Expanded Capability of the Edge CXRS System on the Joint European Torus

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** See the appendix of M.L. Watkins, et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006).*

ABSTRACT

A new instrument has been added to the Joint European Torus (JET) edge charge-exchange recombination spectroscopy (CXRS) suite of diagnostics. The new instrument consists of a short focal length spectrometer coupled to a fast framing CCD camera. With the addition of this instrument, the number of (predominantly poloidal) sightlines is increased by 20 to a total of 58 views. The radial range of the edge CXRS system extends from $r/a \sim 0.5$ to ~ 1.0. The time resolution of this instrument is improved to 10 ms (signal permitting.) This diagnostic observes simultaneously the neutral-beam induced charge-exchange emission of C VI at 529.1 nm and of Ne X at 524.8 nm, complementing the existing edge CXRS instruments, which can be tuned to observe any wavelength of interest. The entire edge CXRS diagnostic suite has been absolutely calibrated and provides measurements of impurity ion temperatures, as well as the toroidal and poloidal components of impurity ion rotation. An overview of the edge CXRS diagnostic system on JET will be presented. Additionally, preliminary data will be shown from the current JET campaign. In particular, the temporal and spatial improvements afforded by this instrument will provide additional data during the formation of ion internal transport barriers (ITBs) in JET, especially on the relative timing and location of emerging rational-q flux surfaces and poloidal flow spin up. Moreover, the ability to simultaneously measure the poloidal dynamics of multiple ion species (particularly Ne in addition to C) will facilitate "puffed" impurity transport studies.

CXRS SYSTEMS ON JET [1,2,3]

- JET core Charge Exchange Recombination Spectroscopy (CXRS) [1,2] consists of:
  - Two horizontally mounted periscopes (Octants 1 and 7) viewing the heating neutral beams (Octant 8, primarily PINI's 6 and 7)
  - Three vertical views of NBI PINI's and background plasma
  - 44 spatial views/periscope covering from outboard mid-plane to beyond the magnetic axis
  - 7 instruments providing coverage of spectral range from 430 to 750 nm
- JET edge Charge Exchange Recombination Spectroscopy (eCXRS) [3] consists of:
  - Three vertically mounted periscopes viewing the heating NBI PINI's
    - 40 paired views on Octant 4 (20 radial locations)
    - 18 Octant 8 views extending into core region
    - Slight toroidal offset from the NBI's allows for toroidal and poloidal rotation measurements
  - 4 instruments providing coverage of spectral range from 430 to 750 nm

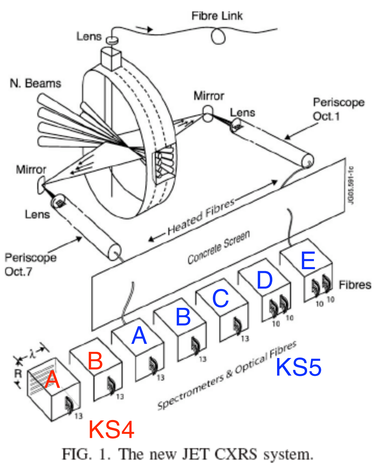


FIG. 1. The new JET CXRS system.

*Figure 1: Fig. 1 from Ref. [1] showing details of the JET **core** CXRS system, viewing Octant 8 neutral beams.*

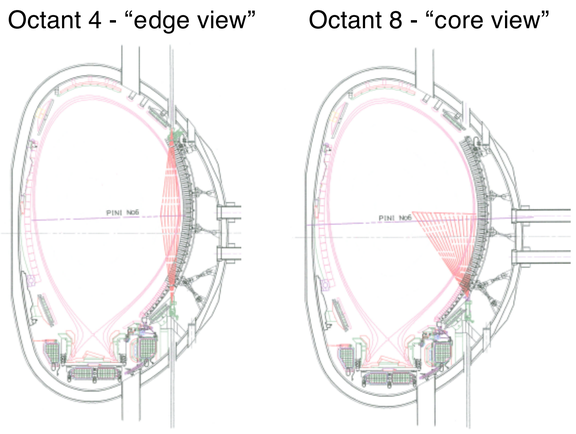


*Figure 2: Line-of-sight coverage of the JET **edge** CXRS system (KS7), viewing Octant 4 and Octant 8 neutral beams.*

NEW EDGE CXRS HARDWARE (KS7D) [4-8]

- New hardware installed and calibrated in 2007
  - Fixed wavelength, complements tuneable system
  - Utilizes "unused" JET views
- Spectrometer [4,5]
  - Kaiser Optical Systems Holospec *f*/1.8
  - 2 curved entrance slits
  - "low dispersion" grating: ~400 nm/mm
    - Center wavelength at 529.1 nm
  - 10 nm BP filter
  - CXRS lines measured simultaneously
    - 529.1 nm C VI, n=8-7
    - 524.8 nm Ne X, n=11-10
- CCD Camera [6]
  - Roper PhotonMax 512
  - 512x512, 16x16 μm pixels, 16 bit depth
  - Thermoelectrically cooled to -70 ºC
  - Binned to 10 "tracks" = 20 views
- Rotary Chopper [7,8]
  - Scitek Instruments 300CD
  - Prevents image "smearing" during CCD read-out
  - 10 ms framing period
- Future Upgrades
  - 5 ms framing period with new chopper tabs
  - "high dispersion" grating: ~125 nm/mm

Figure 3: Photograph of the new KS7D hardware during calibrations at JET.

MEASUREMENTS [9,10,11]

- *Caveat*: Work is ongoing to incorporate this new edge CXRS instrument and the other edge CXRS instruments into the analysis package CXSFit[9], which will facilitate direct comparisons between the "edge" and "core" CXRS measurements on JET.
  - In this poster line-of-sight rotation velocities and apparent temperatures will be shown for the new edge CXRS instrument.
  - Toroidal effects need to be removed from line-of-sight measurements to yield poloidal dynamics.
- Preliminary result indicate good signal levels at 10 ms framing period.
- CX light from both C VI and Ne X ions are observed simultaneously.

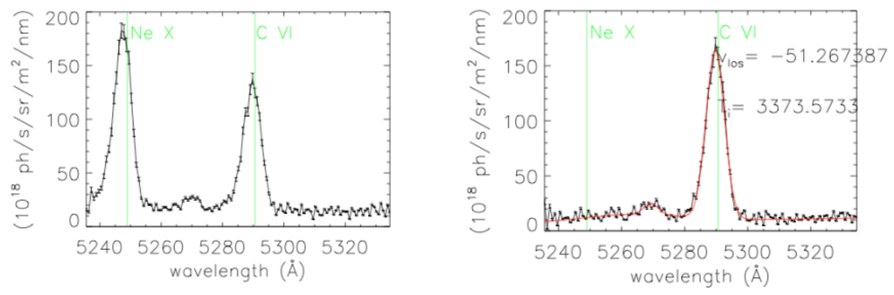
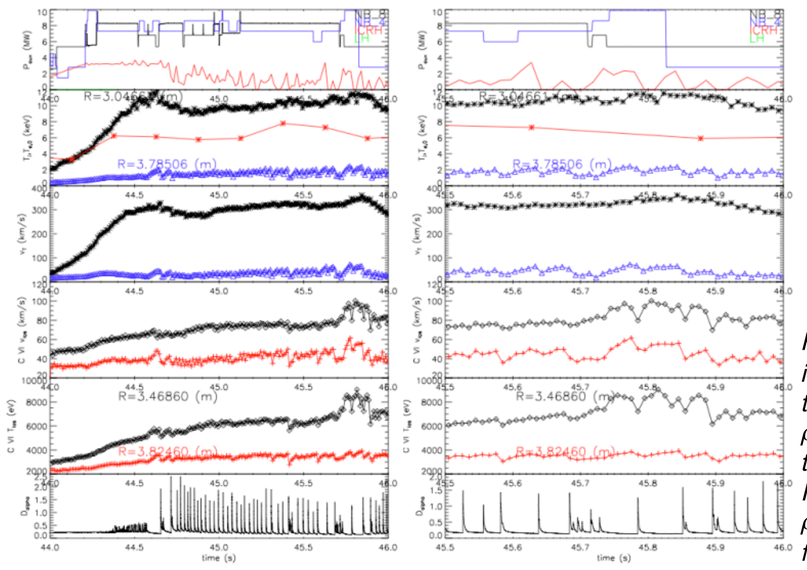


Figure 4: Spectra from the KS7D diagnostic on JET pulse 72428 with and without neon puffing. A gaussian fit to the C VI line is shown (in red) with the resulting line-of-sight velocity and temperature.

- Preliminary results from experiments in the current JET campaign show the presence of ion internal transport barriers (ITBs) in the poloidal dynamics.[10]
  - The 10 ms framing period of the new edge CXRS system now matches the core CXRS system.
  - The effects of individual ELMs can be examined.
  - The relative timing of poloidal flow spin up and the emergence of ITBs can be investigated.



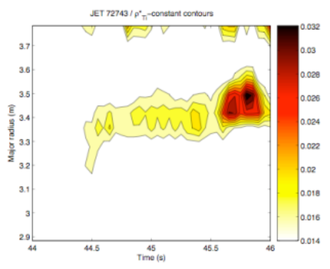


Figure 6: Contour plot of ρ^*_{Ti} in JET pulse 72743, showing the presence of an ion ITB. ρ^*_{Ti} >0.020 is considered the threshold for a "sustained" ITB in JET. $\rho^*_{Ti} = \rho_s/L_{Ti} = (c_s/\omega_{ci})/(\nabla T_i/T_i)$ from Ref. [11].

Figure 5: Time evolution of KS7D measured line-of-sight T_i and v in JET pulse 72743, showing the effect of ion ITBs on poloidal dynamics and that individual ELM events are resolvable at this time resolution.

SUMMARY

- A new instrument is described, which enhances the coverage of the JET "edge" (i.e. poloidal dynamics) CXRS suite of diagnostics.
- Incorporation into the CXSFit analysis package is underway.
- Upgrades to the edge CXRS system are planned to improve spectral resolution and achieve a 5 ms framing rate.

REPRINTS

Electronic copy available at: http://sprott.physics.wisc.edu/biewer/EPS08poster.pdf

ACKNOWLEDGEMENTS

"This work, performed under the European Fusion Development Agreement, supported by the European Communities and the U.S. Dept. of Energy, has been carried out within the Contract of Association between EURATOM and the U.S.D.O.E, Contract DE-AC05-00OR22725. The views and opinions expressed herein do not necessarily reflect those of the European Commission or the U.S.D.O.E."

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