Physics Studies of ADITYA & ADITYA-U Tokamaks Plasmas using Spectroscopic Diagnostics

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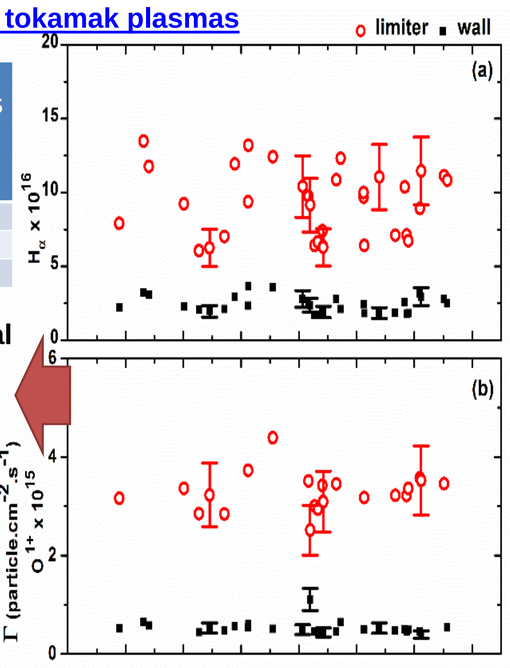
Introduction

- Spectroscopy is tool to measure electromagnetic radiation coming from the plasma.
- Main advantage of this diagnostic is that it does not perturb the plasma because it is non-invasive.
- Starting from lower wavelength at VUV to up to IR range many studies and parameter can be explored using spectroscopy.
- Aditya tokamak is in operation since 1989 and is now upgraded to Aditya-U in 2016. This is been upgraded to add divertor coils and produce shaped plasmas.
- Aditya tokamak having a poloidal ring limiter and now its upgraded version Aditya-U with toroidal belt limiter
- ADITYA and ADITYA-U tokamak is highly enriched with spectroscopic diagnostic systems to measure different plasma parameters such as ion temperature T_i, ion density and plasma rotation velocity.

PMT based measurements

Investigation of recycling and impurities influxes in ADITYA-U tokamak plasmas

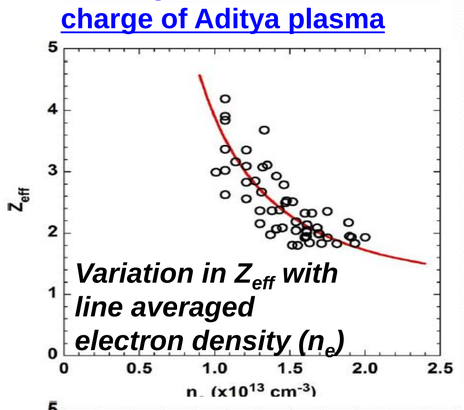
Species	Particle influx limiter LoS (particle·cm^{-2}·sec^{-1})	Particle influx Wall LoS (particle·cm^{-2}·sec^{-1})	Integrated influx Limiter LoS (particle·sec^{-1})	Integrated influx wall LoS (particle·sec^{-1})
H	9.0×10^{16}	2.6×10^{16}	1.8×10^{21}	1.4×10^{21}
O^{1+}	2.5×10^{15}	6.0×10^{14}	5.0×10^{19}	3.2×10^{19}
C^{2+}	1.9×10^{15}	1.7×10^{15}	3.8×10^{19}	9.2×10^{19}



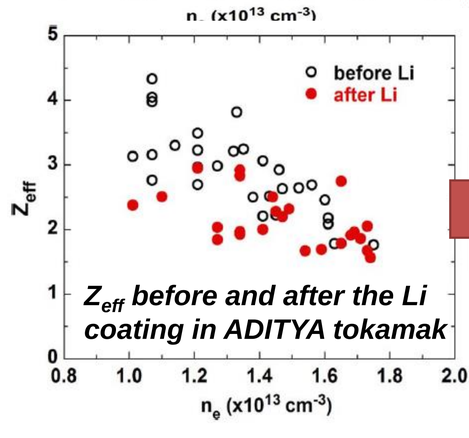
- Particle influxes is measured from carbon limiter with radial viewing chord and bottom SS wall from top view port.
- Two sets of PMT has been arranged to measure Hydrogen neutral, carbon and oxygen ion impurities influxes

Results indicates that the limiter is a big source of oxygen impurities and hydrogen neutrals.

Investigation of the effective charge of Aditya plasma



Variation in Z_{eff} with line averaged electron density (n_e)



Z_{eff} before and after the Li coating in ADITYA tokamak

- Visible bremsstrahlung emission is measured with 2 nm near 523.0 nm (line free region)
- To increase the light input, a fiber bundle of six optical fibers has been used.
- Fiber core diameter: 1 mm
- Numerical aperture 0.47
- Data is taken from top view port

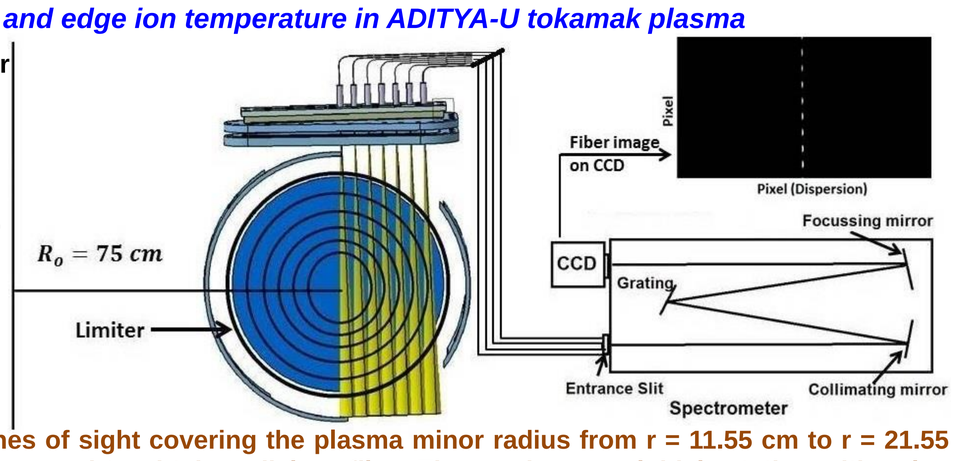
High-resolution multi-track spectrometer based diagnostic system

- Plasma rotation study is of utmost importance in understanding the momentum transport and its influence on plasma confinement.
- In ADITYA-U tokamak, measurements of the impurity poloidal rotation velocity and the edge ion temperature have been carried out using Doppler shift and Doppler broadening of C^{2+} visible spectral line at 464.7 nm, respectively.
- A high-resolution spectroscopic diagnostic system has been used for these measurements.

Measurement of poloidal rotation and edge ion temperature in ADITYA-U tokamak plasma

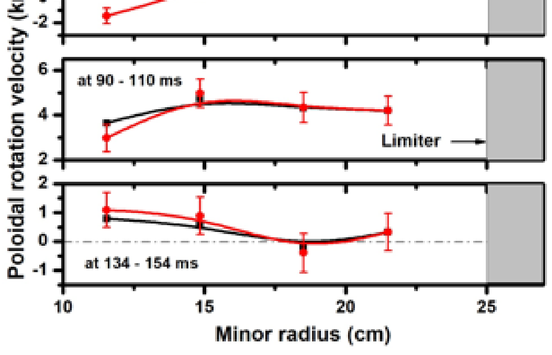
1 m, *f*/8.7 Czerny – Turner Spectrometer
Grating: 1800 grooves/ mm blazed at 518 nm
CCD: 1024 × 256 pixels
This spectrometer is capable of recorded spatial and temporal profiles.

Lines of sight for poloidal rotation measurements on Aditya-U tokamak with an image of fibers on the CCD detector.

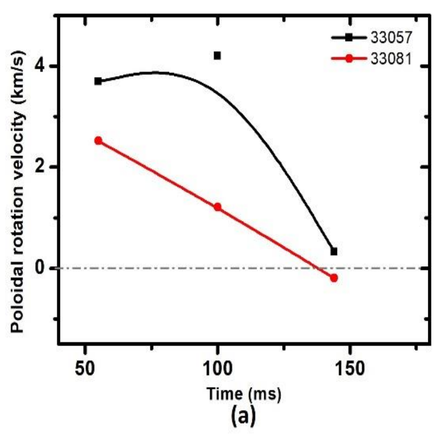


line emissions monitored using four lines of sight covering the plasma minor radius from r = 11.55 cm to r = 21.55 cm viewing from the top port have been used to obtain radial profiles. The maximum poloidal rotation with value ~4.5 km/s has been observed at the radial location of ~21.55 cm.

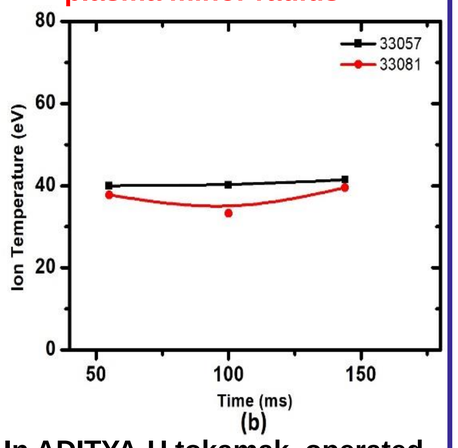
Radial profile of carbon ion poloidal rotation velocity (km/s) along with error bars for Aditya-U tokamak for shot no. 33057.



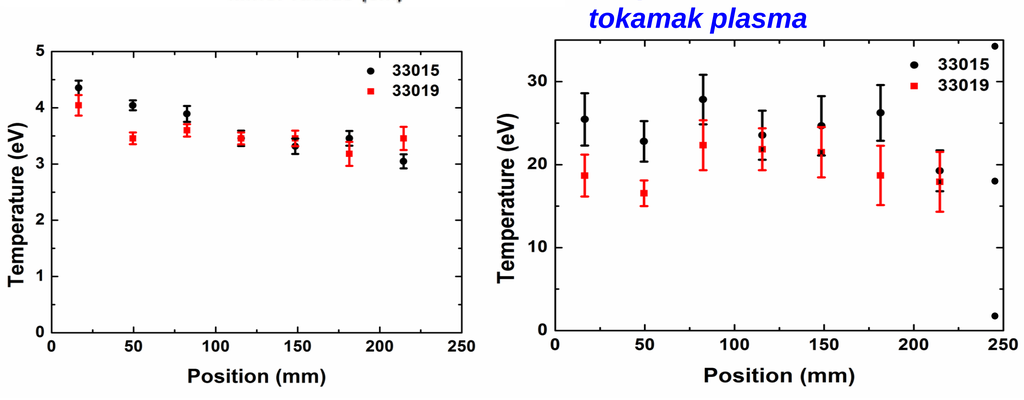
Temporal profile of poloidal rotation velocity (km/s)



Edge ion temperature (eV) measured at 21.55 cm of plasma minor radius



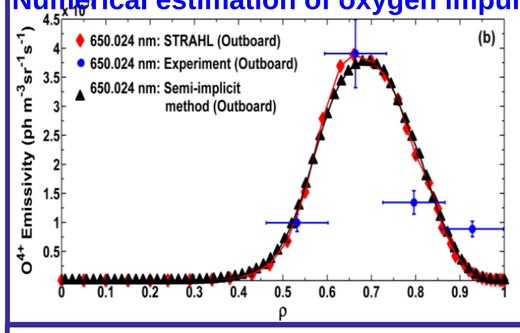
Measurement of neutral temperature in ADITYA-U tokamak plasma



- In ADITYA-U tokamak, operated at magnetic field of 1.2 to 1.5 Tesla
- Hydrogen fuel neutrals influenced by high magnetic field and produce Zeeman effect.
- This Zeeman effect produce extra broadening in spectral line shape, produce error in temperature measurement
- Hydrogen get split into total 48-lines and gives the broadening.
- hydrogen neutrals performed by measuring neutral temperature from spectral line emission at 656.28 nm.

For estimation multi temperature components (warm < 10 eV and hot > 10 eV) needed to be considered
Spatial profile for warm component ~ 3 - 5 eV and hot component ~ 15 - 30 eV.

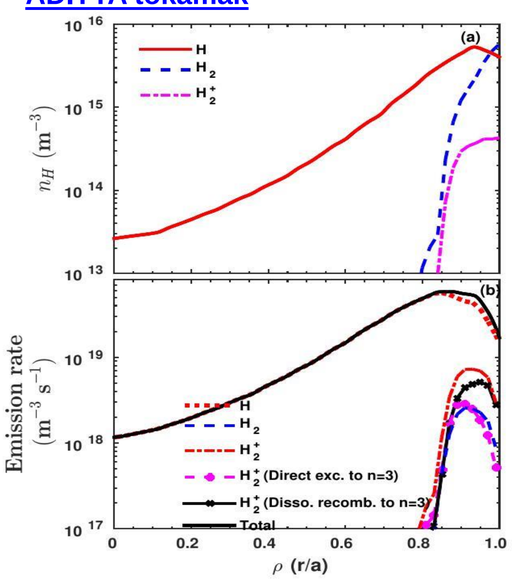
Numerical estimation of oxygen impurity transport in ADITYA tokamak



The oxygen impurity transport studies carried out through the indigenous development of impurity transport code using semi–implicit numerical method.

Comparison between the experimental data and calculated emissivity profiles of O^{4+} ion spectral line at 650.024 nm in outboard regions of Aditya plasma using O^{4+} number density profiles from STRAHL and semi-implicit method with PEC-ADAS

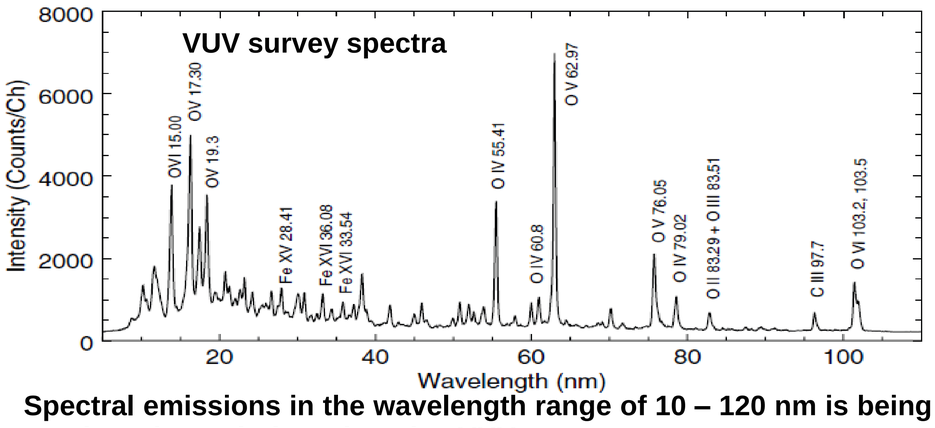
Investigation of atomic and molecular processes in H_α emission through modelling of measured H_α emissivity profile using DEGAS2 in ADITYA tokamak



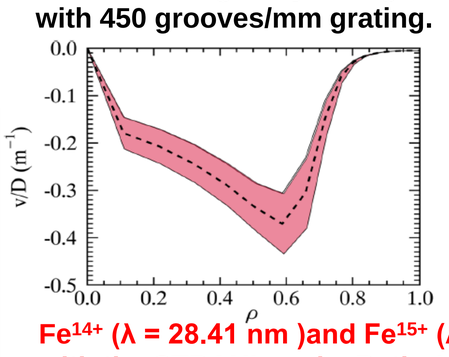
Density profiles of atomic hydrogen, hydrogen molecule and molecular hydrogen ion, (b) H_α emission rate from molecular processes and atomic process along with the total emission rate as evaluated from DEGAS2 for the shot no. 29029.

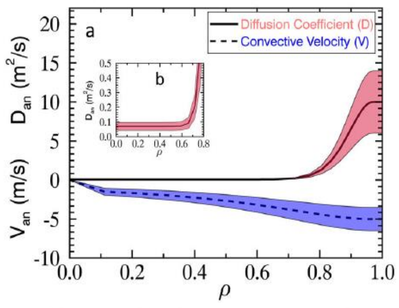
Both molecular hydrogen and hydrogen ion densities fall quickly as they enter the inner region of the plasma, whereas the hydrogen atoms significantly penetrate into the plasma inner region.

Study of Iron impurity behaviour in Aditya tokamak using VUV spectroscopy system



Spectral emissions in the wavelength range of 10 – 120 nm is being monitored regularly using the VUV survey spectroscopy system with 450 grooves/mm grating.





Fe^{14+} (λ = 28.41 nm)and Fe^{15+} (λ = 33.54 nm)impurity ions are modelled with the STRAHL code. Ratio $I_{28.41}$ / $I_{33.54}$ has been calculated using STRAHL code and matched with the experimentally observed ratio

References:

1. CHOWDHURI, M.B. et al., Measurement of spatial and temporal behavior of H_α emission from Aditya tokamak using a diagnostic based on a photomultiplier tube array, Rev. Sci. Instrum. 85 (2014) 11E411.
2. BANERJEE, S. et al., Space- and time-resolved visible emission spectroscopy of Aditya-tokamak discharges using multi-track spectrometer, Meas. Sci. Technol. 19 (2008) 045603.
3. PATEL, S. et al., Study of iron impurity behaviour in the ADITYA tokamak, Nucl. Fusion 59 (2019) 086019.
4. SHUKLA, G. et al., Poloidal rotation and edge ion temperature measurements using spectroscopy diagnostic on Aditya-U tokamak, Atoms 7 (2019) 93.
5. BHATTACHARYA, A. et al., Numerical estimation of the oxygen impurity transport in the Aditya tokamak, Phys. Plasmas 27 (2020) 023303.
6. CHOWDHURI, M.B. et al., Evaluation of an oxygen transport coefficient in the Aditya tokamak using the radial profile of O^{4+} emissivity and the importance of atomic data used therein, Atoms 7 (2019) 90.
7. YADAVA, N. et al., Spatial profile of neutral temperature measurement in Aditya-U tokamak plasmas, Atoms 7 (2019) 87.
8. YADAVA, N. et al., Investigation of recycling and Impurities in ADITYA-U tokamak plasmas, Plasma Fusion Res. in press
9. CHOWDHURI, M.B. et al., Investigation of the behavior of effective charge of Aditya tokamak plasmas, Plasma Phys. Control. Fusion 62 (2020) 035015.
10. DEY, R. et al., Investigation of atomic and molecular processes in H_α emission through modelling of measured H_α emissivity profile using DEGAS2 in the ADITYA tokamak, Nucl. Fusion 59 (2019) 076005.