

Development of Penning Plasma Discharge Source for VUV Spectrometer Calibration and Its Characterization



G.L. Vyas

Plasma Devices and Technology

CSIR-Central Electronics Engineering Research Institute (CSIR-CEERI) Pilani, India

Joint ICTP-IAEA Workshop on Fusion Plasma Modelling Using Atomic and Molecular Data.

Outline

- **Motivation**
- **Concept**
- **Experimental set-up**
- **Observed spectrum**
- **Discharge Characteristics**
- **OES for Density calculations**
- **Conclusions**

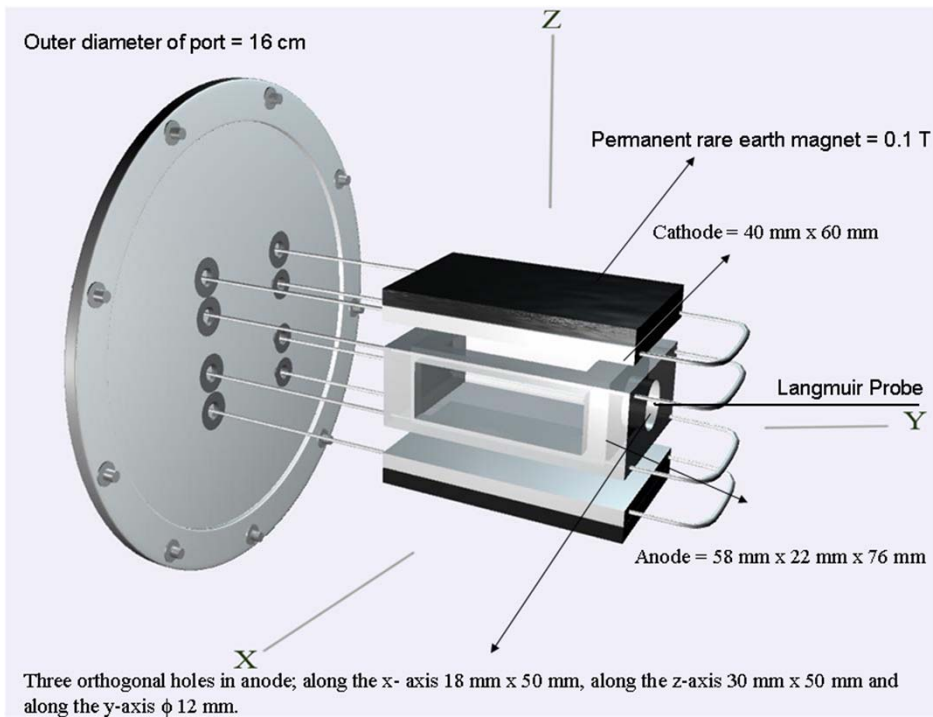
Motivation

- ❖ VUV spectrometer-detector system calibration is essential needed in order to use it on fusion plasma devices.
- ❖ At present, such calibrations are possible by branching ratio method or by synchrotron radiation sources. In branching ratio method, ratio of two lines one visible line and other VUV line originate from the same energy level is used. It is difficult to find out such line pairs and tokamak machine operation is important.
- ❖ Calibration through synchrotron radiation sources is also not user friendly because spectrometer-detector system have to displaced time to time.
- ❖ Recently our group has developed a simple laboratory based method to calibrate a VUV spectrometer detector system by collisional-radiative modeling of penning discharge source .
Ram Prakash et al. J. Phys. B: At. Mol. Opt. Phys. 5 July 43 (2010) 144012
- ❖ It is expected that the penning plasma discharge source may provide an alternate for VUV spectrometer calibration schemes, therefore, we are motivated to develop a larger dimension penning discharge device to cross-check our calculations by other diagnostics and establish our proposed model understanding.

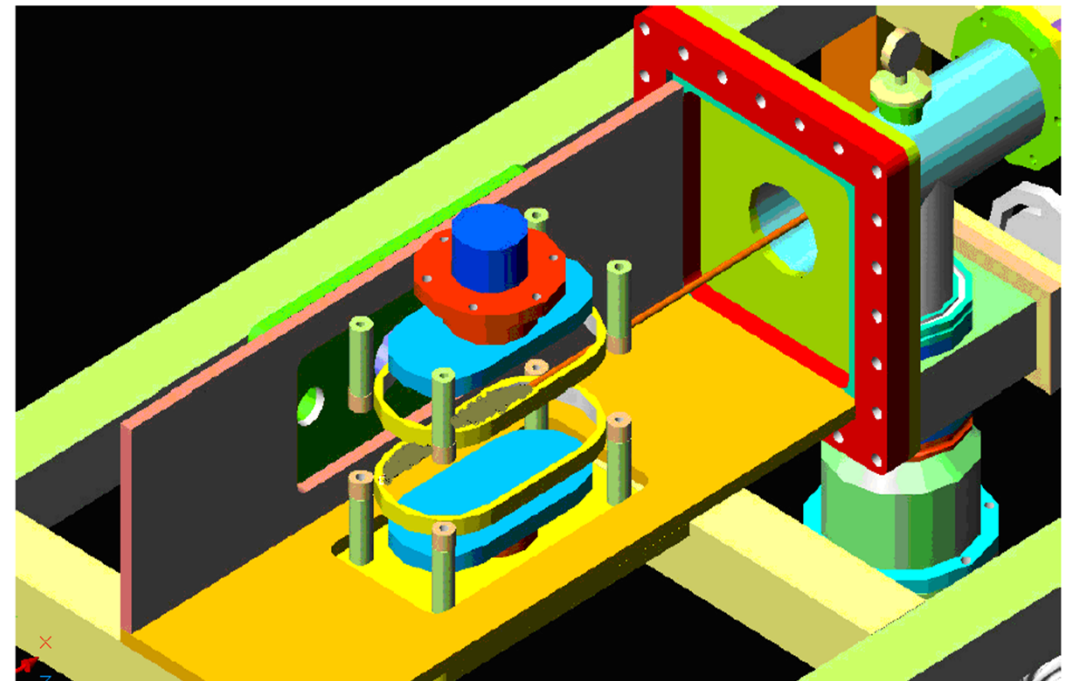
Concept

- ❖ In the penning discharge source, the plasma is produced between two end cathodes and a ring anode, with power derived from high voltage DC power supply. The electron confinement is maintained very high in this geometry by end cathodes (electrostatic confinement) and a pair of permanent magnets, which produces an axial magnetic field (magnetic confinement). Multiple reflections of the electrons between the end cathodes through the anode many times causing multiple collisions with neutral atoms. This allows penning discharge to operate at low pressures and can emit spectral lines from VUV range to Visible range simultaneously.
- ❖ The visible and VUV spectrum can be recorded simultaneously from the penning discharge source by keeping the VUV spectrometer at one end and the visible spectrometer at another end. For visible spectrometer the absolute intensity calibration is a routine task so from the observed visible intensities one can calculate the basic plasma parameters. Then one can predict the VUV intensities from the basic parameters to compare with the VUV spectrometer-detector measurements to find the calibration factors .

Electrode Geometry of Penning Discharge Source

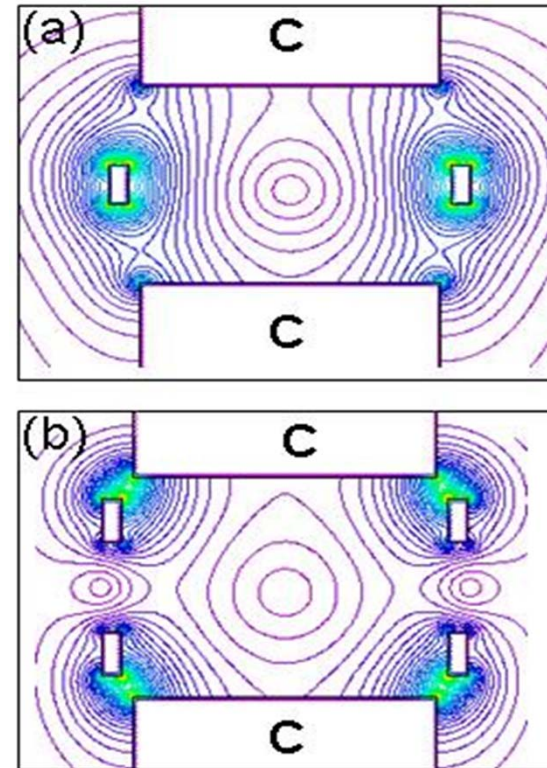
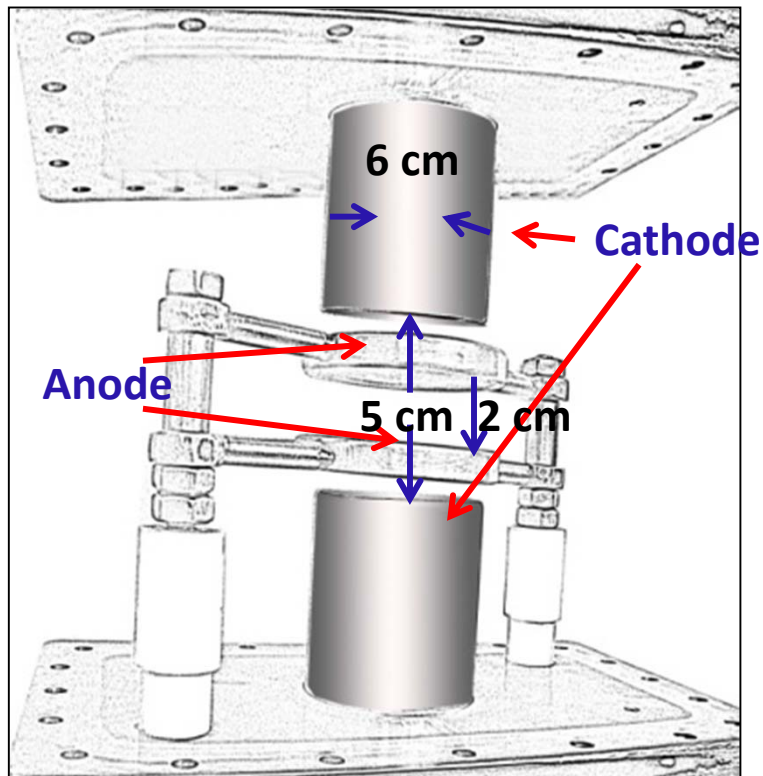


First geometry



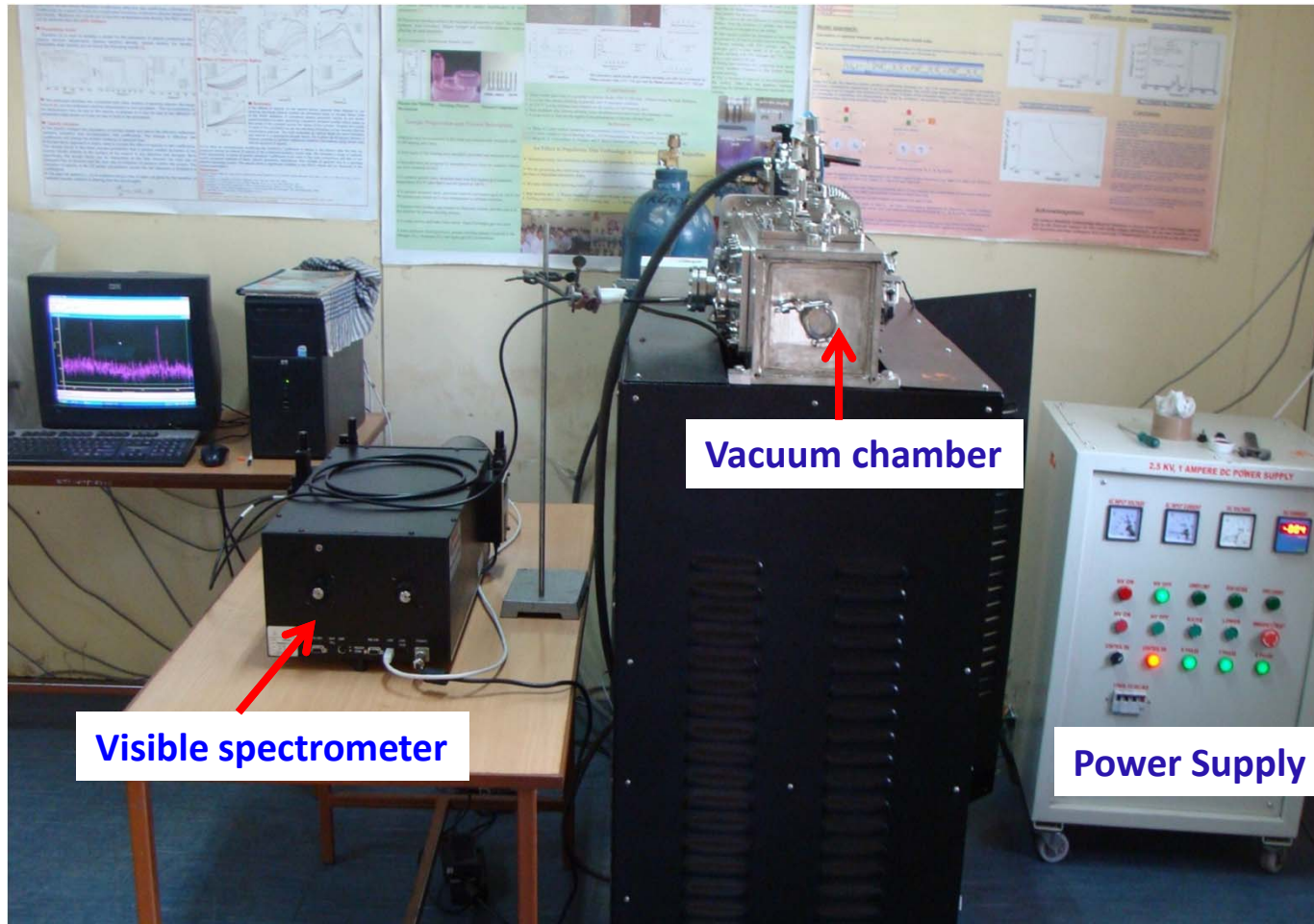
Modified geometry

Electrode geometry and its Electric field configuration



The electric field contour plot of a penning discharge source, for first 40 contours, at 500 volt. (a)single ring (b)Double ring using E-STAT simulation software from Field Precision Inc.,USA.

Experimental Set-up

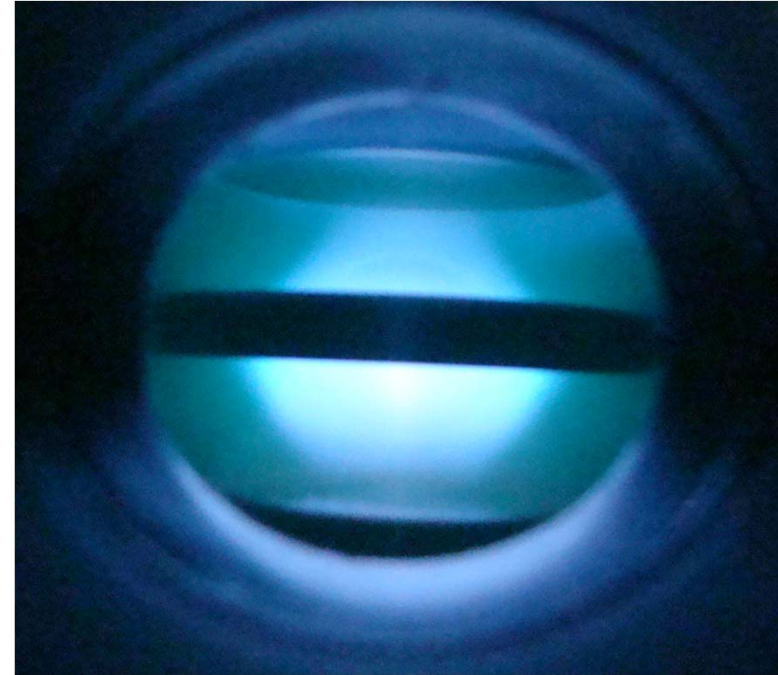


The spectrums are recorded using Acton SP series Spectrograph having focal length 500 mm, spectral resolution 0.05 nm and gratings 600g/mm blaze at 500nm. Entrance and exit slit width is kept 20 μ m and exposure time is 1 second.

Helium Discharge



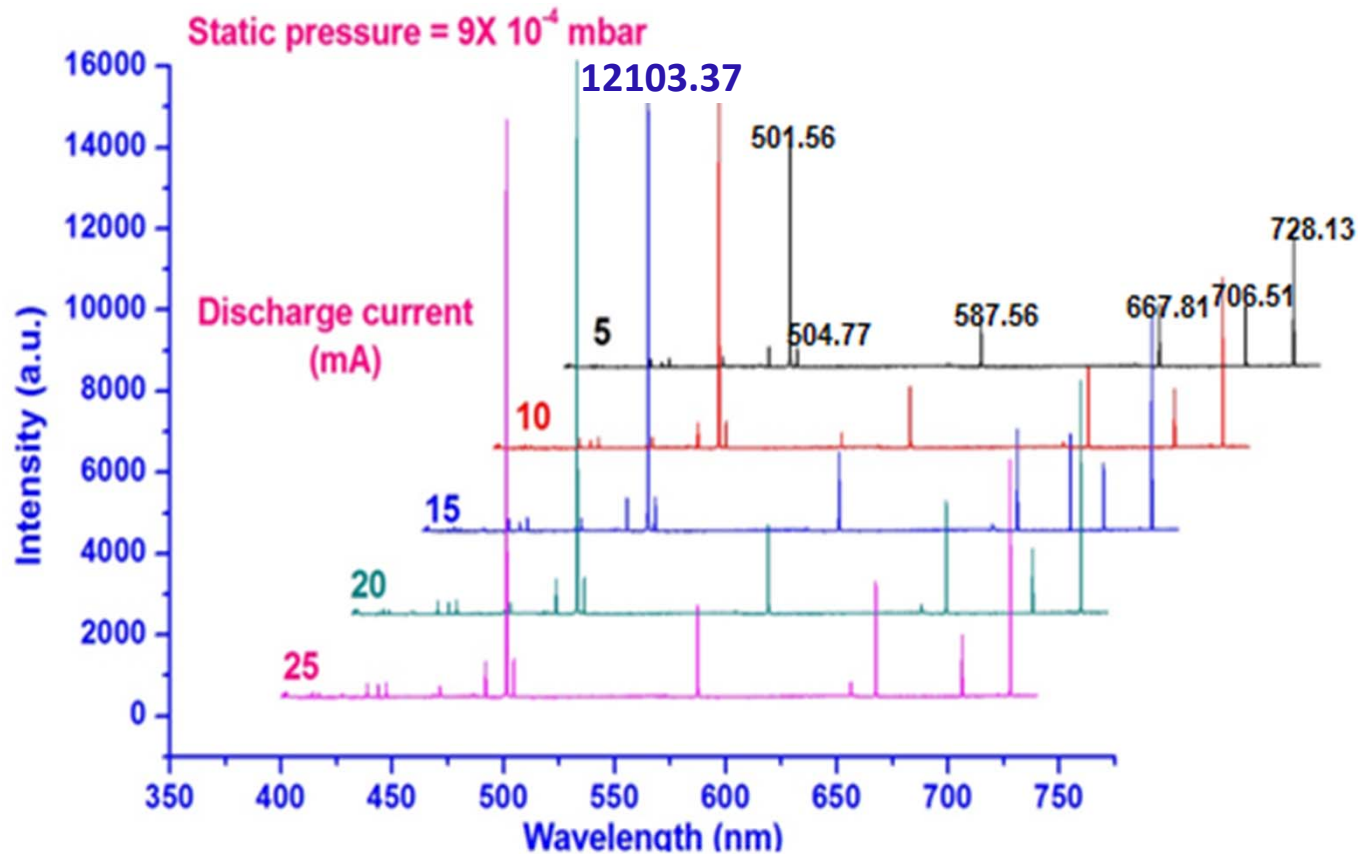
Double ring configuration



Single ring configuration

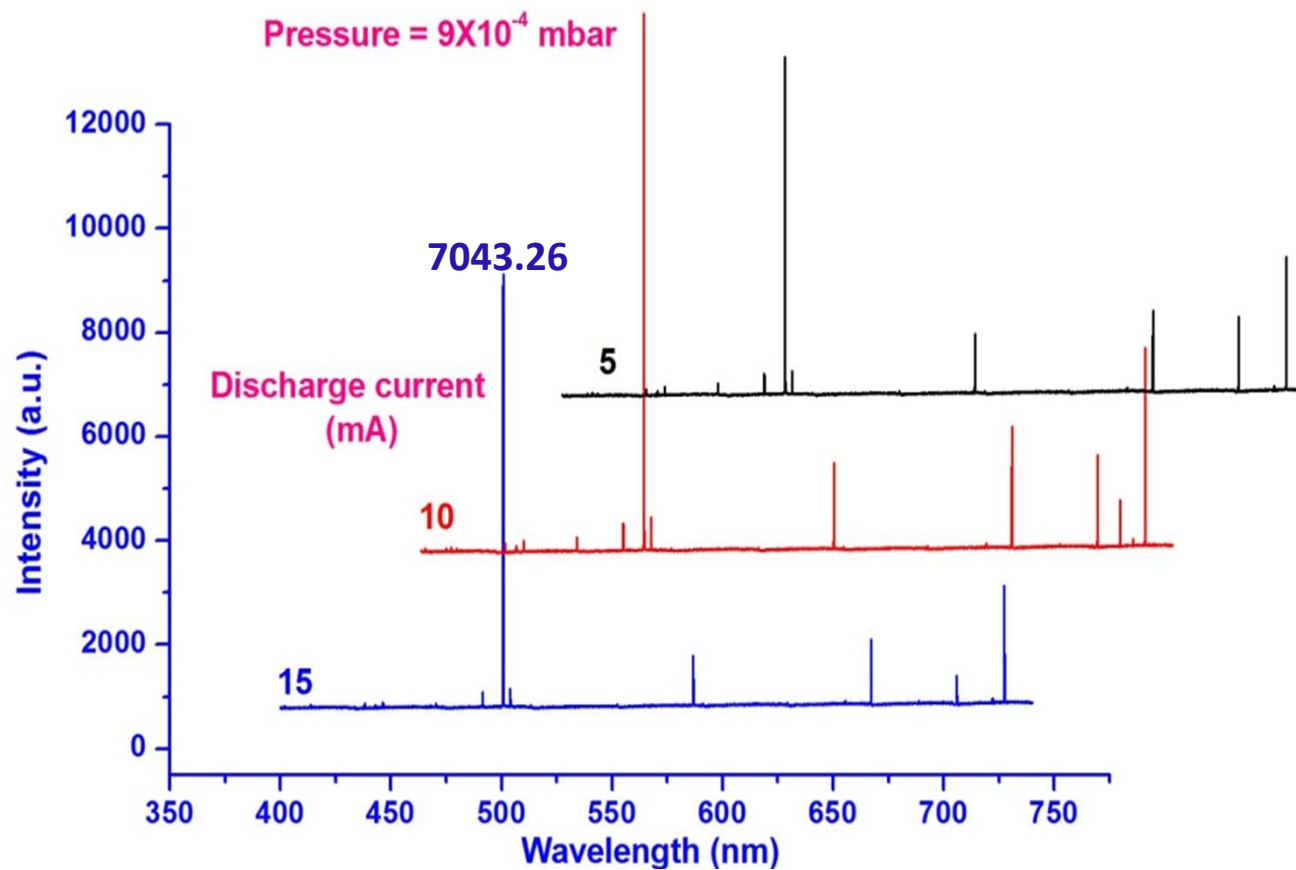
Observed spectrum

- ❖ Observed spectrum for neutral Helium using double ring configuration at fix pressure and different discharge currents.

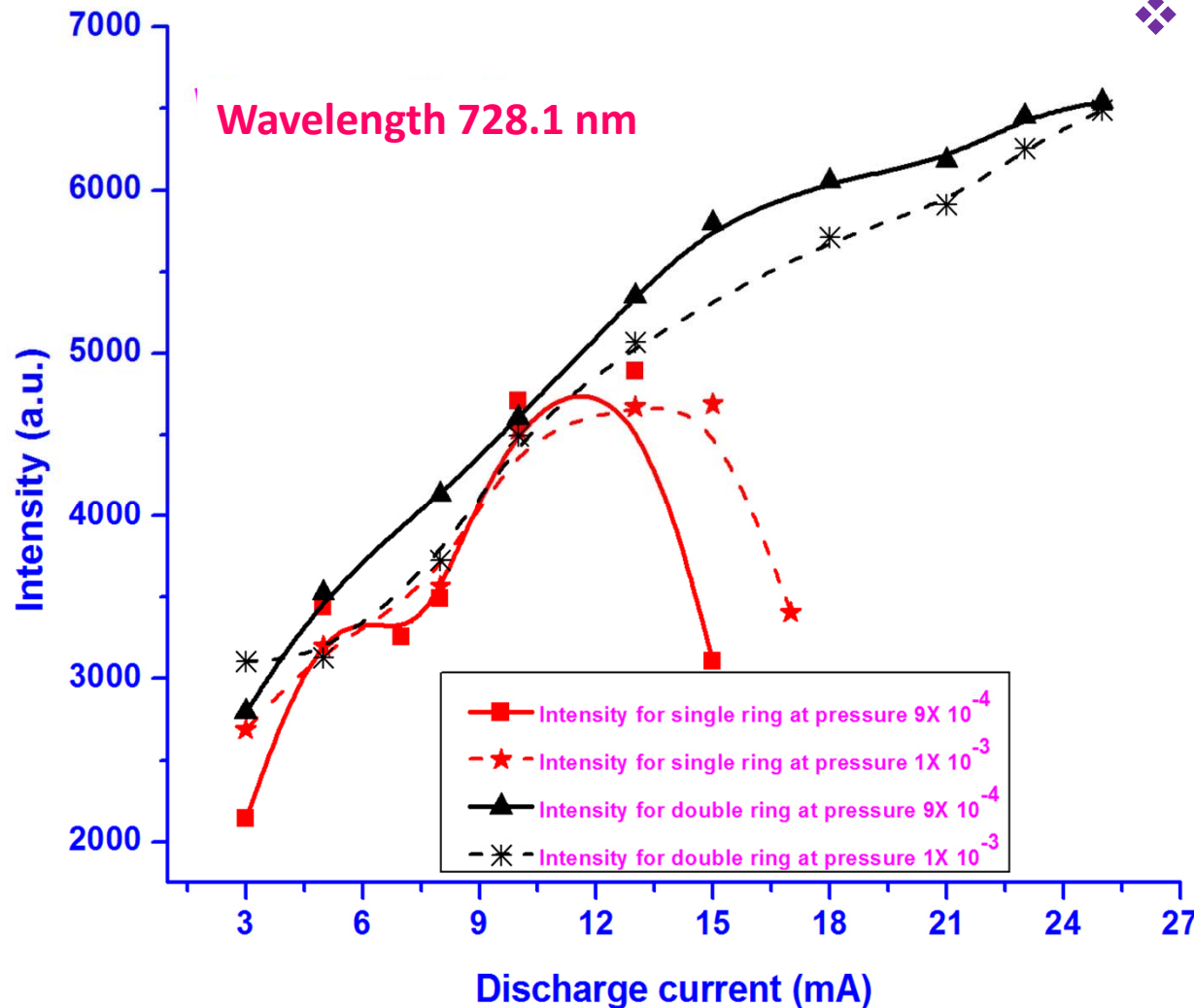


Observed spectrum For Single Anode Ring

- ❖ Observed spectrum for neutral Helium using single ring configuration at fix pressure and different discharge currents.



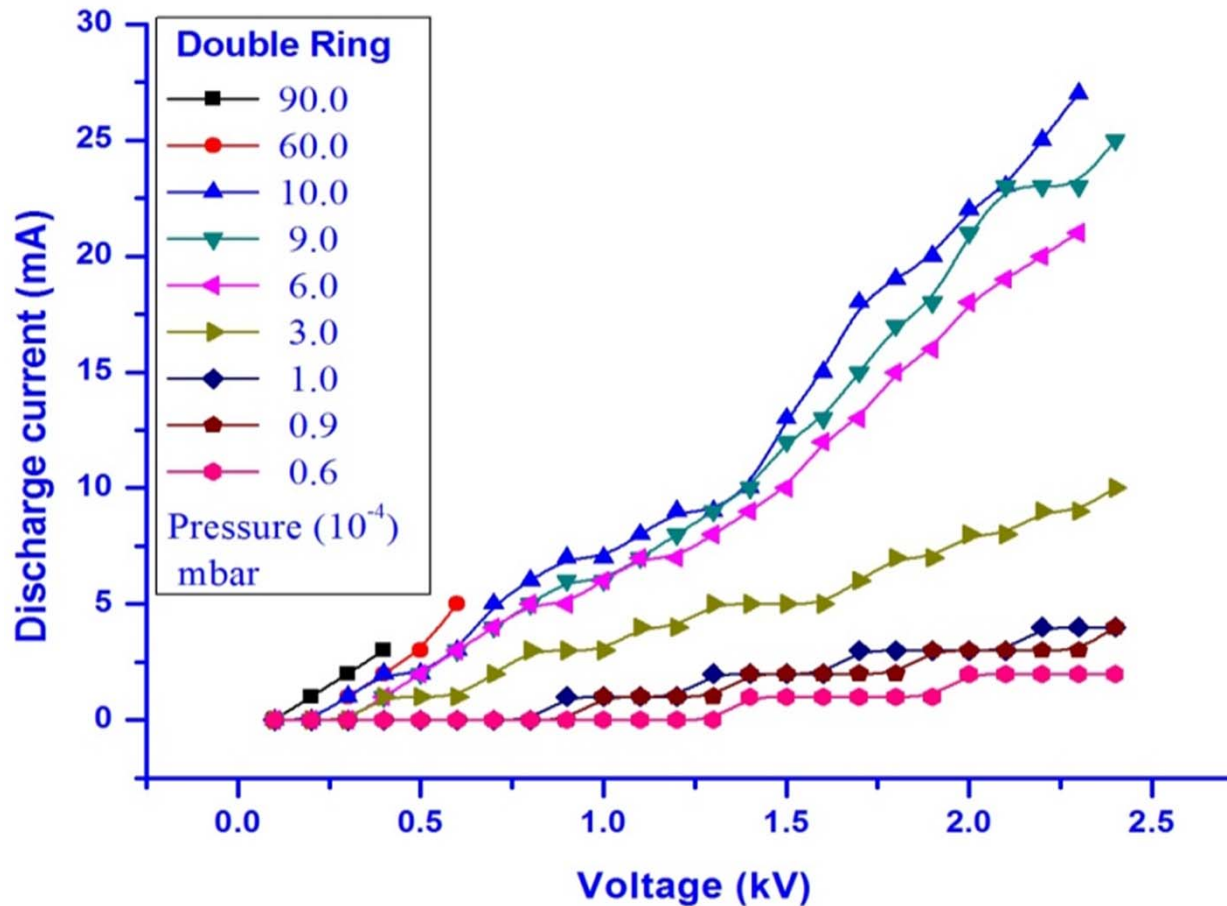
Intensity variation with Discharge Current



❖ The intensity of spectral line 728.1 nm linearly increases with discharge current in double ring configuration. For single ring configuration the intensity increases linearly but for the further increase of current its value lower down than the previous value. The similar behaviour is observed at different pressures (9×10^{-4} , 1×10^{-3}) with same experimental conditions. So, it is inferred that double ring configuration is more suitable as compare to single ring configuration.

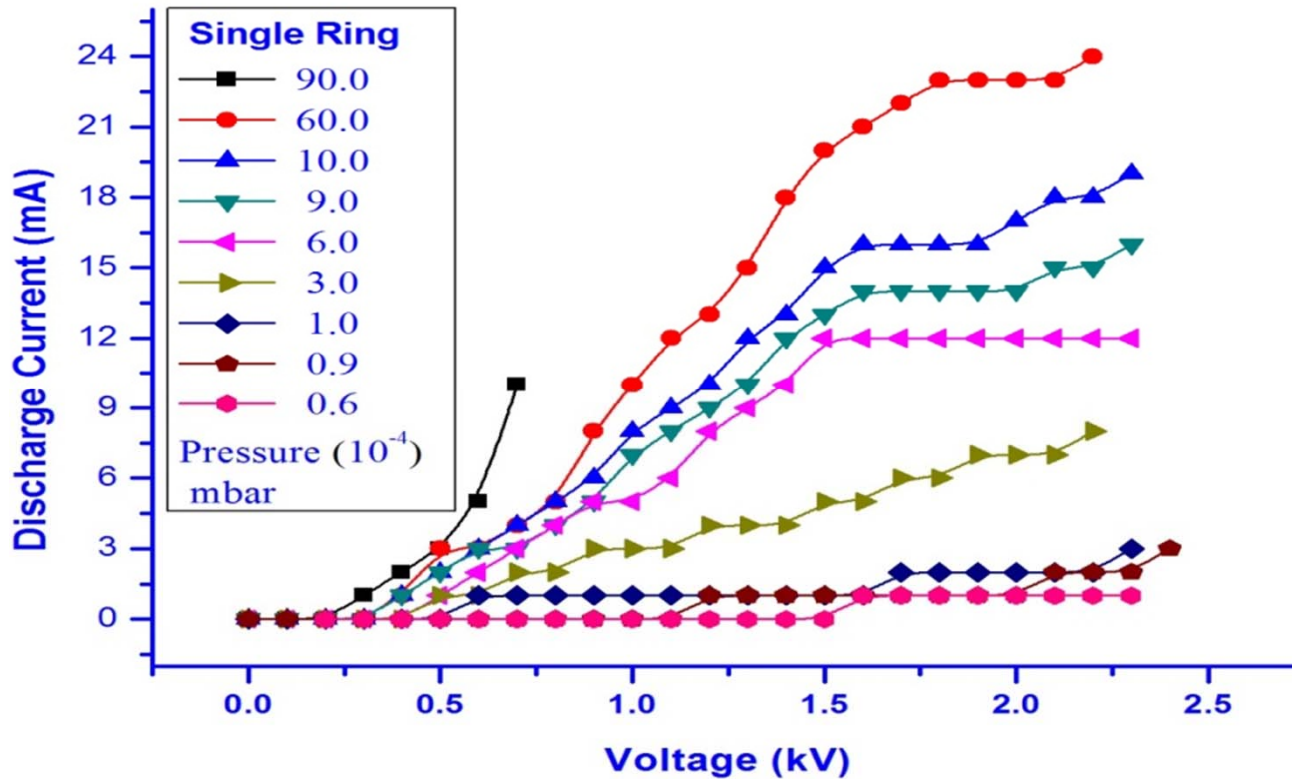
Discharge characteristics

❖ I-V Characteristics for double ring configuration at different pressures.



Discharge characteristics for Single ring configuration

❖ I-V Characteristics for single ring configuration at different pressures.



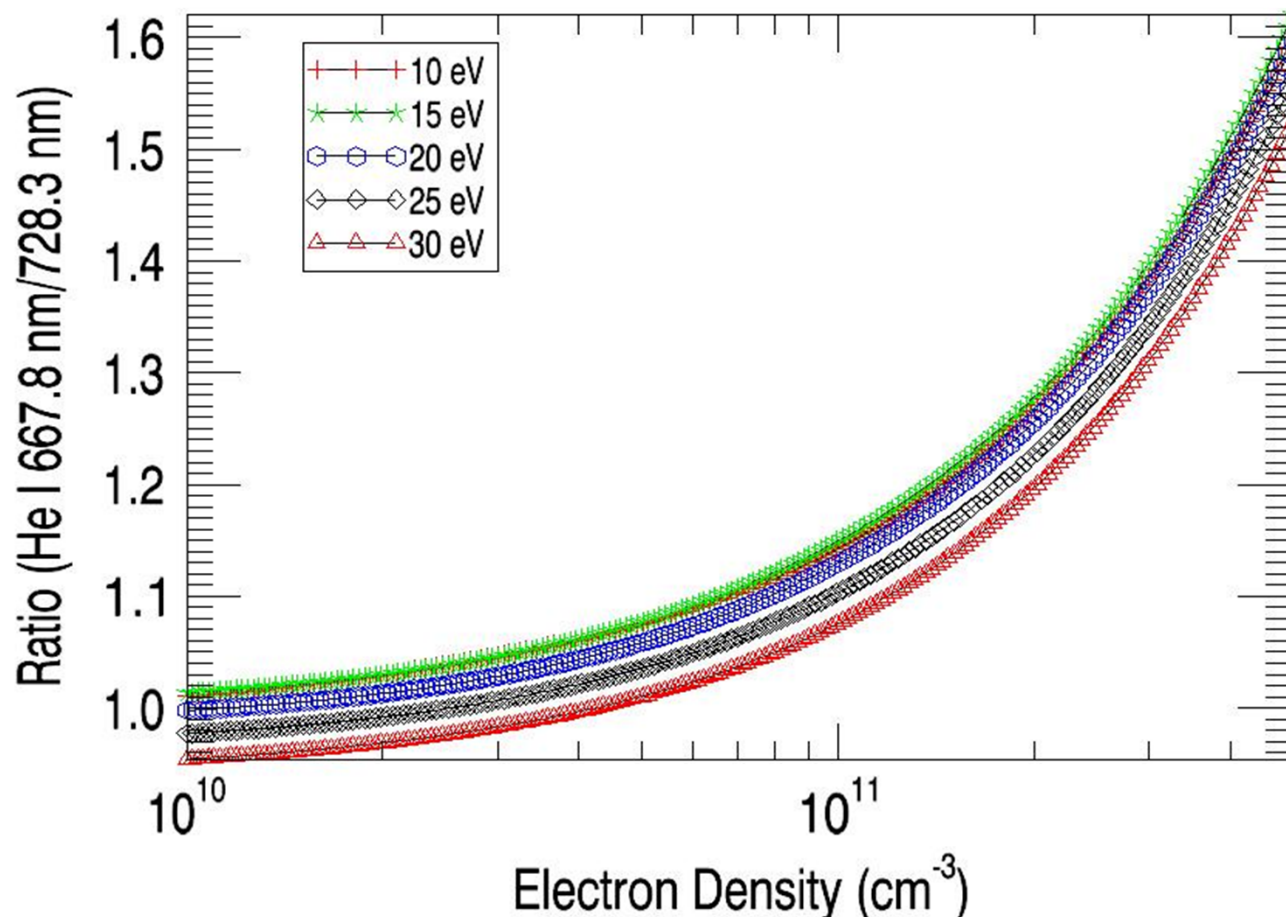
Line ratio (He I 667.8nm/He I 728.1 nm) calculations

- ❖ The obtained ratio for double ring configuration is larger as compare to single ring configuration for filled pressure 9×10^{-4} mbar and at discharge current 15 mA.

Discharge Current (mA)	Double Ring		Single Ring	
10	Gas Pressure (mbar)		Gas Pressure (mbar)	
	9×10^{-4}	1×10^{-3}	9×10^{-4}	1×10^{-3}
	0.916	0.831	0.6218	0.618
15	1.399	1.261	1.046	1.034

Electron Density Calculations

❖ The intensity ratio of the spectral lines (667.8nm/728.1nm) is plotted using CR model is shown in below figure. According to the spectral intensity ratio, plasma electron densities in the developed source for double ring configuration $\sim 2 \times 10^{11} \text{ cm}^{-3}$ and for single ring configuration $\sim 2 \times 10^{10} \text{ cm}^{-3}$.



Conclusions

- ❖ A discharge of helium gas has been produced in a penning plasma discharge source for double ring and single ring configurations.
- ❖ It is found that double ring configuration gives higher intensities than the single ring configuration.
- ❖ I-V characteristics show that for the double ring configuration the discharge current linearly increases with applied voltages unlike single ring configuration.
- ❖ Spectroscopic diagnostics using line ratio technique provide the electron density of plasma $\sim 2 \times 10^{11} \text{ cm}^{-3}$ for double ring configuration and $\sim 2 \times 10^{10} \text{ cm}^{-3}$ for single ring configuration. The double ring configuration density estimation is quite similar to the observed density in the small geometry penning discharge source of 1 cm cylindrical size, which is good achievement.

Ram Prakash et al. J. Phys. B: At. Mol. Opt. Phys. 5 July 43 (2010) 144012
- ❖ Now, we will explore and pursue other analysis to work out for VUV spectrometer-detector system calibration.
- ❖ We are in the process of procurement of certain equipments.

Acknowledgment

- ❖ *Dr. Ram Prakash, CSIR-CEERI, Pilani*
- ❖ *ADAS consortium, Prof. Martin O' Mullan & Prof. H. P. Summers from University of Strathclyde.*
- ❖ *BRFST Govt. of India for financial support to this project*
- ❖ *CSIR-CEERI Pilani*
- ❖ *BIT Jaipur Centre*
- ❖ *Institute for Plasma Research, Bhat, Gandhinagar*

Thanks

