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# High power RF components for the IBW experiment on FTU

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**Abstract**

The ion Bernstein wave (IBW) experiment on the Frascati Tokamak upgrade (FTU) is aimed at heating the plasma bulk ions by utilising the mode-conversion of lower hybrid (LH) waves coupled by two waveguides' antennas. The results show that the antennas couple the useful LH wave and that moderate effects of non-linear physics occur in the edge. The toroidal magnetic field of 7.9 T, at the working frequency of 433 MHz, locates the fourth ion cyclotron harmonic of the hydrogen at one third of the minor radius. The maximum power density achieved of 1.5 kW/cm$^2$, in agreement with the trend of the performances of the LH experiments operating at higher frequency, represents the record of the power handling capability in this range of low frequency. The RF system is powered by two klystrons connected to standard rigid coaxial lines which feed the antenna through coaxial to waveguide transitions. This paper reports the design and construction criteria of the tight vacuum window and the design of a new coaxial–waveguide transition able to operate at high RF power (0.3 MW and VSWR = 4). Then new facilities will be described, consisting in the automatic cycle necessary for conditioning the waveguide launcher and the protection module that prevents the antenna by high levels of power reflected from the plasma.


*Keywords:* IBW; RF; Coaxial

## 1. Introduction

The main goal of the IBW experiment on FTU at the frequency of 433 MHz is to demonstrate that the ion Bernstein waves can be coupled to tokamak plasmas by waveguide antennas. The design of the system started by the end of the 1980s after good results of the IBW experiments on PLT [1] and Alcator C [2]. In the following, as a consequence of the negative results on DOUBLET III-D [3] and TFTR [4] concerning the plasma heating effectiveness of the IBW waves, the Frascati experiment had the further goal to prove that IBW can heat the ions and improve the confinement through induced plasma sheared flows. The IBW experiment on FTU started in 1997 by utilizing only one launcher. In 2001 a second launcher was installed in a

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different equatorial port and the routine RF power coupled, 400 kW for 200 ms, was sufficient for the physics programs. Details about the effects on the plasma of the IBW power are reported in [5,6] while the RF system is described in [7,8].

## 2. Waveguide antenna

The present launching system consists of two identical antennas installed in different equatorial ports of FTU. Each antenna is made by a grill of two phased rectangular waveguides with reduced cross-section joined together along their broad side. A single double tight window separates the pressurized region of the launcher from its terminal section exposed to the vacuum vessel. The transmission of high RF power has been obtained by utilizing all the possible techniques for the prevention of RF breakdown within the antenna vacuum region:

(i) rough gold coating on the inner walls of the waveguides;
(ii) antenna conditioning process through automatic cycle operation;
(iii) ceramic window placed close the antenna mouth.

The current window position is about 1.4 m from the launcher mouth; in the first set-up antenna with the window located at about 2.5 m from the plasma, the maximum coupled power was only 10 kW for each waveguide. The present more advanced position of the windows reduces the evacuated portions of the waveguides and locates the electron cyclotron resonance due to the outer residual magnetic field and plasma current of the machine, in the pressurized section of the launcher. The advanced vacuum window, placed in position B in Fig. 1, represents the main component of the RF system.

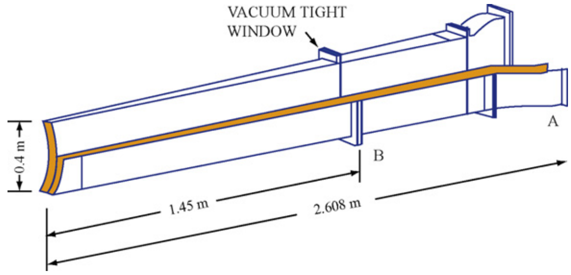


Fig. 1. IBW launcher schematic representation.

## 3. Vacuum tight window simulations

An analysis by means of the “high frequency structure simulator” (HFSS) code considered two different types of vacuum windows allowing to choose the high power RF component with the best performances.

In Fig. 2 are shown the shape of dielectrics used (type1 and type2) and the geometry of the windows. In the first type the rectangular dielectric (alumina with relative permittivity 9.7 and loss tangent $10^{-4}$) is centred in a transverse plane of the rectangular waveguide (400 mm × 76 mm) between two symmetric metallic frames used as matching elements. The

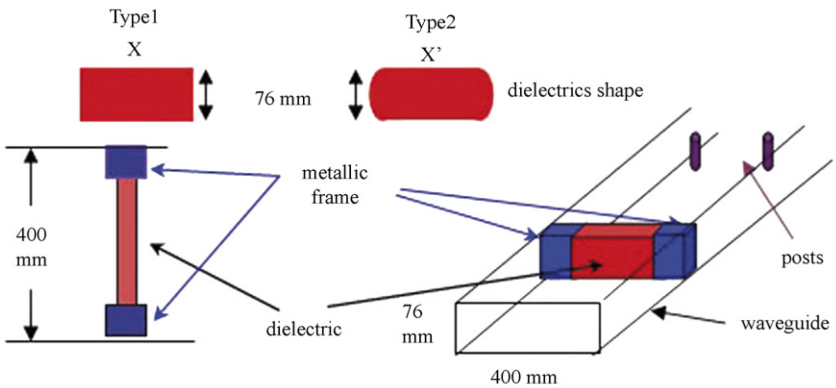


Fig. 2. Cross and longitudinal section of the windows with rectangular dielectric and circular side.