Design, fabrication and test of a 2T superconducting dipole prototype by using tilted solenoids

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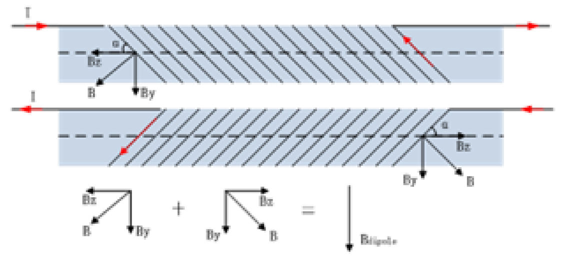
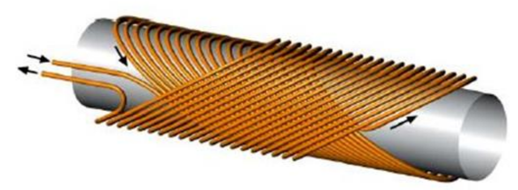
Introduction

A novel configuration for a dipole magnet base on tilted solenoids is characterized by extremely uniform fields, large effective field region and simple mechanical construction. This type of magnet is very suitable in application of the accelerator magnets, gantry and NMR magnets. In view of this unique coil configuration having good prospects in various applications we have taken its R&D aiming at exploring the methods of design and construction for this type of coil. This work is also a pre-research for the superconducting accelerator magnets of HIAF (High Intensity heavy ion Accelerator Facility) project . We start by developing a 2.0 T dipole prototype with a bore diameter of 50 mm.





Conclusion

- A 2.0 T superconducting magnet prototype based on the tilted solenoids has been constructed and tested.
- The construction process of this coil configuration is very simple and efficient which is benefited from the modularity.
- The test results of the magnet prototype agreed with the field design though it quenched at 70% of the design current.
- This work is extending to an elliptical magnet bore design for the requirement of the good field region with large size in the horizontal direction and small size in the vertical direction for the heavy ion accelerator.

Magnetic field design

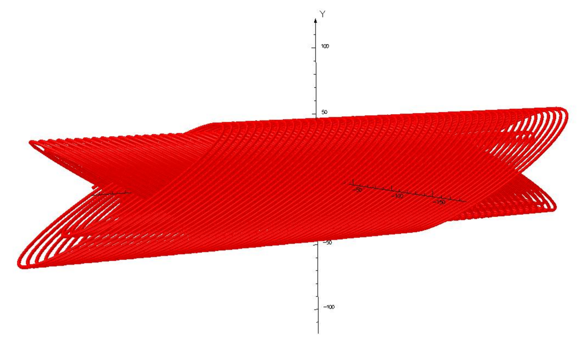
Magnet design

The coil model are created by a series of 20-node brick conductors in the software of OPERA-TODCA.

The magnet prototype with a central field of 2 T consists of four layer tilted solenoids which are wound by cable. The cable is twist by seven strand of 0.7mm diameter.

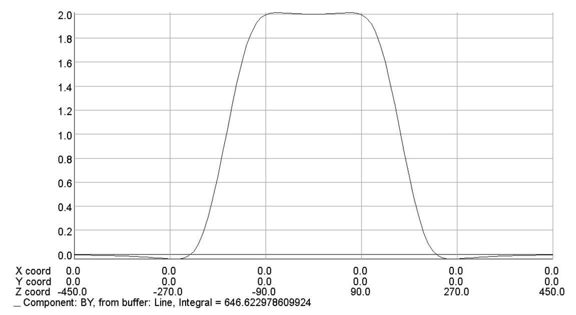
Each coil layer includes 50 turns and the tilted angle is 30 degree.

The superimposed length of the four layers is about 180 mm.

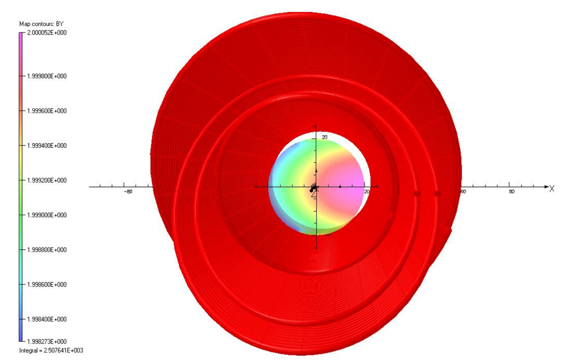


Parameters	Values
Coil aperture	50 mm
Inclination angle	30 deg
Winding twist pitch	6.6 mm
Turns per layer	50
Operating current	3000 A
Inductance	1.1 mH

Calculated field



The dipole field along the axial line is flat at the superimposed area however raises slightly at the transition position from the straight section to the end of the magnet. Then the field decreases rapidly to zero.



The transverse field homogeneity can be reach to $\pm 4.5 \times 10^{-4}$ on a disk with a 40 mm diameter (80% of the coil aperture) in the magnet bore which is at the longitudinal center plane.
Harmonic fields can be found on the contour map of the field.

Construction

Components

- **G10 tube as coil formers:**
  5.6mm thickness; having grooves with the tilted helical geometry
- **7-strands cable:**
  Strand with a 0.7mm diameter; cable insulated by fiberglass tape
- **Aluminum alloy tape:**
  1.2 x 0.8 mm^2 cross-section
- **CTD-101K epoxy resin**

Fabrication

- Firstly, four layer coils are wound by placing the cable into the grooves by manual winding;
- Then put the innermost tube on the end plate, which is used for positioning and fixing;
- After the last three tubes are fixed on the plate one by one, the other end plate is installed on the other end of the magnet;
- Insert a stainless steel pipe with the diameter of 46 mm into the innermost tube for reinforced support;
- Two layers of the aluminum alloy tape are wrapped around the magnet.
- Complete the vacuum impregnated with epoxy resin.

Cryogenic test

Mount

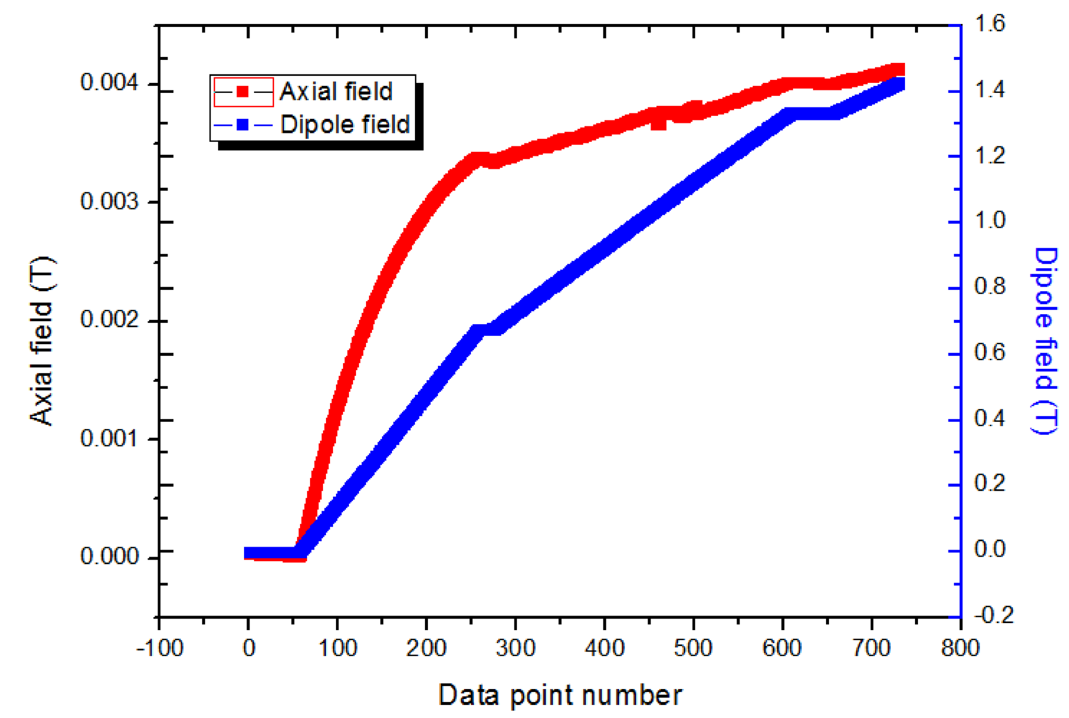
A pair of 4 kA current leads is mounted on the test facility to energize the magnet. The current leads are cooled by the cold helium gas.

Three Cernox cryogenic temperature sensors are applied to monitor the temperature of the magnet and the copper bars connecting the magnet and the current leads.

Two G10 plates are fixed respectively at the bottom and top of the magnet to prevent it rocking at the electromagnetic force.

A warm bore with 28mm diameter is inserted in the magnet aperture for measuring the field at the room temperature. A three dimensions hall probe is mounted on a Aluminum tube. Then the tube is put into the warm bore which can measure the dipole field distribution along the axial direction of the magnet.

Test and results



The magnet is excited from zero to 1 kA at the speed of 5A/s and to 2 kA at 3A/s. When the current is raised to 3 kA at 2A/s , the quench occurs at 2150 A corresponding the field of 1.42T.

The vector field at the magnet center is measured by using the Model 8030 three axis Gauss/Tesla METER at the exciting process . The dipole field increases linearly with the excited current. And the solenoid field component is 40 Gauss at the quench current, which is not completely cancelled.

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