DETUNING OF THE NSLS UV RF CAVITY TO COMPENSATE FOR 1 AMPERE OF STORED BEAM*

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Abstract

A mechanically driven loop tuner in addition to water temperature variation is used to compensate for the reactive detuning of the 52.8 MHz RF accelerating cavity at a 1 ampere circulating current. This combination avoids the higher order resonances that occur with a single mechanical tune. System description and operating results will be detailed.

Introduction

The NSLS VUV ring is an electron storage ring dedicated to synchrotron radiation production and normally operates at 745 MeV. A single 52.887 MHz radio frequency cavity is used to compensate for the 14.7 kW of synchrotron radiation power per ampere of stored beam. Beam was first stored at the end of 1981, and the design current of 1 ampere was achieved in June 1986. The maximum stored beam was 1.2 amperes.

During the early phases of operation, the accelerating RF cavity gap in the VUV ring was nominally run at 150 kilovolts. A mechanically driven, shorted loop tuner was used to provide the reactive tuning necessary to compensate for beam loading. It soon became clear, however, that the loop tuner did not have enough range to compensate for beam loading at higher current levels.

The area of the shorted loop could be increased in size, but due to its unsymmetric perturbation of the RF field, it was feared that transverse modes could be excited. There was some evidence of this by observing beam instabilities during operations.

Further complicating the problem, it was noticed that deeper loop tuner penetrations produced vacuum activity within the cavity, causing ion trapping. Studies showed that this phenomenon only occurred during times of stored beam and the possibility of beam-induced multipactoring caused by a higher order mode in the tuner structure was considered.

It was also found that higher beam current intensities and lifetimes were limited by short bunch lengths. To increase the bunch length, the gap voltage was reduced to 77 kilovolts. This further increased the amount of detuning, since

$$\Delta f \propto \frac{I_b \cos \theta_s}{V_g}$$

where I_b = beam current

θ_s = synchronous phase

V_g = accelerating gap voltage

A solution of this problem was to program the water temperature of the cavity cooling system using a voltage proportional to the amount of stored beam and adding this signal to the original zero beam, temperature setpoint, as shown in Figure 1.

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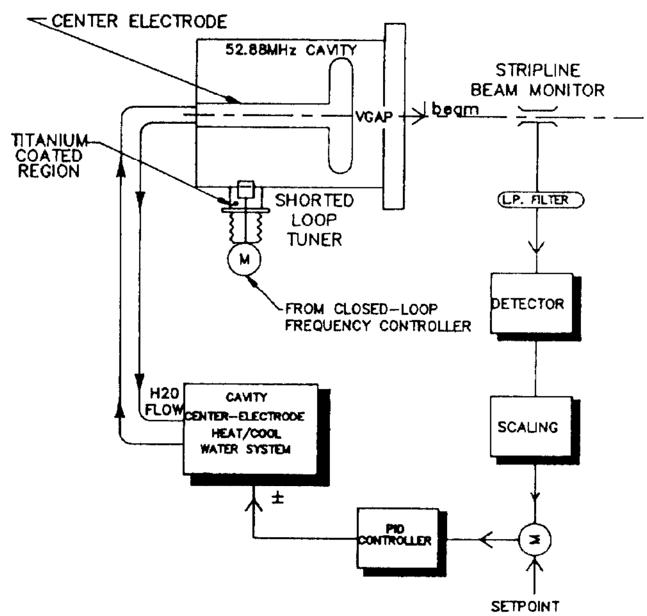

VUV Cavity Tuning Control

Figure 1

Cooling System

Temperature regulation is achieved using a closed loop water system. A recent pump upgrade permits an increase in temperature range. A mixing valve allows cold water to enter and exit the system in the cooling mode, and a 12 kilowatt heater is used in the heating mode. Regulation is accomplished using a commercial PID controller which accepts the zero beam setpoint of 30°C. As the beam is injected to the one ampere level, the cavity temperature is driven to approximately 60°C by the feed forward signal coming from a stripline beam monitor. This signal is filtered and properly scaled in such a way as to minimize the travel of the mechanical loop tuner and also keep the tuner from any position that may produce a higher order mode and thus a possible beam instability.

This method yielded about 30 ma of beam loading compensation for each degree centigrade change.

Temperature Scaling

A combination of temperature and tuner position range was found that gave desirable results. As seen in Figure 2, the normal operational temperature scaling (dashed line) resulted in limiting the tuner travel from 3 to 4 inches penetration. An increase in the scaling forced the tuner into a position at which ion trapping occurred. Decreasing the scaling, eliminated this problem, resulting in stable operation.

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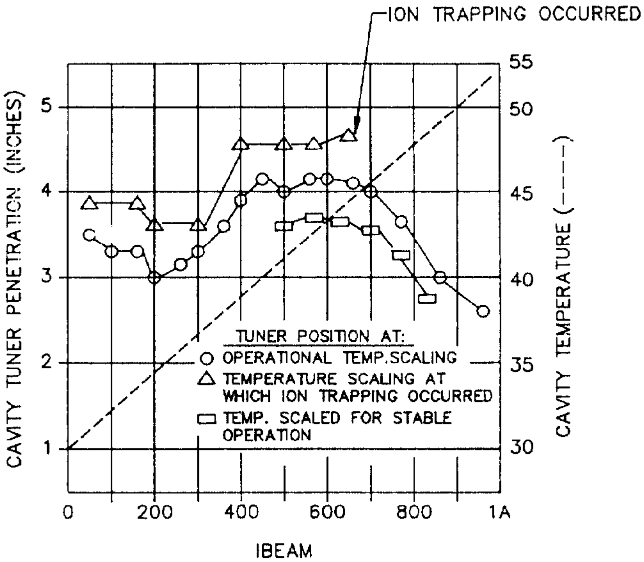


Beam Current VS. Tuner Pos.

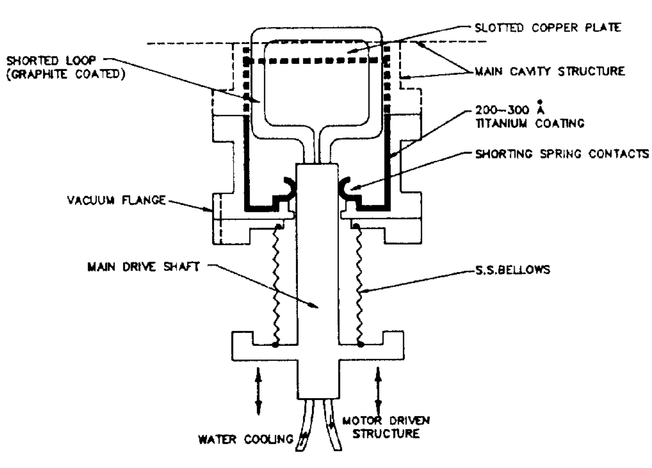
Figure 2

Loop Tuner Modifications

As previously mentioned, at a specific beam current, tuner positions were found that produced vacuum activity measured within the cavity resulting in ion trapping. A study showed that this condition could not be reproduced at any tuner position if there were no beam current present.

After a careful look at the tuner design, it was determined that a mode, coupling into the bellows area, was possible, producing voltages that may cause multipactoring and thus vacuum activity. Furthermore, a copper shield installed from the grill that carries cavity surface currents, to a spring contact on the loop drive shaft, did not adequately ground current from flowing to the bellows region. This copper shield was a magnetic circuit in itself and increased the probability of multipactoring.

During a recent shutdown, several mechanical changes were made to the tuner. The shield was removed, and a proper ground plane was installed from the shaft to the tuner body to keep currents from flowing into the bellows region, as shown in Fig. 3. The area of the loop was increased to produce a total tuning range of 44KHz.



Simplified Loop Tuner Diagram

Figure 3

Multipactoring problems were addressed by coating the inner surfaces of the tuner with 200-300 angstroms of titanium (nitride) using a technique used at SLAC[1]. The area coated is shown in Figure 3. The entire loop surface was also coated with graphite.

A study was done after the tuner was installed into the cavity. Beam was injected into the ring up to 800 mA and the temperature of the cavity changed such that the tuner was driven through its full range. No vacuum activity or ion trapping was observed. This test was done at various current levels. A tuner region was found at which sidebands appeared on the beam spectrum, as observed on a spectrum analyzer, but again, no vacuum increase was noticed. The cause of the sidebands will be studied.

Conclusions

These recent changes have allowed injection to the 1 ampere level without causing vacuum activity. This may be a consequence of the titanium coating eliminating the multipactoring or the changes in the inner loop area configuration. The increased range of the water system in conjunction with the larger shorted loop size allows for greater tuning flexibility.

References

1. E.W. Hoyt and W.P. Schulz, Titanium Nitride Coating of Aluminum Multicavity Accelerating Structures. (SLAC-TN-75-3, March 1975).