THE ROLE OF THE FARADAY SCREEN IN ICRF ANTENNAE:
Comparison of an optically open and optically closed screen in ASDEX

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INTRODUCTION

A Faraday screen has been used on RF antennae since the first days of heating experiments with ICRF waves. Its use on the C-stellarator /1,2/ brought major improvements in the heating efficiency of the plasma. In subsequent heating experiments on other machines the beneficial effect of a Faraday screen, after initial trials without it, was rediscovered on TFR /3/, DIVA /4/ and ERASMUS /5/. Consequently the Faraday screen has become a mandatory component of ICRF antennae, and it has been attributed different functions. To fulfill those functions the screen has become increasingly complicated, and in the next generation of experiments, where the screen has to be cooled, a new round of complexity is added. Can the screen be simplified, and are some of its attributed functions really needed. Those questions were the basis for an experiment on ASDEX.

FUNCTIONS OF THE FARADAY SCREEN

They can be divided in three categories.

A first function is the protection of the antenna against the plasma: the screen should protect the antenna from particles and radiation from the plasma, in order to avoid parasitic loading of the antenna and to increase its voltage stand off. When a ceramic casing covers the antenna, the Faraday screen prevents the metallisation of the ceramic which could occur if Ti gettering is used.

A second function concerns the protection of the plasma: the Faraday screen should act as its name indicates and keep unwanted electric field components away from the plasma. The structure of the screen is chosen so as to allow the fast wave to go through but to short out electric fields along the magnetic field. The Faraday screen also may have a role in suppressing coaxial modes /6/.

A third function, which will not be further discussed is changing the electrical characteristic of the antenna: in order to minimise the voltage

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on the transmission line, and to avoid as much as possible currents in the radial direction /7/, the electrical length of the antenna is adapted, by influencing the distributed capacitance, so that a current node appears at the feeding point. The Faraday shield is one component through which the distributed capacitance can be influenced.

ASDEX EXPERIMENT WITH OPEN SCREEN

In ASDEX two ICRH antennae are installed, 180° apart in the torus, on the low field side (Fig. 1). Each antenna is connected to 1.5 MW generator and consists of two /4 loops, fed top and bottom, and short circuited at the midplane (Fig. 2). One of the antennae was covered with an optically open Faraday screen (Fig. 3a), the other one with an optically closed screen (Fig. 3b). Over a large parameter range (300 kW $\leqslant P_{rf} \leqslant$ 1200 kW, $\bar{n} = 1.25 - 3.5 \times 10^{19}$ m^{-3}) a systematic comparison was made by firing the antennae alternately in successive shots. The experiments were performed at the second harmonic of hydrogen (67 MHz, 2.2 T) with uncarbonised and later with carbonised walls.

Concerning the first role of the screen (protection of the antenna) we found that we had no voltage stand off problem. The generator was pushed to its maximum power, and a voltage of 12 kV on the antenna was reached. Under some conditions of bad coupling higher voltages (15.5 kV) were reached, but a voltage limit would be encountered in the transmission line. Therefore we cannot say whether or not opening up the screen has changed the voltage standoff capabilities of the antenna voltages above this value. Two points would indicate that there are no problems with plasma getting into the antenna. We found no additional arcing traces on the central conductors after two month of operation, and there is no power dependence of the loading of the antenna. This is to be compared with limiter machines (TFR /3/, TEXTOR /8/) with an antenna crossing the resonance layer which have shown that a closed type Faraday screen is necessary.

The second role of the Faraday screen (protecting the plasma) seems to be sufficiently accomplished by an open type Faraday screen. In earlier experiments, without and with a Faraday screen on DIVA /4/large differences were seen on the plasma parameters. We however see no major systematic difference on the plasma centrum. Curves of β, radiated power, soft X-ray radiation are similar for both antennae. No difference is seen on the flux of fast H^{o} /9/. Central electron temperature curves are identical to the point of having the same sawtooth amplitude and frequency (Fig. 4) The density is feedback controlled but there is a difference in the initial rate of increase of the density at the start of the ICRH. Values of 5 x 10^{20} m^{-3}/s at 900 kW and $n_e = 3.5 \times 10^{19}$ m^{-3} are found for the open screen antenna as compared with 8 x 10^{20} m^{-3}/s for the closed screen antenna. Occasionally, for the antenna with the closed screen this could lead to a different density evolution with larger impurity radiation and impurity lines (Fe XVI). The reason for this is unclear but could be related to the fact that the optically closed screen (originally coated with TiC) was already longer in the machine and may have become contaminated with Fe.

One domain where we have found a systematic difference is on the flux of neutral D particles from the edge. Those fluxes appear and disappear rapidly as the RF is turned off (τ=1-3 ms) showing that these ions are badly confined. A toroidal scan method already used for LH /10/ shows that they are accelerated near the plasma edge. It appears that the fluxes due to the open screen antenna are much larger than those due to closed screen antenna. It has to be noticed that the actual tail begins for energies higher than 4 keV. For lower energy values the fluxes almost do not depend on ICRH (Fig. 6). Inverted sawteeth are clearly visible on the charge exchange signals: at low energies ($\lesssim$ 3 keV) for both antennae, at high energies ($\gtrsim$3 keV) only for the open screen antenna. The sawtooth modulation is correlated with the H_α/D_α light emitted by the plasma edge and is an effect of neutral density modification. The fact that the high energy channels are modulated only with the open screen antenna indicates, either that the fast ions are further outside the plasma for this antenna or that the mechanism which produces the fast ions for the open screen antenna is sensitive to plasma edge modifictaions.

The following points are further important in analysing the results: The analyser is toroidaly located between both antennae, the plasma current and toroidal magnetic field are parallel, and in the co-direction for the beams. The gas valve is close to open screen antenna. The particles received by the analyser are mostly bananas with large $v_\perp/v_{th}$ ratio and the geometry is such that they cannot be seen just after their acceleration in front of the open screen antenna. Other measurements have shown that the D^o fluxes are very sensitive to the magnetic field and that they can have large fluctuations during one shot, which do not seem to be correlated to any macroscopic parameter of the plasma. There is no indication that the measured D^o fluxes have a direct correlation with the impurity production, but it is clear, that they depend on the plasma capability to absorb the wave /11/.

In conclusion, these fast D^o tail could depend on the kind of Faraday shield used, but in the case of normal absorption of the wave in the plasma, they are only a parasitic effect without consequence on the plasma heating and impurity production.

SUMMARY

We can conclude from our experiment that in our geometry (divertor, antenna not crossing the resonance layer), the function of the Faraday screen as a shield against the plasma is not necessary.
In its function as a shield for the plasma against the unwanted fields from the antenna an open Faraday screen seems to be sufficient. We see no difference on the central plasma parameters and the boundary effect does not seem to be detrimental. We therefore believe that the Faraday shield can be simplified. However, many open questions still remain in this boundary domain between antenna and plasma.

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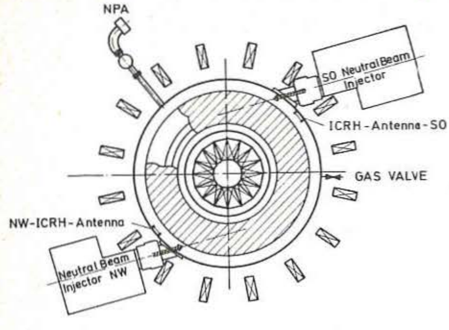

Fig. 1: Horizontal cut through ASDEX, indicating the position of the NB-Injectors, the antennae, the neutral particle analyser and the gas valve.

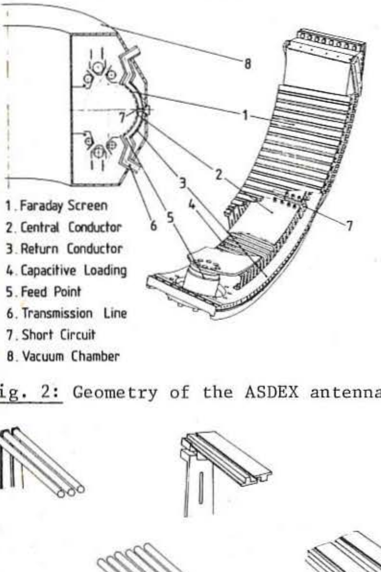

Fig. 2: Geometry of the ASDEX antenna.

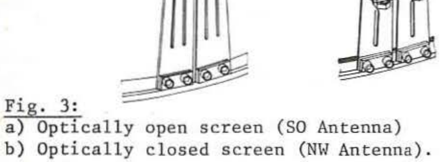

Fig. 3:
a) Optically open screen (SO Antenna)
b) Optically closed screen (NW Antenna).

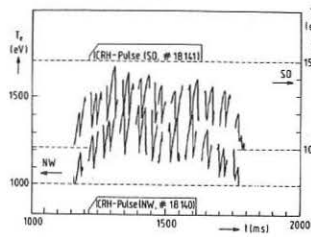

Fig. 4: Central electron temperature evolution. Note: Suppressed null line and its relative displacement for both antennae.

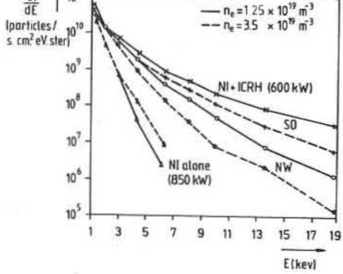

Fig. 5: Flux of D^O at the edge.

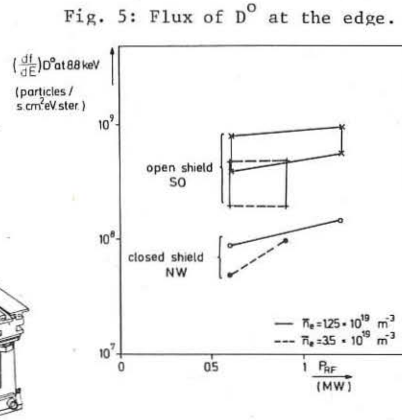

Fig. 6: Dependence of the flux D^O on power and density. For the open shield the modulation due to sawteeth is shown.