Investigation of Toroidal Rotation in Impurity Seeding ADITYA-U Tokamak Plasmas

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Introduction

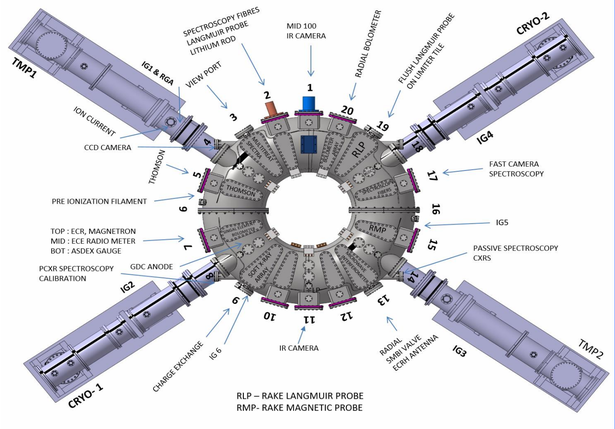
- Neon injection into the tokamak plasma has been done to study impurity seeded plasma properties
- It is observed that plasma confinement is improved in the impurity seeded discharges, reaches Improved Ohmic confinement (IOC) and/or Radiative Improved (RI) mode type of plasma
- Investigation of the toroidal plasma rotation has been also carried out
- As it is believed Also because of the suppression of turbulence due to increase of ExB shear rotation in the impurity injected plasma

Aditya-U tokamak

ADITYA-U machine and plasma parameters

- is designed to be operated with divertor configuration
- to carry out experiment runaway electron generation and its dynamics,
- disruption prediction and mitigation studies along with
- the studies of the plasma position control and confinement improvement with shaped plasma.
- to study the plasma properties under various discharge cleaning and gases injection into the plasma

Major radius, R : 75 cm
Minor radius, a : 25 cm
Toroidal belt limiter : Graphite
Toroidal field B_t: 0.75 – 1.4 T
Plasma current I_p: 100 – 180 kA
Plasma duration: 120 – 360 ms
Electron density, n_e :
$1 – 3.5\times10^{19}$ m^{-3}
Electron temperature, T_e :
300 – 750 eV

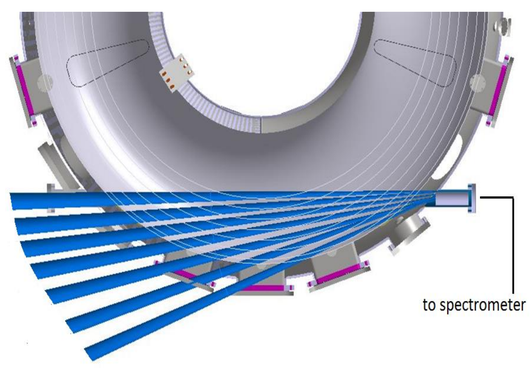


Diagnostics used in this experiment

- Line averaged n_e using 1 channel Heterodyne μwave interferometer
- Diamangetic loop to measure plasma stored energy
- A VUV survey spectrometer used to monitor spectral lines of neon ions
- Plasma stored energy using diamagnetic loop
- Radiation power from Bolometer diagnostics
- AXUV detector array to record radial profile of soft X-ray emissions
- PMT based spectroscopy diagnostics to monitor H_α, spectral lines from CII and OII and also visible continuum emission

Toroidal rotation measurement diagnostics:

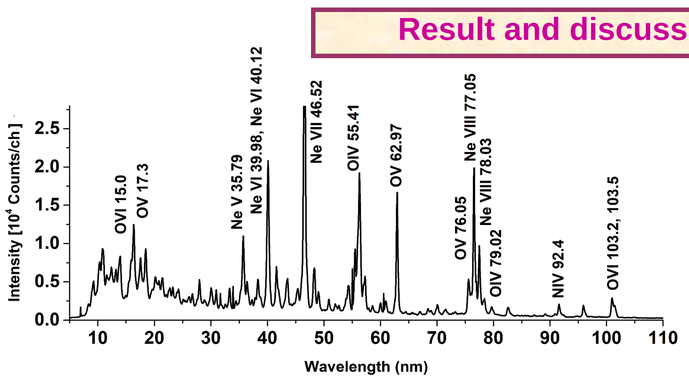
- A high resolution multi-track spectrometer used to collect light from 6 LoSs to monitor passive charge exchange lines at 529 nm from C^{5+}
- A 13.5 um pixel sized, 2048x512 pixels CCD is detector
- Plasma viewed from tangential port covering plasma center to edge
- System dispersion 0.0075 nm/pixel, one pixel shift ≡ 4.5 km/s



Neon gas puffing experiment In ADITYA-U tokamak

- Neon gas puffs were introduced mainly from the bottom port
- Both single as well as multiple puff was applied at different time intervals
- Multiple gas puffs was introduced in the vessel by using a Piezo-electric valve (500 SCCM at 100 V)
- A programmable pulse generator is used for multiple gas puff (for hydrogen and Neon both) to control the fuel gas
- Neon gas was puffed during the current flat-top region.
- Gas puff amplitude, pulse width and its number and time interval adjusted to study its effect on the ADITYA-U tokamak plasma

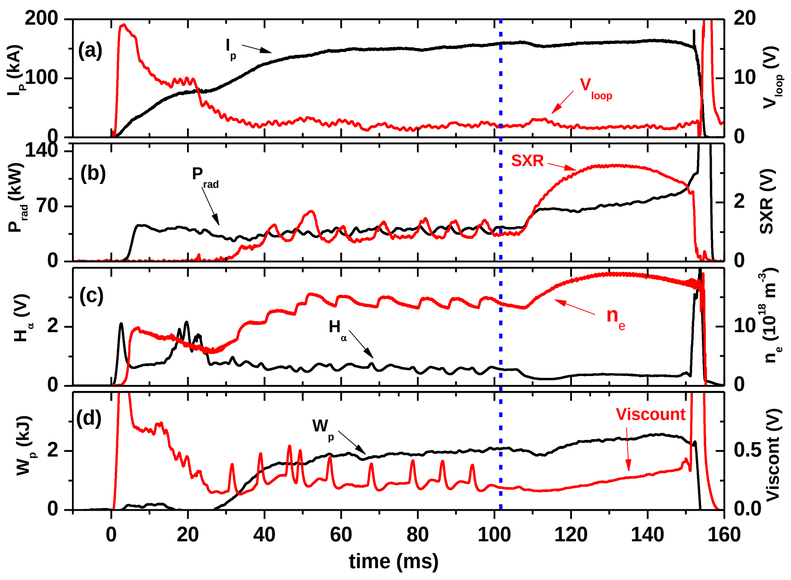
Result and discussions



- VUV survey spectrum acquired to monitor spectral line from neon ions
- Confirm the presence of neon inside the plasma

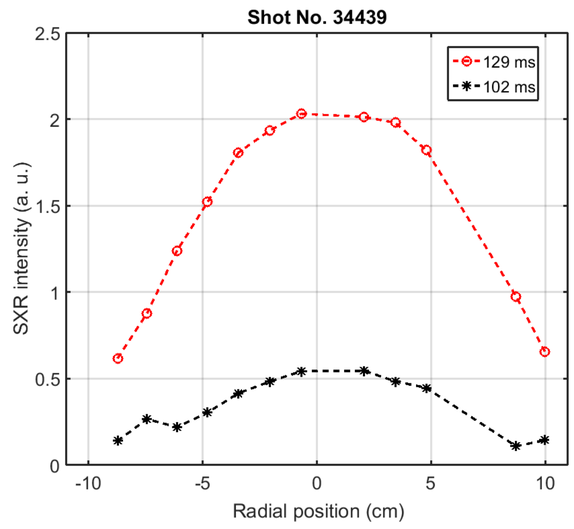
Result and discussions

Effect of the neon gas puffing on the Aditya tokamak plasma



Experimental observation

- Observed significant rise of P_{rad} and Soft X-ray signal after the neon puff
- H_α signal decreases significantly
- Simultaneous decrease in H_α signal and increase in n_e indicates better particle confinement
- W_p increases after the application of neon gas puff
- Visible continuum rises gradually
- Spatial profile of soft X-ray increase amore than 4 times

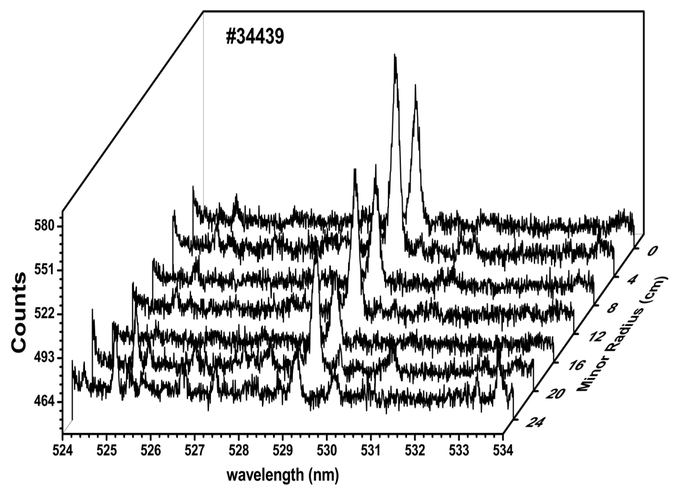


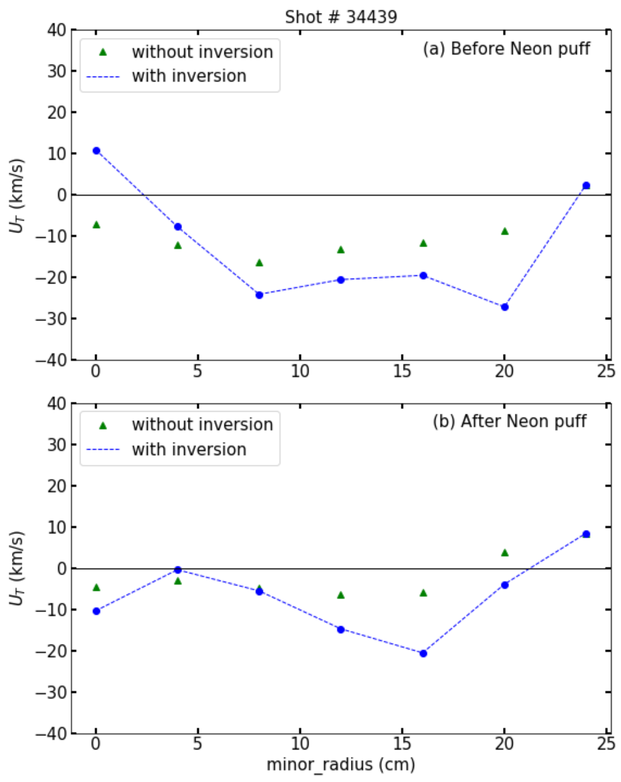
Energy confinement time $\tau_E = \dfrac{W_p}{I_p V_l}$

Neo-Alcator scaling, $\tau_E = 7\times10^{-2} n_e a R^2 q_a$

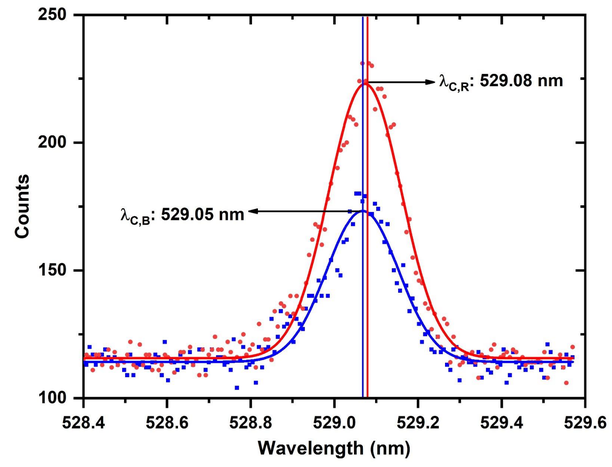
1. τ_e was improved from 6.5 to 9.0 ms
2. Transition to better plasma properties happens at 112 ms, after ~ 7 ms of neon puff application
3. The value 1.4 times the Neo-Alcator scaling for Ohmically heated tokamak plasma.
4. Improved plasma seems to be similar to the IOC mode of tokamak operation

Toroidal plasma rotation study in impurity seeded plasma





- Visible spectrum around 529 nm observed from many LoS viewing the plasma tangentially
- Charge exchange line shows a maximum brightness around 4 cm radial location
- For rotation measurement Doppler shift of spectral line estimated
- Un-shifted wavelength calibration done using same line viewing plasma from opposite direction having red and blue shifts
- Able-like matrix inversion done to get the radial profile of rotation velocity from the chard integrated rotation velocity



- Toroidal rotations are around 15 5 km/s before neon puff.
- Rotation reduces to ~ 5 km/d after neon puff
- Rotations during both times are counter-current direction in most part of the plasma
- Reversal of rotation happening towards the edge plasma region.
- Improved properties is likely related to this change in toroidal rotation

Summary

- ✓ Improved plasma properties almost similar to IOC mode of plasma obtained in ADITYA-U tokamaks by introducing single or multiple neon gas puff.
- ✓ Significant rise in line averaged n_e, edge n_e, W_p and radiation power observed
- ✓ Energy confinement time increase after transition to improved mode, which happen after 7 ms of gas puffing
- ✓ Study of toroidal rotation profile indicates change in rotation related to plasma iprovemnt

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