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Modeling of the Cluster Klystron Solenoid

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Abstract

The code POISSON is used to determine the longitudinal extent of the good field region of the cluster klystron solenoid. The field shape as a function of end-coil current enhancements is determined.

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INTRODUCTION

A central issue in the operation of the cluster klystron is the simultaneous transport of several electron beams from separate magnetron cathodes to separate klystron structures where the power is extracted. This transport is effected through a common solenoidal magnetic field which serves the dual functions of containing the high-current beams and guiding them to the klystron cavity entrances. By necessity, this means that all beams (save perhaps one) must travel off the solenoid's longitudinal axis. An important issue becomes the quality of the off-axis magnetic field.

The first criteria (criteria 1) for the definition of the good field region of the solenoid is that the longitudinal field b_z be constant to within $\pm 0.7\%$. This criteria is imposed[1] in order to insure that the off-axis electron beams are not diverted from their path as they approach the entrance of the klystron cavities.

For a second criteria (criteria 2), we insist that the the radial component of the magnetic field at the cathode source satisfies the constraint

$$b_r/b_z < 2 \times 10^{-3}.$$

This criteria is imposed in order to insure that the electrons leave the cathode within an acceptable envelope.

For phase 1 of the cluster klystron project, the off-axis distance is 1.5 cm. We will assume a longitudinal field of 4 kGauss and therefore require that the radial magnetic field at the cathode be < 8 Gauss. As seen in Fig. 1, the good field length requirement (as defined by the above criteria) for phase 1 of the experiment must extend over a distance of at least 2 x 16 cm.

COMPARISON OF THE MODEL POISSON WITH MEASUREMENTS

As an initial approach, we model the magnetic fields produced by the solenoid with the computer code POISSON. The modeling of the as-built solenoid with POISSON is shown

in Fig. 2. Measurements of the axial field with the magnet energized at 300 A is shown in Fig. 3. The POISSON calculated field has been normalized to the $z=14$ cm data point. In Fig. 4, we display measurements along with the POISSON predicted radial fields off-axis at $r=2$ cm. The three sets of measurements represent first a direct measurement of the radial field and then the radial components inferred from two independent measurements of the longitudinal field using the relationship

$$b_r = \frac{1}{2}r \times db_z.$$

The results show good correspondence between the model and measurements from the center of the magnet at $z=0$ cm to $z=28$ cm which is near the physical ($z=31.2$ cm) end of the solenoid. Beyond $z=28$ cm, discrepancies appear between measurements and model but this is well outside our region of interest where we need good field quality.

NUMERICAL ANALYSIS AND RESULTS

With all coils powered with the same current we find, based on criteria 2, that the good field length is 2×10.55 cm (see Fig. 5). This length can be extended by putting additional current through the end coils of the magnet. There is, however, a limit to this procedure which is encountered when the radial field deviates more than -8 Gauss before going positive. This occurs for the case when the end coil current factor is 1.54. Notice that for a current enhancement factor of 1.35 the radial magnetic field remains less than 8 Gauss (for a 4 kGauss main field) out to 18 cm. In Fig. 6, we show the relationship between the good field half-length and the current factor.

The axial magnetic field is shown in Fig. 7 for three separate end-current enhancement factors. For the 1.35 case, the axial field falls by 0.5% at 18 cm, well within the tolerance dictated by criteria 1.

I. CONCLUSION

We find that the total good field region of the cluster klystron solenoid can be extended from 21.1 cm to beyond 36 cm without the need for attaching additional coils to the solenoid. A total of 36 cm good field is achieved when the end-current enhancement factor is set at 1.35.

FIGURES

FIG. 1. Schematic showing the electron beam path for phase one (from cathode source to beam detector— 2 x 16 cm in this version)

FIG. 2. The magnetic field lines for the as-built cluster klystron solenoid

FIG. 3. The axial magnetic field for the as-built cluster klystron solenoid compared with measurement. The curve has been normalized to the $z=14$ cm data point.

FIG. 4. The radial magnetic field for the as-built cluster klystron solenoid compared with measurement.

FIG. 5. The calculated radial magnetic field with the end coil current boosted by factors of 1.00, 1.35 and 1.50.

FIG. 6. The maximum extent of good field based on criteria 2 described in the text.

FIG. 7. The calculated axial magnetic field with the end coil current boosted by factors of 1.00, 1.35 and 1.50.

REFERENCES

- [1] Amended Proposal for R&D on a Cluster Klystron, BNL CAP Preprint, January 22, 1993

Figure 1

Figure 2

Figure 3

Cluster Klystron Solenoid

Figure 4

Figure 5

Figure 6

Figure 7

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