Perpendicular Biased Ferrite Tuned RF Cavity for the TRIUMF KAON Factory Booster Ring

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Abstract

The rf cavity for the booster ring requires a frequency swing of 46 MHz to 62 MHz at a repetition rate of 50 Hz. The possibility of using the LANL booster cavity design with a yttrium garnet ferrite tuner biased perpendicular to the rf field, in the longitudinal direction, is being investigated. In order to minimize the stray magnetic biasing field on the beam axis, an alternative scheme similar to the design being proposed for the LANL main ring cavity in which the ferrite is perpendicular biased in the radial direction, is being considered. The behavior of the rf cavity and the magnetizing circuit for both designs are discussed.

Introduction

The LANL Booster cavity design [1] is shown in figure 1. It is a single gap cavity with a yttrium garnet ferrite tuner biased perpendicular to the rf magnetic field in the longitudinal direction. Unless adequately shielded, the bias coil will produce a stray magnetic field on the beam axis. An alternative scheme which biases the ferrite in the radial direction [2] is shown in figure 2. This is accomplished by placing the biasing coils between the ferrite rings and alternating the polarity of the coils on either side of the ferrite rings so that one ferrite ring forms part of the return magnetic path for the other. This not only biases the ferrite rings more efficiently but also greatly reduces the stray magnetic fields on the beam axis.

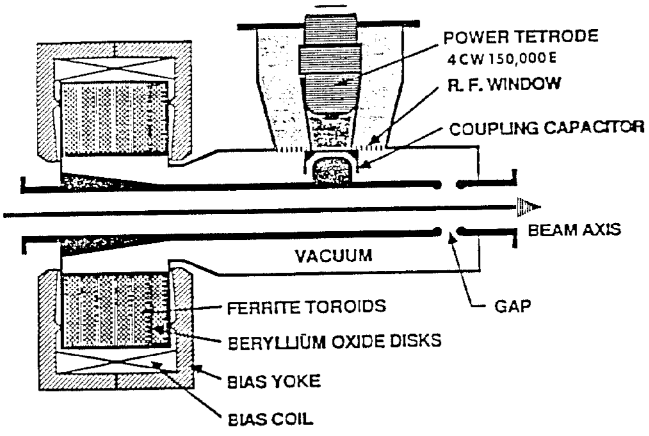

Figure 1: A Cross Section View Of the LANL Ferrite Tuned Cavity.

RF Cavity Analysis

The rf analysis of the LANL booster cavity design has been described in other papers [1,3]. The tuning analysis [4] of a 6 ring radial biased rf tuner,using the same size rings as the LANL booster cavity design, is shown in figure 3. One of the problems encountered with radial biasing is the considerable width of the space between the ferrite rings for the magnetizing coils which makes the input reactance of the tuner less sensitive to changes in the ferrite permeability. As a consequence a larger permeability range and a lower minimum permeability are required. To obtain a low permeability of 1.2 as indicated in figure 3, a

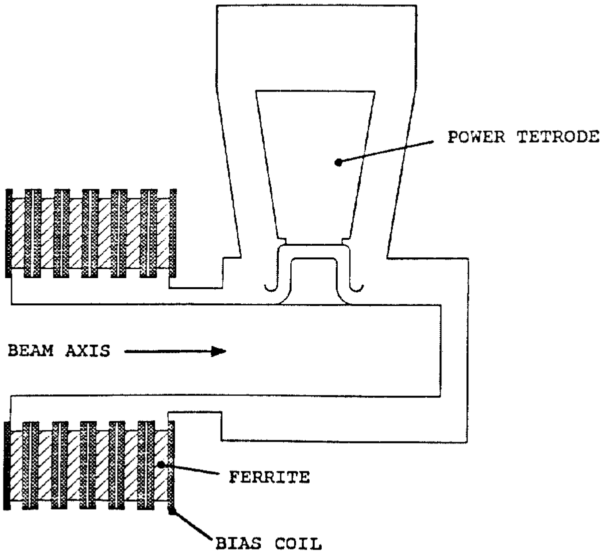

Figure 2: Tuner Design with Ferrite Perpendicular Biased in the Radial Direction.

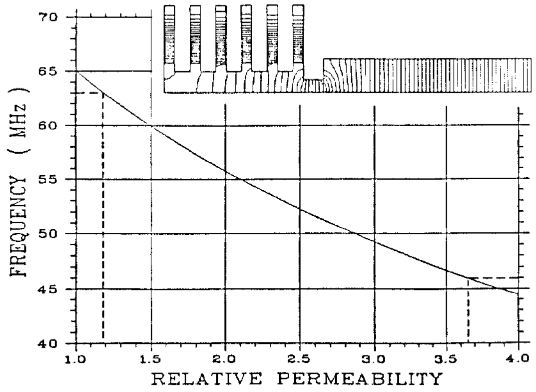

Figure 3: Tuning Characteristics of a 6 Ring Radial Bias Ferrite Tuner.

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large magnetizing current would be required. The power loss and cooling requirements associated with the magnetizing circuit makes this design unrealistic. The tuning analysis of a second design using only 4 ferrite rings but increasing the outer radius of the rings from 30 cm to 35 cm while maintaining approximately the same ferrite volume is shown in figure 4. This gives a reasonable value of 1.5 for the minimum permeability and more realistic values for the magnetizing power losses and cooling requirements.

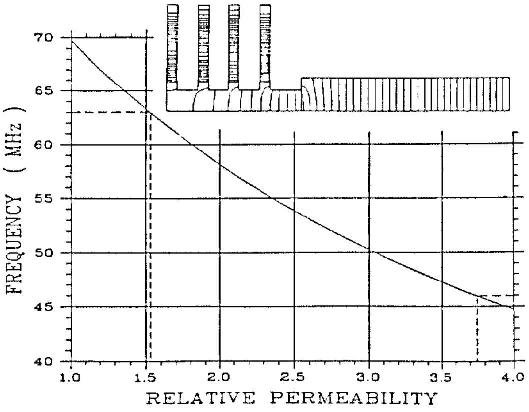

Figure 4: Tuning Characteristics of a 4 Ring Radial Bias Ferrite Tuner.

In the longitudinal biased case, cooling of the ferrites is accomplished by sandwiching beryllium oxide rings between the ferrites with a water bladder at the outer circumference of the rings. Beryllium oxide has very good thermal conductivity to conduct the heat to the cooling bladder but assuring a reliable thermal contact between the beryllium oxide rings and the cooling bladder is not an easy task. Beryllium oxide also has the disadvantage of being poisonous and special safety precautions must be taken when working with this material. In the radial biased case, the water cooled bias coils also cool the ferrite rings and eliminate the need for beryllium oxide.

Magnetizing Circuit Analysis.

The magnetic biasing was studied using the magnetostatic code POISSON. It was noticed that in the LANL design some of the biasing field would appear on the axis of the beam tube, and that this effect might be significant. The magnetic field on the beam axis for the LANL booster cavity design with the biasing field applied longitudinally, i.e in the direction of the beam is shown in figure 5. As can be seen the field reaches a peak value of approximately 1300 Gauss. The field along the beam axis for the alternative geometry is shown in figure 6. In this case the biasing field is applied radially outwards from the beam axis. In each case the B_z component of the field (i.e that component along the beam direction) is plotted along the axis of the beam pipe at the location of the tuner. For comparison between the two geometries, the ampere turns have been set such that the relative permeability of the ferrite is 1.2 in each case, which corresponds to maximum resonant frequency of the cavity. The results therefore represent the highest fields that will appear on the beam axis.

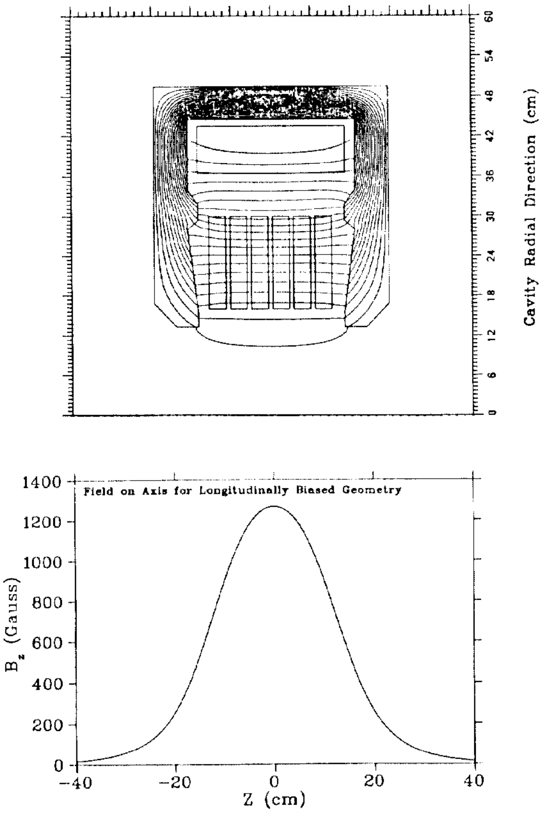

Figure 5: The Magnetic Field Along the Beam Axis with the Biasing Field Applied Longitudinally in the Ferrite Rings.

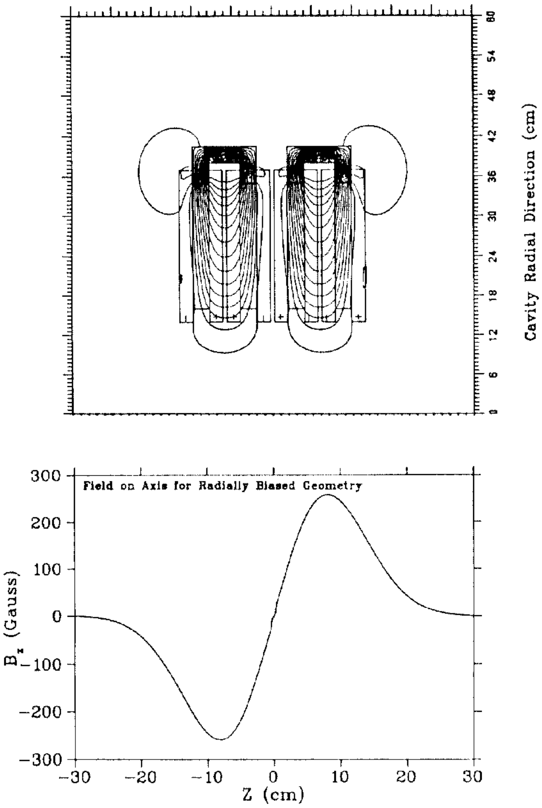

Figure 6: The Magnetic Field Along the Beam Axis with the Biasing Field Applied Radially in the Ferrite Rings.

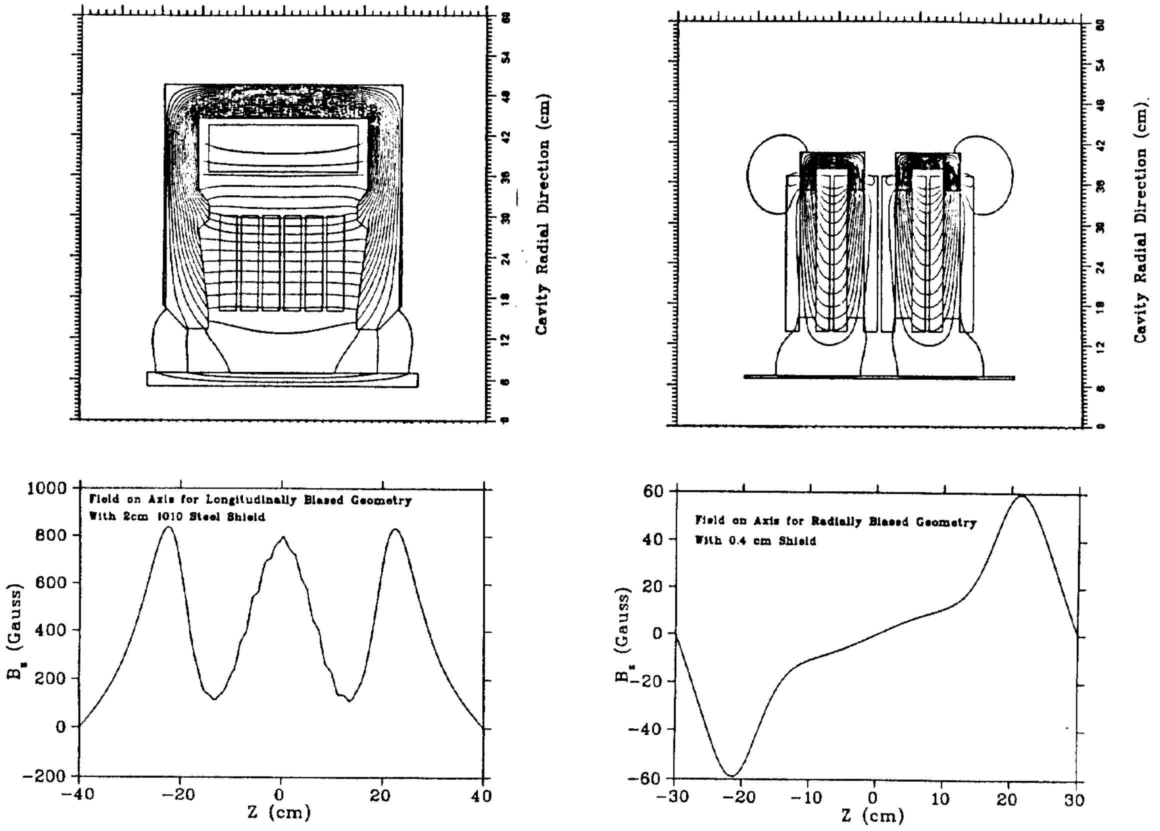

Figure 7: The Effect on the Magnetic Field Along the Beam Axis by Adding a Steel Shielding Tube

As can be seen the field on axis for the radially biased case is more than 5 times less than that for the longitudinal case. It is desirable to reduce the field on axis as much as possible. The results of the addition of a steel shielding tube are shown for each case in figure 7.

A further advantage of the radial biasing scheme is that to first order the integral $\int B\,dz$ of the field on axis is zero. The effect of the B_r component will be small.

Conclusion

The ferrite rings and bias power supply for perpendicularly biasing in the longitudinal direction have already been purchased and therefore the RF hardware development program will continue in that direction. The possibility of radial biasing for the booster rf cavity will continue to be investigated.

References

[1] W. R. Smythe et al., "RF Cavities with Transversely Biased Ferrite Tuning", IEEE Particle Accelerator Conference, Washington D. C. p 2951 (1985).

[2] G.R.Swain, "Design of a Main Ring Cavity", Proc. Int. Workshop on Hadron Facility Technology, Los Alamos, New Mexico Feb 22-27, 1988.

[3] T. Enegren and R. L. Poirier, "Analysis of Booster Amplifier Designs", Proc.Int. Workshop on Hadron Facility Technology, Los Alamos, New Mexico Feb 22-27, 1988.

[4] T. A. Enegren, "RF Booster Cavity Ferrite Rings Perpendicular Biased in the Radial Direction", TRIUMF internal report.