XA9950794

EXP1/02 (C1+C2)

Part One: Hα Line Shape in Front of the Limiter in HT-6M Tokamak

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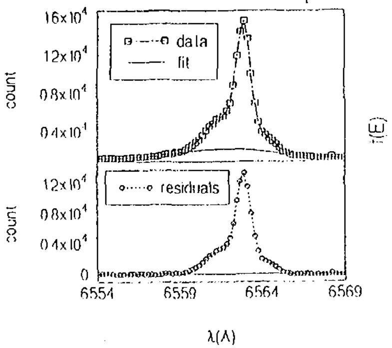
For a better understanding of recycling it is of general interest to know the velocity distribution of neutral particles being recycled at a limiter. It can be derived from the line shape of Hα, Dα for Doppler dominated broadening. In HT-6M Hα spectral line shapes are obtained from observation of particle recycling at main stainless steel limiter. The line of sight is oriented through the plasma center, such that photos from particles moving towards the plasma center are shifted to shorter wavelength and wavelength shift due to plasma rotation is avoided. A typical Hα line shape is displayed in fig.1a. Energy distribution of particles up to 20eV is shown in fig.2. The result shows that particles are dominated by FC (0.3eV), charge exchange (CX) atoms and reflected atoms originating from the limiter surface.

To simplify the interpretation of the characteristic details in Hα line shape, Hα line shape is represented by three Gaussian profiles. Emission of CX atoms is deduced by fitting the Hα line shape in the far wing [1] as shown in fig.1. The FWHM of 6.5Å corresponds ion temperature of 170eV in good agreement with measurements by NPA . The residual shown in fig.2b is fitted by double Gaussian profiles. The first one is from reflected atoms and contributes about 47% of whole Hα emission, corresponding particle reflection coefficient R_N=0.6, comparable to those expected for a clean metal surface (R_N=0.55)[2]. Wavelength shift of -0.7Å, corresponds a bulk velocity of 3.2×10^5m/s. The second one with narrow FWHM from FC atoms contributes 32% of Hα emission, corresponding to 40% of recycled particles.

For typical HT-6M edge conditions with 60% reflected particles and 40% FC atoms, continue equations of particles and a 1D Monte-Carlo simulation reproduce spatial profile of neutral particles derived from multi-channel IF Hα monitoring. Therefore, to lower particle reflection at the limiter surface is an important issue to control recycling in HT-6M tokamak.



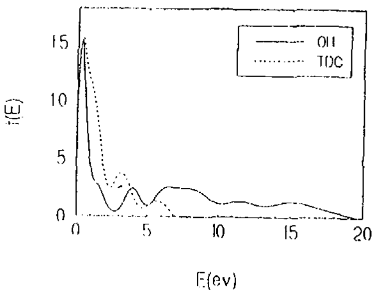


Fig.1 Typical Hα line shape (top) in ohmic discharge. Bottom figure is residual spectrum after emission of charge exchange is subtracted.

Fig.2 Energy distribution of neutral H atoms derived from Hα line shape shown in fig.1. The result obtained in TDC is shown as broken line.

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2). R.Behrish and W.Eckstein. Physics of Plasma-Wall Interactions in Controlled Fusion, Eds. D.E. Post and R.Behrish (Plenum, New York, 1986)

Part Two: Current Relaxation and its Roles in Improved Confinement

In HT-6M tokamak, a mode of an off-axis LHCD with help of second LHW heating was found to be very effective to control current density profile and get improved confinement [1] indicated by dropped loop-voltage, increased plasma current and common features in confinement improvement. The plasma current increases from 60kA to 70-90kA by LHCD and LHH depending on target plasma and power and $N_\parallel$ of LHW. The MHD and fluctuation is suppressed substantially at the onset of Hα dropping. SX radiation shows a complicated behavior such as giant, double, triplet sawteeth, which are relevant to current density profile.

Code simulation shows LHW can produce off-axis current drive in high electron density[1]. Most power of LHW deposits in radial region of 0.3a-0.6a. Both multi-channels HX monitoring and HX PHA toroidal scanning oriented tangentially to electron current show off-axis energy deposition of LH waves. Current density profile can be significantly modified with typical current increment of 20kA by LHW. Formation of reversed shear in half radius and large gradient out half radius in plasma current can be expected. As a result of off-axis current increment, instabilities due to tearing mode cause double or triplet sawteeth in SX radiation [2] depending on position and fraction of current produced by LHW. Typical examples are shown in fig.1. Normally, multi-sawteeth in SX radiation occur at 30-60ms after decreasing of the Hα radiation, which is in order of time scale of resistive diffusing from 0.5a to plasma center. It is also in time scale of electron temperature relaxation as shown in fig.1. Sustain of improved confinement is relevant to LH heating producing higher electron temperature and prolonging current diffusion. Clear evidence was found that developing of MHD corresponding an unfavour current density profile terminates the improved confinement.

Observations by a varity of diagnostics show that current density profile produced by off-axis LHCD and LHH and its relaxation and roles in confinement improvement are strongly correlated. The current relaxes in time scale of resistive diffusion. It governs performance of improved confinement and relevant behaviors.

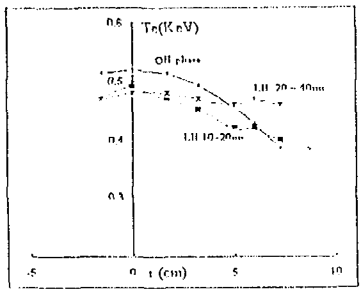

Fig.2 Electron temperature profiles

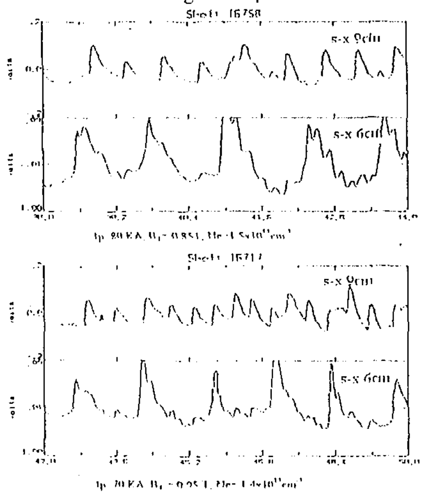

Fig.1 Typical waveforms of double and triplet sawteeth in SX radiation observed in off-axis LHCD and LHH.

1). J.Li et. al. "Quasi-steady State High Confinements at High Density by LHCD in HT-6M Tokamak" IAEA-F1-CN-69-CDP-15
2). W.Pfeiffer. Nucl. Fusion 25 (1985) 673