INTRODUCTION

In order to assess the critical aspects of the construction procedure and operation of the IFMIF-EVEDA RFQ[1], it was decided to perform a High Power Test of a subset of the RFQ. Such subset consists of the last three modules (out of 18) of the structure, 550 mm long each, plus a Prototype Module, 390 mm long, to be used as a RF plug. These modules, the most demanding in terms of voltage and RF Power Density, were planned to be tested at full Power in CW conditions in a dedicated area at the Legnaro Laboratories of INFN, the so-called RFQ High Power Test Stand. For such a purpose a RF tube-based amplifier capable of 220 kW CW output Power at the operational frequency of 175 MHz was purchased from DB Elettronica company. A critical component of this test is the RF power coupler. Therefore INFN-LNL developed a design of two identical water-cooled loop antenna couplers, built with OFE copper and vacuum sealed with a commercially available 6"1/8 Alumina planar window. Moreover, in order to allow a safe operation of this component on the RFQ, it was decided to test separately the couplers on a dedicated aluminum coupling cavity, before inserting one of the two into the RFQ. This cavity is connected with two of the above-mentioned couplers. In particular one of them, connected with the amplifier via a 9"3/16 transmission line system, acts as a power feeder, while the other one, connected with a 200 kW water-cooled load, acts as a power receiver. In this paper, the main aspects of the coupler and cavity design will be described.

THE HIGH POWER COUPLER

The High Power Coupler was designed in order to be critically coupled with the 2 meter long RFQ, in condition of minimum acceptable Q0 value of $Q_0\text{min}=9000$ (ideal $Q_0=15000$), i.e. $\beta=1$. Moreover, it must be properly cooled in order to manage its RF losses induced by the high power feeding the RFQ (up to 220 kW) and travelling on the RF coaxial line. This has led to the design of the loop with a radius $R=20$ mm, an insertion depth of 29 mm and a thickness of 8 mm (Fig.1). The coupling was verified both with analytical calculations and with HFSS simulations. Should the Quality Factor be higher, a rotating flange can accomplish a proper change of the loop orientation angle $\alpha$ with respect to the RFQ axis thus changing the beta coupling accordingly, since $\beta(\alpha)=\beta_0\cos^2(\alpha)$. The dissipated power in the loop is about 100 W for an input power of 200 kW.

As the construction procedure is concerned, the coupler is made of OFE copper and the coolant flows through a double-spiral, in order to have a separate paths of water for inner and outer conductors, and a water cooling of the loop with a only one inlet and outer water tubes (Fig.3). The construction procedure foresees three brazing steps: in the first, the cooling spirals are brazed separately on inner and outer conductors and also the SS flange seats and the water
tubes are brazed on the copper bulk. In the second step, the plugs are brazed at both ends of inner conductor, and finally in the third step the inner and outer conductors are brazed to the loop, and the assembly is completed.

The RF window is a planar type one, purchased from MEGA Industries (USA) The material used is Alumina 99% with 1.5 to 3 nm TiN coating, with nominal RL of -40 dB and Insertion Loss of more than -0.01 dB.

THE COUPLING CAVITY

The coupling cavity is an Aluminium coaxial-re-entrant aluminium resonator, with $R_{ext}=26$ cm, $R_{int}=9.5$ cm, $h=19$ cm and gap = 2 cm. The aim of this device is to allow safe conditioning of the couplers with a relatively low power loss inside the cavity itself. The cavity is designed to have a resonance at the nominal frequency of $f_0=175$ MHz, when all the thermal and pressure-gradient induced effects in operation are taken into account. The main parameters of the cavity (RF designed with HFSS) are the following:

- Maximum $p_d=5$ W/cm$^2$ @ $P_{input}=200$ kW
- Dissipated power = 14 kW @ $P_{input}=200$ kW
- $RL=-29$ dB @ $f=f_0$

The cavity is assembled with aluminum sheets and SS is used for flanges and reinforcement bars. Due to the high frequency sensitivity with gap ($\partial f/\partial g=-3$MHz/mm), the rough tuning of the cavity with the gap variation prior to final machining is foreseen, and a further tuning range of $[0$ MHz, 1 MHz] can be obtained with a plunger tuner insertion depth variation of $[0$ mm, 30 mm] (Fig.5)

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Fig. 4: Inner view of the Coupling Cavity with the main geometrical parameters.

![Fig. 4: Inner view of the Coupling Cavity with the main geometrical parameters.](image)

Fig. 5: The outer view of the Coupling Cavity.

The thermo-structural simulations have shown that, under the RF power loads given by simulations, with a 50% margin, the maximum temperature is equal to 36 °C, localized in the inner conductor. The overall cooling water flux needed to cool the cavity is equal to 125 l/min. The associated maximum deformation of the cavity gap (due both to thermal and pressure effects) is 0.4 mm, and such deformation was taken into account a priori in the simulations for the RF design of the cavity.

![Fig. 6: Temperature distribution in C of the Coupling Cavity.](image)

Fig. 6 Temperature distribution in C of the Coupling Cavity.