The H^-/D^- RF source at the edge towards large area beam extraction and long pulses

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1. Introduction

IPP Garching is currently developing a RF source for the ITER neutral beam system. It has already been demonstrated at the test facility BATMAN that the IPP RF source can achieve and partially exceed the ITER requirements with respect to current density, pressure and electron content, but with only small extraction area (~70 cm^2) and limited pulse length (< 6 s) [1]. On the "MANITU" testbed (multi ampere negative ion test unit) the experiments are focussed on large area beam extraction and operation in D^- with pulses of up to 3600 s.

In first experiments with pulses of few seconds' length the extraction area has been enlarged from the initially 74 cm^2 in two steps to 152 cm^2 and 306 cm^2. The electrically measured H^- current density showed no significant dependence on the extraction area. In order to demonstrate long pulse operation many components of the RF source and of the power supply as well as of the testbed had to be upgraded.

The paper describes this upgrade and contains first results concerning extended extraction area and pulse length.

2. Extension of the extraction area.

For the beam extraction a triode system is used with apertures of 8 mm diameter in the plasma grid, which is biased with 12 - 24 V with respect to the source. The extraction area has been enlarged from the initially 74 cm^2 in two steps to 152 cm^2 (300 apertures) and 306 cm^2 (600 apertures) by changing the grid masking (Fig. 1).

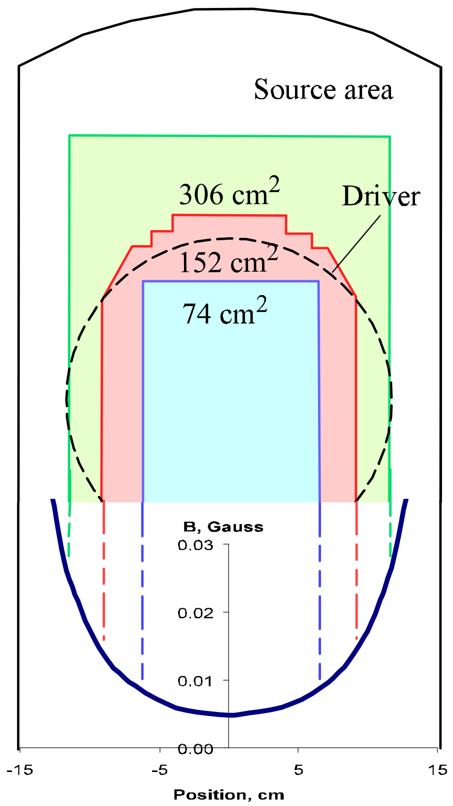

Fig. 1: Shape of the enlarged extraction area and profile of the magnetic filter field

With 152 cm^2 extraction area a maximum current density of 19.3 mA/cm^2 has been achieved on the calorimeter at 90 kW RF power. This is consistent with the results using the small 74 cm^2 extraction area on the Batman test bed [1].

After enlarging the area to 306 cm^2 the ion current density dropped only by 10 – 15 % (Fig. 2). With 10 kV extraction voltage a maximum value of 32 mA/cm^2 corresponding to a total H^- ion current of 9.7 A has be measured at 0.45 Pa and 100 kW. But only a relatively small fraction reaches the calorimeter, basically independent of the extraction voltage. This is most likely caused by the strong increase in the filter field at the edge of the large extraction area which could produce sufficient deflection of extracted ions. Fig. 2 also shows that a high extraction voltage is required for efficiently extracting high negative ion currents.

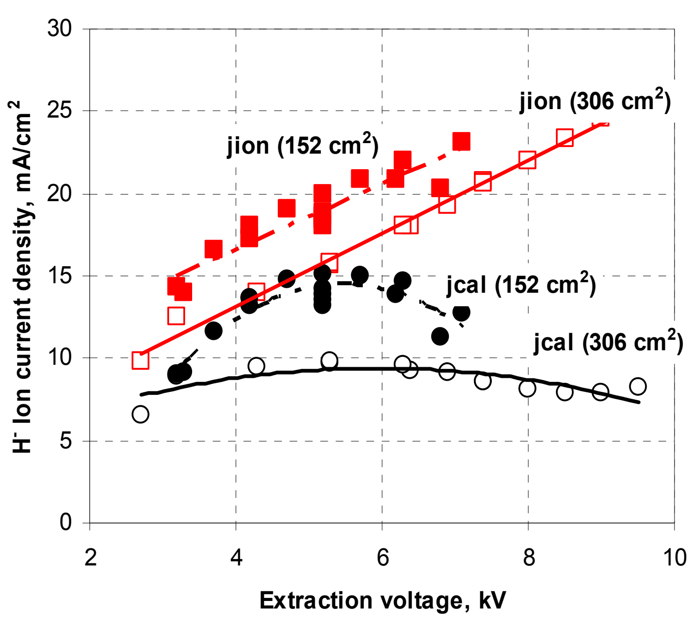

Fig. 2: Dependence of the H current density on the extraction voltage for 152 cm^2 and 306 cm^2 extraction area with 80 kW at 0.45 Pa.

3. Upgrade for long pulses

3.1 RF source, RF and HV power supply

In the currently used RF source the plasma is generated in a cylindrical RF driver and expands into a large expansion volume of 24 x 31 x 59 cm^3 (h x b x l), separated from the extraction system by a magnetic filter field. Further details of this so called "Type 6 source" are described in [2]. The driver consists of an alumina cylinder of 245 mm diameter and is protected from plasma erosion by an internal copper Faraday shield. This part of the source is exposed to a high heat load. For cw operation it will be replaced by an actively cooled version which is manufactured by galvanic copper deposition. This technology allows manufacturing small water cooling channels inside the 3 mm copper wall of the screen.

The source body is water cooled, the plasma grid, which has to be on a temperature of 150 – 250°C for optimal Cesium surface conditions, is gas cooled. The temperature of both will be made controllable during long pulses in order to optimize the H^-/D^- yield and minimize the Caesium consumption.

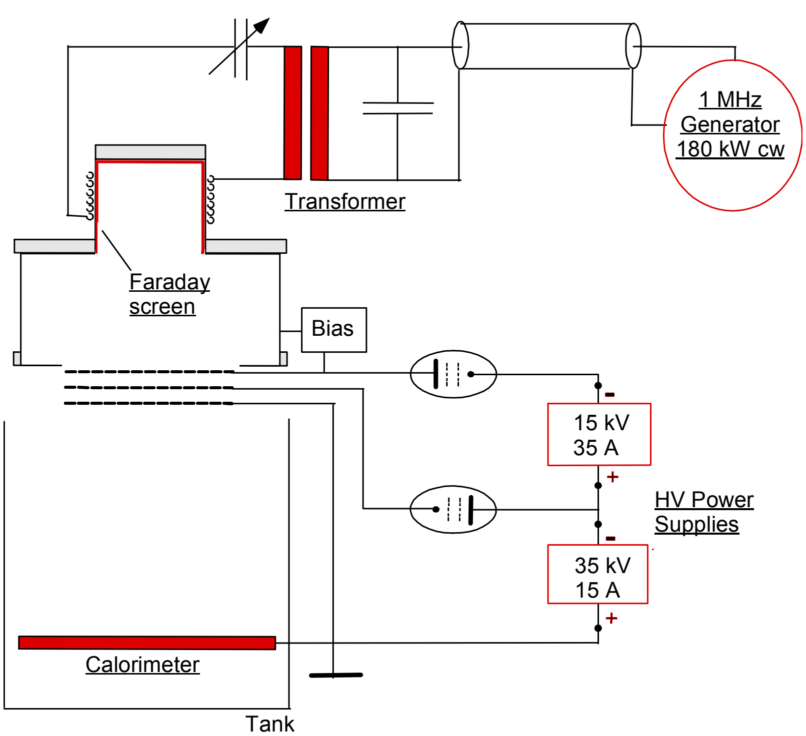

Fig 3: HV and RF power supply at the MANITU testbed, new or upgraded components are underlined

At ITER the RF power supply will be on HV potential, but on MANITU the RF generator is on ground potential and therefore an insulation transformer in the RF circuit is necessary (Fig. 3). During long pulses overheating the ferrites of this transformer could occur. This problem has been solved by using ferrites with low losses and high Curie temperature, an optimized mechanical set-up and appropriate RF matching. The temperature increase could be reduced in this way from 10°C/s to 0.2°C/s at 100 kW.

The old short pulse 120 kW RF generator has been replaced by more powerful one (180 kW, 1 MHz) suitable for cw operation. The new generator is equipped with two tetrodes in push-pull arrangement.

The experiments on MANITU were in the past dependent on the availability of the central IPP HV power supply system. Now the testbed is equipped with its own cw power supplies for extraction (15 kV, 35 A) and acceleration voltage (35 kV, 15 A). A completely new HV circuit and voltage regulation system using two tetrodes has been commissioned.

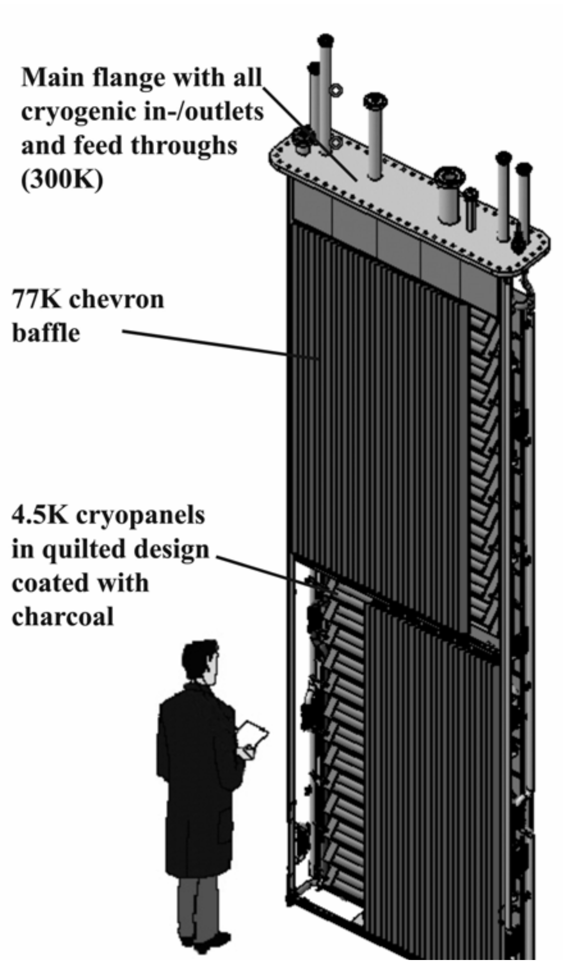

Fig. 4: One of the cryosorption pumps

3.2 MANITU testbed

The former titanium evaporation pumps of MANITU were capable for pulse length up to 10 – 15 s only and have been replaced by a cryo pump system with a pumping speed of 7×10^5 l/s and a pumping capacity of 1×10^6 mbarl. The complete cryo system was designed and constructed within a collaboration with FZK and consists of two cryosorption pumps (Fig. 4) and a cryo supply which partly uses the He liquefier of the ASDEX-Upgrade cryo pump system.

An actively cooled beam calorimeter with a diameter of 800 mm has been designed for cw operation with 350 kW total power capability and a maximum power density of 6 MW/m^2. It consists of four ASDEX-Upgrade calorimeter panels, and two special cooling pipes designed for space resolved calorimetric measurements, provide the beam profile in horizontal and vertical direction.

The deuterium operation requires neutron shielding: the source and the extraction system are enclosed in a cabine with 20 cm thick polyethylene walls, a sliding door and a removable roof slab, the calorimeter is shielded by 30 cm thick double walled water tanks which are placed inside the vacuum chamber. The shielding allows a total pulse duration of 6 hours per year for Deuterium operation.

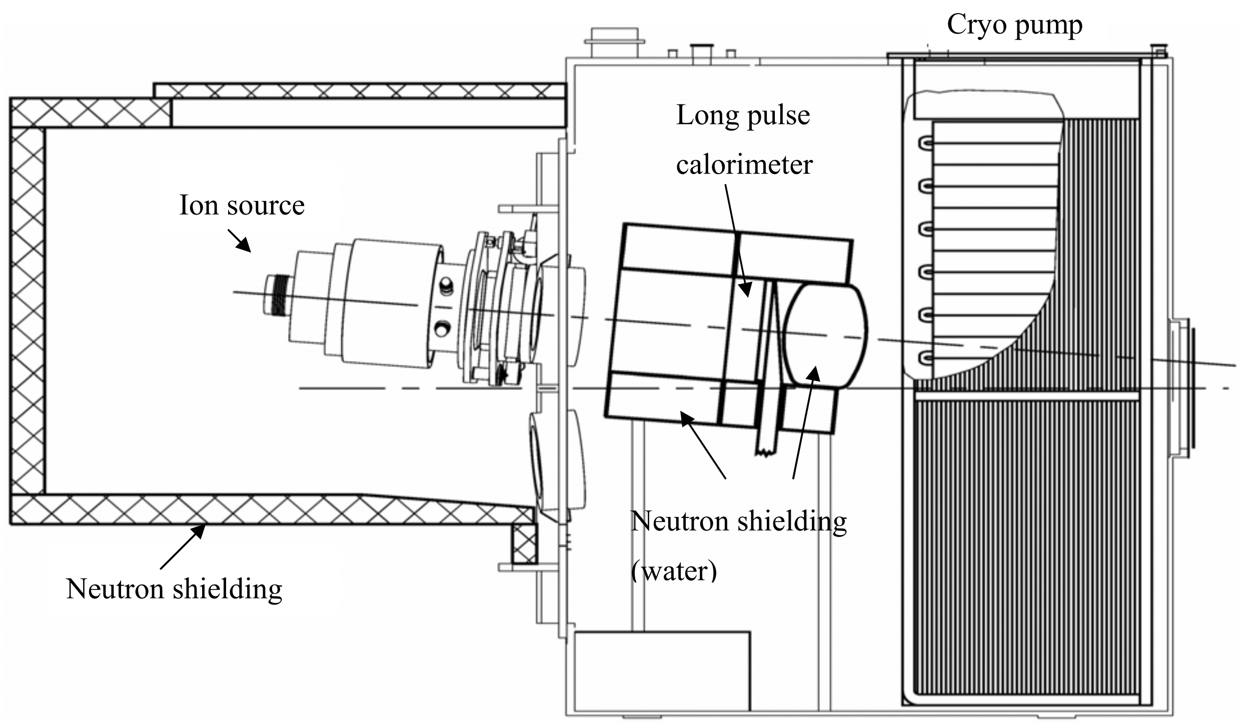

Fig. 5: The MANITU testbed

A new control system including HF and HV power supply, gas and vacuum system as well as a improved data acquisition system compatible with long pulses has been commissioned.

4. First extension of the pulse length

The RF source and the testbed are so far operational using the new RF and HV power supplies, the data control and the data acquisition system. In June the actively cooled Faraday shield and the long pulse calorimeter with the internal neutron shield will be available and the cyro pumps will be operational. As an intermediate solution an inertially cooled calorimeter of sufficiently large thermal capacity is used, which allows pulses of several 10 seconds length.

The maximum pulse length is presently limited by the heat up of the old Faraday shield and the pressure rise in the vacuum tank. With this partly upgraded set-up beam extraction experiments have been started with an extraction area of 152 cm^2 and a standard pulse length of around 10 s. So far it could be demonstrated that pulses with several ten seconds of beam on time on a substantially high ion current level are possible.

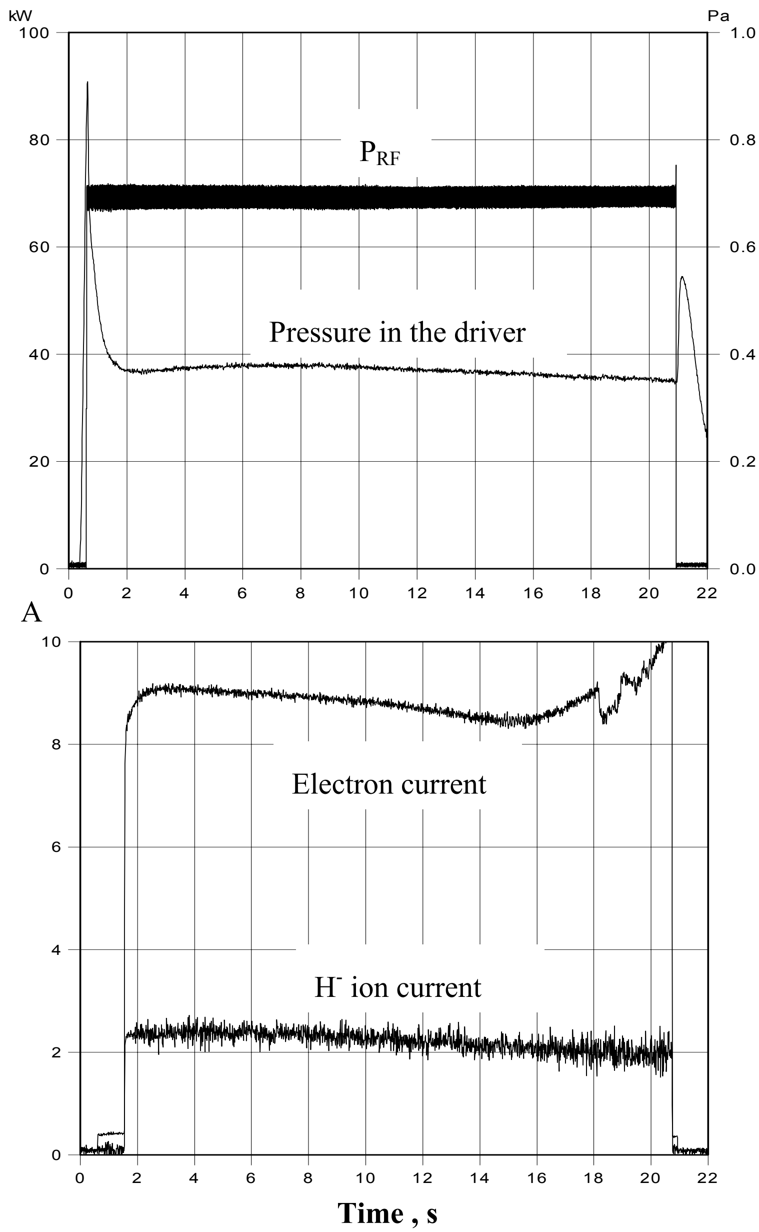

Fig. 6: First 20s beam at 5 kV extraction and 15 kV acceleration voltage

Fig. 6 shows a 20 s pulse at a RF power of 70 kW, and filling pressure of 0.5 Pa. For the ignition of the discharge a short pressure pulse and the preionisation by a small starter filament is necessary. The corresponding ion current density on the calorimeter was 8.7 mA/cm^2. This result, the slight decrease of the ion current during the pulse and the relatively high and non constant electron current are characteristic for some but not yet sufficient surface production. The experiments will be continued using a 2 mm Mo plate with chamfered holes mounted onto the plasma grid. According to the results on Batman [1], a higher H^- current and a reduction of the electron current is then expected.

Conclusion

The results with enlarged extraction area have shown that the RF source has the potential to deliver a H^- current of nearly 10 A with one driver over an area corresponding to that supplied by one driver in the ITER source. The usable area is presently limited by the ion deflection due to the increasing magnetic field close to the filter magnets. The extension of the pulse length required substantial modifications of the source and the MANITU testbed, which will be finished in summer. Using a partly upgraded system, first beam extraction experiments with pulse lengths up to 20 s were successfully carried out.

References

[1] P. McNeely, this conference

[2] W. Kraus et al, Fusion Engineering and Design, 56-57(2001)499