CONCEPTUAL DESIGN OF ILSF RF SYSTEM

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Abstract

The Iranian Light Source Facility (ILSF) RF system, consisting of RF cavities, power sources and low-level RF systems, is conceptually designed in accordance with the requirements of ILSF 3GeV storage ring. To achieve the desired 400mA beam current, utilization of the existing HOM-damped cavities is explored and RF system parameters are compared based on the usage of each cavity. Moreover, the choice of solid state amplifier as the RF power source is presented with its available power and structure. This paper, furthermore, explains the conceptual design and functionality of the selected digital LLRF system.

INTRODUCTION

The Iranian Light Source Facility, ILSF, is a third generation synchrotron radiation source with 3GeV four-fold symmetric storage ring. In the conceptual design phase it is envisaged that it should provide a 400mA beam current with 3.278 nm.rad emittance, covering the users requirement [1]. The main parameters of ILSF storage ring are given in Table 1. In order to achieve the desired 3% momentum acceptance and 20 hours Touschek lifetime corresponding to about 10 hours total life time, 3.6MV RF voltage is required. It should be noted that in these calculations, a further 350keV and 50keV energy loss per turn have been assumed as insertion devices' radiation losses and parasitic losses respectively. The conceptual design of ILSF RF system consisting of the cavity considerations, RF power source and low level RF system is discussed in the following sections of this paper. Moreover, the status of the prototypes under fabrication is briefly pointed out in each section.

CAVITY CONSIDERATIONS

As in all modern storage rings, it is necessary to utilize HOM damped cavities in ILSF storage ring to prevent beam instabilities from impairing its desirable low emittance. Having a wide beam tube which allows the HOMs propagate down the vacuum chamber and become damped by the surface resistance of the chamber walls, super conducting cavity seems to be a good choice for high current low emittance rings. However, in ILSF, the medium straight sections with small beam sizes are reserved for IDs and the 2.82-meter length of the short straight sections is not enough for a SC cavity. Consequently, SC cavities are ruled out for ILSF lattice.

Table 1: ILSF storage ring main parameters

Parameter	Unit	Value
Energy	GeV	3
Current	mA	400
Circumference	m	297.600
Horizontal emittance	nm.rad	3.278
Bare lattice energy loss/turn	MeV	1.02
Momentum compaction factor	-	7.6×10^{-4}
Energy spread	-	1.04×10^{-3}
Damping time (τ_x τ_y τ_z)	ms	5.9, 3.4, 4.6

Exploring the existing normal conducting cavities in high current rings, EU [2], ELETTERA [3], PEP II [4] and KEK-PF [5] cavities are considered as candidates for the ILSF storage ring due to their resonance frequency and HOM damping characteristics. To make sure that the cavity HOMs are sufficiently damped, their HOM impedances were compared to ILSF stability threshold impedances in both longitudinal and transverse directions (see Fig. 1). Equipped with three broadband waveguides as an efficient HOM damping method, EU and PEP-II longitudinal HOM impedances are lower than ILSF threshold. Whilst, additional HOM damping methods such as temperature tuning and damping antennas have to be utilized to reduce ELETTRA and ASP HOM impedances sufficiently for ILSF. In the transverse direction, the measured HOMs of all of the candidates exceed the thresholds at some points. This is not a serious problem as it can be dealt with by a feedback system. According to the cavities maximum handling RF voltage and power, and the total 3.6MV accelerating voltage, six of any selected cavity is required, except in the case of PEP-II where 5 cavities would be enough. The total required RF power is in the same range (about 950kW) for all cavity candidates. Thus, the cost of the cavities and the number of required sub-system components (waveguides, LLRF systems and amplifiers) would be a crucial deciding factor. The space the cavities occupy in the storage ring tunnel should also be considered as it

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affects the space available for the insertion devices. Two EU, ELETTRA, or ASP cavities fit into one short straight section so a total of 3 short straight sections are required for these cavities. However, PEP-II cavity with a longer length requires one short straight section per cavity, hence five short straight sections would have to be used for PEP-II cavities.

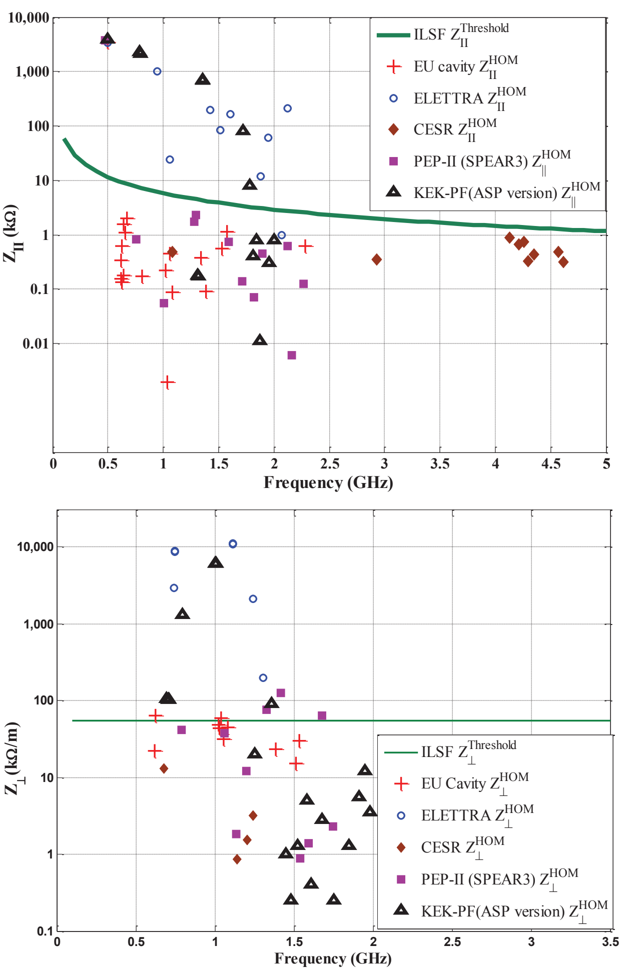

Figure 1: Comparison of HOM impedances of cavity candidates with ILSF threshold impedance: longitudinal impedances (up), transverse impedances (down).

RF POWER SOURCE

Microwave tubes such as klystrons and IOTs have been used to provide the high RF power required in synchrotron light sources for many years. Due to their advantages such as modularity, easy maintenance and graceful degradation solid state amplifiers have been recently proposed and utilized as an attractive alternative to microwave tubes. Based on the successful experience carried out in SOLEIL and LNLS and also existence of local expertise in Iran, solid state amplifiers have been chosen as ILSF RF power sources in the storage ring and booster.

The unit amplifiers (UAs) or amplifier modules constitute the heart of the solid-state amplifier. High-power amplification can be achieved by the parallel combination of the output power of several individual UAs. Two different unit amplifiers based on two LDMOS transistors (MRFE6VP61K25HR6 and BLF578) have been designed and tested at ILSF. The out-put powers of 700W and 660W have been achieved from these UAs (shown in Fig. 2) respectively. A thorough comparison of their characteristics such as available power, gain, efficiency, lifetime and price is under progress. Finally, one will be selected as the final UA of ILSF solid state amplifier for mass production.

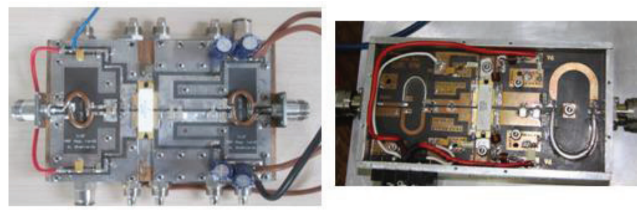

Figure 2: ILSF RF Unit Amplifiers based on MRFE6VP61K25HR6 (left) and BLF578 (right) transistors.

To build up 200kW RF power for each cavity, a combining network has been designed (see Fig. 3). At the first stage, 4kW power is achieved with the combination of 8 unit amplifiers. Note that the unit amplifiers are assumed to be operating at lower power for longer lifetime. A 4kW amplifier is now under development at ILSF. The design of an 8:1 radial power combiner is finished and it is ready for fabrication.

Combining eight of these 4kW amplifiers generates 30kW of power. A 55kW tower is then produced by combining two 30kW amplifiers. For the generation of 200kW power, four towers of 55kW solid state amplifier in two steps by means of two 2:1 combiners will be utilised.

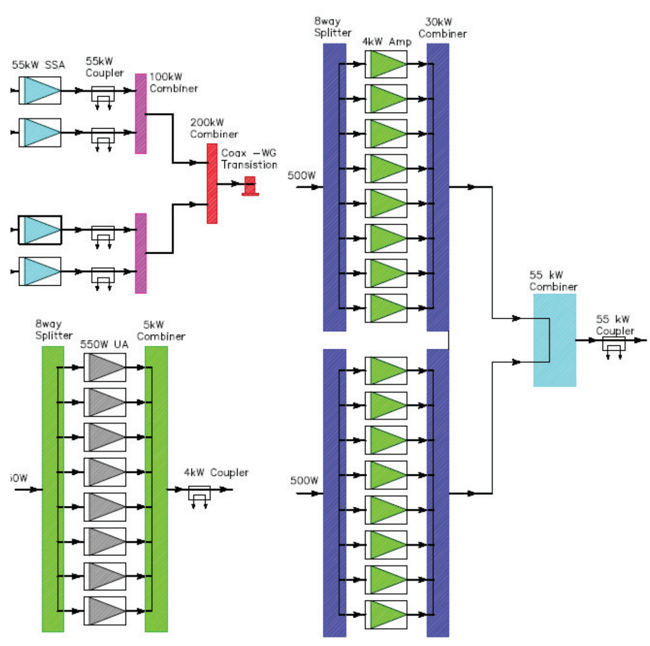

Figure 3: 200kW solid state amplifier combining network.

LOW LEVEL RF SYSTEM

The main goal of LLRF system is to stabilize phase and magnitude of the cavity resonating field. The stability of the resonating field is crucial, since any fluctuation in the cavity field will translate into fluctuation in the beam of electrons and the synchrotron radiation will be degraded. To have more flexibility, a digital LLRF system is proposed to be implemented for ILSF RF system. The development of a semi digital prototype is briefly presented here. Its analogue signal conditioning unit will be replaced with digital processors like FPGA and/or DSPs for a final fully digital system.

A self-excited loop architecture for the LLRF system has been used. This means the cavity, the power amplifier and the LLRF system comprise a closed loop, and the loop oscillates at a certain frequency.

As shown schematicly in Fig. 4, the system has three main sections; a) the analogue interface which down/up converts the RF/IF signal, b) the digital hardware section which samples the IF signal and sends the data to a computer and converts the digital commands from the computer to analogue signals, C) the software section that performs the processing and controlling algorithms.

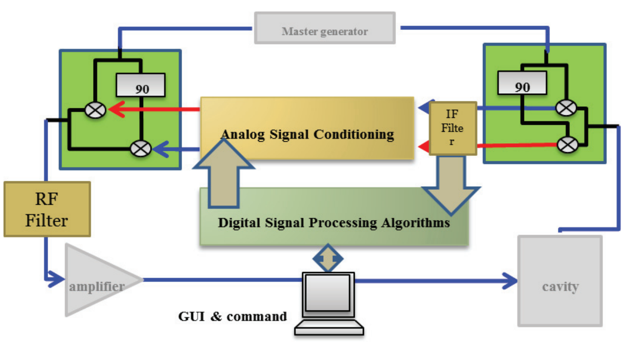

Figure 4: Schematic of ILSF LLRF system prototype.

The frequency (or phase) of the cavity field is determined by the amount of phase shift introduced by the LLRF system. In other words the following condition should be met at the resonance frequency:

$$\theta_{LLRF} + \theta_{cavity} + \theta_{other} = 0 \quad at\ f_{resonance}$$

where θ_{LLRF} is the phase shift introduced by LLRF system, θ_{cavity} is the phase shift across the cavity, and θ_{other} is the phase shift caused by other parts (e.g. cables). Hence, by changing θ_{LLRF} one can easily change the resonance frequency (or phase) of the cavity field. It is obvious that by changing the amplitude of the IF signal the amplitude of the cavity field will change.

The phase and amplitude of the IF signal is compared to a reference value and then the controlling algorithm generates a command. This command is translated into a voltage which makes proper phase shift to the IF signal passing the signal conditioning section. This way the LLRF system maintains a desirable phase and amplitude for cavity field in spite of any fluctuations.

The analogue/digital hardware is developed and the software is under development. The LLRF system is tested using an aluminium pillbox cavity, (see Fig. 5) and some promising results are obtained. The work is progressing to finalize the test and operation routine of the LLRF system.

Figure 5: Analogue and digital sections of semi digital LLRF system prototype (up), system under test using an aluminium pillbox cavity (down).

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