A High Precision Magnetic Field Shimming algorithm for Inclined 45° Continuous Cutting on Spiral Pole of SC Cyclotron

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Introduction

Magnetic field shimming is a critical procedure to achieve isochronous acceleration for cyclotron. The superconducting cyclotron has the characteristics of high field saturation and compact structure. The commonly used shimming bar processing method, such as the IBA C235, is not suitable for the field shimming of the superconducting cyclotron. The trimming coil and the trimming rod are commonly used to adjust the field for multiple different types of particle acceleration, such as the Kolkata K500, which is operated too complicated for only proton acceleration.

Requirements of Field Shimming

From the perspective of extractopm design, the first harmonic at extraction position should be less than 2Gs, and other positions are less than 4Gs.

Shimming Algorithm

Equation for average field shimming:

$$\Delta B = B_0 + C_1 \cos \theta + S_1 \sin \theta$$

Equation for first harmonic shimming:

$$4F_iX = B_0$$

$$2(F_1X_1 - F_2X_2) = C_1$$

$$2(F_1X_1 + F_2X_2) = S_1$$

Least square equation with Ridge regression:

$$M = 4F_i \cdot X$$

$$M_1 = B_0$$

$$M_1 = B_0$$

$$MX = B_0$$

$$M_1^T = B_1$$

Conclusion

A general analytical model is established to shim the average and first harmonic field simultaneously for cyclotron. Based on the least square method and magnetic saturation approximation, a processing method of inclined 45° continuous cutting on the two pole sides is at the first time proposed to shim the field in compact superconducting cyclotron. The results of the shimming algorithm applied to the CYCIAE-230 show that, after four times of shimming, the isochronous error converges quickly, greatly reducing the cyclotron construction time. In the next step, the effects of the shimming algorithm on first harmonic compensation will be investigated by means of coil shift and cutting the pole edges.