Commissioning and First Results of the ITER-Relevant Negative Ion Beam Test Facility ELISE

ITR/P1-01

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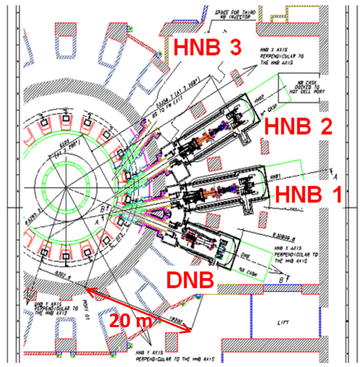
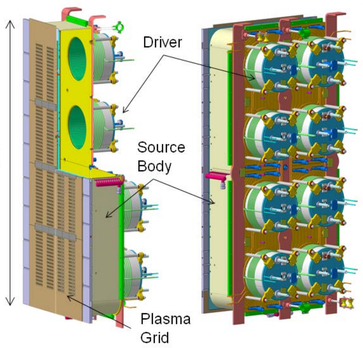
Introduction

ITER Neutral Beam System

- **Heating Beams:**
  - 33 MW injected power
  - 2 injectors, tangential
  - 1 MeV, 40 A Deuterium, 3600 s
  - procured by EU (50%) & JA (50%)
- **Diagnostic Beam:**
  - 3 MW injected power
  - 1 injector, radial
  - 3 s pulse, 5 Hz, every 20 s
  - 100 kV, 60 A Hydrogen
  - procured by India





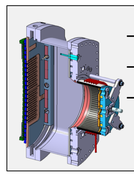
ITER RF source (based on IPP Design)

- **2000 cm² extraction area**
- **1280 apertures (16x5x16), 14 mm Ø**
- **58 A ≡ 290 A/m² D^-, $j_e/j_{D^-} < 1$**
- **70 A ≡ 350 A/m² H^-, $j_e/j_{H^-} < 0.5$**
- **Cs seeded at 0.3 Pa filling pressure**
- **8 drivers (4 RF circuits)**
- **4 × 200 kW at 1 MHz**

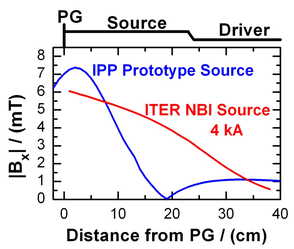
Ion Source Challenges: F4E NBI Roadmap

Extrapolation of small IPP prototype ion source operation experience not straight forward

- **Plasma homogeneity:**
  - sufficient plasma overlap (done by RADI)
  - Cs coverage of plasma grid
- **Suppression of co-extracted electrons & achievable negative ion current**
  - different magnetic filter field and bias area



– 1 driver 0.6x0.3 m²
– O(100) apertures
– filter field by permanent magnets



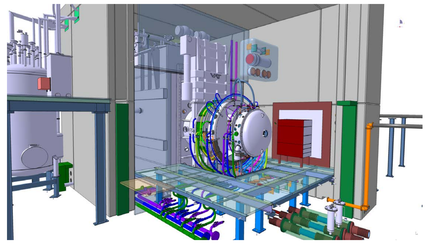
F4E R&D program established

- **Neutral Beam Test Facility (Padua, Italy)**
  - 1 MV Test Facility, operational 2017
  - 100 kV Ion Source Test Facility (2015)

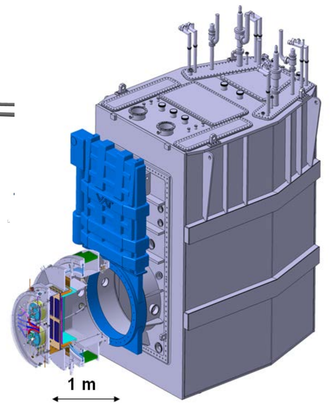
see A. Masiello, ITR P1-04

- **ELISE test facility at IPP as important intermediate step**
  - cw plasma operation, pulsed HV
  - flexible design, wide operational margins ($j_e/j_{D^-} < 1.5 \div 2$)
  - fast and cheap track for exploitation of a large RF driven ion source
  - use of existing hardware from MANITU/RADI and IPP infrastructure

ELISE (Extraction from a Large Ion Source Experiment)



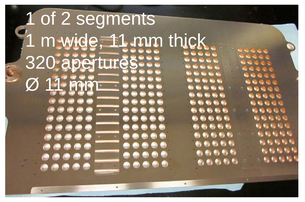
Isotope	H, D	Ion Current	20 A
Source Area	1.0x0.87 m²	Apertures	640 (8x5X16)
Extr. Area	1000 cm²	RF Power	2 x 180 kW
Total Voltage	<60 kV	Plasma Pulse	cw
Extr. Voltage	<12 kV	Beam Pulse	10 s every 180 s
PG Current	< 8 kA	PG Temp.	< 200 °C

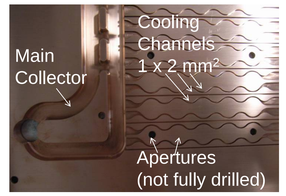


Construction & Assembly

Grid Manufacturing (w/o problems):

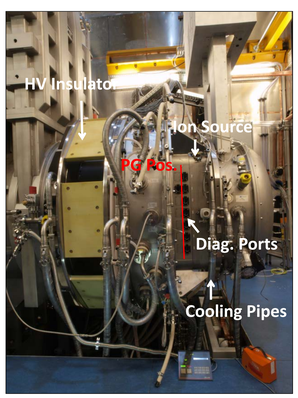
- **Technologically most demanding**
  - thin walls (1-2 mm) between vacuum and 20 bar water at **200 °C** (PG)
  - up to 32 MW/m² and 2x200 kW due to co-extracted electrons (EG) **→ 40 A ≡ 400 A/m² @ 10 kV**
- **Made out of electrodeposited copper**
  - qualification of thermal and mechanical properties (in coll. with RFX Padua)
  - input for design (also for ITER NBI)

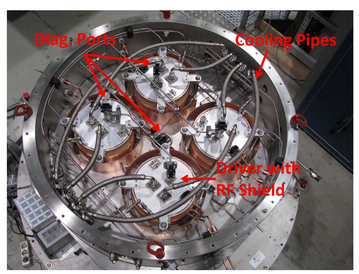


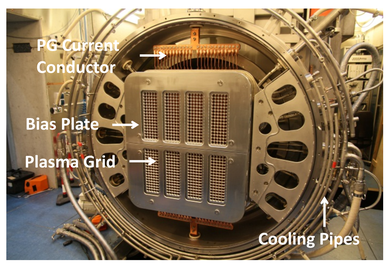


Assembly mainly finished

- **Delay of 12 months**
  - manufacturing problems (ion source, grid coating, calorimeter)
  - defects parts from MANITU/RADI



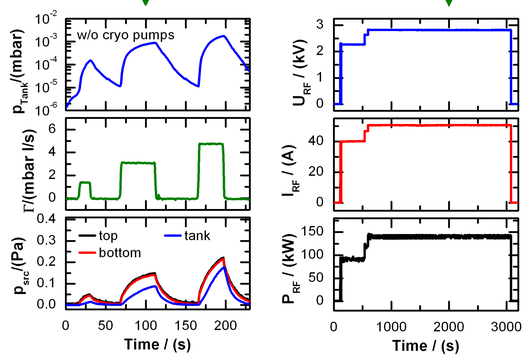


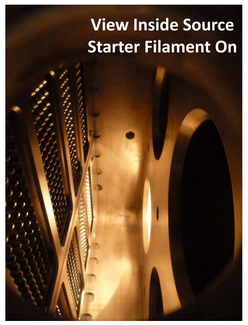


Integrated Commissioning

Integrated Commissioning has been started:

Mode of Operation \ Subsystems needed	Control & DAQ	Vacuum	Gas	Cooling	RF	HV	Safety	Radiation Protection	Status
Maintenance									–
Standby	+	+							–
Filament Pulse	+	+							DONE
Gas Pulse	+	+	+						DONE
RF Pulse	+	+	+	+	+		+		End of Oct.
HV Pulse w/o Gas	+	+		+		+	+		Started
HV Pulse with Gas	+	+	+	+		+	+		End of Oct.
Beam Pulse in H	+	+	+	+	+	+	+		End of Oct.
Beam Pulse in D	+	+	+	+	+	+	+	+	2013
Status	OK	Conv. OK Cryo started	OK	OK	OK on test load	OK on test load	OK	OK	



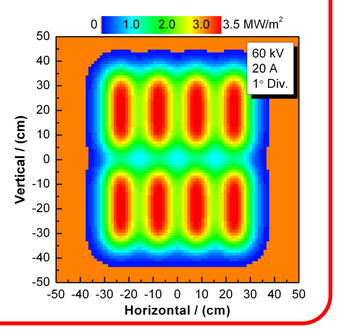


Experimental Plan

Goal: Achievement of ITER parameters within 2 years (F4E contract)

Start in Nov. 12

- **Phase 1 (Months 1-6): initial experiments**
  - Plasma homogeneity w/o and with Cs in H & D
  - First extraction and PG bias studies
  - < 100 s pulses
- **Phase 2 (7-12): optimization in H**
  - Beam homogeneity at high RF power
  - Optimisation of magnetic FF and bias
  - 400 s pulse
- **Phase 3 (13-18): optimization in D**
  - 3600 s pulse
- **Phase 4 (19-24): final demonstration**



Conclusion

- **ELISE test facility at IPP is ready for exploitation of a large RF driven negative hydrogen ion beam source for the first time**
- **Important prerequisite for establishing the ITER NBI system in-time**

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