MOGA Optimization of Superconducting LGB Based on NbTi Wire

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Abstract Multi-bend achromat (MBA) lattices with unit cells are used in Diffraction-limited storage ring (DLSR) designs. The longitudinal gradient bend (LGB) can reduce the horizontal emittance below the theoretical minimum of a given magnet structure, and generally the horizontal emittance reduces with the peak field grows. Therefor superconducting longitudinal gradient bends (SLGB) can produce higher peak field values and quasi-hyperbolic field profiles to minimize emittance at locations of radiation and generate better hard X-rays. Nb-Ti conductor, rather than Nb3Sn conductor, is selected to keep the design and the manufacturing of the SLGB magnet as simple as possible. In this paper, how the field profile of racetrack coils and solenoid coils change by their geometrical parameters are studied, and Multi-objective genetic algorithm (MOGA) is used to optimize the SLGB considering lattice design demand and NbTi critical current.

Introduction

In this paper, we study how do the coil's geometry parameters influence the distribution of B-field, including the B-field profile along the beam path, the ratio of the integration of B-filed along the available longitudinal length to the center B-field, the ratio of maximum B-field in the coils to the center B-field, the homogeneity of the integration of B-field. Basing on the above studies, we can reduce the number of coils' geometry parameters to be optimized, and thus improve the optimization speed.

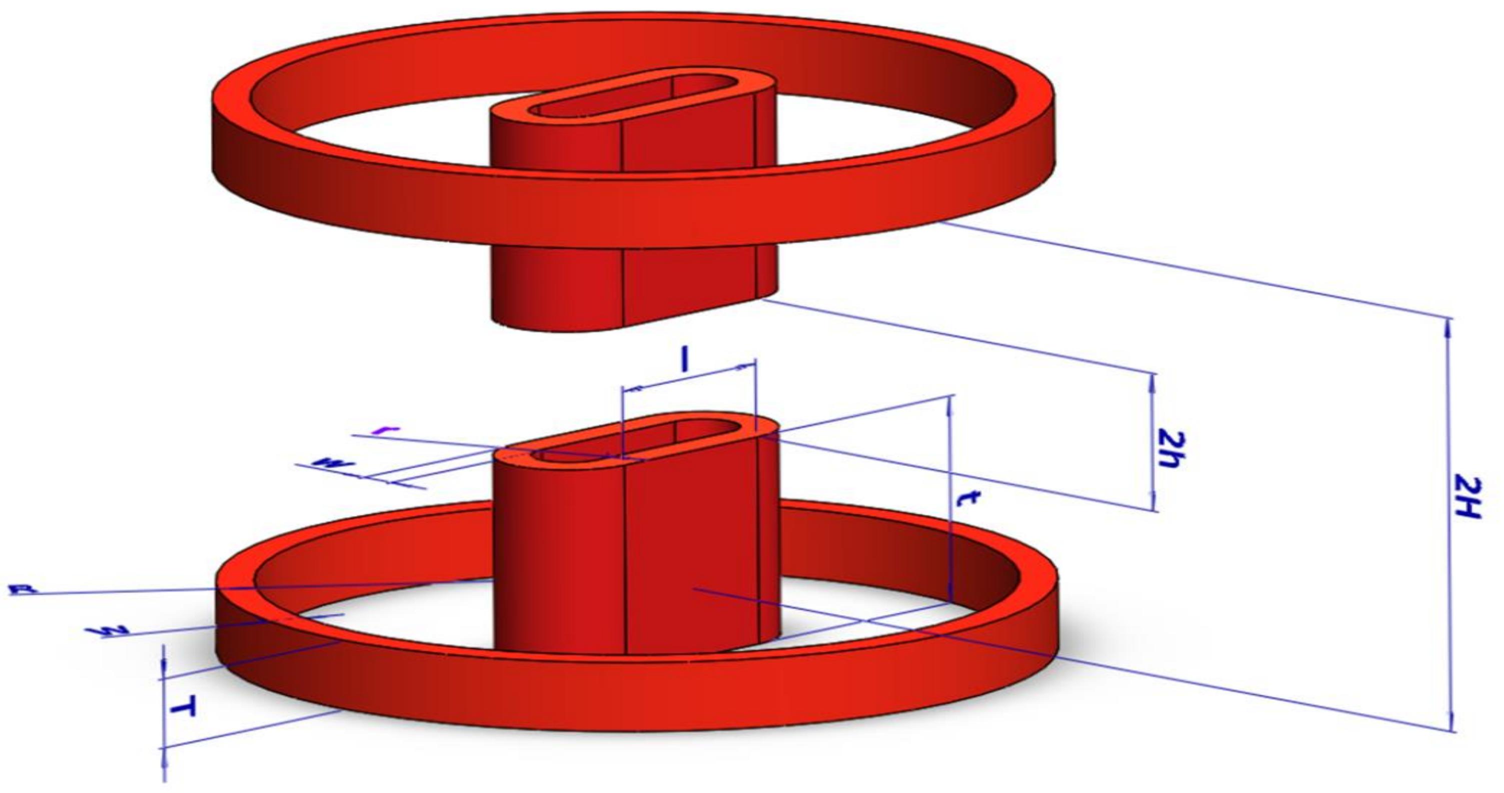

Fig. 1. Geometry parameters of race-track coils and solenoid coils, **(r w h t l)** for race-track coils & **(R W H T)** for solenoid coils

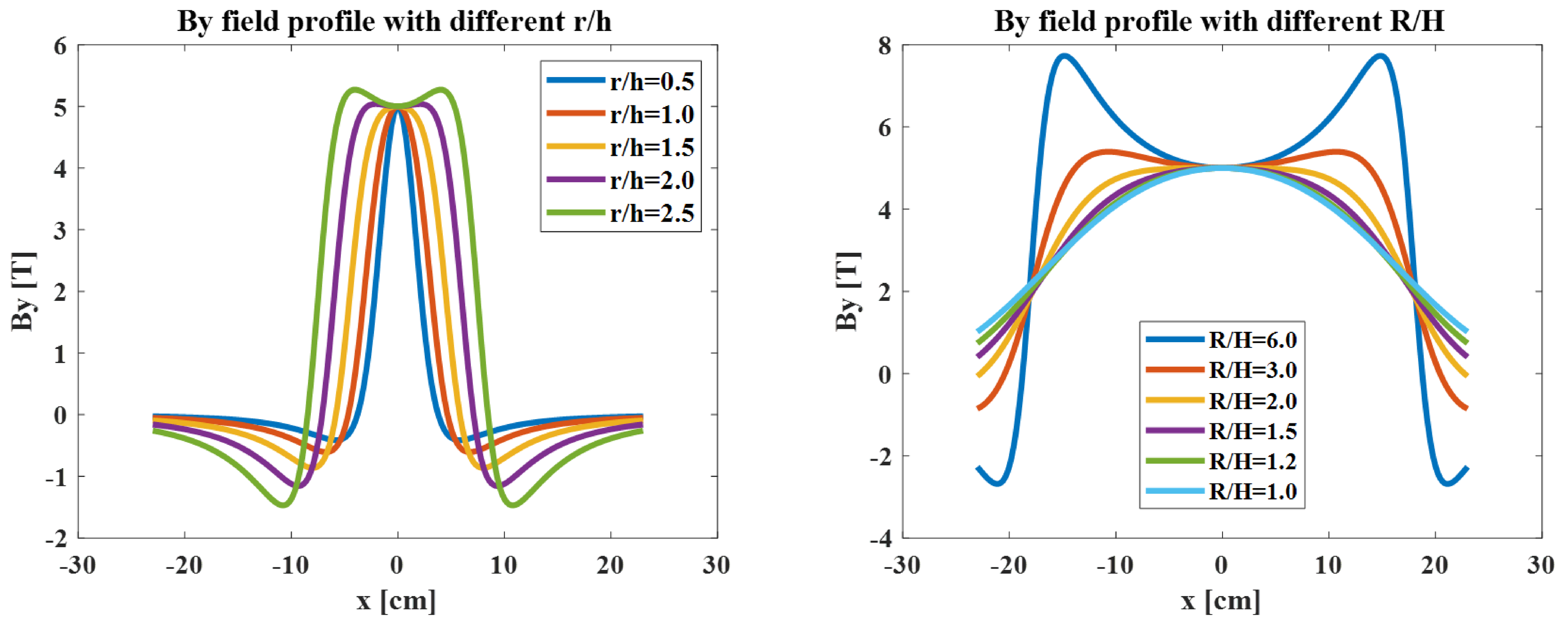

Fig. 2. (left) By-field generated by race-track coils along the beam path varies with different r/h (h=2.5 cm, l=12 cm). (right) By-field generated by solenoid coils along the beam path with different R/H (R=18 cm).

B-field influenced by coil parameters

The coils can be divided into many small similar coils which can be treated as line current. By this way we can simplify the triple integral to single integral, then the influence of coil parameters on B-field can be shown (Fig. 2-5).Fig. 2 shows the By-field profile changes with r/h (R/H), and small r/h (R/H) corresponds to narrow By-field. Fig. 3 shows r & h (R & H) affect the B-field integral non-independently. Fig. 4 shows the cross section of coils affect the maximum B-filed in coils. Fig. 5 shows how the field deviation affected by h & l.

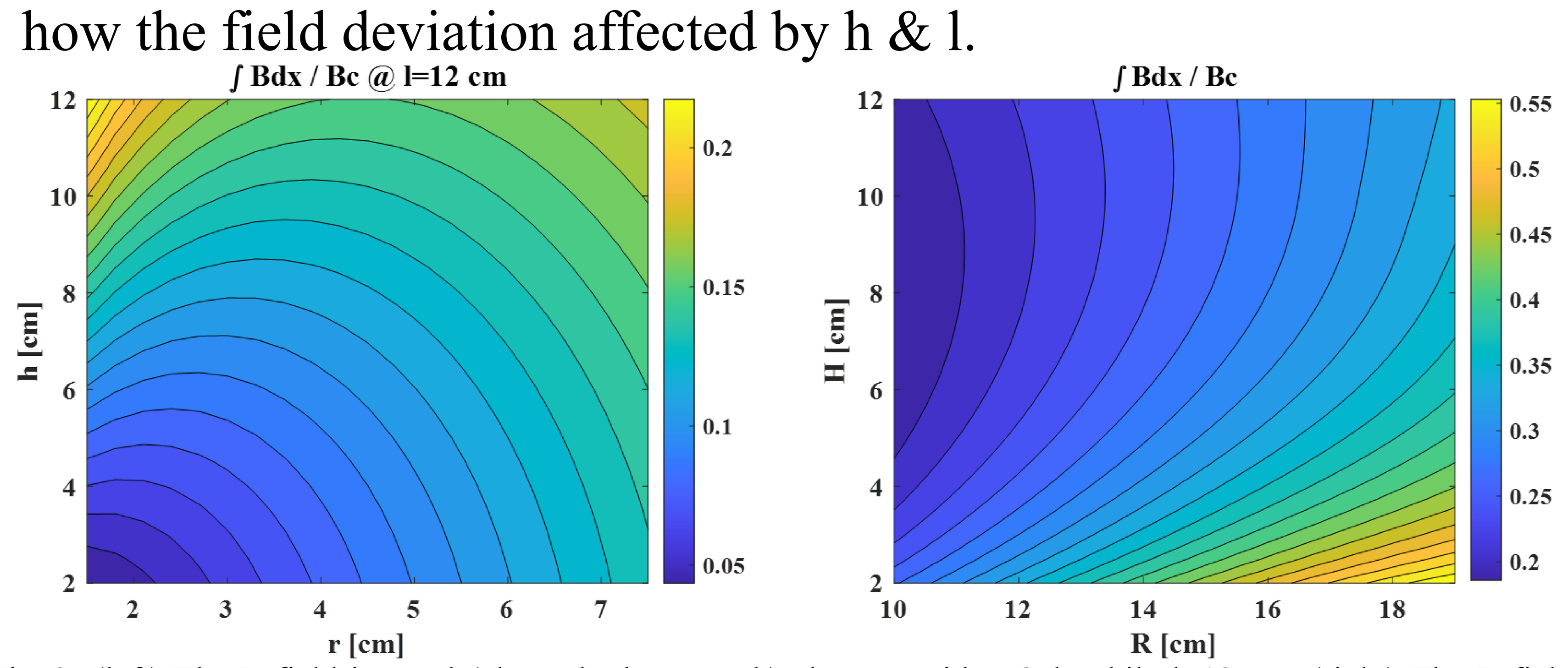

Fig. 3. (left) The B-field integral (along the beam path) changes with r & h while l=12 cm. (right) The B-field integral (along the beam path) changes with R & H. The maximum longitudinal magnet length is 46 cm.

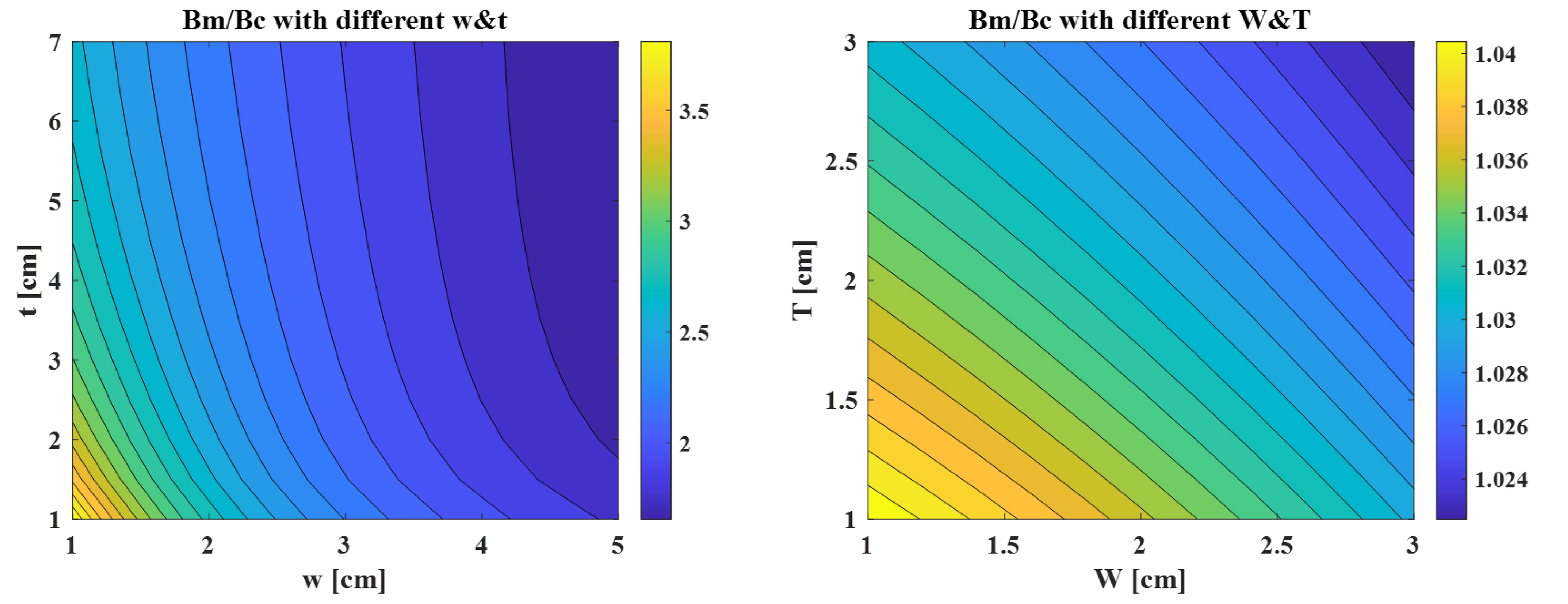

Fig. 4. (left) The maximum B-field in the racetrack-type coil changes with w & t (r=1.5 cm, l=12 cm). (right) The B-field generated by solenoid coil at the maximum B-field point in racetrack-type coil changes with W & T. (r w h t l)=(1.5 3 2.5 5 12)cm is chosen for the solenoid coil and R=18 cm, H=h+t-T.

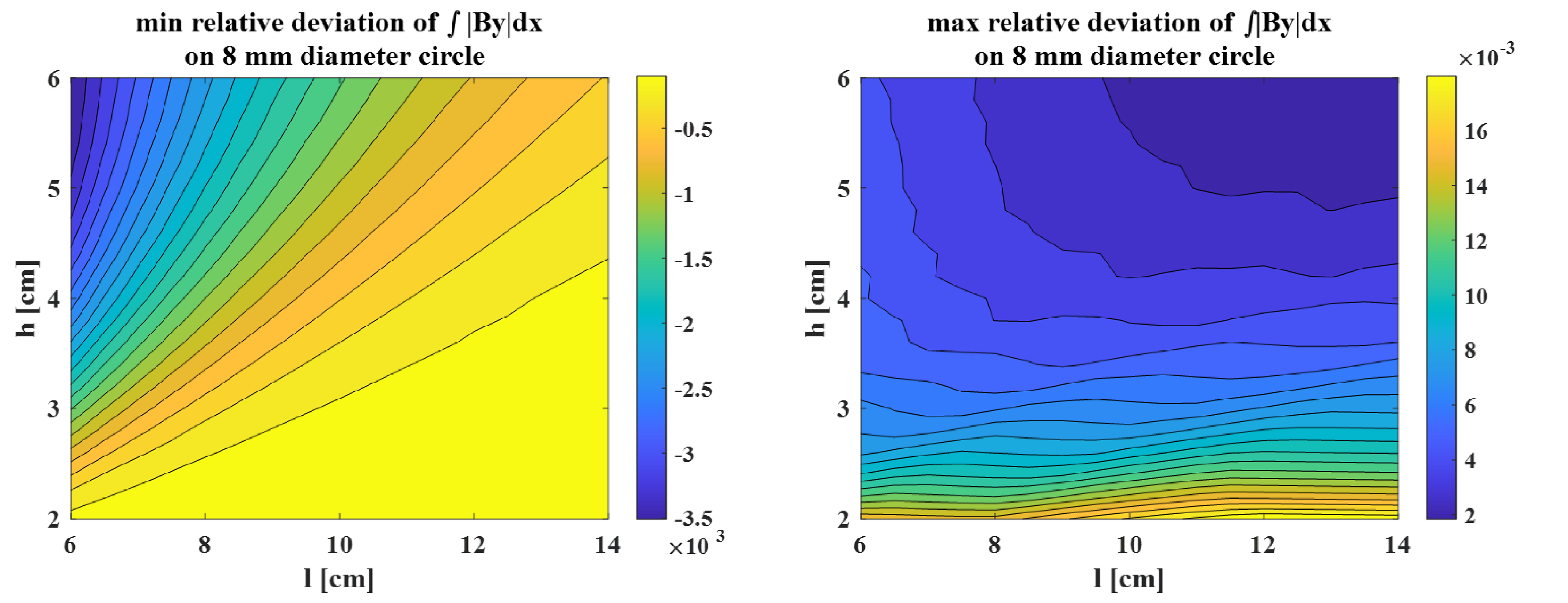

Fig. 5. (left) The relative deviation between the |By|-field integral along the path from (-46,0,0.4) to (46,0,0.4) and along the standard beam path . (right) The relative deviation between the |By|-field integral along the path from (-46,0.4,0) to (46,0.4,0). The coordinate unit here is cm.

MOGA for coil optimization

The step function field profile from optimization of beam emittance is shown in Fig. 6 (left), the critical current density of NbTi strands is shown in Fig. 6 (right). The load line can be get by $\boldsymbol{load\ line} = \frac{137.95B_m + J_{in}}{1325.18}$ here. In view of the results here didn't take the yoke and core into account, the load line can be reduced by about 20%. We can approximate non-linear calculation to linear calculations. Fig. 7 show the optimization result of two kind of coils.

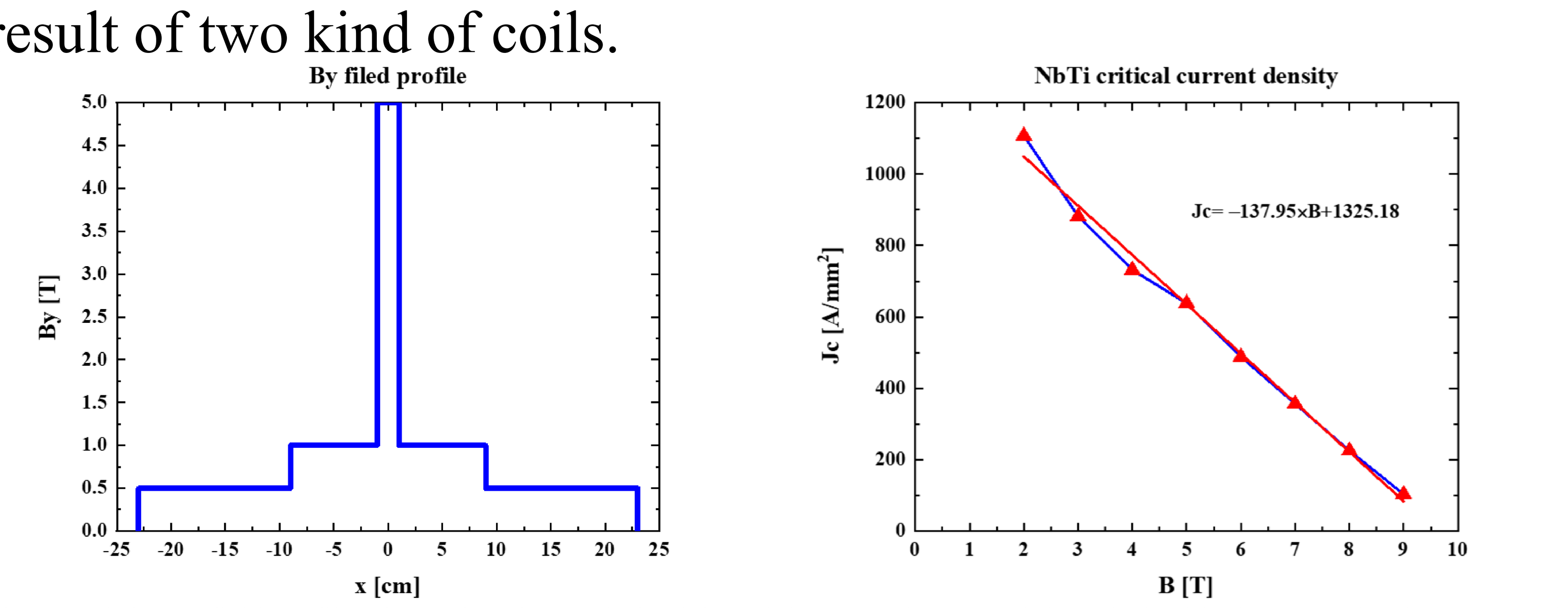

Fig. 6. (left) By-field profile of step function optimized for minimum emittance. (right) NbTi critical current density measured (red triangles) and fitted (red line).

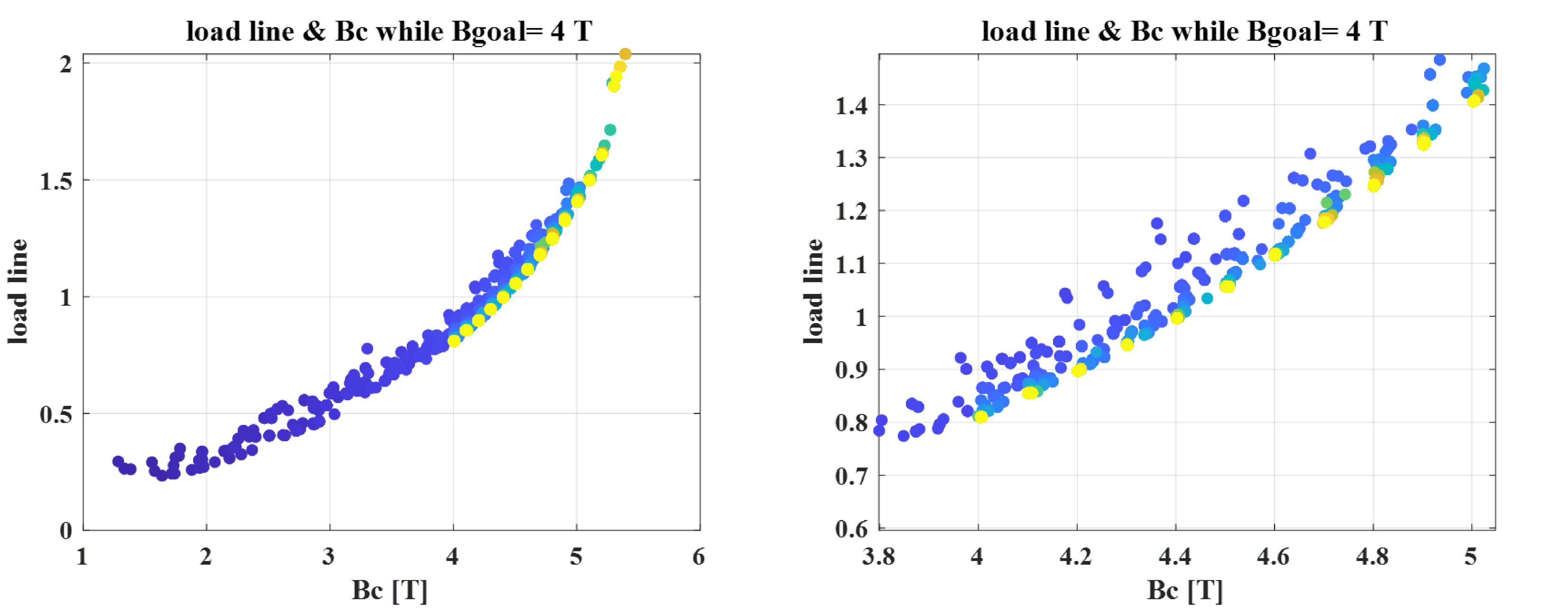

Fig. 6. (left) Original MOGA optimization result. (right) Load line of the Bc (field at center point) in the range of (3.8,5.0) T. The color refers to the best results of different generation. (h=2.5 cm, l=12 cm)

Conclusion

How the geometry parameters influence B-field is studied. With a giving B field profile, MOGA is used to optimize the coils based on NbTi critical current.