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CHARACTERIZATION OF SPIDER BEAM OPTICS WITH VISIBLE CAMERAS

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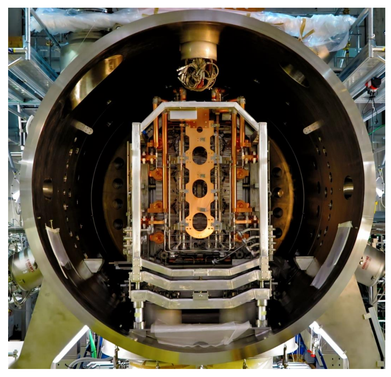
1. SPIDER

- **S**ource for **P**roduction of **I**ons of **D**euterium **E**xtracted from **R**F plasma
- Full size prototype of the ITER neutral beam injector
- 4 RF generators for 8 drivers up to 800 kW total power
- 100 kV maximum acceleration – 12 kV maximum extraction

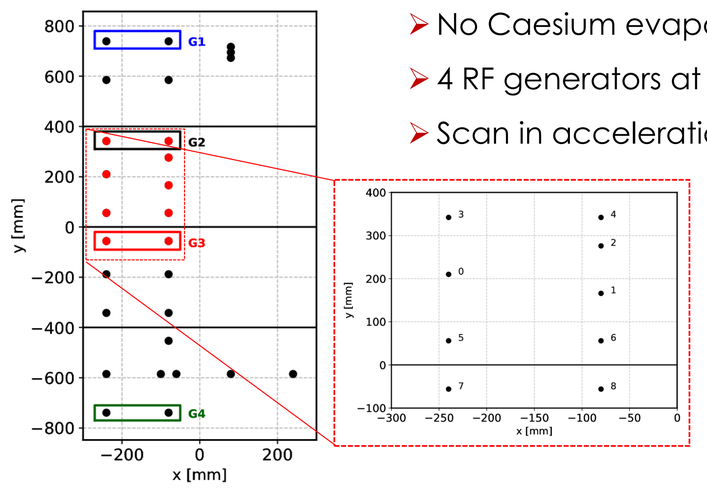


- Goal of the poster: characterize the optics of the accelerated beam at different experimental conditions
- Visible cameras as main diagnostic

Toigo et al, FED **168** (2021) 112622
Serianni et al. RSI **91** (2020) 023510

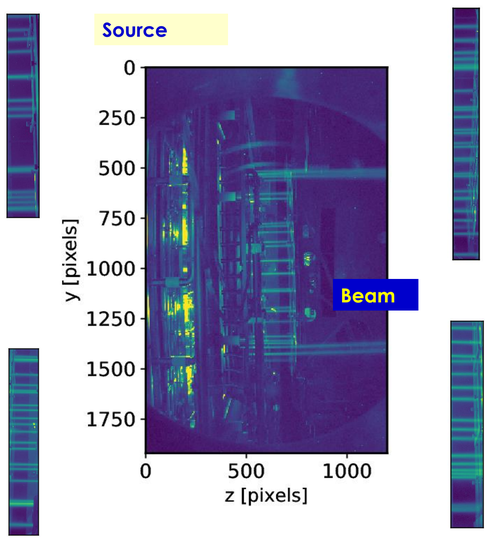
2. PERFORMED EXPERIMENTS

28 holes in the PG



- Hydrogen as main gas
- No Caesium evaporation: volume operations
- 4 RF generators at 100kW each
- Scan in acceleration, extraction, filter field, bias
- Only 28 beamlets out of 1280 compose the beam
- The 1/e width w of the single beamlet is estimate with a Gaussian fit from camera signals
- The average width of extreme row of each beamlet groups G1 G2 G3 G4 is evaluated
- Inside G2, the width of the single beamlet highlighted with numbers is estimated
- Uniformity in the optics is studied at two spatial scales: coarse (beamlet group) and fine (inside beamlet group)

3. VISIBLE CAMERAS



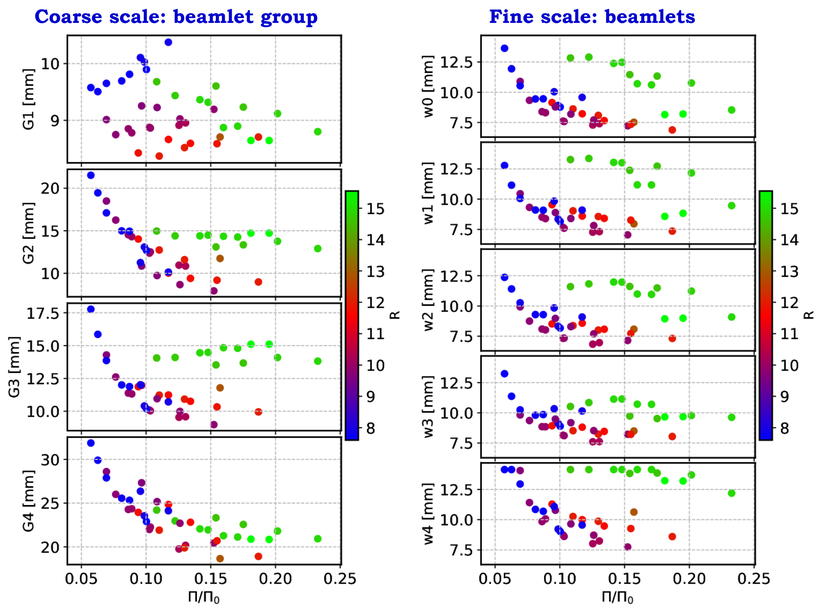
- 15 cameras installed all around the vessel look at the beam from different points of view
- They measure the H_α emission: interaction between beam and neutral gas

Ugoletti et al, FED **169** (2021) 112667

4. PERVEANCE SCAN

$$\Pi = \frac{I_{acc} + I_{eg}\sqrt{\frac{m_e}{m_i}}}{V_{EXT}^{3/2}}$$

Average width of the 4 beamlet groups (left) and of the single beamlet of the G2 (right) as a function of perveance and $R=V_{ACC}/V_{EXT}$



- ✓ w decreases by increasing the normalized perveance
- ✓ For R=15 V_{EXT}<2kV and the beam impinges the extraction grid

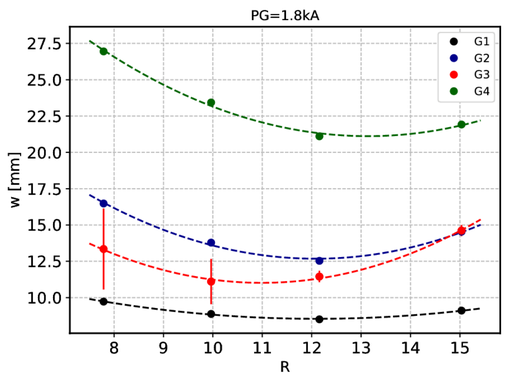
Veltri et al, IEEE TPS **40** (2012) 2279

The beam is not spatially uniform: w varies in the different groups

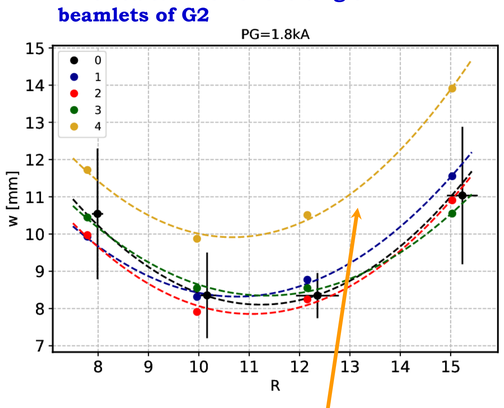
5. Vacc/Vext SCAN

Beamlets width as a function of $R=V_{ACC}/V_{EXT}$ at fixed PG current

Coarse scale: average width of the beamlet groups



Fine scale: width of the single beamlets of G2

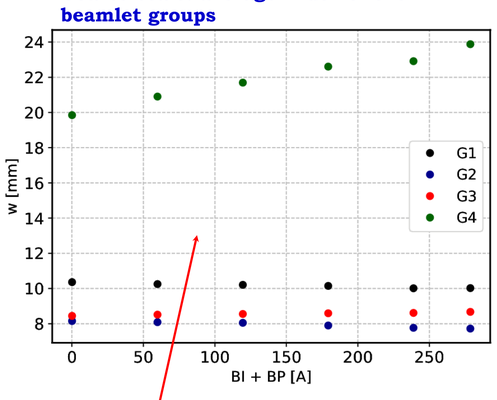


- Parabolic trend with a minimum around R=10 as expected
- Similar behaviour of the 4 groups but not exactly the same: non uniformity
- G4 (bottom group) shows the worst optics with double width respect to the other groups
- Inside the beamlet group the largest beamlet is the outermost (B4): non uniformity also at finer spatial scale

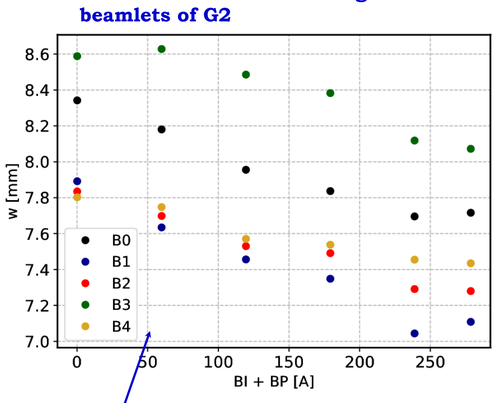
6. BIAS SCAN

- BI: current that polarizes PG respect the source
- BP: current that polarizes bias plate respect to the source
- Scan of bias current at R=10 (best ratio) PG= 750kA with BI=BP

Coarse scale: average width of the beamlet groups

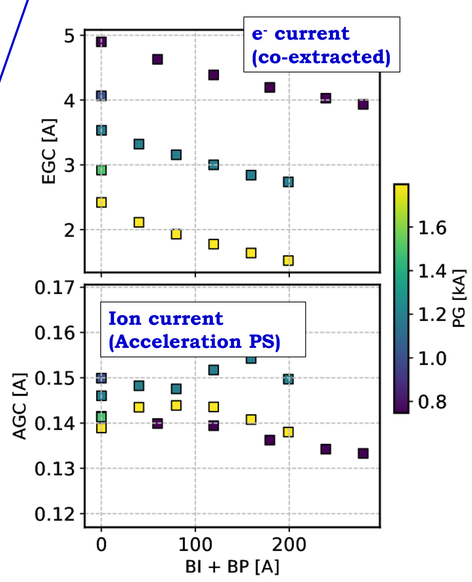


Fine scale: width of the single beamlets of G2



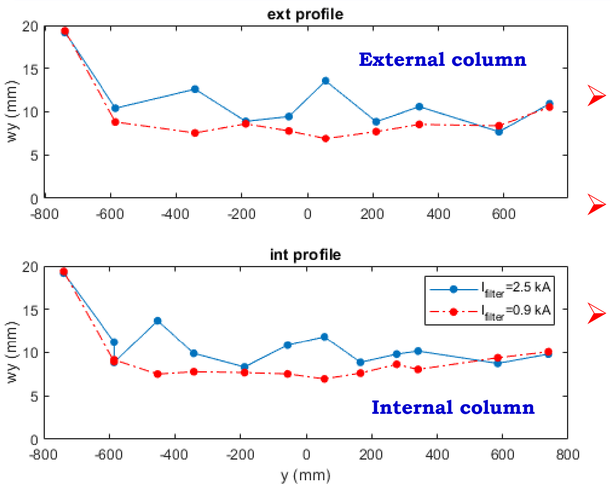
- Average width of the beamlet groups decreases by increasing bias currents
- G4 (bottom group) has an opposite behaviour

- Inside the beamlet group the width of the single beamlets decreases by increasing bias currents



- Optics is modified since the bias decreases the co-extracted electrons
- No clear effect on ion current

7. VERTICAL NON-UNIFORMITY



- Vertical profile of beamlets width for the external and internal columns
- Bottom group is always the one with worst optics (lowest current)
- Non-uniformity inside the beamlet groups increases at large PG current

8. CONCLUSIONS

- Visible cameras are powerful non-invasive diagnostic for characterizing the optics of the beam
- In volume operation co-extracted electrons have a strong impact on the beam optics
- Best optics at $R=V_{ACC}/V_{EXT}$ in the range 10-12
- Improvement of the divergence by decreasing the amount of co-extracted electrons