Spectroscopic Characterisation of the PSI-2 Plasma in the Ionising and Recombing State

TRILATERAL EUREGIO CLUSTER

JÜLICH FORSCHUNGSZENTRUM

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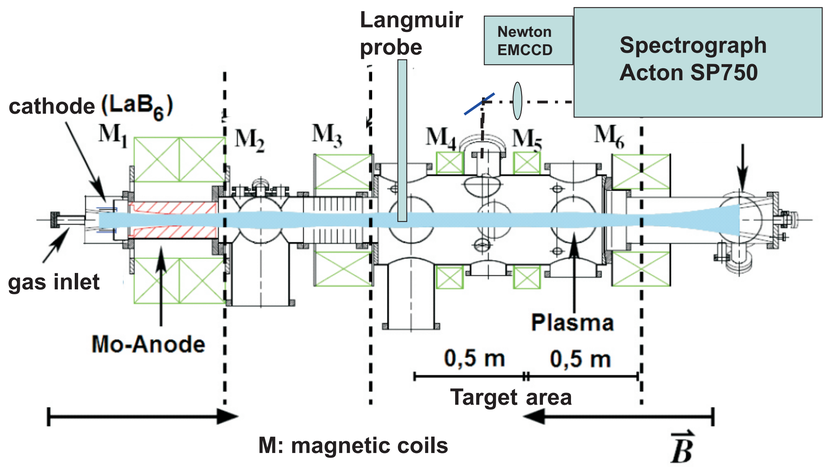
PSI-2 Experiment: Experimental Outline



Motivation

- **Applicability of different spectroscopic methods** for plasma diagnostics in linear plasma generators (in comparison to Langmuir probe measurements)
- **Investigation of a recombining deuterium plasmas** by variation of the neutral gas pressure in the target region (continuation of former experiments [1])
- Contribution of **different recombination mechanisms** to the level population

Technical details

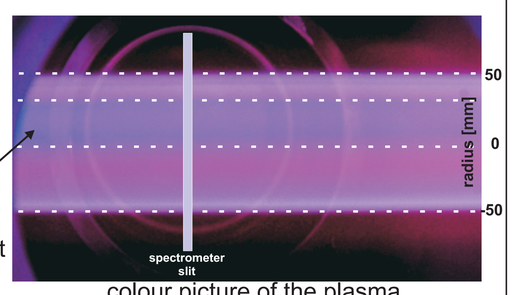
Plasma source: DC-discharge between a cylindrical cathode and hollow anode - currents up to 300A
Plasma parameters in the target region:
6 cm diameter, electron density up to $10^{20} m^{-3}$, electron temperature up to 20 eV
magnetic field strength: 100 mT on axis in the target region
Diagnostics: Langmuir probe and 2D-spectrometer for a radial recording of the plasma column

recombining plasma in PSI-2

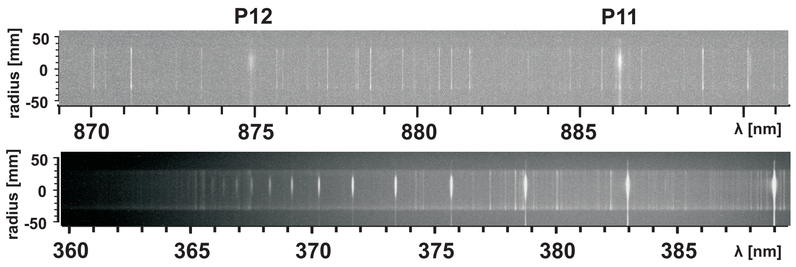
- discharge current 50 A additional gas inlet in the target region
→ **recombining plasma**

- hollow plasma profile can be well recognized

- recombining area (blue light emission) is slightly shifted



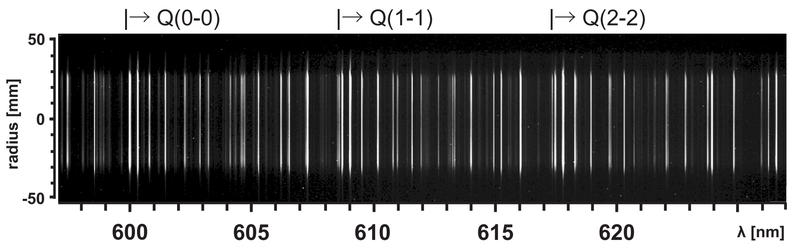
colour picture of the plasma
image of the spectrometer slit is indicated



recordings of the radially resolving spectrometer

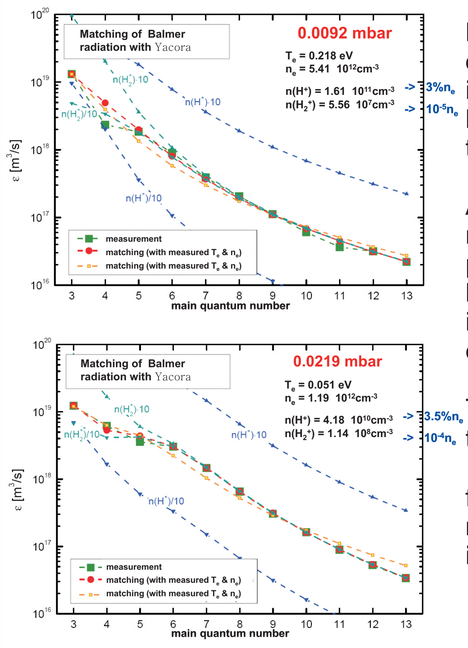
- **Paschen-series** (n =11→3 and 12→3; upper graph)
Balmer-series (from n =8→2; lower graph)

- The line intensity helps to identify the range of the recombining area **Stark broadening** (Paschen-Serie) can be used to determine the **electron density** in the recombining area.



recording of the radially resolving spectrometer
- Q-branch of the Fulcher-α band
determination of the **rotational temperature** of the D_2 molecules -> n_e

Level population - measurement & modelling



Modelling of the light **emission** from the individual **Balmer levels** by the**Yacora code** [4] for the **recombining plasma**

A new collisional radiative model for low pressure, low temperature hydrogen plasmas, which includes six possible excitation channels.

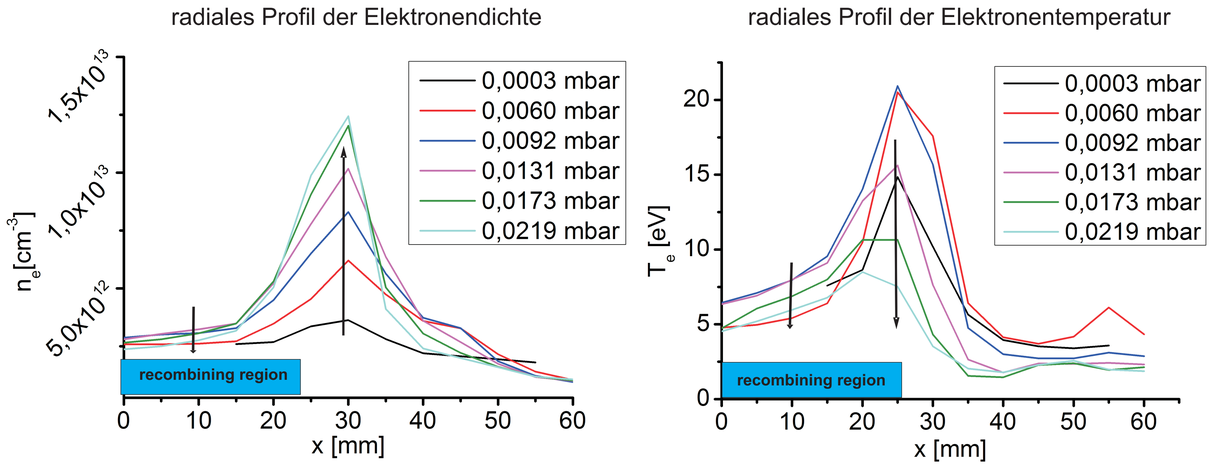
The **major ionic part** in these plasmas is H_3^+

for **low temperatures** the **molecular ion** plays an increasing part

probe measurements

- **maximum of the electron density and temperature at the edge** of the plasma column (hollow profile) because of the geometry of the cylindrical cathode

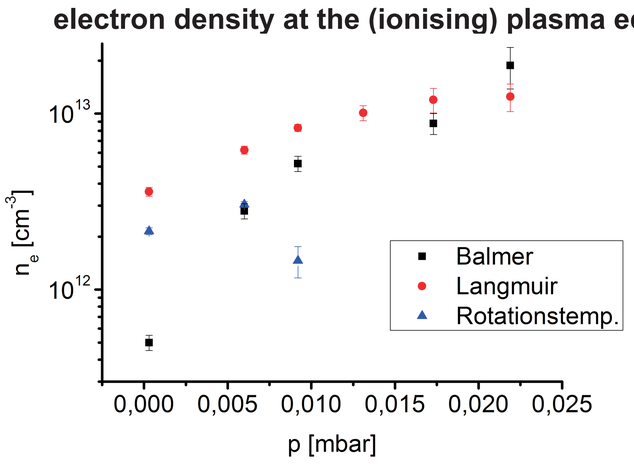
- the **electron density** at the edge of the plasma column **rises with increasing neutral pressure** in the target area



plasma centre: x=0 cm, plasma edge: x=3 cm

electron density and temperature

electron density at the (ionising) plasma edge



Determination of the **electron density** via:
D_α / D_γ ratio, Langmuir probe, rotat. temperatures Fulcher-band

- **electron density** from the D_α / D_γ ratio shows **increase with rising neutral gas pressure** (similar to Langmuir probe)

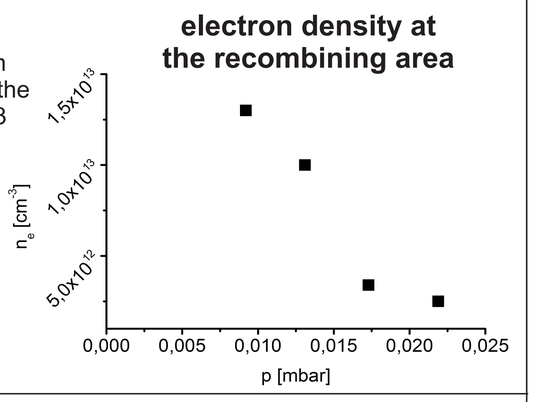
- differences may be explained by the **different z-positions** of probe and optical diagnostics

- rotational temperatures provide only reasonable values for small neutral gas pressures - further validations necessary

electron density at the recombining area

- **electron density** from **Stark-broadening** of the Paschen line n =10→3

- the **electron density decreases** in the recombining area with **rising neutral gas pressure**

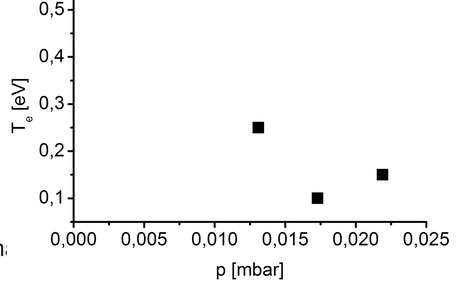


electron temperature in the recombining area

- **electron temperature** from the **ratio of the Paschen lines** n =9→3 and n =7→3

- the **temperature** in the recombining area **decreases with rising neutral gas pressure**

- the values are one order below the ones measured with the Langmuir probe (larger distance to the plasm source)



Summary & Outlook

Detection methods

electron density		electron temperature	
recombining	ionisierend	recombining	ionising
Langmuir probe	Langmuir probe	Langmuir probe	Langmuir probe
Stark broadening (Paschen lines)	rotational tem-peratures of D_2 lines	Paschen line ratios (large n)	
	Balmer line ratios (D_a/D_g)		

- **Balmer- und Paschen line intensity and profile** measurements are suitable for the diagnostics of a deuterium PSI-2 plasma.

- **Comparison with probe measurements** is presently - predominantly in the recombing state - of limited use. Further measurements have to study the variation along the z-axis in more detail.

- **Modelling of the light emission** from the individual Balmer levels can provide a deeper insight into the distribution of the different ionic species

- **Further detection methods** (e.g. He line ratios for the determination of electron temperature and -density) will be tested in order to enhance the spectroscopic capabilities.

references:
[1]U. Wenzel, D Schröder, W. Bohmeyer, G. Fussmann, A Plasma Beam passing From the Ionizing to the Recombining State, IEEE Transactions of Plasma Science, 33, No.2, 366-367 (2005)
[2]U.Wenzel, D. Schröder, G. Fussmann, Appearance of a H_α Minimum at the Onset of Net Recombination in Hydrogen Plasmas, Contrib. Plasma Phys. 47, No. 6, 451 – 457 (2007)
[3]B. Koch, W. Bohmeyer, G. Fussmann, Angular Resolved Energy and Particle Flux Measurements in a Magnetized Plasma, Contrib. Plasma Phys. 44, No. 7-8, 601 – 606 (2004)
[4]D. Wünderlich, S.Dietrich and U.Fantz, Journal of Quantitative Spectroscopy & Radiative Transfer 110, 62 (2009)