



# EFFECT OF PLASMA GRID AND BIAS PLATE BIASING ON THE SPIDER NEGATIVE ION BEAM

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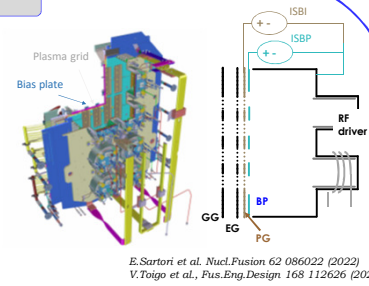
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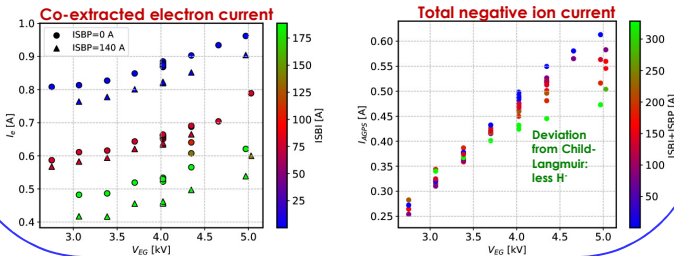
## 1. SPIDER

- **SPIDER:** Full size prototype of the ITER neutral beam injector
- 4 RF generators for 8 drivers up to 800 kW total power
- **Bias Plate (BP)** and **Plasma Grid (PG)** can be polarized with respect to the source
- **ISBP:** power supply for the polarisation of the BP
- **ISBI:** power supply for the polarisation of the PG

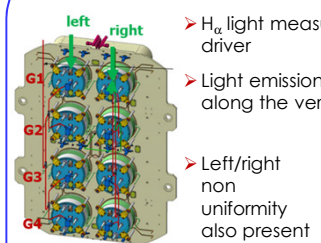


➤ ISBI and ISBP necessary for reducing the co-extracted electrons

- Electron current decreases by increasing PG polarization - polarization of the bias plate has smaller effect
- By increasing BP and PG polarization the total negative ion decreases at large extraction voltage
- Smaller availability of negative ions at large BP and PG polarization

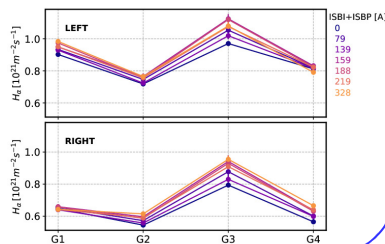


## 2. PLASMA INSIDE THE DRIVERS



- $H_{\alpha}$  light measured inside each driver
- Light emission is not uniform along the vertical direction
- Left/right non uniformity also present

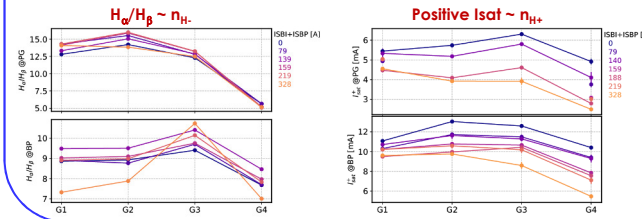
45 kW x 4 generators  
PG = 1.05 kA (=1.7mT)  
P<sub>source</sub> = 0.36Pa  
Main gas: H  
Cs evaporation  
28 beamlets



B. Zaniol et al. Rev. Sci. Instrum. 91, 013103 (2020)

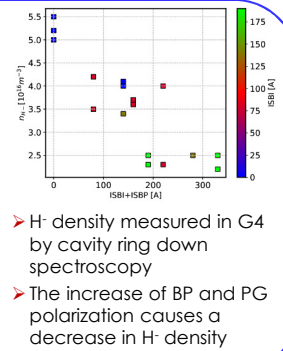
## 3. PLASMA SOURCE AND GRIDS

- In front of the BP and PG plasma is non-uniform
- $H_{\alpha}/H_{\beta}$  measured by spectroscopy
- Positive ion saturation current measured by electrostatic probes



- In front of BP  $I_{sat}^{+}$  is lower at G4 (bottom part of the grid)
- In front of PG  $H_{\alpha}/H_{\beta}$  is lower at G4
- Top-bottom non uniformity at spatial scale of the driver is present
- The increase of the polarization causes a clear decrease in the positive ion saturation current and not a clear effect on  $H_{\alpha}/H_{\beta}$
- BP and PG polarization modifies the plasma in front of them
- Changes in the plasma in front of the PG has strong impact on the beam since it is the region where the H<sup>+</sup> are formed in surface operations

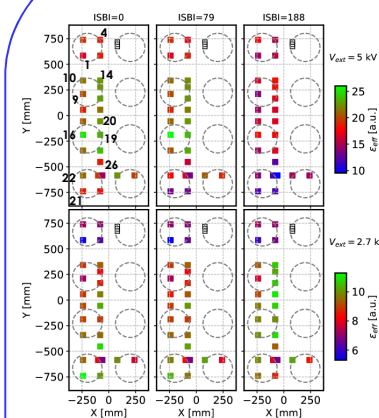
C. Poggi et al. IEEE trans. plasma science, to be published  
M. Barbisan et al., Plasma Phys. Control. Fusion 64 065004 (2022)



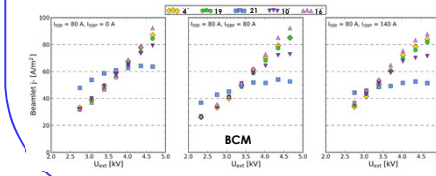
- H<sup>+</sup> density measured in G4 by cavity ring down spectroscopy
- The increase of BP and PG polarization causes a decrease in H<sup>+</sup> density

## 4. BEAM: BEAMLETS CURRENT

- The accelerated beam highlights the plasma non uniformities
- Tomographic reconstruction of the single beamlets emissivity proportional to beamlets current
- **High V<sub>EG</sub>:** by increasing the bias the current decrease everywhere except at the top
- **Low V<sub>EG</sub>:** by increasing the bias the current increases everywhere except at the top
- **High V<sub>EG</sub>:** too less H<sup>+</sup> in G2-G3-G4 further reduced by increasing the bias
- **Low V<sub>EG</sub>:** beamlets scraping into the EG



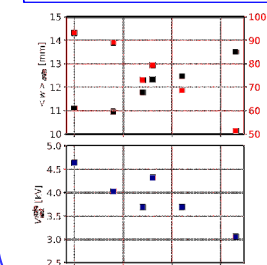
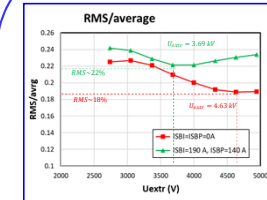
- Beamlet current monitor (BCM) measures the current of the single beamlet
- BCM and tomography shows similar behaviour
- In G4 the lower H<sup>+</sup> availability is further reduced by increasing the biases



A. Shepherd et al. IEEE trans. plasma science, to be published  
M. Ugoletti et al. IEEE trans. plasma science, to be published

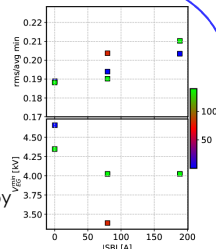
## 5. BEAM: SPATIAL UNIFORMITY

- Beam spatial uniformity estimated with tomography
- We can evaluate the minimum of RMS/avg and V<sub>EG</sub> of this minimum
- Uniformity increases by increasing the bias
- Best uniformity moves at lower V<sub>EG</sub> by increasing the bias



A. Pimazzoni et al. Rev. Sci. Instrum. 91 033301 (2020)

- For low extraction voltage, the space charge dominates: scraping at the EG
- For high extraction voltage: H<sup>+</sup> availability dominates
- PG and PB polarization changes the plasma and H<sup>+</sup> density in front of the PG
- Beamlets widths and current reflect the behaviour of the uniformity



## 6. CONCLUSIONS

- The effects of the polarization of PG and BP has been characterized
- The polarization modifies the plasma in front of the PG in particular the negative ion density
- The accelerated beamlets reflects the non-uniformity of the plasma in front of the PG
- Lower part of the beam is affected more by lower H<sup>+</sup> availability
- By increasing the plasma density would reduce the beam non-uniformity