Numerical and experimental characterization of beams of negative ions and improvement investigation

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SPIDER @ Consorzio RFX (Padova)

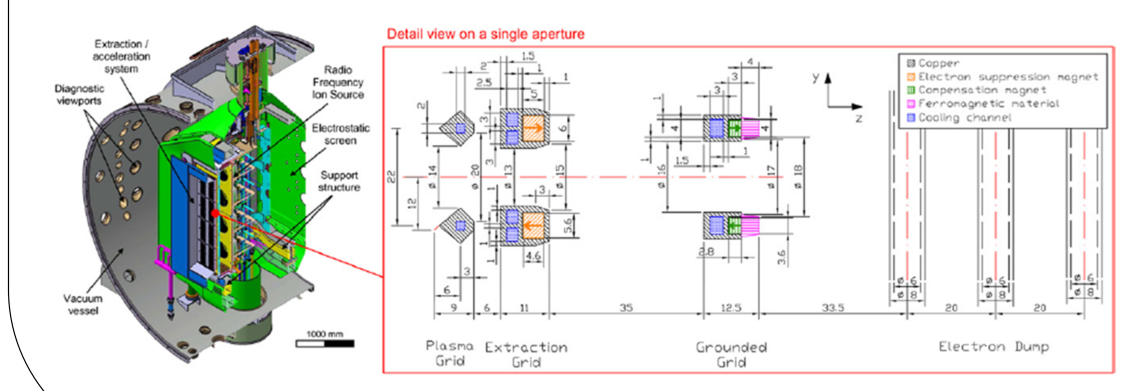
- Full size ITER NBI RF ion source
- 1280 beam apertures
- H^- (D^-)current density: 355 A/m2 (285 A/m2)
- Beam energy: 100keV
- 3 electrodes for extraction and acceleration

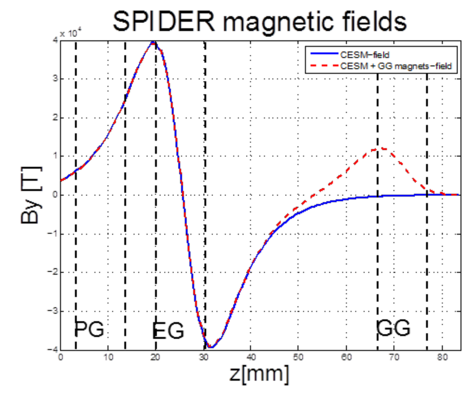
Compensation systems:

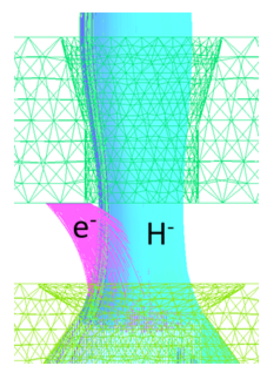
- GG aperture offsets for beamlet repulsion
- Embedded GG SmCo magnets to counteract the deflection induced by CESM-field (magnetic compensation system)
- GG alternated aperture offsets to counteract the deflection induced by CESM-field (electrostatic compensation system)

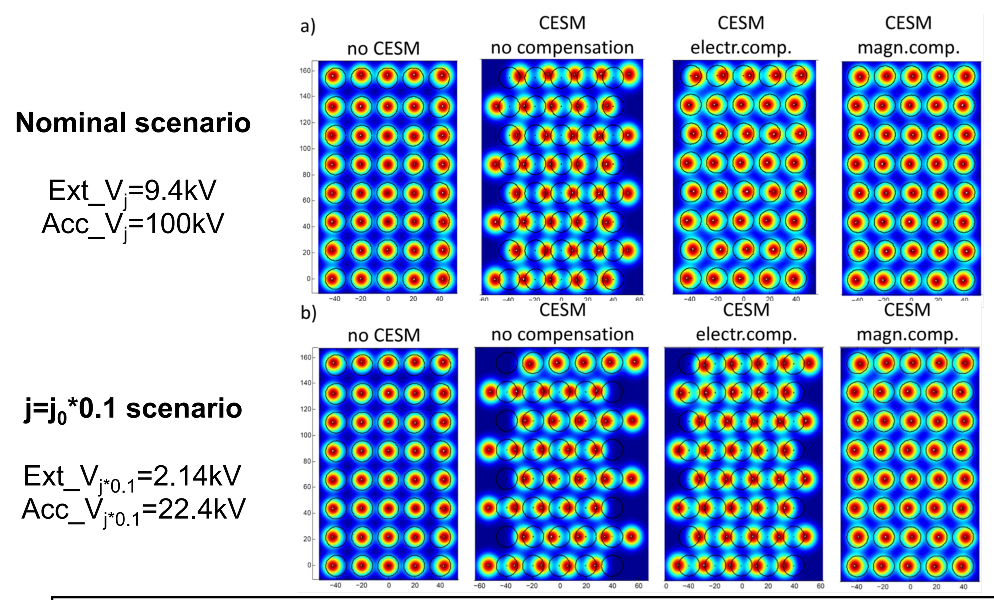
Simulation parameters and constrains:

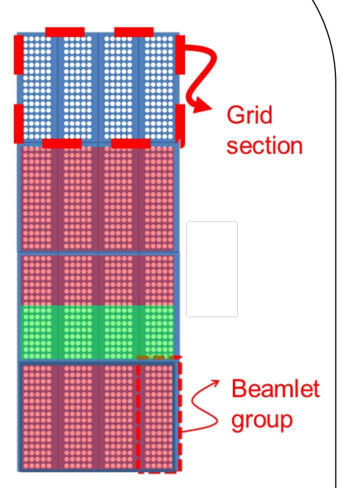
- voltages and current
- beamlets repulsion
- relative position between beamlets and grids aperture
- CESM field
- Interaction with the background gas (stripping)
- Interaction with surrounding beamlets groups

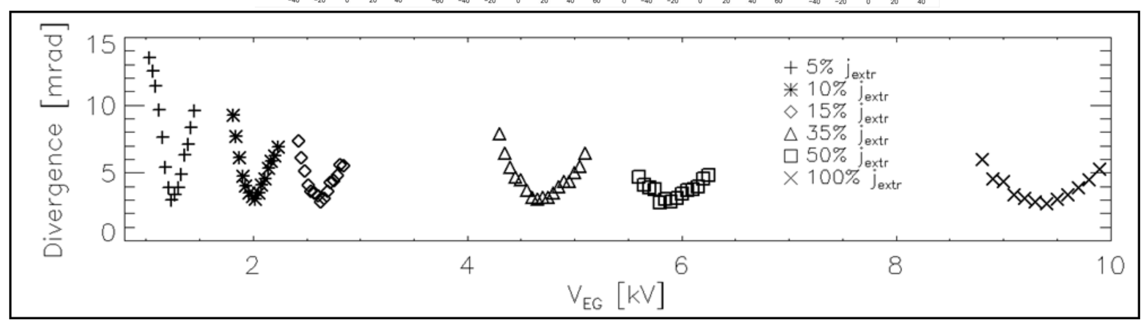










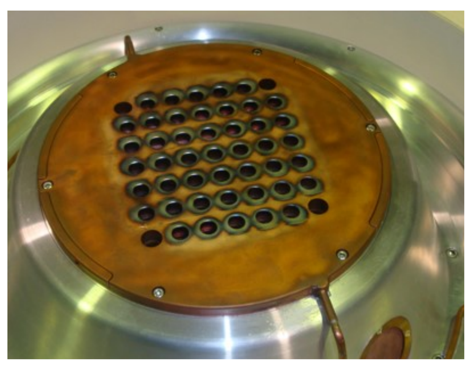


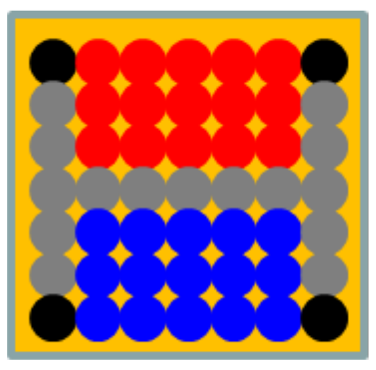
NITS @ JAEA (Japan)

- RF ion source
- 46 beam apertures
- H^- current density: 100 A/m2
- Beam energy: 30keV
- 3 electrodes for extraction and acceleration

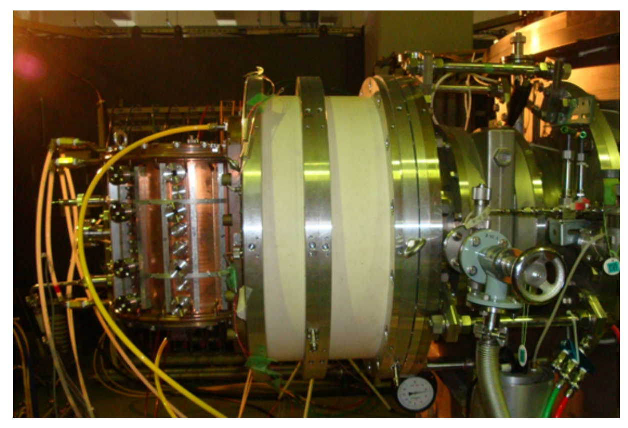
Ojectives:

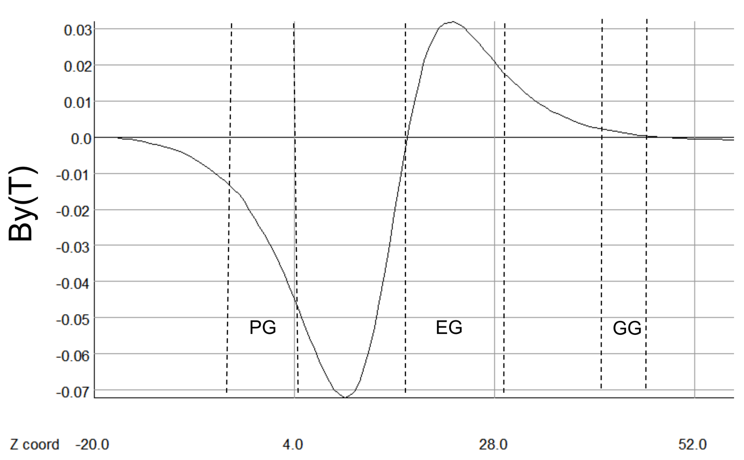
- New extraction grid MITICA-like design for ADCM test
- ADCM Br dimensioning
- Code benchmark
- Code – experiment comparison

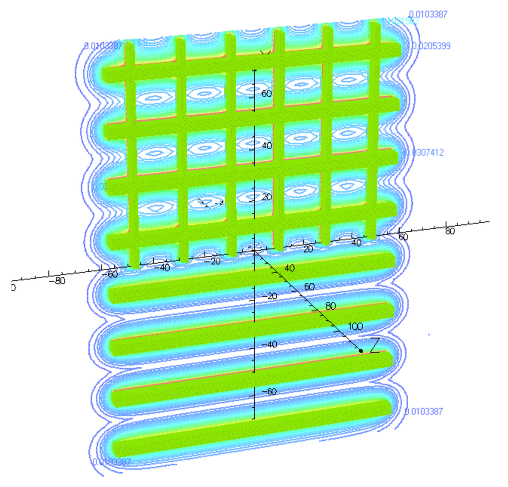


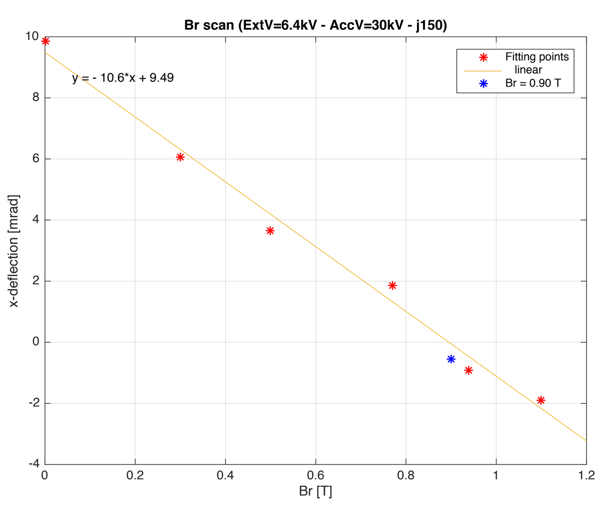


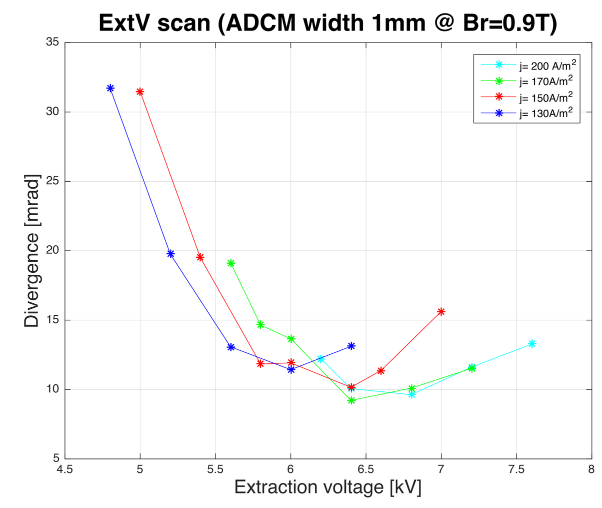
with ADCM
w/o ADCM
Not used
For Alignment

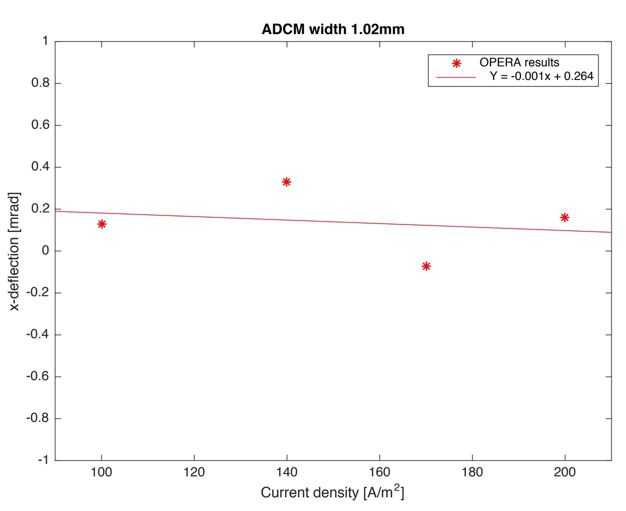










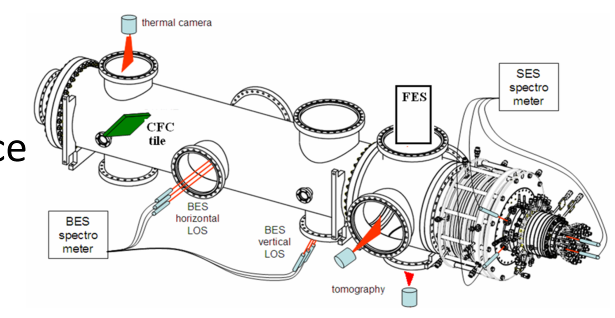


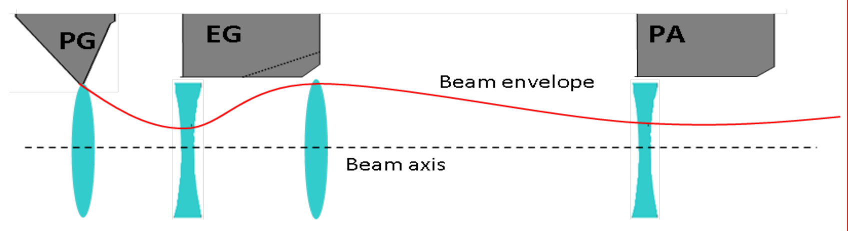
NIO1 @ Consorzio RFX (Padova)

- Compact 2 MHz RF negative hydrogen ion source
- 9 beam apertures on a 3x3 lattice
- H- current: 130 mA
- Acceleration voltage: 60kV
- 3 stage acceleration + repeller electrode

Objectives & Studies:

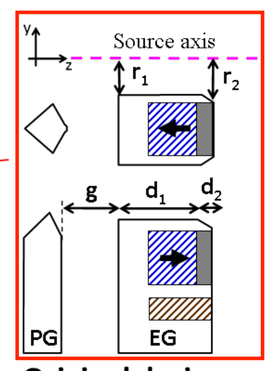
- Radiofrequency coupling
- Space charge compensation
- Test of source and beam diagnostics
- Validation of codes against experiments
- Alternative uses of caesium or alternatives to caesium
- Photoneutralization processes





A scheme of round beam optics assuming cylindrical symmetry with equivalent converging and diverging lenses.

The net effect of the EG is a converging lens, which has to balance space charge up to PA, and in NIO1, the diverging effect of PA. This shows the advantage of enlarging the beam a(z) at exit of EG (by reducing VEG from nominal design of 8 kV for 340 A/m2 to 7 kV or less), to make lens effect greater and space charge less, in order to reduce the final divergence of the beam after PA. The EG profile was optimized starting from the actual configuration. In particular, the final goal was to increase the clearance between the EG aperture and the beamlet envelope, maintaining a low beam divergence. This can be achieved by increasing the penetration of the PA potential into the EG aperture; this induce a beam widening at the EG exit, that compensate the successive focusing induced by the converging lens at PA aperture entrance

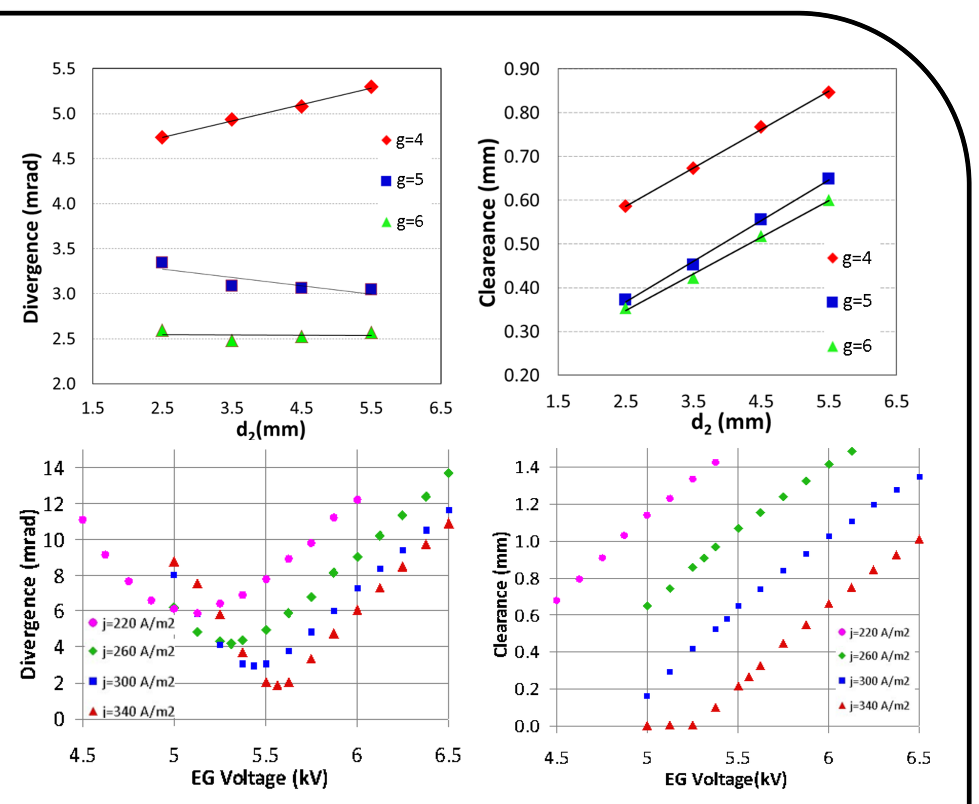


Original design

- r_1=3.1 mm
- r_2=4.1 mm
- d_1=8.8 mm
- d_2=1.5 mm
- g= 5+/-1 mm

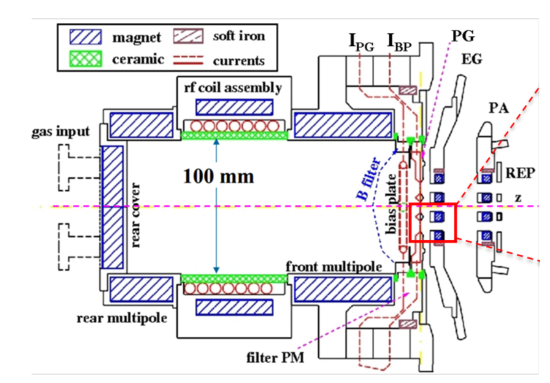
New design

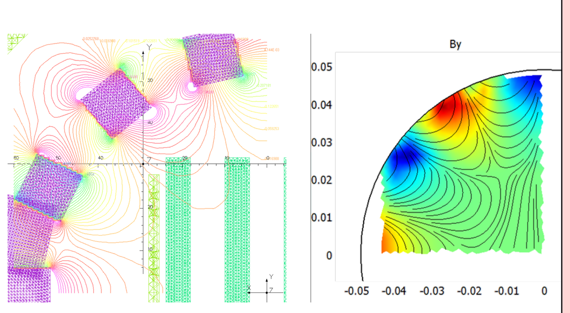
- r_1=3.5 mm
- r_2=5 mm
- d_1=4.8 mm
- d_2=5.5 mm
- g=5mm

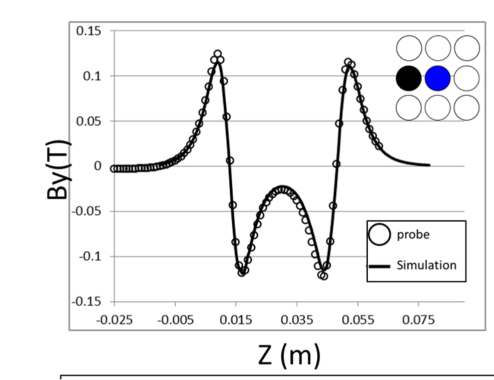


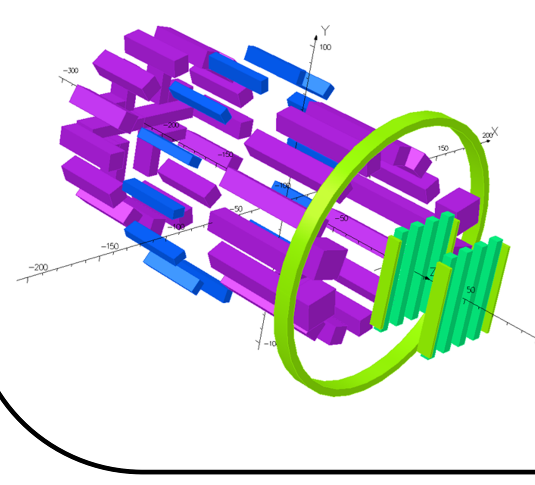
New EG design

Magnetic simulations



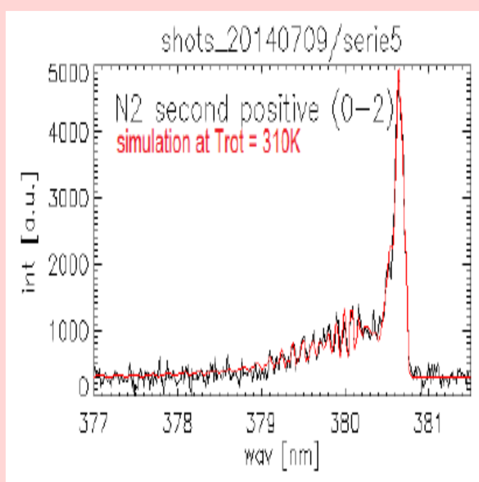




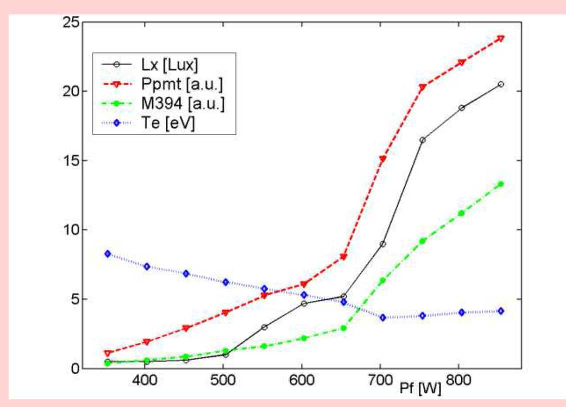


NIO1 experimental measurements

- The source was operated with a long single pulse often lasting the entire experimental session, during which the different pulse conditions were explored.
- <u>From H_2 spectra the rotational temperatures have been found</u>: H_2 rotational temperature has been derived from the simulation of the rotational bands. The simulated spectra at different rotational temperatures were superimposed to the experimental data in order to find the best match.



Capacitive to inductive coupling transition (E-H mode transition)



YACORA: simulate the population coefficients (X_H) of H and H_2

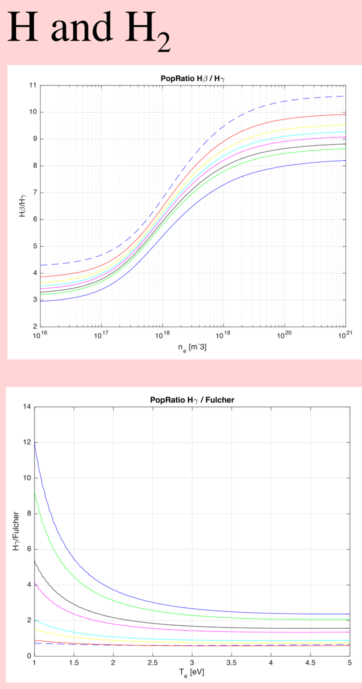
- T_e, n_e, n_H/n_{H2} and n_{H+}/n_H obtained comparing the experimental emissivities ratios, $\varepsilon_{H\beta}/\varepsilon_{H\gamma}$ and $\varepsilon_{H\gamma}/\varepsilon_{Fulcher}$, with YACORA model predictions.

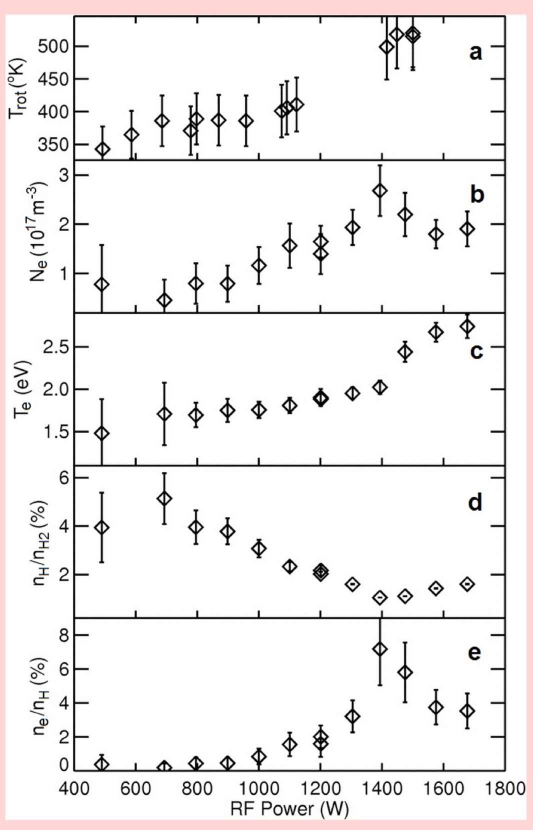
$$P = n_{H_2} K_B T_{rot} \qquad n_e = n_{H^+}$$

$$\varepsilon_{H\gamma} = (n_e n_H)^{-1} X_{H\gamma}(n_e, T_e)$$

$$\downarrow$$

$$\frac{n_H}{n_{H_2}} = \left(\frac{\varepsilon_{H\gamma}}{\varepsilon_{Fulcher}}\right) \cdot \left[\frac{X_F(n_e, T_e)}{X_{H\gamma}(n_e, T_e)}\right]$$





Optical Emision Spectroscopy (OES)

A great variety of plasma parameters from spontaneous radiation: t_e, n_e, t_{rot}, t_{vib}, impurities content…

The light emitted has been observed from two viewports at 26 mm from the PG, looking one into each other (light collected from the same region). Each viewports hosts optic head (BK7 lens: f=50 mm, ϕ=10 mm) conveying light into quartz optical fibers.

- <u>Hamamatsu C10082CAH</u> (resolution 1nm - spectral window from 200 to 850 nm) monitors the presence of impurities in the plasma, and records the intense and isolated lines of the Balmer series
- <u>Acton SpectraPro-750</u> *(resolution 50pm)*, solves the rotational and vibrational H_2 molecular spectra.