Preliminary Test of Resistive Shim Insert in the Keck Magnet

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Introduction

Resonance experiments typically require a homogeneous field. A ferromagnetic correction insert or "shim" has been developed to provide this homogeneous field in the Keck magnet [1]. However, the passive shim corrects the field only with the magnet at its full 25 T field. In order to achieve the same level of homogeneity at lower fields as well, a six channel resistive shim tube has been designed and constructed [2]. The shim tube employs single turn coils of novel design wound on the outside diameter of the bore tube where it exposed to the magnet cooling water. It was recently installed in the Keck magnet for a preliminary test, and here we report the results.

Experimental

Prior to installation of the shim tube in the Keck, each shim coil was individually mapped in a shimmed 9.4 T wide bore superconducting magnet (which provides a uniform and constant background field) to test for shim strength and purity. The purity of each term was 95% or better purity. The measured shim strengths were 5-15% lower than the predicted values, perhaps due to a combination of conductor thickness and inaccuracy of the mapping radius.

Upon installation in the Keck magnet, tests were performed to measure the coil resistance over a range of currents at zero and full field. All coils on the shim tube were connected in series, and the current was varied from 30 A to its design maximum of 150 A at both zero field and full field. The voltage across each coil was noted, and later used to calculate the temperature-dependent resistance. A resistance increase faster than linear, or one that is not reversible with current, would be taken to indicate a problem in the coil. All coils tolerated the 150 A and full field condition, except for z2. The z2 resistance increased faster than linear above 140 A, and was to some extent irreversible. This could be attributed to the structural changes happening in the coil or in the insulation layer around the z2 coil.

In conjunction with the shim test, the unshimmed magnetic field of the Keck magnet was mapped at various field strengths as shown in Figure 1. The field inhomogenity in ppm remained approximately constant. The maps indicate that to achieve 10 ppm inhomogeneity over 1 cm DSV at full field will require a minimum of 160 A in the x-zx, y-zy coils, slightly more than the design current. Correction of z2 will require about 60 A, much less than the design current. Therefore, although z2 experienced some resistance increase at high current, it appears that it will have the capability to correct the measured inhomogneity.

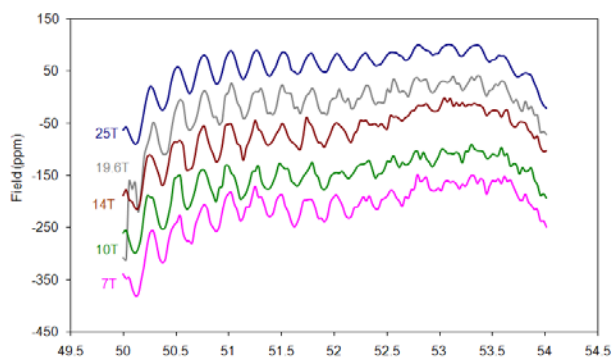

Figure 1. Field profile of the Keck magnet at various field strengths

Conclusion

The Keck magnet has been mapped over a range of fields from 7 to 25 T, and the field deviations in ppm were found to be approximately constant. This indicates that it will be a simple matter to varying the resistive shim currents proportionally to homogenize the field. Except for the z2 coil, all coils tolerated operation at full field and at their design current without excessive change in resistance. The z2 coil may not be an issue for its usage in the Keck since it is only required to carry 60 A of current. Complete optimization of the Keck homogeneity can be achieved with currents slightly higher than the design value.

References

[1] Gan, Z. *et al.*, J. Magn. Reson. **191** 135-140 (2008).
[2] Painter, T.A., *et al.*, IEEE Trans. Appl. Supercond. **18** (2) 579-582 (2008) .