INTRODUCTION

IFMIF (International Fusion Material Irradiation Facility) is a facility based on two high intensity deuteron linacs (40 MeV, 125 mA each) designed to test material main components under high level neutron fluxes to be used in the future Fusion Reactors, such as ITER (Fig 1).

This report summarizes the work performed in 2007 by LNL Team, in the framework of the Engineering Validation and Engineering Design Activities of the IFMIF project, one of the three projects of the Broader Approach (BA) agreement signed in Tokyo on 5 February 2007 and officially started in June 2007.

LNL, besides having the vice responsibility of the Accelerator System Group, is in charge of the design and construction of the high intensity RFQ structure.

A reference design of the RFQ is now available. The CDR reference design has been significantly improved (shorter length, more homogeneous electric field). The heat load and cooling system proposed enable small deformations, compatible with its foreseen operation. Beam losses are concentrated in the low-energy part of the RFQ, enabling its hands-on maintenance. Preliminary tests of welding and brazing lead to the latter solution as preferential.

PHYSICS DESIGN OF THE RFQ

The aim of the RFQ task is to build an accelerator of four vanes RFQ kind with the following characteristics; the parameters have been frozen as milestone in June:

- Input energy = 100 keV
- Output energy = 5 MeV
- Input emittance RMS = 0.25 mm mrad (norm.)
- Frequency = 175 MHz
- Max surface field < 25.2 MV/m (1.8 kilopat)
- Input Current = 130 mA
- Particle = Deuteron

The zero current phase advance/meter is about 220 deg/m transverse and about 90 deg/m longitudinal at the end of the RFQ.

The accelerator will be powered by two 1 MW rf systems (to be reconsidered in case of superconducting choice for the main linac). The RFQ will be designed for IFMIF, with the aim to insure high availability for 30 years operation, and hands on maintenance after radiation cooling time. The logistic implication of the first complete installation in Japan has to be taken into account from the design phase.

The analysis of a wide ensemble of beam dynamics and associated vanes and cavity geometry has been performed. The work is well advanced for the freezing of the beam dynamics design in winter 2008. Moreover a first lay-outs and preliminary thermo mechanic analysis of the cooling system has been performed.

To accelerate 130 mA of D+ particles from 0.1 to 5 MeV, a RFQ has been designed, where the main parameters are: length = 9.58 m, min aperture a = 3.5034 mm, odulation m = 1.8979, surface field < 25.2 MV/m.

Simulations have been performed with the PARTEQM...
and TOUTATIS codes (Fig. 3) which have given very similar results. While waiting for the actual parameters of the beam phase space coming from the injector system, several input beam types have been considered, with emittances ranging from 0.2 to 0.3 \( \pi \text{mm.mrad} \). For the most realistic case of a Gaussian distribution, an input emittance of 0.22 results in an exit emittance of no more than 0.26 \( \pi \text{mm.mrad} \), with a transmission of 95.5\%.

Some further optimizations are still possible, and error simulations remain to be studied.

**CAVITY DESIGN**

The RFQ profile has been calculated cell by cell so to ensure the design vane voltage profile. In particular the thickness of vane base has been changed so to assure the correct cut-off frequency (Fig.4). The power dissipation on copper surface calculated with Superfish (2d Poisson equation solver) is in all analyzed cases less or equal to 500 kW for the entire RFQ. The resulting RF power requirement, according to: 

\[
P_{\text{out}} = 1.2(P_{\text{cu}} \cdot 1.3 \cdot 1.21 + P_{\text{cool}})
\]

is about 1710 kW. Here 1.3 is the factor for additional losses due to 3d geometry and construction imperfections, 1.21 allows to operate the RFQ at field 10% higher than nominal, 1.2 is the margin needed for phase and voltage stabilization and RF transport losses.

Four vanes RFQs several \( \lambda \) long (like LEDA, IPHI or TRASCO) are divided in segments resonantly coupled. In this way the unwanted mode components (dipoles and higher quad) is decreased. With this design \( L/\lambda = 5.6 \), and the two configurations with two coupled segment and one single RFQ can be considered.

Theoretical analysis of the error sensitivity of RF field for the two configurations has been preliminary analyzed. Possible measurements and RF tuning of 5 meters at CEA (equivalent to 10 m of IFMIF). The reduction of the number of coupling cells simplifies the mechanics and reduces the number of hot points and the overall power dissipation. The decision is needed for June 2008. Various technologies have been explored for the construction of the cavity. In the following figure the profile and the temperature distribution for a preliminary cooling channels distribution is shown. The structure is in bulk CuOFF and the cooling channels operate with 19 deg demineralized water, flowing at approximately 3 m/s. The possibility to bolt the various parts with RF contacts (cfr. SPIRAL2) was considered not reliable enough at this frequency for IFMIF. The possibility of a light welding from inside (e-beam or laser welding) (cfr. JPARC) was object of various tests. Concerning the brazing, that is the main solution adopted for four vanes RFQs, there are not examples at such low frequency. The choice between electro beam welding, laser welding and brazing will be closed at the first months of 2008. Ports of CF100 standard on lateral faces will be used for slug tuners, vacuum ports and power couplers. The large flanges between elements are still to be decided concerning the interface with the power couplers, the 2D calculations allow for determining the loop area for critical coupling. The bore available for access into the cavity is 90 mm diameter, and the flange is CF100. The flange on the coupler should be rotating, so to allow the coupling coefficient tuning via loop rotation. The mechanical details of the power coupler have still to be decided. A preliminary vacuum system lay-out (Fig. 5) has been designed, based on cryogenic pumps mounted on pumping manifolds able to use multiple vacuum ports (each protected by a proper RF grid).