IFMIF SUPERCONDUCTING β=0.094 HALF-WAVE RESONATOR DESIGN

E. Zaplatin, Forschungszentrum Juelich, Germany

P. Bosland, Ph. Bredy, N. Grouas, Ph. Hardy, J. Migne, A. Mosnier, F. Orsini, J. Plouin, CEA-Saclay, France

Abstract

The driver of the International Fusion Material Irradiation Facility (IFMIF) consists of two 125 mA, 40 MeV cw deuteron accelerators [1]. A superconducting option for the 5 to 40 MeV linac based on Half-Wave Resonators (HWR) has been chosen. The first cryomodule should contain 8 HWR's with resonant frequency of 175 MHz and β=v/c=0.094. The paper describes RF design of half-wave length resonator. The requirements on high power coupler define its installation in the cavity central region. Few options of cavity tune were investigated, the capacitive tuner installed opposite to the coupler port have been accepted.

CAVITY RF DESIGN

The goal of the cavity electrodynamics design is to optimise the cavity geometry to minimize values of peak electrical and magnetic fields on the cavity surface relative to the accelerating electrical field on the cavity axis (B_{pk}/E_{acc} and E_{pk}/E_{acc}). Also it should take into account the fabrication technology and resonator structural properties. Since an accelerator should work in cw regime, the final goal of the cavity structural design will be a minimization of the resonant frequency dependence on the external pressure fluctuations. The general basics of the cavity structural design are to avoid using the plane surfaces. This was the reason of the choice of a round shape of the beam port electrodes.

Table 1: Some parameters of half-wave resonator.

Frequency	MHz	175
β=v/c		0.094
$R_{aperture}$	mm	20
βλ	mm	161.04
R_{cavity}	mm	90
E_{pk} / E_{acc} *)		4.42
B_{pk} / E_{acc} *)	mT/MV/m	10.12
*) $L_{cav} = N_{gaps} * \beta\lambda/2$, where N_{gaps}=2 – number of gaps		

The racetrack shape of the central electrode and the transaction part from racetrack to circular part were made as short as possible. Together with the round beam port shape this makes cavity more rigid and allows avoiding the parallel surfaces in the central region to minimize the risk of multipactor. To achieve a higher mechanical stability the resonant line of the central electrode was made conical. The conical shape will also reduce the peak magnetic field value. For the RF cavity design the whole geometry has been parameterised and all parameters have been optimised. The cavity geometry and parameters are shown in Fig.1 and Table.1.

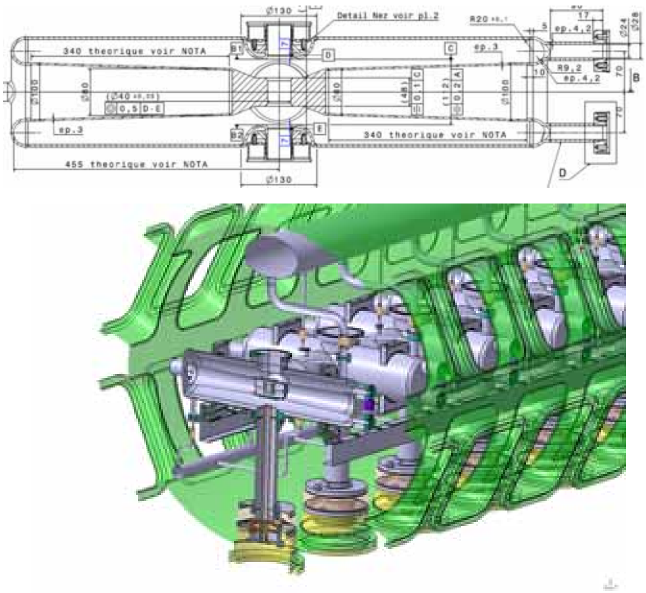

Figure 1: Half-wave resonator view.

The cavities will be placed horizontally in the cryostat. For such position, the required calculations of the cavity cooling have been provided. They show, that the central electrode cone angle is enough to provide the helium gas evacuation. Also, the helium gas bubbles accumulated in the upper central part of the central electrode (Fig. 2) should not cause the problems for the cooling in this region. Still, this volume will be filled with niobium.

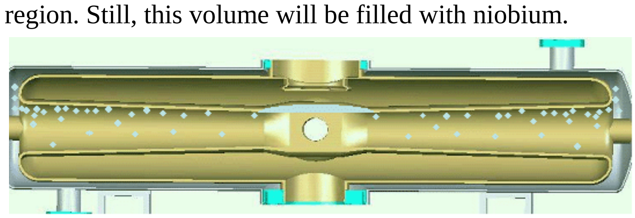

Figure 2: Gas Helium pockets.

CAVITY TUNE

Wall Deformation

The standard way to tune HWR is to apply the tuning force on the beam ports for deformations to change the accelerating gap capacitance. This is quite effective method with the resulted high frequency change sensitivity (in our case df/dz=-176 kHz/mm, where dz is a beam port displacement along the beam path). The disadvantages of such method are the apparently change of E_{pk}/E_{acc} (not large), relatively high stresses (still acceptable if to take into account the high frequency sensitivity and as a results small displacement) and the requirements on the additional space for the tuner structure between the cavities. Also, it requires an application of a high tune force since the beam port structure has rather high rigidity.

The cavity tune with deformation of the outer conductor wall in the central part of the cavity (Fig. 3) has been investigated.

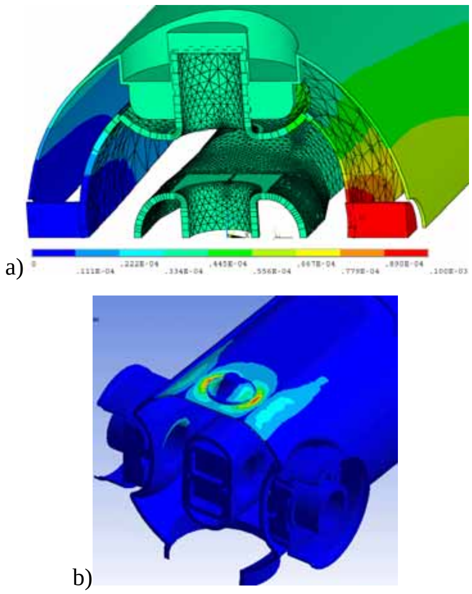

Figure 3: Cavity tune by wall deformation (a – displacements, b – stresses von Misses).

To allow easier wall deformation and to make the gap between central electrode and outer cavity wall smaller one side of cavity outer conductor is considered elliptical. By asymmetric tune force application there is also displacement of beam port, which changes accelerating gap capacitance. The positive or negative sign of frequency shift is defined which effect prevails – accelerating gap capacitance reduction or tuner-central electrode capacitance enhancement. Still, the limited space for tune area defines the stresses on cavity wall above elastic deformations.

Capacitive Plunger

The capacitive tuner installed in the electric field region under 90^{o} to the beam axes that should change the capacitance to the central electrode (Fig. 4) was developed. The capacitive tuner design is a trade-off between E_{pk}/E_{acc} and tuning sensitivity. To avoid an enhancement of E_{pk}/E_{acc} the capacitive gap is kept low (4 mm plunger penetration in the cavity volume with nearly the same field distribution). To achieve certain tune sensitivity (50 kHz/mm) the plunger diameter has been made 100 mm. The plunger is connected with the flexible membrane (1.5 mm thick) via 5 mm long stem. The membrane will be deformed in the range of ±2 mm.

The whole tuner structure will be dismountable from the cavity body. To reduce the joint RF current an additional radial line at the region of the membrane flanges has been installed. It reduces the short-cut field down to the required level and simultaneously the stresses at the membrane. An optimum length of the tuner housing is 60 mm with 50 mm radial line.

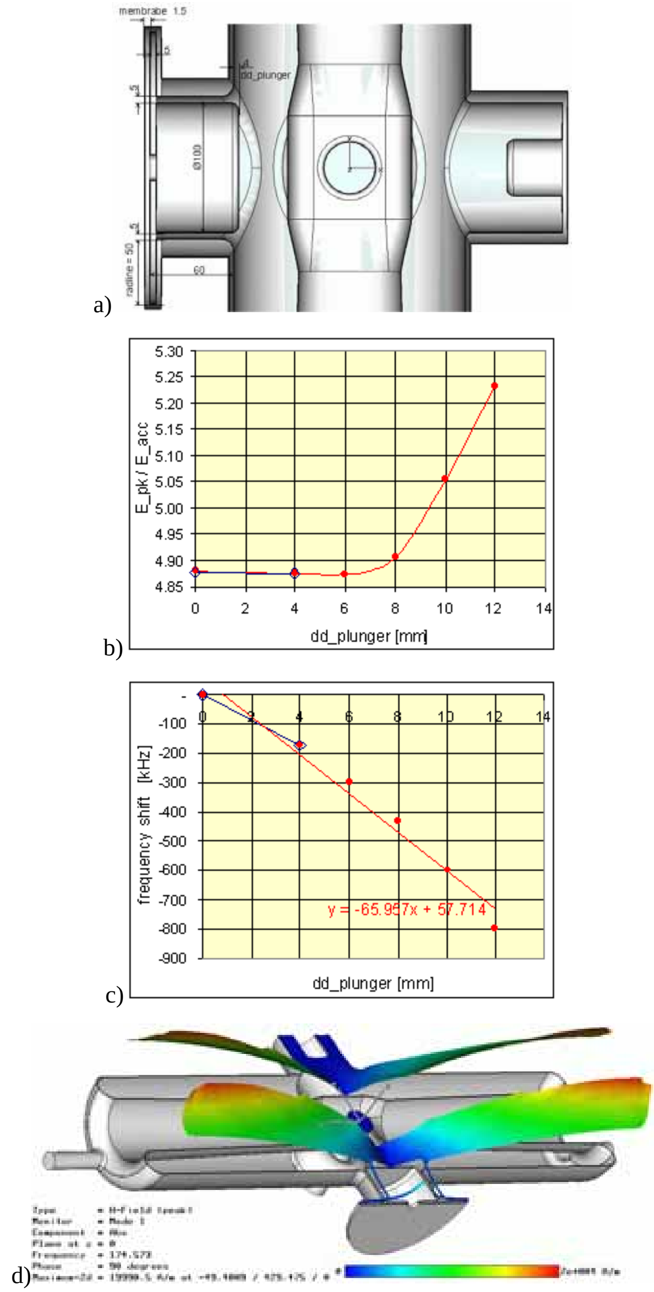

Figure 4: Capacitive tuner optimisation.

Since the tuner installation violates the cavity symmetry, the transverse component of electrical field along the beam path is investigated. Because of the large plunger's size it is less than 10^{-4} of an accelerating component with 8-10 mm of the plunger penetration in the cavity.

The detailed optimization of the tuner housing to minimize the multipactor resonance discharge has been provided. Initially, the tuner plunger with long stem has been considered (Fig. 5a). Because of the strong first order multipactor in the membrane region the plunger shape was changed and all gaps in the tuner housing were optimised. The results of multipactor simulations for long stem plunger and final tuner geometry are shown on Fig.5b.

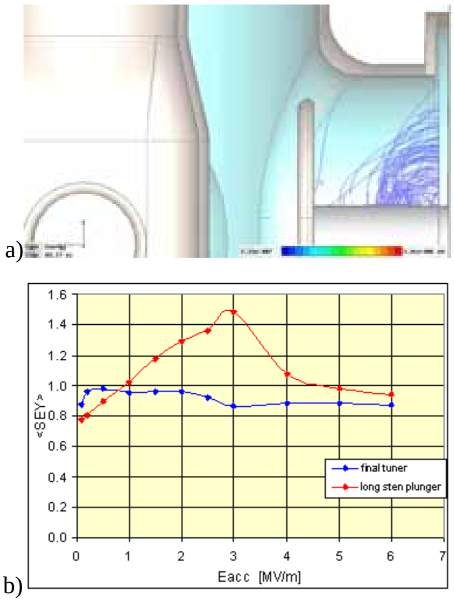

Figure 5: Capacitive tuner housing multipactor simulations.

Inductive Plunger

The cylindrical plunger installed at the cavity dome was investigated (Fig.6a). This plunger by insertion in the cavity disturbs the magnetic field volume and changes inductance of the cavity. Since the cavity magnetic field occupies much bigger volume in comparison with disturbed one, the frequency change from the “magnetic” plunger is low. Our simulations result in few kHz per mm of the insertion depending on plunger length. Another negative aspect of the inductive tuner is the large enhancement of the peak magnetic field value. The peak magnetic field region with the use of the inductive plunger is moved from the surface of the central electrode to the plunger structure surface. This results in the surface current density increase (up to 20%).

CAVITY WITH COUPLER

The power coupler is installed in the cavity central region opposite to the tuner. The position of the coupler tip is 32 mm from the outer cavity conductor inside the coupler resonant line for required $Q_{ext}=5.7*10^4$. The coupler line wave impedance is 50 Ohm with the coupler outer conductor diameter 100 mm (Fig. 4a).

An asymmetric coupler installation relative to the cavity axes results in the transverse electric field component along beam path (about 0.1%, Fig. 7). According to the conducted beam tracking calculations such value of transverse accelerating field is fully acceptable.

REFERENCES

[1] A. Mosnier, this conference.

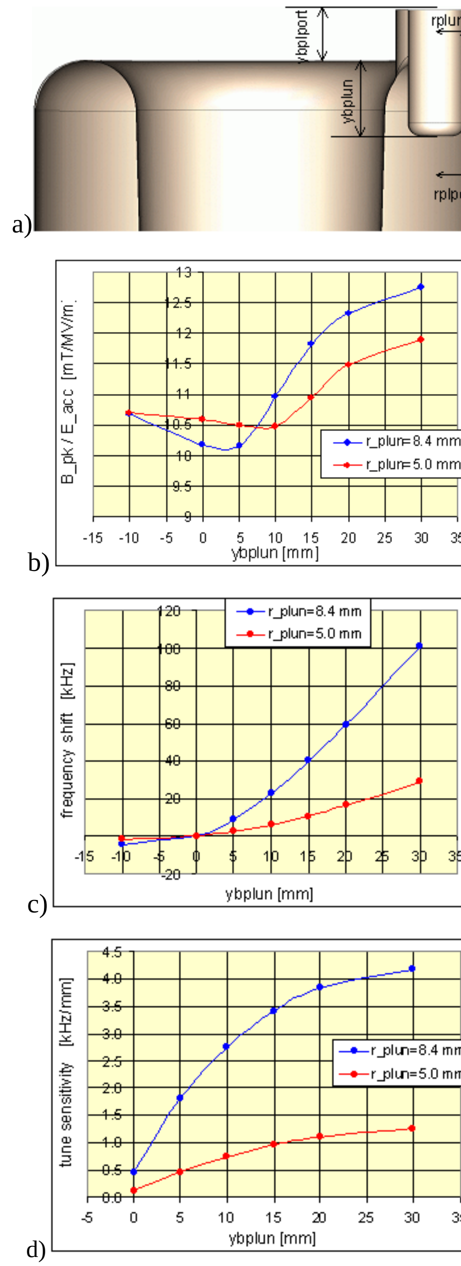

Figure 6: Inductive tuner optimisation.

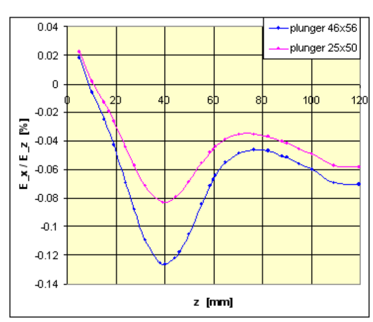

Figure 7: Cavity transverse component of accelerating field along beam path.