DESIGN AND CONSTRUCTION OF 126 MHz CAPACITY LOADED ALUMINIUM CAVITY PROTOTYPE

Sasan Ahmadiannamin†, Javad Rahighi, Mohammad Lamehi Rachti, Khorshid Sarhadi, Iranian Light Source Facility (ILSF), Institute for Research in Fundamental Sciences (IPM), Tehran, 19395-5746, Iran

Fereydoon Abbasi Davani, Shahid Beheshti University,Tehran, 1983969411 , Iran

Abstract

I Iranian light source Facility (ILSF) is a 3 GeV Ultra low emittance synchrotron with 528 meter circumference that will be constructed in the city of Qazvin, located 150km west of Tehran. Motivated by the development of HOM damped cavity with simpler structure at 100 MHz at MAX Lab and also lower costs, 100 MHz RF system is envisaged for ILSF booster and storage ring. An RF cavity prototype was fabricated for better understanding of characteristics of capacity loaded RF cavities by practical investigation. In this paper, design and development of this prototype is presented with the simulation and measurement results.

Introduction

The Iranian Light Source Project (ILSF) is a 3rd generation light source containing a 3 GeV storage ring with 0.27nm.rad emittance, a full energy booster injector and a 150 MeV linac as pre-injector. The stored beam current of 100mA at commissioning phase will gradually increase up to 400mA in top up mode at final phase of operation [1].

After a thorough study of the RF frequency effects on the beam and machine parameters [2] and also cost estimation and feasibility study of RF components realization, 100MHz RF frequency was chosen for ILSF. Capacity loaded cavities based on MAX Lab Design [2] will be used in the booster and storage ring. Three RF stations with maximum power of 25kW will be required for powering 3 booster cavities while 5, 60kW stations are required in the storage ring for ILSF initial phase of operation with 7 beamlines and 100mA beam current. At final phase of operation when the storage ring is equipped with 17 beam lines and the beam current reached 400mA, one more station will be added in the storage ring and the power of all 6 stations will increase to 120kW. A modular design of RF amplifiers with units of 30kW provides desirable uniformity, extendibility and reliability to the system. Local companies with the experience in fabrication of high power FM transmitters are recognized as potential suppliers.

To check the ability of local industry in cavity fabrication, the electromagnetic and mechanical design of a 100MHz cavity based on MAX Lab design has been performed [2].

Fabrication of a copper cavity prototype is planned in order to conclude the possibility of the cavity development in house. Prior to that prototype, a 500MHz aluminium pillbox cavity available at RF laboratory has been modified to a capacity loaded structure by adding a mushroom section. By optimizing the mushroom part dimension, the resonant frequency of 126MHz has been achieved for this aluminium prototype with the available cylinder. Having similar characteristics with the main cavity, this prototype will be helpful for crosschecking the simulation and measurement results and better understanding of the structure. In this paper the RF simulation and measurement results of this cavity are represented. Further studies and measurements are in progress to evaluate impedances of higher order modes, compare different tuning mechanisms (plunger and squeezing) and etc.

Design and Simulation

For this prototype, our goal was to change the available 500 MHz aluminium pillbox cavity as close as possible to the capacity loaded 100 MHz cavity similar to MAX-IV design. The cavity structure was optimized to have similar shunt impedance close to MAX-IV case. Since the diameter of our aluminium cavity is fixed, we could reduce the resonating frequency to 126MHz for the capacity loaded cavity. The simulation model of the cavity with the optimized dimensions is shown in Figure 1. The simulated electric and magnetic field profiles are shown in Figure 2. As it can be realized, the maximum field gradient is created at the edge of the mushroom head. Also, the energy density of magnetic field that causes the thermal loss is concentrated around the stem of mushroom. This information is important for study of multipacting and thermal loss calculations that was done for the main accelerator cavity. Also, the profile of magnetic field shall be used for location selection of coupling and pick up loops. Based on these studies, the best location for RF coupler and pickup loops is close to the cavity sidewall in connection with the stem. Since the cavity cylinder was constructed previously, the same allocated position was used for location of the coupling loop.

† Ahmadiannamin@ipm.ir, Sasan.ahmadiannamini@gmail.com

ISBN 978-3-95450-182-3

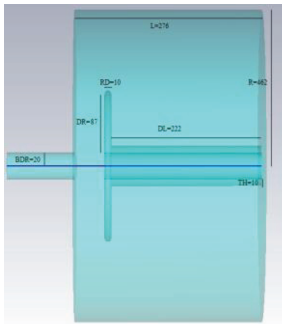
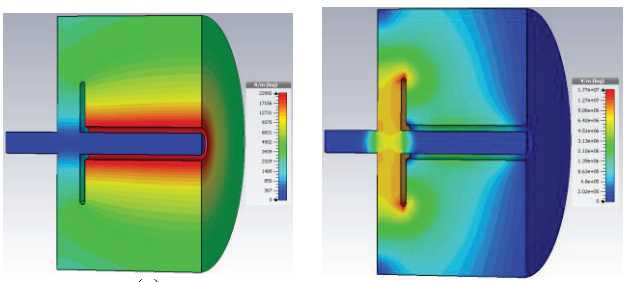


Figure 1: Simulation model of the cavity with optimized dimensions



(a) (b)

Figure 2: simulated fields profiles of TM_{010} mode at126.2 MHz (a) Magnetic (b) Electric.

The cavity parameters obtained from electromagnetic simulations in CST Eigenmode Solver are reported in table 1. On axis electric field profile is represented in Figure 3.

Table 1: Simulated Cavity Parameters

Parameters	Value
Resonant frequency	126.174 MHz
Shunt Impedance	1.96×10^{6}
Quality Factor (PEC Boundary condition)	13190
Quality factor (Aluminium Loss with 3.69×10^{7} Siemens/m)	10524

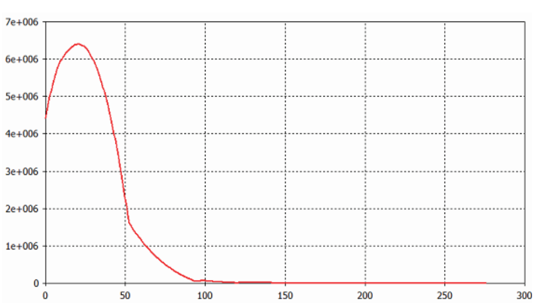
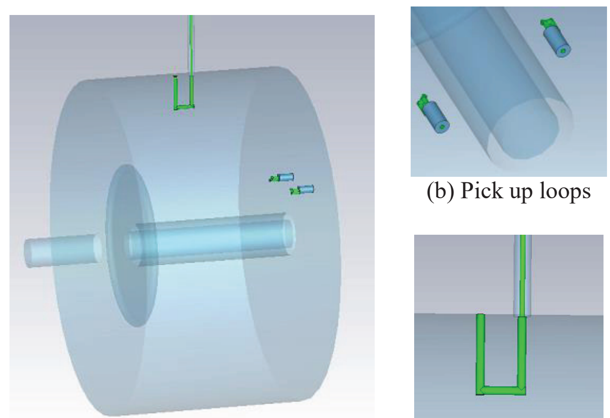


Figure 3: Simulated electric field along cavity axis.

The frequency domain (FD) simulation of cavity was done for optimization of coupling and pick up loops and also calculation of the higher order modes. The location of pick up loops shall be selected with proper angle relative to vertical symmetric plane of the cavity in order to make the observation of dipole and other higher order modes with different polarities possible. We assume two symmetric pick up loops according to Figure 4. Based on typical values on other cavities, the critical coupling of our prototype was set to S11= -42 dB and transmission loss between pick up loops was set in the range of 50 to 80 dB for the main and higher order modes. The results of frequency domain simulations are shown in Figure 5. All simulations were done by CST Microwave Studio [3]. Differences between the values of quality factor resulted from CST Eigenmode and FD Solvers is because of addition of coupler and pickup loop losses in FD Solver.



(a) Modelled cavity (b) Pick up loops (c) Coupling loop

Figure 4: Simulation model infrequency domain solver.

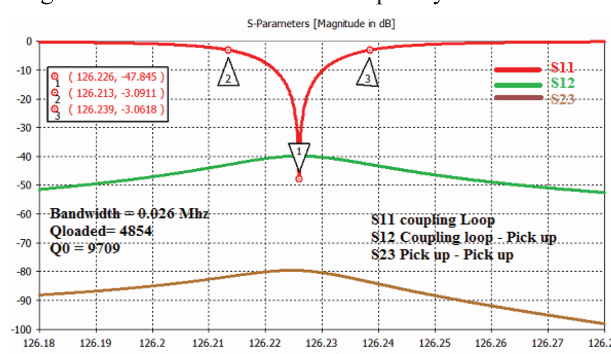


Figure 5: Frequency domain simulation results.

Construction, Tuning and Measurements

After simulation estimations, the mushroom part was constructed to place inside the existing pillbox cavity. Higher percent of RF loss takes place around the end of the mushroom where is connected to the sidewall. So, for increasing the quality factor and better matching of simulation with construction, we used shrinking method to connect the mushroom to the sidewall. The connection area is shown in Figure 6. This sidewall was then bolted to the cylinder.

In this prototype we plan to study and compare two tuning procedures; application of a plunger (inductive tuning) and sidewall movement (capacitive tuning). We had the plunger in 500MHz pillbox cavity. To add the capacitive tuning, a mechanical mechanism is designed and fabricated to push or pull the sidewall. By 2.5 mm deformation of the sidewall in both directions, 2.5MHz frequency tuning range is accessible. Assembling of the cavity components can be seen in Figure 7. The cavity final structure is shown from different views in Figure 8.

As shown in Figure 9, the resonant frequency of 126.045 MHz and quality factor of 8000 was measured by network analyzer for the main accelerating mode which is close to simulation results. The degradation of the quality factor is due to the casting of the cavity cylinder which did not provide a good surface roughness. Moreover, the frequency spectrum of the cavity from 500 to 1000 MHz was measured and compared with simulation results in Figure 10. The required components for performing the coaxial wire impedance measurement methods [4] are under design and construction. This method can be used effectively for practical coupling impedance measurement in cavities with this type of structures. The design, fabrication and measurement of higher order mode dampers will be one of the important achievements from the ongoing activities.

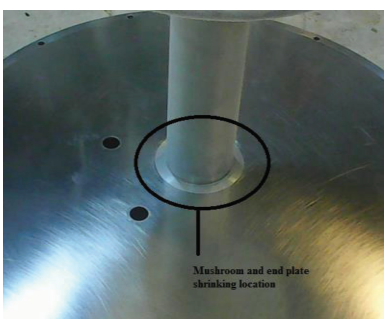


Figure 6: Mushroom part connected to the sidewall by shrinking method.

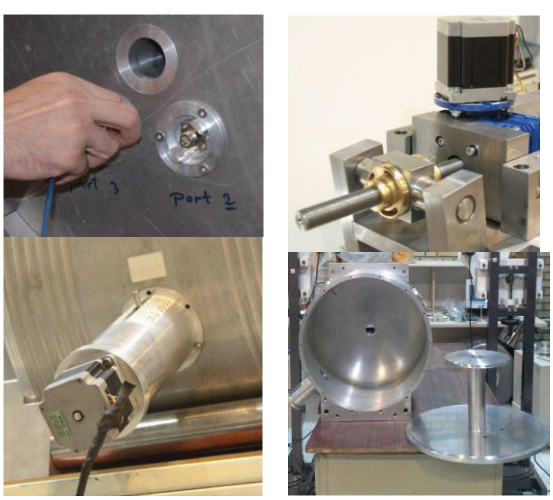
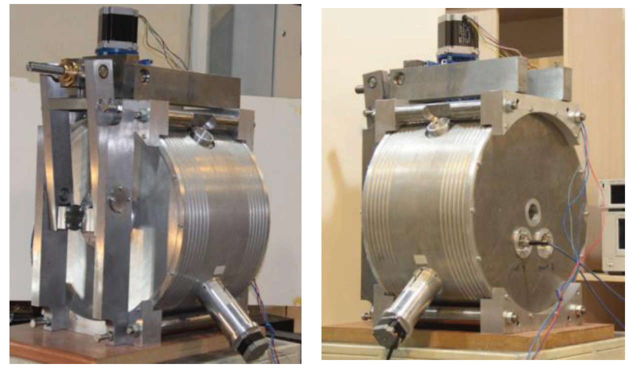


Figure 7: Assembling of the cavity components.



(a) Capacity tuning wall (b) Mushroom-connected wall

Figure 8: Finalized 126 MHz capacity loaded RF cavity prototype.

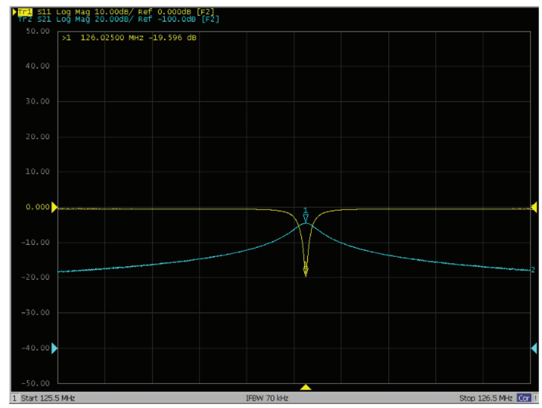


Figure 9: The frequency spectrum from 125.5 to 126.5 MHz

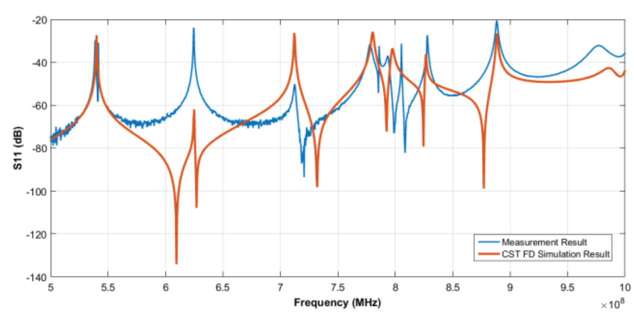


Figure 10: Higher order modes spectrum between 500 to 1000 MHz

CONCLUSION

A capacity loaded RF cavity was designed and constructed. This aluminum prototype cavity will be used for better understanding of higher order mode characteristics, development of coaxial wire impedance method for coupling impedance measurements and crosschecking the simulation and measurement results. The measurements on the main and higher order modes are in progress. Another important subject that will be evaluated is to compare two types of tuning procedures and how they affect the higher order modes of the cavity. The next step will also include the design and fabrication of higher order mode dampers for the most dangerous modes.

ISBN 978-3-95450-182-3

REFERENCES

[1] J.Rahighi *et al.*,"Recent progress on the development of Iranian Light Source Facility (ILSF)", Proceedings of IPAC2016, Busan, Korea.
[2] S. Pirani, Kh. Sarhadi, V. Moradi, "100 MHz RF system as an alternative for Iranian Light Source Facility", IPAC14 , Dresden, Germany.
[3] CST Computer Simulation Technology, `http://www.CST.com`
[4] S. M. Hanna, P. M. Stefan, "Application of impedance measurement techniques to accelerating cavity mode characterization", Nuclear instruments and methods in physics research A 335 (1993) 367-376