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HIGH ORDER MODE DAMPING IN THE NSLS ACCELERATING RF CAVITIES BY THE USE OF DAMPING ANTENNAE*

Norman Fewell and Zhou Wen**
Brookhaven National Laboratory
Upton, NY 11973

Abstract

High order modes have been successfully damped in the existing NSLS accelerating cavities by the insertion of damping antennae. The location of the antennae was aided by cavity field plots using superfish and their lengths determined experimentally. A description of their construction is presented together with the results of their insertion upon higher order cavity modes and beam stability.

Introduction

High order mode measurements on the NSLS 52 MHz accelerating cavity[1] led to a predicted longitudinal coupled bunch instability threshold of 2 mA with 9 bunches in the VUV storage ring. This prediction was confirmed[2] during the commissioning of the storage ring, and therefore an effort was made to damp the high order modes in the X-ray and VUV acceleration cavities.

RF Cavities

The RF cavities are heavily capacitively loaded quarter wave T.E.M. resonant structures, which are described fully in Ref. 1. Acceleration is provided by one of these cavities in the VUV ring and by two similar cavities in the X-ray ring. Two additional cavities will be installed in the X-ray ring at a later date.

Choice of Mode Damping Method

As the VUV cavity was already in operation and the two X-ray cavities were complete, damping the high order modes was a retrofit task with several constraints. One obvious constraint was that the Q of the fundamental mode should not be appreciably reduced. The physical constraints (which limited the areas where damping could occur) included the RF feed loop, cavity tuner and vacuum pump ports, water-cooling channels and tank strengthening bars. Other factors governing the choice of damping method were, that we wished the dissipative elements to be easily cooled and if possible external to the vacuum.

If we look at the SUPERFISH[3] electric field configuration of the fundamental mode (Fig. 1a) we see that there is an area of relatively weak electric field toward the rear of the cavity. A large number of the higher order modes however do have strong electric fields in this area (Fig. 1b). We can couple to these high E fields in the high order modes without strongly perturbing the H field of the fundamental mode, and it is possible to dampen them without effecting the Q of the fundamental mode. This is accomplished by thin electric field probes (antennae) that are inserted through the cavity wall away from the physical constaints mentioned above.

Model Measurements

Before making penetrations through the walls of the existing 52 MHz cavities, measurements were made on a 200 MHz model of a beam split cavity, that was slated to be inserted into the VUV ring. High E field areas were determined by superfish and by measurement (Fig. 2). Mode spectra with longitudinal E fields in the accelerating gap, were taken with E field monitors either side of the gap and an Eton spectrum analyzer with tracking generator, and the following modes identified (Fig. 3).

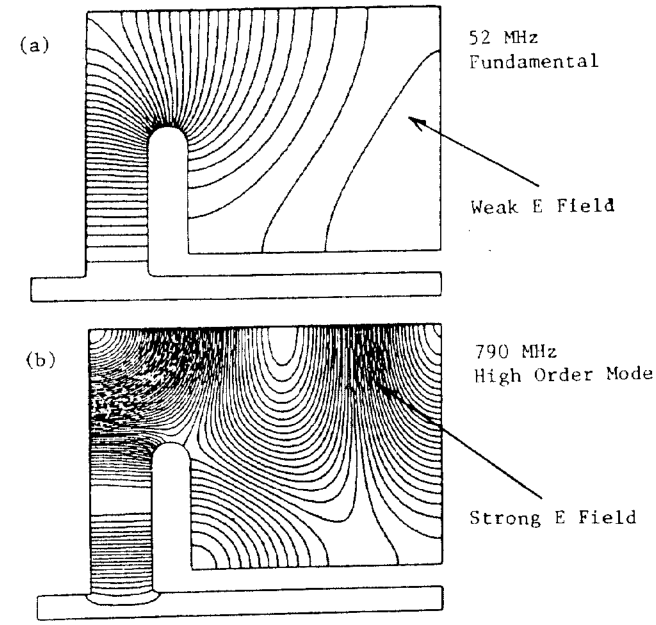

Fig. 1. 52 MHz Cavity Modes.

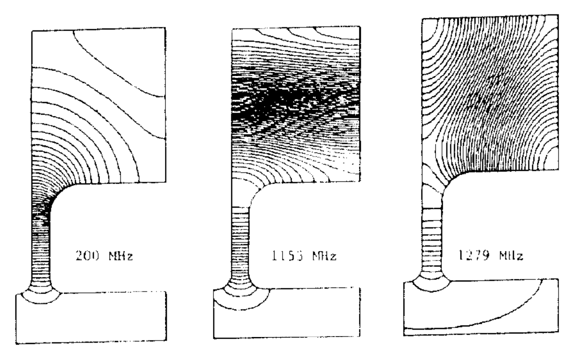

Fig. 2. Beam Split Cavity Modes.

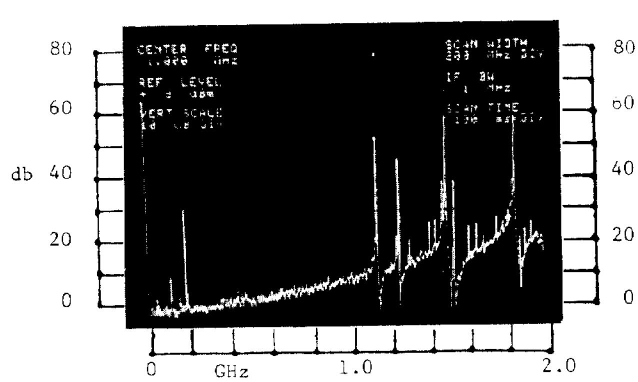

Fig. 3. Beam Split Cavity Spectra.

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**Visiting scientist from Zheljing University, Hangzhou, Zhejiang, The People's Republic of China.

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E field probes were inserted at the high order mode strong E field points, parallel to the E field and terminated in 50 ohms. The probes were then tuned to achieve maximum damping. Tuning consisted of changing the length of the probe to produce a minimum spectrum analyzer response signal. The length of the tuned probes are approximate 1/4 λ at the high order mode frequency. The results of these measurements are given in Fig. 4 and show that the high order modes can be successfully damped by approximately 40 db using 1/4 λ antenna terminated in 50 ohm.

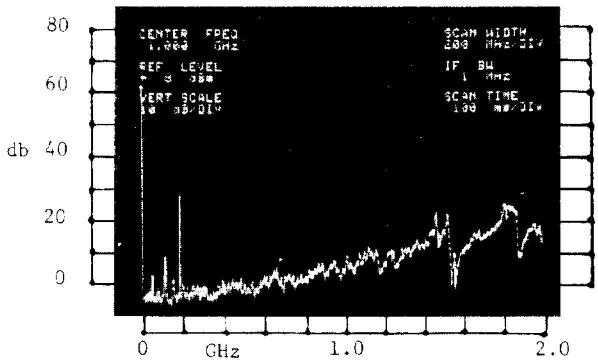
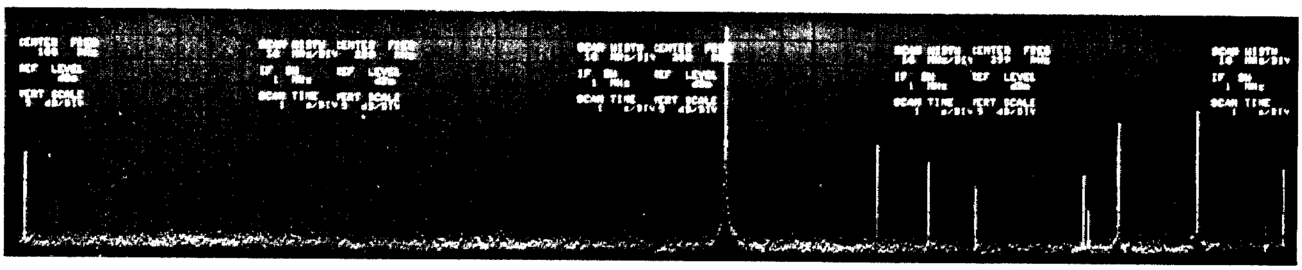


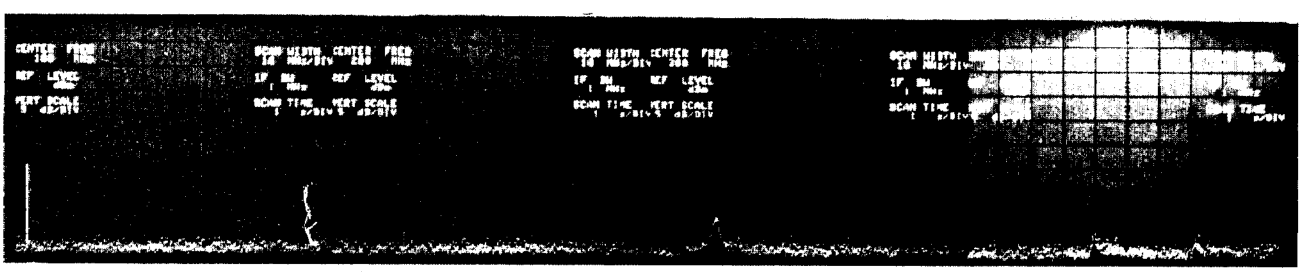
Fig. 4. Beam Split Cavity Spectra with Damping Antennae.

52 MHz Cavity Measurements

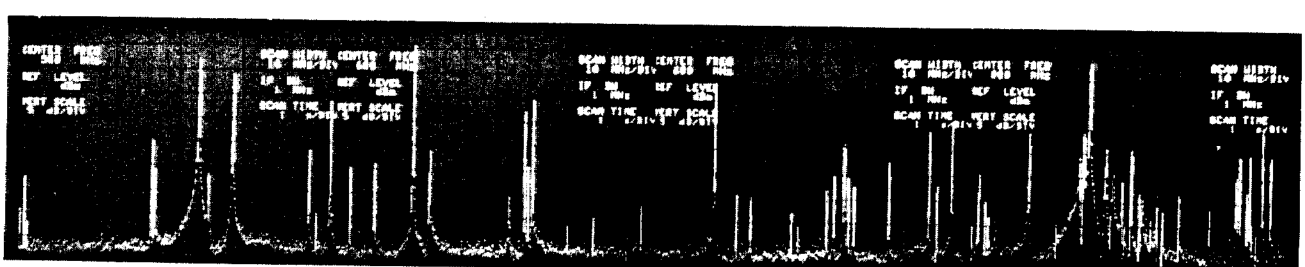
As the above model measurements were positive and the 50 ohm termination solved the dissipative element cooling problem, we decided to go ahead with the installation of damping antenna in the existing 52 MHz cavities. Superfish runs on the high order modes led to the determination of the insertion points in the cavity. Holes were drilled at these points and vacuum flanges welded in place. E field probes with adjustable tips were inserted and tuned for minimum high order mode signal as above. Although each probe was tuned for a specific mode it also dampened other high order modes so we installed only a total of six



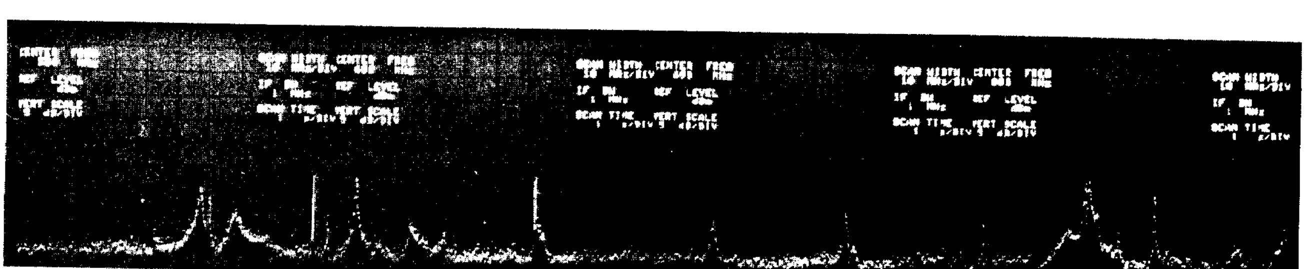
52 MHz Cavity Frequency Spectra from 50 MHz to 450 MHz, Undamped.



52 MHz Cavity Frequency Spectra from 50 MHz to 450 MHz, with Damping Antenna.



52 MHz Cavity Frequency Spectra from 450 MHz to 850 MHz, Undamped.



52 MHz Cavity Frequency Spectra from 450 MHz to 850 MHz, with Damping Antenna.

Fig. 5. 52 MHz Cavity Frequency Spectra

probes. The results of these six damping antenna are shown in Fig. 5. In this figure the undamped high Q modes are somewhat higher than shown, due to the writing rate and sweeptime of the spectrum analyzer. The results show that the high order modes are substantially reduced (up to 40 db) while the fundamental mode is virtually unchanged.

In addition to the above frequency spectra, we also measured the longitudinal impedance of the cavity using a transmission line technique similar to that described by Hahn and Pedersen.[4] These measurements confirmed that the fundamental impedance was little changed and that most other impedances had been reduced to about 1K Ω or less.

An advantage of using a 50 Ω termination as the dissipative element and matching the feedthrough to 50 Ω, is that we are able to use standard RF test equipment to measure the coupling of the antennae to the fundamental mode very easily, and thus determine the power rating required for the 50 Ω load.

Antenna Design

After the probe lengths were determined as above, fixed probes were made up as shown in Fig. 6. They are constructed in OHFC copper and brazed through a standard ceramic vacuum feed through. Although they dissipate little RF power, they are in vacuum and must be cooled. This is accomplished by modifying standard 1-5/8" EIA, 5 kw, water-cooled, 50 ohm terminators, to allow the cooling water to pass through the load, through a spit tube, and return out again through the load. In addition the 273 MHz probe which is the lowest frequency (and therefore the longest) was also fitted with a water-cooled 1/2 λ stub at 52 MHz to reduce the fundamental frequency pick up of this probe. At the present time the maximum RF power obtained in the cavity with damping antenna installed has been 80 KW.

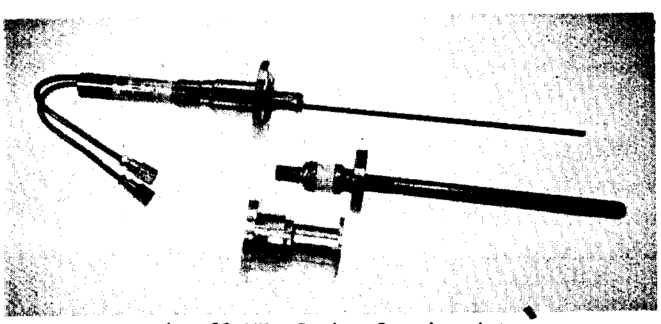


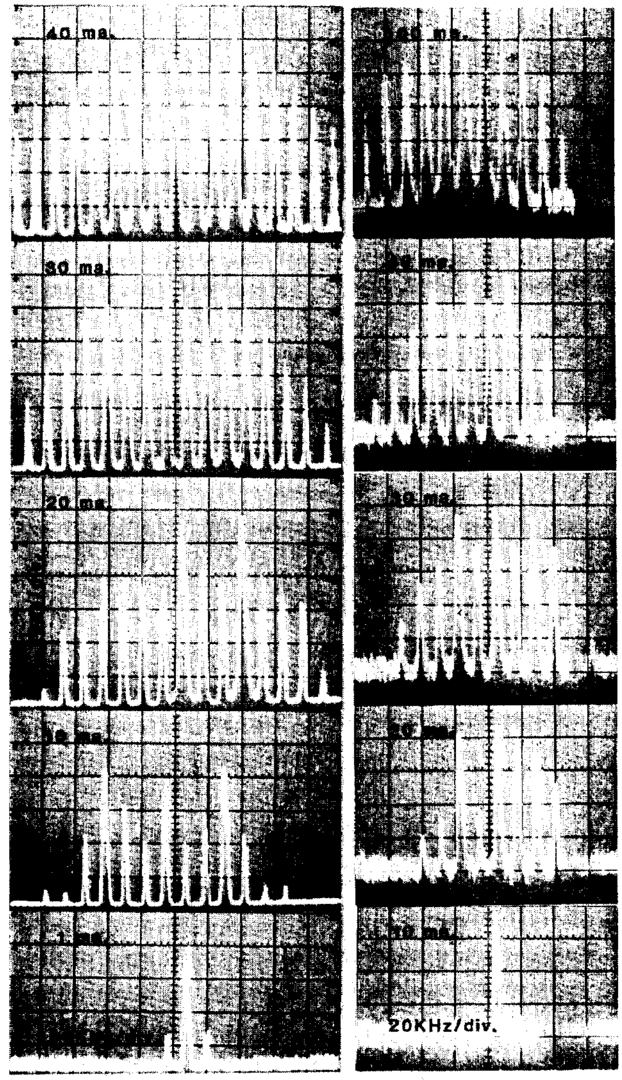
Fig. 6. 52 MHz Cavity Damping Antenna.

Beam Stability

Longitudinal oscillations of the beam were monitored by observing both the phase jitter of a pickup ekectrode signal on a fast oscilloscope, and by measuring the amplitude of the synchrotron sidebands. J. Galayda[2] reported that with 9 bunches in the VUV ring, persistent oscillations of up to ±0.75 ns (corresponding to ±0.2% energy oscillation) occurred at currents from 40 to 150 mA. After installation of damping antennae this was reduced to ±.25 nS at 150 mA. Instability threshold was also reduced by a factor of about 9. As shown in Fig. 7. This figure shows the sidebands at one of the rotation frequencies for various current levels with 9 bunches in the VUV ring.

Conclusion

We have demonstrated that it is possible to dampen high order modes in existing RF cavities with



Without damping antennae   With damping antennae

Fig. 7. VUV 9 Bunch Synchrotron Sidebands.

the use of very simple and inexpensive damping antennae terminated with readily available RF water loads.

Acknowledgments

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