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Determination of the fast electron distribution on HT-7 tokamak

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Abstract: Fast electron bremsstrahlung emission during lower hybrid current drive experiments on the HT-7 superconducting tokamak has been measured by a recently developed tangential hard x-ray diagnostic based on CdTe detectors. There are 14 sight lines set to observe the forward parallel emission of fast electron with spatial resolution of 4cm and 6 sight lines set to observe the backward parallel emission of fast electron with spatial resolution of 8cm. The fast electron bremsstrahlung in the energy range of 30keV to 400keV can be measured. In this paper, the tangential hard x-ray diagnostic is described, the behaviors of fast electron bremsstrahlung are presented.

1. Introduction

The achievement of steady state operation and long pulse is one of the major challenges in the tokamak plasma. One of the most effective means to sustain tokamak steady state operation is non-inductive current drive (NICD) by Lower hybrid wave. Lower hybrid current drive (LHCD) as an effective NICD tool has been demonstrated in many tokamaks. Current carrying fast electron are generated by lower hybrid waves through parallel electron Landau damping (ELD) when the resonance condition is fulfilled. The fast electron distribution function is the result of the combined effects as follow: Coulomb slowing down, pitch angle scatting, the radial diffusion, and the acceleration of residual toroidal electric field. Measurement of the fast electron bremsstrahlung (FEB) in the hard X-ray energy range is the most efficient means for the investigation of LHCD experiments in plasma physics. It offer a direct insight of the fast electron tail build up by the LHW and the propagation, absorption of the LHW, the details of momentum dynamics and the relativistic angular anisotropy in the direction of fast electron flow [1,2]. Powerful FEB diagnostics have been developed in many tokamaks like PBX-M [3], and Tore Supra

[4] to assess the LHCD performance.

The main mission of HT-7 is to achieve advanced plasma performance under steady-state condition and to understand relevant physics. LHCD is the main tool for realization of this goal. A tangential FEB diagnostic dedicated to detailed studies of the FEB in the energy range of 30 keV to 400 keV during LHCD experiments has been developed on HT-7 machine. In this paper, the tangential FEB diagnostic is described in section 2, the preliminary results from FEB diagnostic in the HT-7 tokamak are presented in section 3.

2. FEB diagnostic

HT-7 is a superconducting tokamak with major radius R=1.22 m and minor radius a=0.27 m [5]. The schematic view of the FEB system on HT-7 is shown in Fig.1. There are 14 sight lines set to observe the forward parallel FEB with spatial resolution of 4cm from –0.9a to +0.9a, and 6 sight lines set to observe the backward parallel FEB with spatial resolution of 8cm from –0.7a to +0.9a. The CdTe detector has the desirable virtues for diagnosing of tokamak plasma: compact size, high stopping efficiency and energy resolution in hard X-ray energy range, fast timing characteristics, no sensitivity to magnetic field.

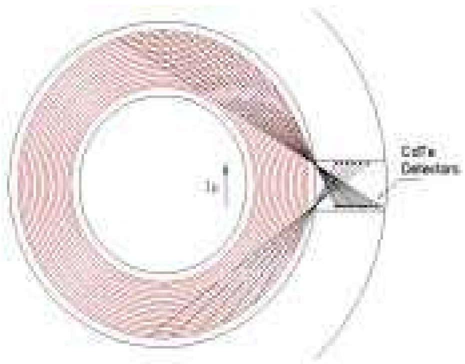

Fig.1 The setup of sight lines for tangential FEB diagnostic on HT-7 tokamak.

Owning to the virtue of no sensitive to magnetic field, the CdTe detectors were arranged inside the port close to the inner wall to achieve tangential full space configurations in spite of no tangential port in HT-7 tokamak. The detecting system used in HT-7 is shown in Fig.2. It was produced by EURORAD company. The preamplifier has two stages, the first stage is directly connected to the detector and mounted in a housing of 20×20×20 mm^3, which can support the vacuum of

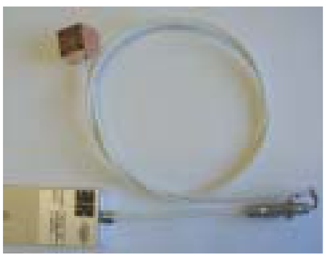
Fig.2 CdTe detector system

10^{-6} Pa. The second stage used outside torus is connected to the first stage by a shielded cable of 1 m length with a metallic airproof connector between them. The collimator is a pinhole with radius of 1mm, and there are also collimators before the detectors with radius of 1.5mm. An aluminum foil with 1mm thickness is arranged on the collimator to cut off the low energy photon. There is 2cm tungsten wall around the detectors to reduce the noise induced by neutrons and γ rays.

Two branches performed the data acquisition are shown in Fig.3. One is standard pulse height analyzer, the other is the flux integrated signal to provide the intensity of FEB with 1ms time-resolution. A multi-channel analyzer (MCA) system has been developed specially for the long-pulse requirements.

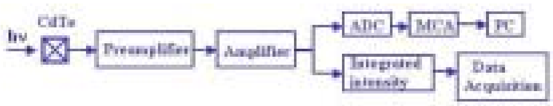

Fig.3 The data acquisition system for FEB diagnostic.

3. Preliminary experimental results

The LHW with parallel refractive index of $n_{//}$=2.35 and power of 100kW ~500kW was operated on HT-7 machine during 2004 campaign. A typical LHCD discharge is shown in Fig.4. The center intensity of FEB from forward parallel and backward parallel was plotted in the figure. By combined the FEB diagnostic and PHA analysis, the photon temperature (T_{ph}) of fast electron can be derived from the FEB spectrum as shown in Fig.5. The T_{ph} is about 70 keV and 20 keV for forward parallel and backward parallel respectively in this pulse, and it is not sensitive to space.

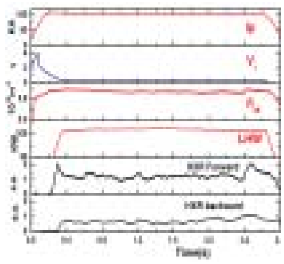

Fig.4 Waveform of LHCD discharge

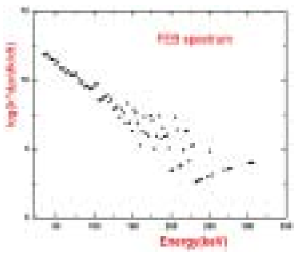

Fig.5 FEB spectrum at 1.5s

The sawtooth activity on FEB signal during current ramp-up experiments by LHW on HT-7 has been observed. Fig.6 is the waveform of current ramp-up discharge on HT-7. The chord integrated signals of FEB were plotted in Fig.7, the FEB intensity has a peaked profile in space during ramp-up phase, the profile of FEB is broaden after ramp-up phase, and a large oscillation was presented in the signal which is well corresponded to sawtooth activity on the soft-x-ray signal. The amplified signals of sawtooth activity from soft x-ray, ECE signal, and FEB during 1.1s to 1.2s were plotted in Fig.8. This showed the ability of tangential FEB diagnostic on studying the dynamics of fast electrons.

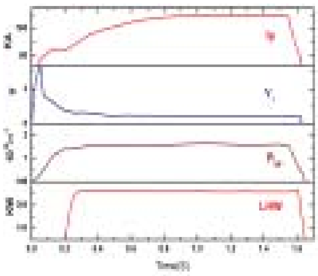

Fig.6 The waveform of current ramp-up discharge

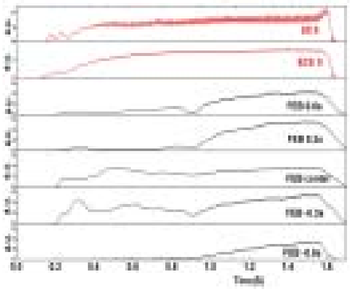

Fig.7 The intensity of FEB in space

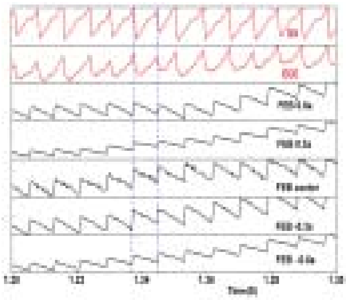

Fig.8 The swatooth activity on the FEB signal

4. Summary

The tangential FEB diagnostic based on CdTe detectors has been developed on HT-7 tokamak to study fast electron behaviors and optimize LHCD scenarios. Owning to the virtue of no sensitive to magnetic field, the CdTe detectors are arranged inside the port to achieve tangential full space configurations in HT-7 tokamak. By combining the FEB diagnostic and PHA analysis, the FEB spectrum is obtained. The profile of FEB intensity by integrated flux is obtained from integrated signal with 1ms time resolution. And the dynamics of fast electron may be studied by flux integration signal which has high time resolution.

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