

Application of a radio frequency helium filter in TEXTOR-94

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Introduction

First experiments at TEXTOR-94 have been made to investigate the effect of a resonant interaction of a radio frequency (RF) field with helium [1]. The basis of the investigation is the application of a ponderomotive force interacting resonantly with He⁺ ions at the angular ion cyclotron frequency ω_{c-He^+} . For this purpose an antenna is installed in TEXTOR in front of the pumping scoop of one of the toroidal belt limiter blades (Out of eight).

The aim of these investigations is the development of a mass/charge selective filter for application in fusion devices. Our estimates show that - for a reactor application - such a filter could impede the tritium flow to the exhaust channel while it allows full conductance e.g. for helium. The present experiment is considered as a first test to show the proposed effect on He⁺ (which has - in contrast to He⁺⁺ - a different m/z ratio than D⁺). The actual achievable helium pumping improvement is of less relevance because competing effects such as ionisation obscure the magnitude of the effect if not properly taken into account.

Experiment on TEXTOR-94

To demonstrate the effect of the ponderomotive force, a copper antenna with five rectangular windings and a width of 14 cm is installed in front of the scoop entrance of one of the ALT-II pump limiters as shown in figure 1. The antenna is located 1.7 cm behind the ALT-II limiter blade. In figure 1 only one half of the limiter blade is shown, to demonstrate the location of the RF antenna and the pumping scoop. A Langmuir probe for local measurements is mounted at the end of the pumping scoop next to the plenum box. A gas inlet pipe is located at this position. The RF antenna is grounded at the liner in the vacuum vessel. The RF is fed by a coaxial wave guide where a special flexible part is included, so that a movement of the liner relative to the vacuum vessel, which can occur due to heating of the liner or due to disruptions, is possible. The matching of the antenna is done directly after the ceramic vacuum feedthrough in a matching box. There the dc insulation between liner and TEXTOR-ground potential is done. The RF generator is capable of delivering 3.5 kW of RF power at 8 MHz. Usually about 20 % of the RF power are reflected, depending on the plasma conditions.

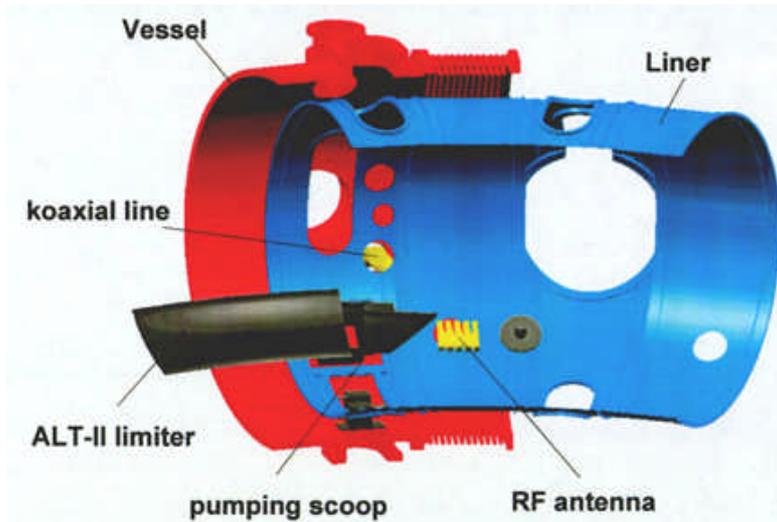


Figure 1: Schematic cut of one sector of TEXTOR-94 showing the installation of the RF antenna in front of one of the ALT-II limiter blades.

The experiment is done by measuring the change in the pressure of the exhausted helium. The helium is used as a test particle instead of tritium produced by fusion, which should be reflected under the same conditions [1] and stay in the plasma volume. The experiment reported here is the first test of a mass/charge selective filter in a fusion device. For this purpose a continuous helium gas flow is injected into the scoop. Part of this additional injected helium is directly pumped out and about 50 % - depending on the conductance of the scoop - are flowing towards the RF antenna. This helium is ionised mostly as low energy He^+ . The production rate can be written as

$$a_i = 1 - \exp(-L/\lambda_{\text{ion}}),$$

where $\lambda_{\text{ion}} = v_0(n_e \langle \sigma v \rangle_{\text{ion}})^{-1}$ is the ionisation mean free path at a electron density n_e . The helium ions have a velocity v_0 and an ionisation rate $\langle \sigma v \rangle_{\text{ion}}$. The RF field is applied at the antenna in front of the scoop with a frequency ω which is slightly higher than the resonance frequency $\omega_{\text{c-He}}$ for the helium ions. The ponderomotive force reflects the helium ion depending on the ponderomotive potential Ψ_{rf}

$$R_{\text{rf}} = 1 - \exp(-Y_{\text{rf}}/W_i),$$

where W_i is the average energy of the reionised helium. The helium ions are dragged back into the scoop and are neutralised at the neutraliser plate. Again about 50% of these neutrals are pumped and the amount of pumped helium increases. The pumpout rate of the helium is measured with a modified Penning ion gauge, which can distinguish the amount of pumped deuterium exhausted from the plasma and the additional injected helium. By measuring the relative rate of the partial helium pressure increase the influence of the ponderomotive force can be deduced.

Figure 2 gives a compilation of some data taken during the application of the RF. The RF is applied from 2.55 s during a time of one second. The RF power is 3 kW (curve a) and stays constant after a short period at the beginning of the application. During this time the local density in the scoop increases by about a factor of 4 as shown in curve b, where the Langmuir probe current is monitored. The temperature decreases by about a factor of two. The electron temperature in the scoop is about 1.5 times lower than the edge temperature measured at the same radius by a thermal beam method. The curve marked c displays the total pressure measurement, where no remarkable change in the signal can be seen. To increase the sensitivity of the measurement the ratio of the absolute helium pressure in the discharge with the RF filter on and the RF filter off has been determined. With the spectroscopic observation of the Penning pressure gauge the partial pressures of helium and deuterium are resolved.

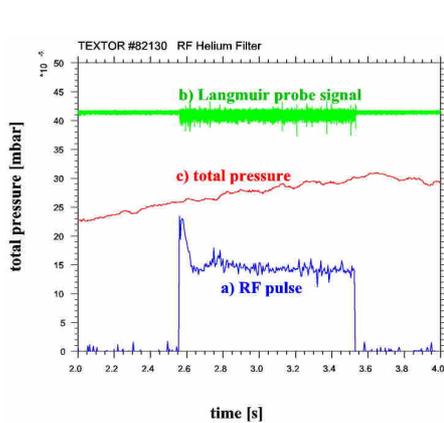


Figure 2: Application of an RF pulse from about 2.5 to 3.5 s. The density in the scoop increases as seen by the Langmuir probe current (b).

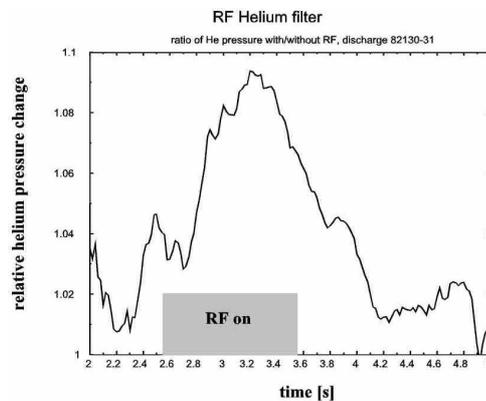


Figure 3: Ratio of the partial helium pressure in a discharge with and another discharge without RF application.

An example of the results is given in figure 3 where the ratio of the relative helium pressure for a discharge with and another discharge without RF is given. During the time of the application of the RF the helium pressure increases and decreases after the RF is turned off. Figure 4 shows the results of the measurements taken for different electron densities and two magnetic fields. The relative increase in the helium pressure for conditions where the RF filter is on increases with the electron density. It has not been possible to measure the local electron density and temperature for all conditions, therefore the line averaged density is given as a parameter. The upper curve is measured at a toroidal magnetic field of 1.9 Tesla, which is about 1.3 times higher than the resonance magnetic field. The maximum change in the relative pressure is 20% at a line averaged density of $4.2 \cdot 10^{13} \text{ cm}^{-3}$. As it has not been possible to vary the frequency of the RF generator easily, we varied the magnetic field instead. At a higher magnetic field of 2.25 Tesla the effect for lower densities is much lower than for the lower magnetic field. This reflects the resonant behaviour of the RF filter, as shown

previously in a cusp device [2]. For higher densities the improvement is nearly the same as for 1.9 Tesla. For comparison the change in the deuterium pressure for the experimental conditions necessary for the measurements is shown. Only at very high densities a change in the deuterium pressure is measurable. However, as shown in other experiments [e.g. 3], the conductance in the throat of the ALT-II limiter can be changed by ionisation processes in the throat. This effect can obscure the magnitude of the results if not properly taken into account.

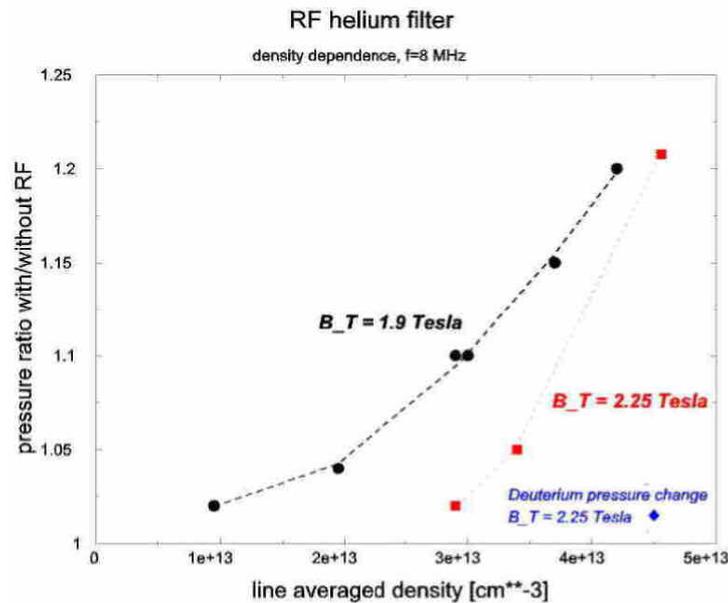


Figure 4: Density dependence of the helium pressure ratio for discharges with and without application of RF. Values for two different magnetic fields are shown. Additionally a point for the deuterium pressure is marked, where only a minor change is found.

Conclusions

In the experiments the influence of the RF on the helium flow under different plasma edge conditions and toroidal field strength conditions has been measured. The results show some favourable behaviour for the helium exhaust and are the first use of a RF mass/charge selective filter in a medium fusion device. This method can in principle be adopted to divertor tokamaks as proposed in [4].

References

- [1] T. Shoji, et al., J. Nucl. Mat. **220-222** (1995) 483-487.
- [2] S. Hidekuma, et al., Phys. Rev. Letters **33**, No. 26 (1974)1537-1540.
- [3] G. Mank, et al., Nucl. Fusion **34**, No. 12 (1994)1641-1651.
- [4] T. Watari, et al., Nucl. Fusion **33**, No. 11(1993)1635-1644.