AC Bias Operation of the Perpendicular Biased Ferrite Tuned Cavity for the TRIUMF KAON Factory Booster Synchrotron

R. L. Poirier and T. A. Enegren, TRIUMF,
I. B. Enchevich, Sofia University, Bulgaria.

Abstract

The rf cavity for the Booster Synchrotron requires a frequency swing from 46 MHz to 61 MHz at a repetition rate of 50 Hz and a maximum accelerating gap voltage of 65 kV. A dc biased prototype cavity built at LANL using perpendicular-biased yttrium-garnet ferrites, rather than the more conventional parallel-biased NiZn ferrites, has now undergone major reconstruction at TRIUMF for ac bias operation. RF signal level measurements have shown that the frequency swing at a repetition rate of 50 Hz can be accomplished and still handle the eddy current losses in the cavity structures with minimal effect on the magnetizing field The prototype cavity is now undergoing high power rf tests with full power ac bias operation. The results of these tests and operational experience is reported.

I. Introduction

A cross section view and a rendering of the ac bias ferrite tuned cavity are shown in Figs. 1 and 2, respectively. The

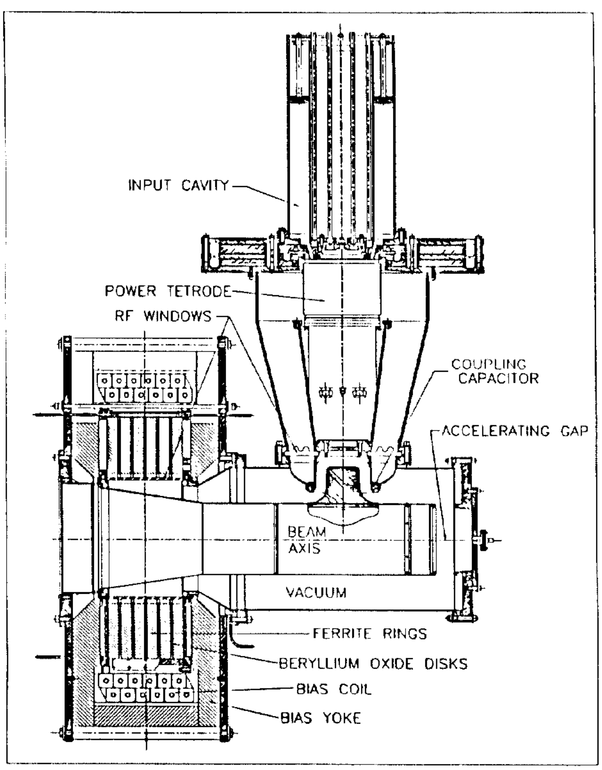

Figure 1: Cross section view of the ac biased ferrite tuner cavity.

power tetrode is capacitively coupled to the accelerating cavity and the ferrite tuner is located on the beam axis.

A toroidal magnet surrounds six yttrium garnet ferrite rings establishing a bias field in the longitudinal direction which is perpendicular to the azimuthal rf magnetic field. Beryllium oxide (BeO) cooling spacers are placed between the ferrite rings and conduct heat from the spacers to a

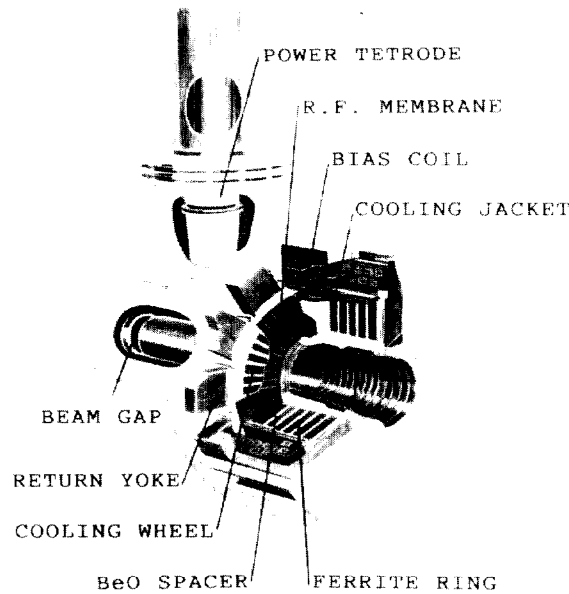

Figure 2: Rendering sketch of the ac biased ferrite tuner cavity

copper water cooling jacket at the outer radius. The return yoke for the magnetic field consists of 12 sectors which are held together by an aluminum clamping plate and a set of tie rods. The sector design allows for easy access to the various water cooling lines and provides room for the entrance and exit of the stranded cable from which the bias coil is made. The rf conducting surface of the ferrite tuner surrounding the ferrite rings is formed by the copper water cooling jacket, a tapered inner conductor and two thin rf membrane end walls. Figure 3 is a graph of the rf signal level measurements showing that the required frequency swing can be accomplished at a repetition rate of 50 Hz. Under these conditions the eddy current losses in the cavity structures are manageable and have minimal effect on the magnetizing field [1].

II. RF Conditioning

In order to test the amplifier itself for any parasitic oscillations or operational problems it was decided to first

0-7803-0135-8/91$03.00 ©IEEE

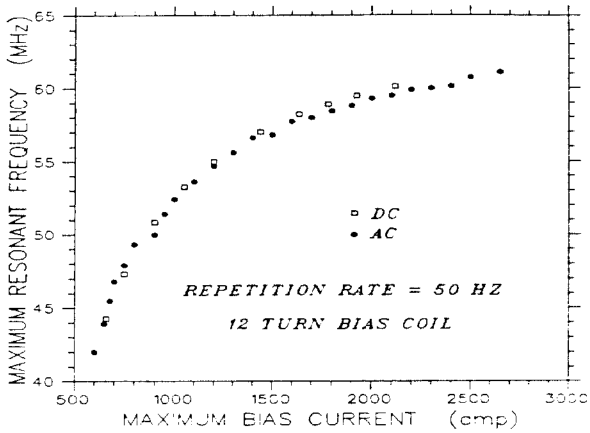

Figure 3: Frequency tuning range of the ac biased ferrite tuner.

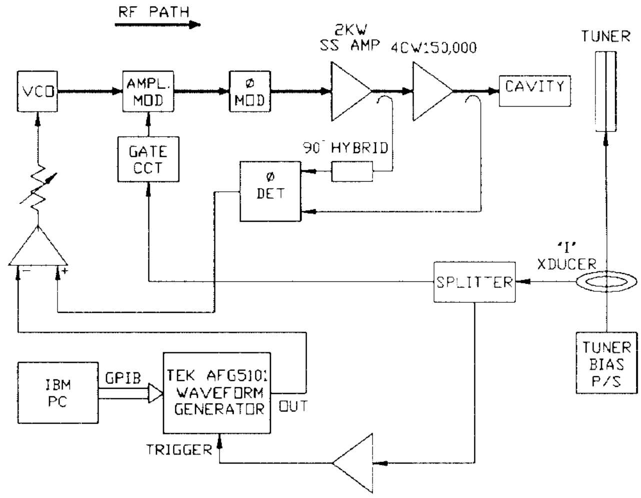

Figure 4: Block diagram of the rf controls.

assemble the cavity tuner with no ferrite rings giving a resonant frequency of 66 MHz. Limited by the use of a temporary anode power supply of 11 kV it was possible to easily overcome multipactoring and achieve 50 kV cw During this test the amplifier was generating 37 kW of rf power of which 7 kW was dissipated in the structure to develop the gap voltage and 30 kW was dissipated into a capacitively coupled 50 ohm load. With a 2% duty cycle 2 msec pulses at 65 kV were achieved at the gap, again limited by the temporary anode power supply. The above set-up also allowed the testing of the solid state driver, the input matching and the high voltage rf choke.

The cavity was then assembled with the ferrite rings installed. At a dc bias current of 800 A (49 MHz), rf conditioning through multipactoring proved to be very difficult. After 14 hours of continuous conditioning it was possible to punch through multipactoring and achieve 90 msec pulses at 25 kV with a 90% duty cycle. With further conditioning and operating in the self- excited mode it was possible to operate with 30 kV CW at the gap at 49 MHz. This represents approximately 0.2 W/cc power density in the ferrite. With a 1% duty cycle 1 msec pulses at 100 kV were achieved. A multipactoring discharge was observed in the vicinity of the narrow throat section in the outer conductor where the rf membrane makes a fingerstock connection to the outer conductor. The area of discharge was easily identified on the centre conductor and was painted with aquadag to prevent multipactoring discharge in that area. This made rf conditioning through multipactoring much easier. Within one half hour it is now possible to achieve stable rf voltage on the gap either in cw or pulsed mode operation. At a fixed tuner bias of 1000 A (52 MHz) the cavity has been run for several one hour intervals at 45 kV cw and at 67 kV 50% duty cycle with no adverse effects. In pulsed conditions above 67 kV we still observe a discharge in the same tuner area but not as strong as initially observed. The discharge in the tuner area does not collapse the voltage at the gap but appears only as a very small perturbation on the top of the pulsed waveform. Under any of the conditions above we have not observed any discharge in air to indicate any problem with imperfect discharge at the surface of the ferrite rings.

III. High Power AC Bias Operation

High power ac bias operation requires a well synchronized rf control system to insure that the rf is switched on and off at the proper time and that the ferrite bias program is synchronized to the frequency program. For our development work, since the bias power supply program is fixed, the frequency program is synchronized to the ferrite bias program. A block diagram of the rf control system is shown in Fig. 4. The rf source is a vco driven by a programmable function generator which is programmed to follow the fixed ferrite bias program. The output of the phase detector which compares the input to output phase of the amplifier is fed to a summing junction along with the output of the programmable generator to the vco to correct the predicted program. An amplitude modulator is triggered at the beginning and end of the operating period to turn the rf on and off. Although there were many iterations under various conditions the last results are in vacuum and are shown in Fig. 5. The top trace is the voltage at the accelerating gap (65 kV) at a repetition rate of 50 Hz. The variation in voltage amplitude during the cycle is caused by the inadequate bandwith response of the low level rf components and the absence of a voltage regulating program which has yet to be incorporated. The 7 msec "on" time instead of the required 10 msecs is a function of the fixed program supplied by the power supply manufacturer and will eventually be replaced by a programmable function generator to provide the proper waveform. The bottom trace is the signal from the output of the bias power supply and the minimum and maximum bias current are

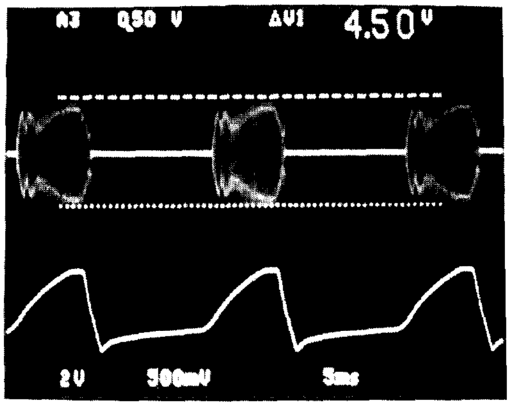

Figure 5: High power operation of the ac perpendicular biased tuner cavity. Top trace is the voltage at the accelerating gap (65 kV), and the bottom trace is the output signal from the ferrite bias power supply.

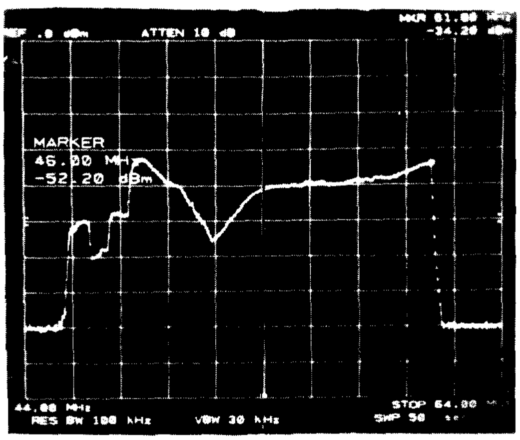

Figure 6: Spectrum analyzer measurement showing frequency swing from 46.0 MHz to 61.0 MHz.

720 A and 2520 A, respectively. Figure 6 is a measurement taken with the spectrum analyzer showing the corresponding frequency swing from 46.0 MHz to 61.0 MHz for the cycle shown in Fig. 5.

IV. Conclusions

A very important milestone in the rf development program has been reached. To the best of our knowledge this is the first time that anyone has operated a fast ac perpendicular biased yttrium garnet ferrite tuner over such a large frequency swing at high rf power levels. Hopefully in the future, ac perpendicular biased tuners will become as popular as the now well established parallel biased NiZn ferrite tuners.

V. Acknowledgements

The authors wish to acknowledge the following people for their dedicated time and effort in reaching this goal: Glen Blaker, Norm Carlson, Ken Fong, Peter Harmer, Slawomir Kwiatkowski, Joseph Lu, Amiya Mitra and Vojta Pacak. We would also wish to acknowledge the collaboration with LANL where the initial development of perpendicular biased ferrite tuners began.

VI. References

[1] R. L. Poirier *et al.*, *A Perpendicular AC Biased Ferrite Tuned Cavity for the TRIUMF KAON Factory Booster Synchrotron*, European Particle Accelerator Conference, Nice, p. 988 (1990).