EFDA JET

# Enhancements to the Edge CXRS System on the Joint European Torus


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** See the appendix of F. Romanelli, et al., Proceedings of the 22nd IAEA Fusion Energy Conference 2008, Geneva, Switzerland.*



## ABSTRACT

Enhancements have been made to 2 of the 4 instruments comprising the edge ($r/a \sim 0.5$ to $\sim 1.0$) charge-exchange recombination spectroscopy (CXRS) suite of diagnostics on the Joint European Torus (JET). Both enhanced instruments now consist of short focal length spectrometers coupled to fast framing CCD cameras at "high dispersion." Between these two instruments the number of (predominantly poloidal) plasma viewing channels increases from 24 to 34 views. The time resolution is improved to 10 ms (signal permitting.) The neutral-beam induced charge-exchange emission of C VI at 529.1 nm, of Ne X at 524.8 nm, and of Ar XVIII at 522.4 nm is observed simultaneously, complementing the existing edge CXRS instruments, which can be tuned to observe any wavelength of interest. These enhancements enable the simultaneous observation of the temperature, rotation, and concentration of multiple plasma impurity ions at improved temporal and spatial resolution. An overview of the edge CXRS diagnostic system on JET will be presented. Preliminary data will be shown from the recent 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.


## 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 the 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

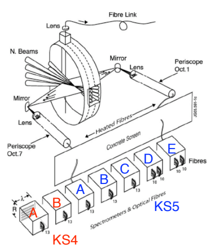


FIG. 1. The new JET CXRS system.

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

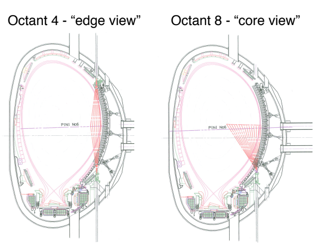


*Figure 2: Line-of-sight coverage of the JET **edge** CXRS system (KS7), viewing Octant 4 and Octant 8 neutral beams.*

## NEW EDGE CXRS HARDWARE (KS7C & KS7D) [4-8]

- New hardware installed and calibrated in 2009
  - Fixed wavelength, complements tuneable system
  - Redistributes 24 JET Octant 4 & 8 views
- Spectrometer [4,5]
  - Kaiser Optical Systems Holospec *f*/1.8
  - 1 curved entrance slit/spectrometer
  - "high dispersion" gratings: ~125 nm/mm
    - Center wavelength at 529.1 nm
  - CXRS lines measured simultaneously
    - 529.1 nm C VI, n=8-7
    - 524.8 nm Ne X, n=11-10
    - 522.4 nm Ar XVIII, n=16-15
  - Bremstrahlung background at 523.5 nm
- CCD Camera [6]
  - Princeton Instruments PhotonMax 512B
  - 512x512, 16x16 μm pixels, 16 bit depth
  - Thermoelectrically cooled to -70 °C
  - Binned to 17 "tracks"
- 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
  - Sm calibration lamp data on every discharge

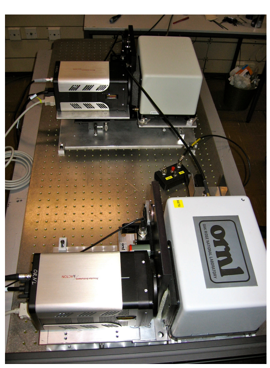

*Figure 3: Photograph of the new KS7C and KS7D hardware as installed at JET.*

## MEASUREMENTS [9,10,11]

- *Caveat*: Work is ongoing to incorporate these new edge CXRS instruments 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 instruments.
  - 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.

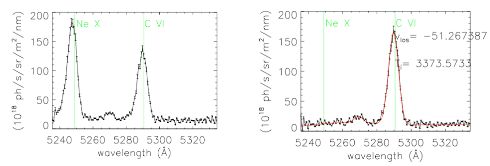


*Figure 4: Spectra from the KS7D diagnostic on JET pulse 72428 with and without neon puffing. A gaussian fit to the C VI line is shown (in red) with the resulting line-of-sight velocity and temperature.*

- 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.

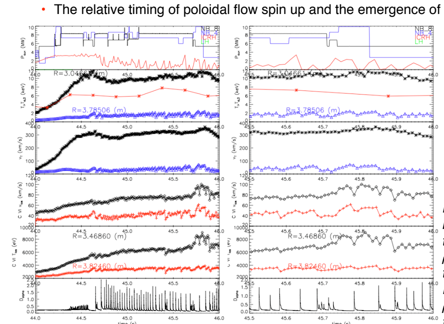


*Figure 5: Time evolution of KS7D measured line-of-sight $T_i$ and v in JET pulse 72743, showing the effect of ion ITBs on poloidal dynamics and that individual ELM events are resolvable at this time resolution.*

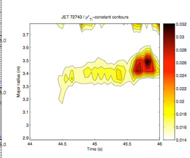

*Figure 6: Contour plot of $\rho^*_{Ti}$ in JET pulse 72743, showing the presence of an ion ITB. $\rho^*_{Ti}$ >0.020 is considered the threshold for a "sustained" ITB in JET. $\rho^*_{Ti} = \rho_s/L_{Ti} = (c_s/\omega_{ci})/(\nabla T_i/T_i)$ from Ref. [11].*

## SUMMARY

- New instruments are described, which enhance 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 calibration confidence and achieve a 5 ms framing rate.

## REPRINTS

Electronic copy available at: http://sprott.physics.wisc.edu/biewer/APS09poster.pdf


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