

100 MHZ RF SYSTEM AS AN ALTERNATIVE FOR IRANIAN LIGHT SOURCE FACILITY

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Abstract

The Iranian Light Source Facility (ILSF) RF system was conceptually designed based on ILSF requirements for a 3GeV storage ring and 400 mA beam current at 500 MHz RF frequency. The development of HOM damped cavity with simpler structure at 100MHz and advantages of reducing frequency as investigated at MAX Lab, provided an alternative of 100MHz RF system to be explored for ILSF. RF frequency change and its effects on the beam and machine parameters as well as the availability and cost of RF system components have been studied for ILSF. The conceptual design of a 100MHz RF system and comparison between 500 MHz and 100 MHz RF frequencies are presented in this report. This paper, also provides details about the 100MHz RF cavity designed by ILSF RF group based on MAX Lab cavity.

INTRODUCTION

The Iranian Light Source Facility, ILSF, was conceptually designed as a third generation synchrotron radiation source with 3GeV four-fold symmetric storage ring providing 400mA beam current and 3.278 nm.rad emittance [1]. A 500MHz RF system consisting of 6 HOM-damped cavities, solid state amplifiers and digital LLRF was envisaged to provide the required acceleration, momentum acceptance and life time [2].

To be competitive in the operation years, the storage ring design has been changed to a multi-bend achromat lattice with sub-nanometer radian emittance. To make the local fabrication of the magnets possible, low field magnets have been considered which also results to energy save and lower operation cost due to lower required RF power, power supply and cooling systems [3]. The main parameters of low emittance lattice candidate for ILSF storage ring are given in Table 1. Along with the changes in the lattice design and motivated by the development of HOM damped cavity with simpler structure at 100MHz at MAX Lab., 100MHz RF system is under exploration as an alternative to 500 MHz at ILSF. The circumference of the lattice is designed in compatible with both of the RF frequencies. The effects of RF frequency change on the beam and machine parameters have been studied which are discussed in the next section of this paper. The comparison of two (100 and 500 MHz) RF system parameters and components realization are also pointed out. To check the ability of local industry in cavity fabrication, the electromagnetic and mechanical design of a 100MHz cavity based on MAX Lab. has been performed. In the last section, the simulation results will be presented.

Table 1: Main Parameters of Low Emittance Lattice Candidate for ILSF Storage Ring

Parameter	Unit	Value
Energy	GeV	3
Current	mA	400
Circumference	m	528
Horizontal emittance	nm.rad	0.477
Energy loss/turn (Dipoles)	KeV	536
Total energy loss/turn (Dipoles+ IDs + parasitic)	KeV	886
Momentum compaction factor	-	1.53×10^{-4}
Energy spread	-	7.03×10^{-4}
Damping time (τ_x, τ_y, τ_z)	ms	19.709, 19.716, 9.859

COMPARISON OF 100 AND 500 MHZ RF FREQUENCIES

To decide about changing the ILSF RF frequency, the effects of RF frequency have been studied in three main areas; beam and machine parameters, RF system parameters and realization of RF components.

Beam and Machine Parameters

Bunch length and thus the photon pulse width are the main parameters which are influenced by the RF frequency. The higher the frequency is, the shorter bunch length and pulse width is available for the users. Users need short pulse width for some time-resolved measurements. However, their required time resolution is in the order of 10fsec to 1psec which cannot be produced by any of RF frequency choices, comparing the calculated values in Table 2. Thus, for this kind of experiments, micro-bunching or beam slicing methods should be used in both cases. However, some new operation modes (low alpha) are under investigation at SLAC and HZB [4] to provide variable bunch lengths down to the range of several 10 fsec which might be not valid for low RF frequency but these modes are dedicated to some specific experiments only which are not demanded by ILSF users community. Therefore, the change of RF frequency won't affect the users or at least ILSF users side.

Table 2: Effect of RF Frequency on Beam Parameters

Parameter	@ 500MHz	@ 100MHz
Bunch length (mm)	2.14	7.09
Pulse width (ps)	7.13	23.64
Bunch charge density (pC/mm)	468	705

While the longer bunches are available at 100MHz, the bunch charge density is higher due to less number of buckets. As a result, the single bunch instabilities might be more critical. In contrast, coupled bunch instabilities are less driven in a ring with lower frequency. Higher coupled bunch instability impedance threshold of ILSF ring at 100MHz in comparison to 500MHz, calculated by [5] and plotted in Figure 1, shows this argument. It should be noted that the frequency axis is normalized to the RF frequency to have a reasonable comparison. This means that at lower frequency, less HOM damping is required which makes the cavity fabrication simpler.

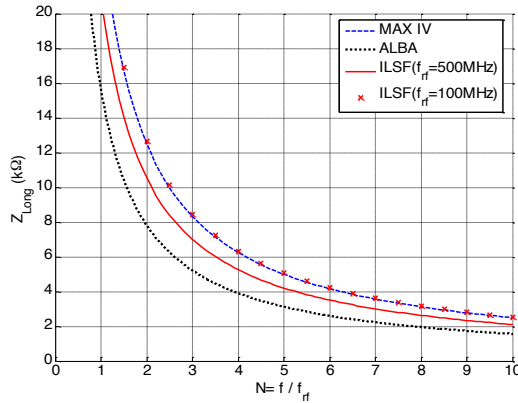


Figure 1: Longitudinal beam instability impedance thresholds of ILSF at both frequency alternatives in comparison to ALBA and MAX-IV.

RF System Parameters and Components

The RF parameters of two alternatives are calculated and compared in Table 3. The ILSF RF system design goal is to provide more than 3% momentum acceptance and about 7 hours total lifetime (corresponding to about 11 hours of Touschek lifetime) in both cases for final operation phase where 350keV losses is assumed for IDs. Although one more cavity is required at 100MHz according to the maximum handling voltage of the cavities, MAX cavity has simpler structure and thus lower cost. Besides, this makes the cavity fabrication more probable in house which is attractive for ILSF. As expected, less RF power is required for 100MHz RF system which results to energy save and lower operation cost. This is in addition to the fact that providing the same power at lower frequency is cheaper and easier. However, by using Tetrodes at 100MHz as a reasonably priced choice, we will lose the modularity and graceful degradation of solid state amplifier which is now becoming very desirable in synchrotron light sources [6]. Combining of several medium power tetrodes or FM transmitters instead of a high power one might be foreseen to bring some modularity to the system. Certainly, the construction of the bulky high power combiners at this frequency will be challenging. The same case is true for high power circulator which is more expensive than 500MHz one. However, the overall cost of 100MHz seems still lower than 500MHz. Since, no critical issue is found in changing the frequency, fabrication of a prototype cavity is planned in order to

conclude the possibility of the cavity development in house and thus the frequency.

Table 3: Comparison of RF System Parameters for Two Frequency Alternatives

Parameters	500 MHz RF System (based on EU cavity)	100 MHz RF System (based on MAX cavity)
Total RF voltage (MV)	2.64	1.44
RF Voltage/cavity (kV)	660	288
Number of cavities	4	5
Cavity Insertion length(m)	0.5	0.5
Cavity Insertion height(m)	1.6	0.9
SR tunnel space	1 straight section (5m)	1 straight section (5m)
HOM damping	✓	✓
Shunt Impedance (MΩ)	3.3	1.6
RF power/cavity (kW)	155 = (66+89)	97 = (26+71)
Amplifier Power (kW)	172	108
Total RF power (kW)	687	538
Amplifier Type	Solid State	Tetrode
Transmission line	Waveguide	Coaxial

100 MHZ CAVITY DESIGN

The 100 MHz cavity designed in ILSF RF group based on MAX Lab design [7] is seen in Figure 2. It is of the capacitor loaded type. Tuning of the cavity will be accomplished by changing its capacitance by a slight movement of the right (back) sidewall of the cavity. The inner profile of this cavity is illustrated in Figure 3. Designed cavity has 4 ports for placement of HOM damping antennas, one port for input coupler, one port for RF monitor and one port for connecting ion pump to the cavity. Designed RF monitor is a simple coaxial loop adoptable with N-type feed-through. Cavity coupler is designed based on Doris coupler with two planar ceramics. Cavity coupler consists of two alumina ceramics, an input and output conductor, a tapering for impedance matching and a short circuit at the end of tapering. This coupler will couple RF power into the cavity inductively. Cavity coupler have two water cooling and one air cooling pass.

Based on required copper cavities for ILSF booster and storage ring fabrication of a prototype cavity is planned in order to conclude the possibility of the cavity development in house. The cavity fabrication will be in 2 phases. In the first phase, in house industrial capabilities in providing leak rate less than 10^{-10} mbar / lit.s and proper ceramic to copper brazing required for cavity coupler will be tested. In the second phase, cavity HOM damping antenna design and also cavity resonant frequency tuning system design and fabrication will be accomplished.

For more reliability cavity simulation performed by three different codes: Superfish [8], HFSS [9] and CST [10]. Figure 4 illustrates longitudinal E-field of cavity

axis calculated by CST and HFSS and Table 4 shows simulation result comparison for these three software.

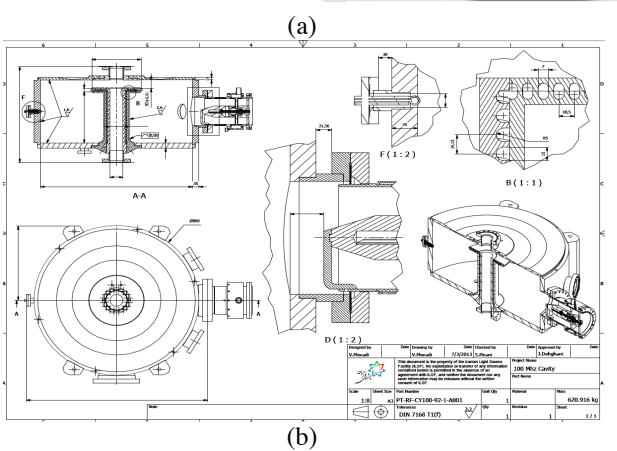
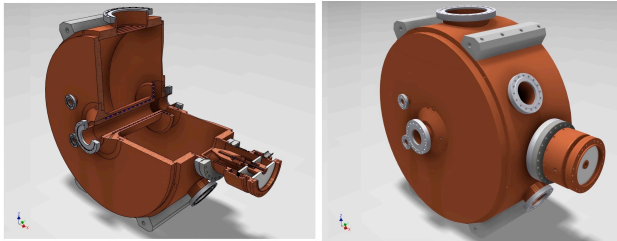


Figure 2: (a) 3D mechanical drawing. (b) 2D mechanical drawing.

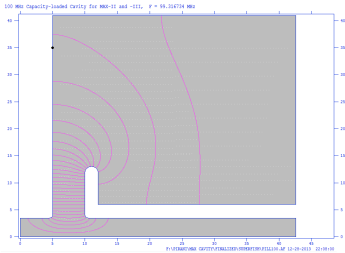


Figure 3: Superfish cavity simulation profile result.

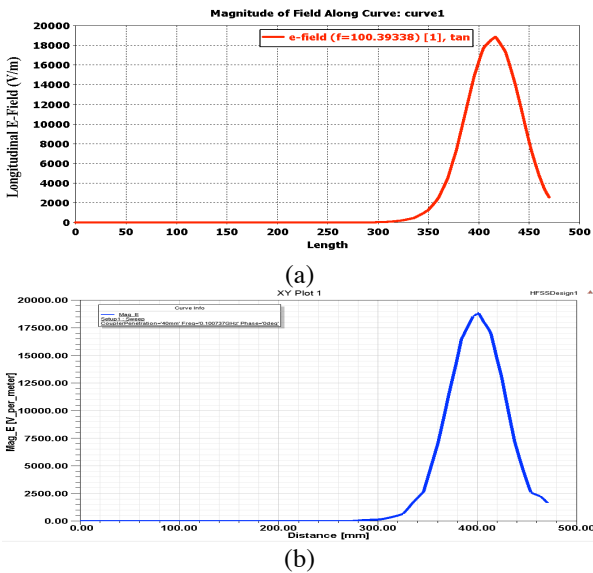


Figure 4: Cavity longitudinal E-field comparison derived by (a) CST. (b) HFSS (1 W input power).

Table 4: SuperFish, HFSS and CST Simulation Result Comparison

Parameter	SuperFish	HFSS	CST
Resonant frequency	99.31 MHz	100.74 MHz	100.39 MHz
Q factor	25356	21434	21390
Shunt impedance	2.16 MΩ	1.75 MΩ	1.75 MΩ

CONCLUSION

The development of HOM damped cavity with simpler structure at 100MHz at MAX Lab., encouraged ILSF RF group to consider 100MHz RF system as an alternative to 500 MHz at ILSF. The machine and RF parameters at two RF frequencies have been compared in this paper. The electromagnetic and mechanical design of a 100 MHz cavity based on MAX Lab. design is performed. Cavity cooling and stress calculations are under progress to finalize cavity design and starting the fabrication procedure. If the cavity fabrication is accomplished by local industry, the frequency will be change to 100MHz. Otherwise, 500MHz RF frequency will be remained to benefit from solid state amplifiers advantages and also keep the option of new short pulse operation available for ILSF ring in future.

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