§28. Development of Profile and Turbulence Diagnostics for Improved Confinement Studies in Heliotron-J

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In order to untangle the complexity related to the dynamics of improved confinement in a comprehensive manner amongst various toroidal confinement systems, we have been undertaking the comparative studies of Heliotron-J with LHD and tokamak devices with much emphasis on the spontaneous formation of transport barriers and viscous damping of sheared flow in the edge, in addition to the influence of rational surfaces and magnetic topology. In particular, as an effort related to resolving the geometrical structure of turbulence that may govern the anomalous transport in various discharges, an exploratory 3-D fluctuation correlation reflectometer has been newly proposed for application in Heliotron-J, and rudimentary experiments have been performed in 2007. As it is fundamental to simultaneously acquire the profile information as detailed as possible, the designed AM reflectometer shown in Fig.1 is equipped with the broadband frequency sweep capability in Q-band (33-50GHz).

The anticipated time and spatial resolutions are respectively 1ms and 1-2 mm., and the X-mode system was employed to cope with hollow density profiles. Accordingly, the observation range is extended from -0.7 to 1.0 in ρ for n_{co}=1x20^{19}m^{-3}. The phase resolution is 0.25 degrees, and the 1st IF frequency of 100MHz and sweep frequency of 1kHz was chosen in our work. In addition, the VCO signal is fed into the active multiplier (Millitech Model AMC-22-R0000), in order to improve the conversion efficiency. Furthermore, the fundamental waveguide was mainly used to reduce the spurious components in the transmission line, considering the frequency sweep. The final IF signals are lead to the heterodyne quadrature detection circuitry, which is less vulnerable to the fringe loss, following the conventional schemes.

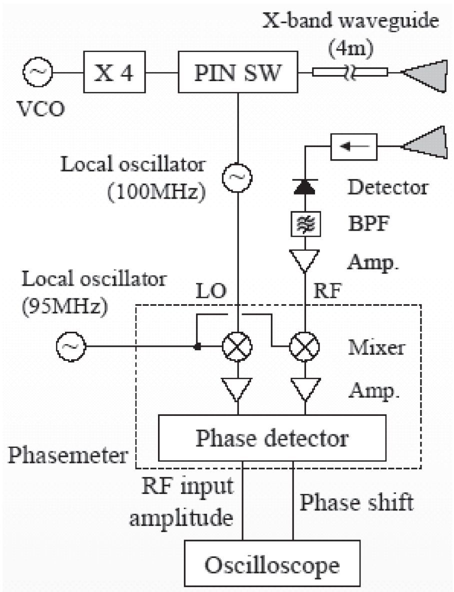

Fig.1 Schematics of the AM broadband reflectometer with frequency sweep and quadrature circuit.

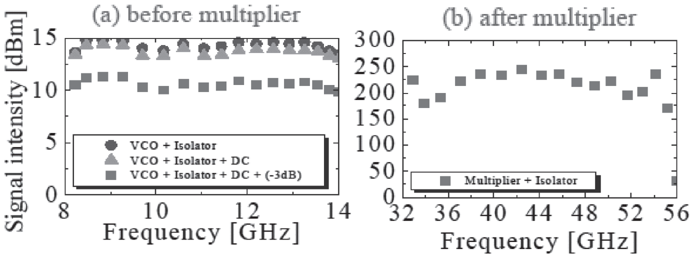

Fig.2 (a) The frequency characteristics of the VCO output frequency and (b) multiplied components.

The frequency characteristics of the VCO output signal and its multiplied components are shown in Fig.2(a) and (b), respectively. In comparison with BWOs, it is clear that a substantially flat nature over the whole band was observed. The insertion loss of the PIN modulator was as small as 5dB.

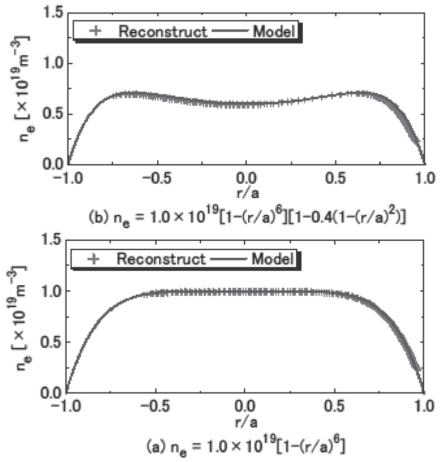

Fig.3 The reconstructed density profiles from the calculated phase data for the (a) flat and (b) hollow cases.

The profile reconstruction software has also been developed and numerically examined. Fig.3 depicts the density profiles reconstructed using the Abel inversion of the calculated group delay for given profiles. It is obvious that the profiles are well reproduced, although the resolution is somewhat degraded in the edge.

The actual phase data detected with the quadrature circuit was examined using the delay line as well as the metallic reflector, the result of latter after calibration is shown with the calculated values in Fig.4.

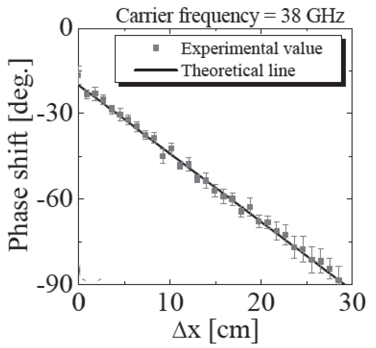

Fig.4 The detected phase data in the bench test after calibration