA using RF powers of up to 100 kW. The effective temperature of the observed hard x-ray energy spectrum is about 50 keV, confirming the existence of a large population of high energy electrons. In addition, two electron cyclotron wave (ECW) heating systems (5 kW at 2.45 GHz and 10kW at 8.2 GHz) are available. Plasma currents of up to 2 kW and 4 kW, respectively, have been achieved using these ECW systems. Effects of parallel acceleration (by the LHW) and perpendicular acceleration (by the ECW) can be compared. It is known from previous RF power modulation experiments that the confinement time of energetic electrons is much shorter than the collisional slowing down time. Orbit losses due to the large poloidal gyroradii (several to tesn of cm) of high energy electrons are believed to be dominant. Since the plasma is formed and maintained by RF power alone, and because the plasma density is low, it is clear that high energy electrons are playing a dominant role in these plasmas.

During the fiscal year 2014, optimization of LHW excitation by the CCC antenna was performed. Coupling from the antenna to the plasma was controlled by adjusting the density in front of the antenna by varying the radial position of the antenna protection limiter located on both sides of the antenna. The maximum driven current was increased from 10 kA to 18 kA. Experimentally, a density is observed, above which the current drive effects disappear abruptly. It is found experimentally that sufficient discharge cleaning by inductively driven discharges is important to improve the quality of RF driven plasmas.

In order to obtain tangential sightline coverage over most of the plasma, four tangentially viewing ports have been added to the TST-2 vacuum vessel. A hard x-ray detector system, consisting of a 5-channel NaI(Tl) scintillator array (Leading Edge Co., 5 mm diameter, 20 mm length), compact photomultipliers (Hamamatsu Photonics H10721-110) and optical fibers was developed to measure x-ray emission along five sightlines simultaneously. This system was calibrated for energy response using a radioactive source, and was used to measure both the tangential (toroidal) angular profile.

The arrangement for the tangential profile measurement and the measurement results are shown in Fig. 1. It can be seen clearly that the emission in the co direction (direction to view emission from current carrying high energy electrons) is much stronger than the emission in the counter direction. It is also clear that the emissions detected along the chords viewing the inboard and outboard periphery ($R_{\tan}$ = 130 mm, 516 mm) are stronger compared to the emission for chords viewing the plasma core ($R_{\tan}$ = 271 mm, 402 mm). In addition to this system, another system utilizing avalanche photodiodes is also being developed to realize a more compact system with a higher signal to noise ratio. While a higher efficiency can be obtained with this system, it is found to be more susceptible to RF noise.

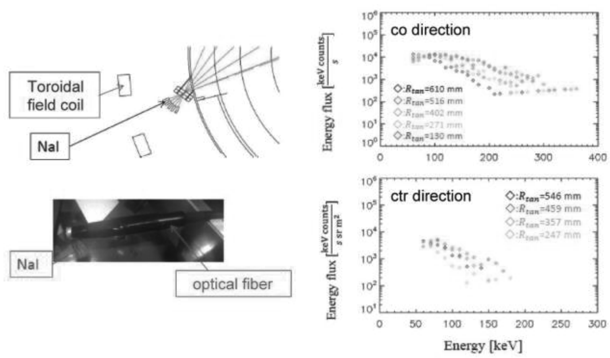


Fig. 1. 6-channel hard x-ray detector array utilizing fiber optics (left) and data obtained using this diagnostic 8right). Emission in the co direction is much stronger than in the counter direction, and emission along outer chords ($R_{\tan}$ = 130 mm, 516 mm) are stronger than central chords ($R_{\tan}$ = 271 mm, 402 mm).