

THE RF SYSTEM FOR THE 3RD HARMONIC CAVITY OF ALS*

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Abstract

A higher harmonic cavity system is under construction in the ALS to extend beam lifetime. The implementation will be carried out in stages. The plan is to operate the system in the passive mode as a start and, depending on various factors, the plan may evolve into an active system eventually to attain the optimum beam lifetime at all beam current levels. The RF system must be designed accordingly to support the various stages of implementation. This report will describe the various RF systems along the path leading to the fully implemented system.

Introduction

To a user of synchrotron radiation, the beam lifetime is one of the most important aspects of a synchrotron light source. In low to medium energy storage ring light sources, the lifetime is usually dominated by large-angle intrabeam (Touschek) scattering in which elastic collisions of electrons within the bunch have a finite probability of transferring enough longitudinal momentum to each electron such that they no longer are within the momentum acceptance of the storage ring and are lost. This process is particularly important for storage rings such as the Advanced Light Source (ALS) because of the high density of electrons resulting from the small transverse beam size. One proven method for increasing the lifetime from Touschek effect without compromising the transverse beam brightness is to reduce the peak charge density of an electron bunch. This requirement can be met by adding a second voltage to the 500MHz main RF voltage with an amplitude and phase such that the slope at the bunch center is zero. The energy distribution is unaffected but the bunch lengthens and the peak charge density decreases and the lifetime improves. This voltage must be a higher harmonic of the main RF voltage.

We have chosen to add five third harmonic (1.5GHz) cavities to the storage ring to achieve the goal. Furthermore we are going to start with a passive system using the beam to induce the required voltage in the cavities. This mode of operation will enhance the beam lifetime at higher beam current. A complete discussion on this subject are given in reference 1 and 2.

Cavity

The ALS third harmonic cavity is a single cell re-entrant type resonator much like the two main 500MHz cavities. The cavity shape and size were modeled with Urmel and Mafia extensively before cutting metal. Figure 1 shows a picture of the final shape of the cavity design.

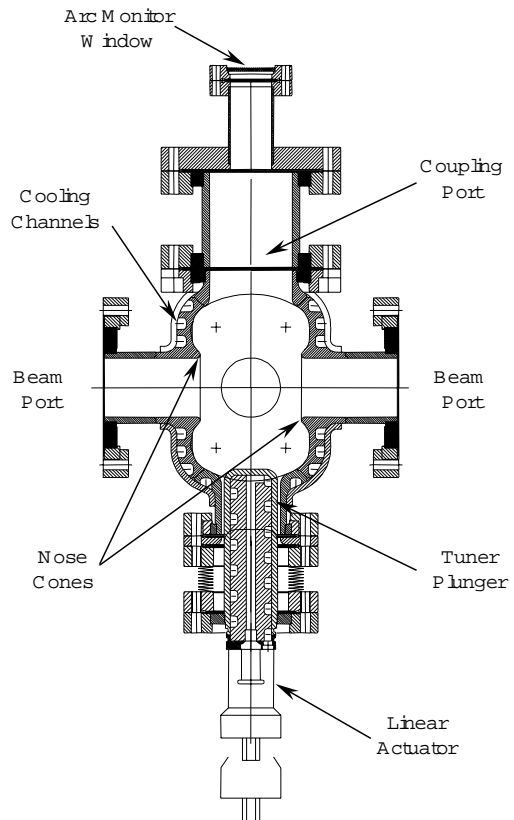


Fig. 1 The ALS Third Harmonic Cavity

There are a total of six ports on the cavity body, two beam ports, two tuner ports, one coupling port and one other port for signal probe. The shunt impedance of the cavity with all the ports is about 1.5Mohm and the loaded Q is about 12000. Detail design, modeling and construction technique are given in separate reports^{3,4}.

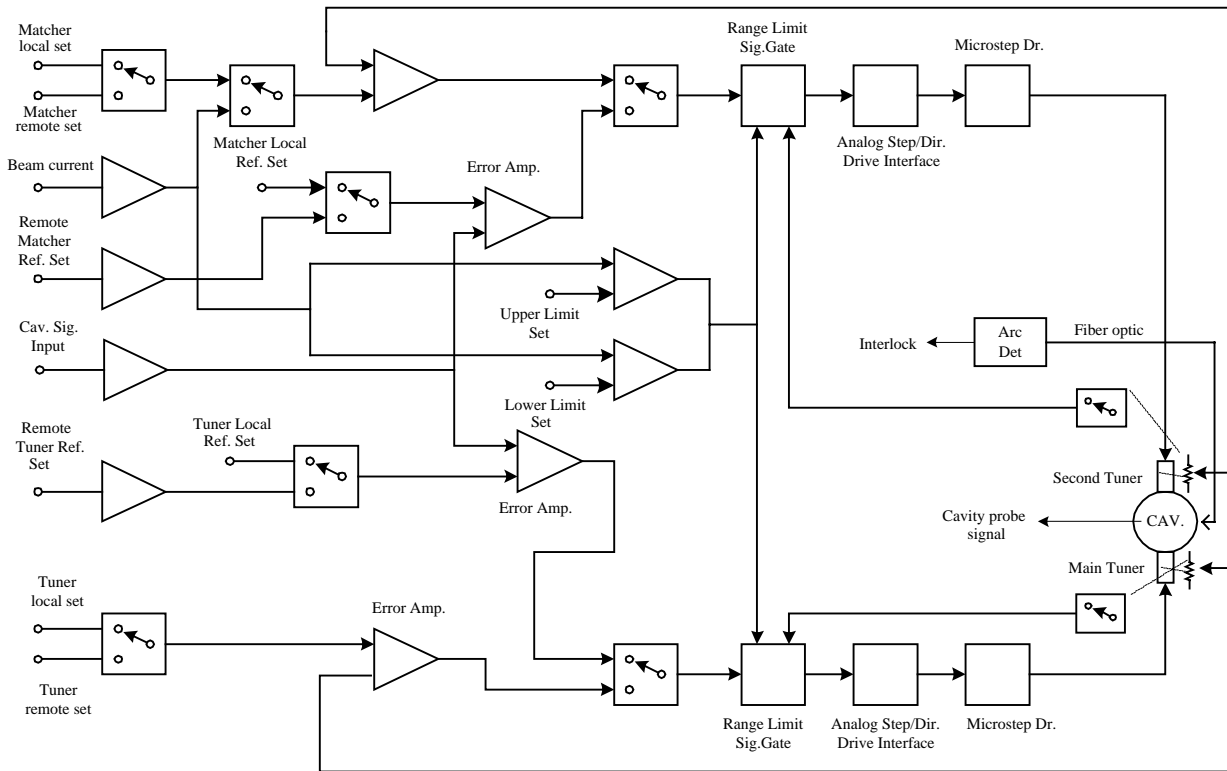


Fig. 2 ALS Third Harmonic Passive RF System Block Diagram

The Passive RF System

Figure 2 shows the block diagram of the passive RF system. Since we are not using the coupling port in this phase of operation, an arc detector will be mounted on this port to monitor cavity arcing. This detector will shut off the main RF system and hence the beam when an arc is detected. The main tuner can be controlled either manually or with the amplitude loop. Each cavity has its own amplitude loop that can be tuned off resonance individually and parked at some frequency that would not affect the main RF signal. A second tuner is installed in a side port. This tuner is manually settable via remote control and could possibly be used for tuning HOMs to safe frequencies. With the passive system, the power of the cavities comes from the main 500MHz RF system via the beam. Each cavity will require 5kW of power, therefore, 25kW of additional power will be taken from the main RF system. The total maximum voltage produced by these five cavities is 500kV, one third of that of the main RF voltage at the optimum level.

The operation of this phase one system can be summarized as the following:

At maximum beam current level, the cavities will be tuned right at resonance and then de-tuned to a higher frequency to set the voltage operating point at a level lower than the resonant peak. As the beam current decays, the tuner will tune the cavity back towards resonance to keep the voltage amplitude constant. It is obvious that this tuning scheme would only work through a limited beam current range, and also this amplitude can only be set to one optimum operating point¹.

The phase-two version of the passive system or an active system, as the case may be, will include a tunable wave guide coupler (not shown) that will be mounted on top of the input port of the cavity where an arc detector is located at this time. The adjustable coupler could be used to set the coupling factor to a to an optimum value according to the beam current or a predefined value in a feed forward scheme. This will maintain an optimum voltage in the cavity for maximum beam lifetime operation across most of the spectrum of the beam current. The detail of such scheme and specifics of future RF system will be formulated as we gain more experience in the performance of this phase one passive system.

The Amplitude Loop Control Module

There are two separate loops in this module as mentioned in the last paragraph. See fig. 2. In this phase one system, one loop is used by the tuner to hold the cavity voltage amplitude constant at a predetermined value, the other loop is used to set the second tuner position in the 'loop open' mode. This second loop was intended for a tunable matching coupler for the phase two passive system or an active system. In this phase one operation this is used for controlling a second tuner. When operating in the closed loop mode the main tuner is actively engaged to hold the cavity voltage amplitude constant. Caution must be exercised to make sure that the loop is active only in a well defined range of beam current. Outside of this range the loop must be deactivated and the tuner plunger will hold its position until such time the beam current would fall back to within the operational range of the system again. This window is extremely important to prevent run away tuners causing de-tuning of all the cavities. The amplitude loop control module has been designed to have maximum flexibility to accommodate various operational requirements. The same module can be used to control klystron output power should an active system be implemented in the future.

The Active RF System

In the active RF system only 4 cavities will be needed to generate the 500kV of voltage required. We intend to power each cavity with a separate klystron. Each klystron will be capable of providing at least 5kW of RF power. In the active system there will also be a phase loop that keeps the RF phase constant by using the cavity main tuner. The amplitude loop, in this case, will be using either the klystron's modulation anode or the klystron's drive power as the amplitude control element. At the input coupling port of each cavity there will be an adjustable coupler to set the coupling factor to the desirable value. The setting of this coupling factor may be done according to the beam current or some other parameters. The fiber optic of the arc detector will be moved to either the second tuner port or could be installed side by side with the cavity signal pick up probe. The active system will require RF windows. We will mostly likely locate the windows away from the cavity input port to reduce undesirable effects of RF heating and breakdown due to high cavity electric field. The signal source in the active RF system will be derived from the main storage ring cavity probe signals to keep the third harmonic RF voltage phase locked to that of the main cavities.

Conclusions

All sections of this project are progressing well. We expect to commission the phase-one passive system in June 1999. Results from operation will determine which

direction the next step would be. Most components in this phase-one passive system have been designed with the possibility of upgrading to either the phase-two passive system or an active system.

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