Charge Exchange Spectroscopy (CXS)

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1. Objective

Measure radial profiles of ion temperature, poloidal/toroidal rotation velocities, and impurity density (carbon or helium) using charge exchange collisions between neutral beam and impurities.

2. Appratus

2.1. Abstract

Charge eXchange Spectroscopy (CXS) system consists of diagnostic beam, object lens, optical fiber bundle array, spectrometer, CCD detector and controllers. The charge exchange collisions between fully ionized ions of light impurity (typically C6+) and hydrogen beam result in an excited ion with one more electron (C5+ (n=8)) and ion temperature, plasma rotation velocity and impurity density are inferred from the Doppler shift broadening, Doppler shift, and line intensity of CVI (n=8-7). Neutral beam (NB) with the beam energy of 40keV injected from the 5O port is used as a diagnostic beam. The NB is modulated (typically at 10Hz with 80ms beam-on 20ms beam-off) to subtract the background emission due to the charge exchange collisions between fully ionized ions and thermal neutral at the plasma periphery.

There are optical systems to measure toroidal and poloidal rotation velocity. The optical fibers of the toroidal system are installed at 7T port inside the beam line of NBI #3 base on negative ion source with 160- 180 keV, where the change exchange collision can be negligible. The optical fibers of the toroidal systems are also installed at 6O port and 9O port.

The optical fibers of the poloidal system are installed on the 5O port and view the plasma in poloidal direction with curved minor set inside the vacuum vessel. NBI #4 is used as the diagnostic beam for the lines of sight at 7T, 6O, and 5O port. NBI #5 is used as the diagnostic beam for the lines of sight at 9O port.

These optical fibers transmit the light of charge exchange line from each port to the junction panels in a diagnostic room. The measured position in the poloidal/toroidal view can be changed by selecting the optical fibers on the junction panels and connect to the spectrometers.

2.2. Spectrometer and CCD systems

There are four systems with different spatial resolution and time resolution for ion temperature measurements. The system with high spatial resolution provides 50 channels in toroidal view and 25 channels in poloidal view with time resolution up to 20Hz. The systems with high time resolution provides 8 - 32 channel depending on number of binning fibers with the time resolution up to 200 or 400Hz.

(a) System with high spatial resolution

System Name: lhdcxs7

Detector: CCD with Electron Multiplier;

ANDOR Model: DU-888D-C00-#BV;

1024(W)x1024(H) pixels with a pitch of 13um.

Repetition Time: > 50msec (no exposure during the readout time of 20msec)

Bundle fiber array: fiber diameter 200 micron

50x2 channels with double slit with an internal interference filter

50x1 channel with single slit

(Effective numbers of spatial channels is 50 in toroidal and 25 in poloidal view)

Spectrometer: Focal length = 400mm, F/2.8, Grating 2160/mm

(b) System with high time resolution

System Name: lhdcxs6

Detector: Frame transfer CCD with Electron Multiplier;

ANDOR Model: DU-897D-CS0-#BV

512(W)x512(H) pixels with a pitch of 16um.

Repetition Time: > 2.5msec

Bundle fiber array: fiber diameter 200 micron

32x2 channels with double slit with an internal interference filter

32x1 channels with single slit

(Effective numbers of spatial channels are 16 in toroidal 16 in poloidal view with fiber binning)

Spectrometer: Focal length = 400mm, F/2.8, Grating 2160/mm

(c) System with High time resolution with high throughput

System Name: lhdcxs8

Detector: Frame transfer CCD with Electron Multiplier;

ANDOR Model: DU-897E-CS0-#BV

512(W)x512(H) pixels with a pitch of 16um.

Repetition Time: > 2.5msec

Bundle fiber array: fiber diameter 400 micron

16x1 channel with single slit

Spectrometer: Focal length = 400mm, F/2.8, Grating 2160/mm

(d) System for Helium and Hydrogen density measurements

System Name: lhdcxs3

Detector: Frame transfer CCD

PixelVision, Inc. Model: PV652ADVSNR04FGCNNTN

640(W)x512(H) pixels with a pitch of 12um.

Repetition Time: > 5 msec (=Read out time)

Bundle fiber array: fiber diameter 200 micron

16 channel with single slit (8ch for Helium, 8ch for Hydrogen)

Spectrometer: Focal length = 400mm, F/2.8, Grating 2160/mm

(e) System with High time resolution with high throughput for NBI #5

System Name: lhdcxs9 (lhdcxs9a, lhdcxs9b, lhdcxs9c)

Detector: Frame transfer CCD with Electron Multiplier x3;

ANDOR Model: DU-860D-CS0-#BV

128(W)x128(H) pixels with a pitch of 24um (effective pitch is 48um with image zooming (x2)).

Repetition Time: > 1.0 msec

Bundle fiber array: fiber diameter 400 micron

36x1 channels (12 channels per CCD) with single slit

Spectrometer: Focal length = 400mm, F/2.8, Grating 2160/mm

2.3 Figures

(a) Spectrometer

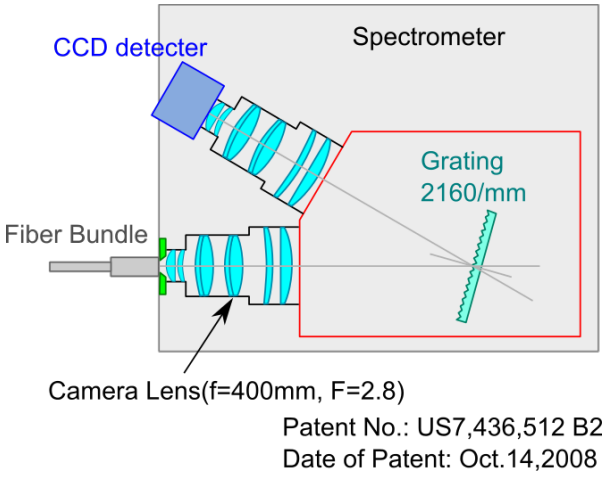

Fig.1: Spectrometer with two F/2.8 camera lenses used for lhdcxs6, lhdcxs7, and lhdcxs8.

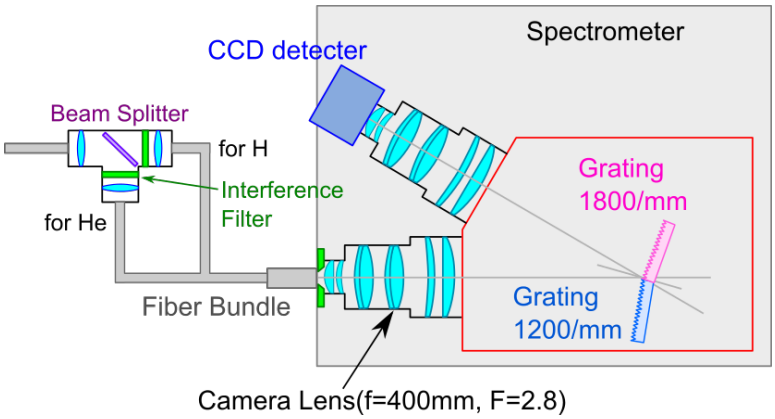

Fig.2: Two wave measurement spectrometer with beam splitter and two gratings used for lhdcxs3.

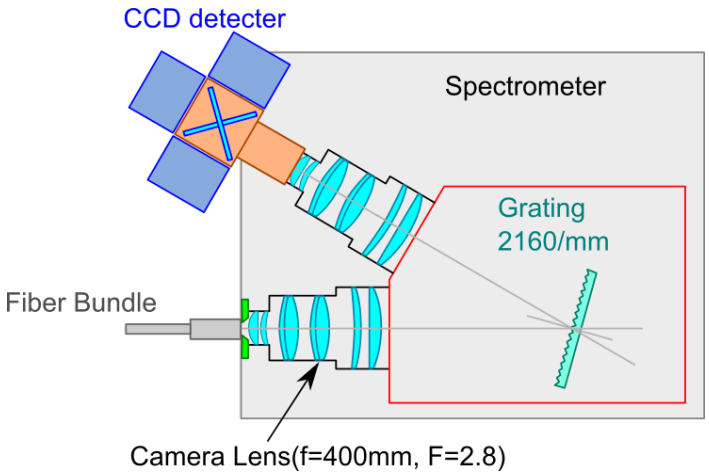

Fig.3: High time sampling spectrometer with three CCD used for lhdcxs9.

(b) Lines of Sight

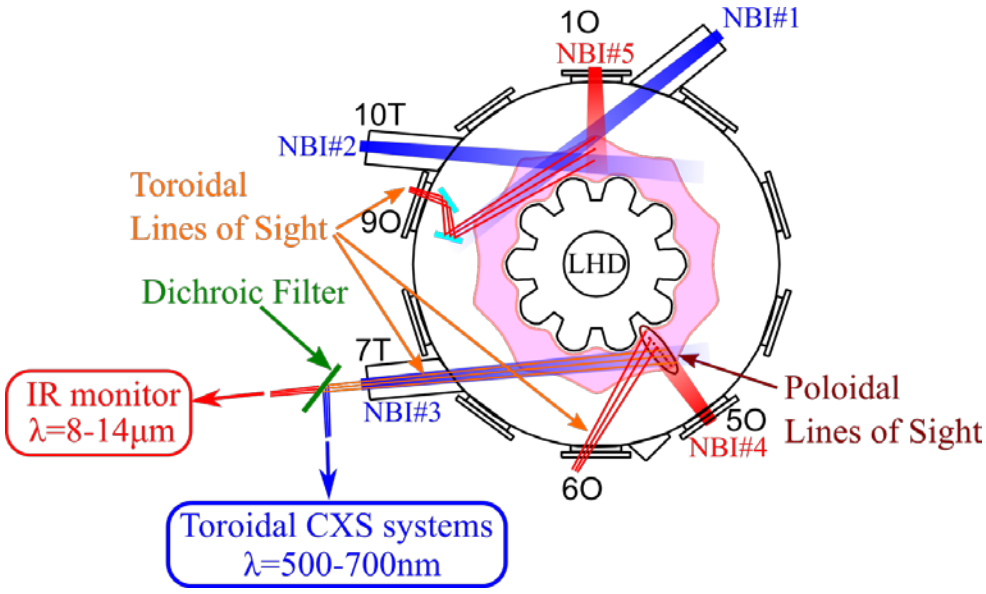

Fig.2 Lines of sight of CXS toroidal view and poloidal view.

3. Operation

3.1. Requirements

Injection of neutral beam as diagnostic beam is required.

BL4 injection is required for 7T and 6O port view.

BL5 injection is required for 9O port view.

4. Diagnostic names of the data on Kaiseki-data server

lhdcxs6_cvi

lhdcxs7_cvi

lhdcxs9a_cvi

lhdcxs9b_cvi

lhdcxs9c_cvi

lhdcxs3_heha

5. Remarks

In the double slit option, the wavelength of the spectrometer should be tuned at 529.05nm, charge exchange line of carbon (CVI). In the double slit fiber measurement, although the wavelength range can be expanded to 400nm-700nm for single slit option

The effective spatial resolution depends on the software fiber binning to improve signal to noise ratio at low impurity concentration.

References

[1] K.Ida et al., Rev Sci Instrum 71 (2000) 2360.

[2] M.Yoshinuma et al., Fusion.Sci.Tech. 58 (2010) 375.