Nb_3Sn UNDULATOR DEVELOPMENT

H.W. Weijers, A.V. Gavrilin, K.R. Cantrell, J. R. Miller (NHMFL)

Introduction

A 2005 study of a short-period Nb_3Sn undulator for the Advanced Photon Source at the Argonne National Laboratory pointed out the feasibility of a 15 mm-period system with 0.8 T on the beam using state-of-the-art superconductors. Conceptually, the windings consist of hundreds of small racetrack-shaped coils on two (mostly) ferromagnetic yokes. The beam tube is thermally insulated from the magnet windings to minimize undesirable magnet-beam interaction in case of magnet quenches and beam losses. The NHMFL is developing an undulator demonstration magnet with a reduced number of racetracks, to assess the cryogenic concept, achievable current density (J_c) and assembly procedures. Progress on the latter two issues is reported here. Regarding current density it is noted that the conductor envisioned for this project is developed primarily for high field applications ($B \geq 12$ T). Standard specifications include non-Cu current densities of over 2000 A/mm^2 at 12 T, 4.2 K with record values approaching 3000 A/mm^2. The maximum field value in the undulator is only about 4 to 5 T and the extrapolated current density at those relatively low field values is more than doubled, to the point that low-field instabilities originating from flux jumps *may* limit the actual performance below the extrapolation.

Possible assembly procedures for the yoke and windings range from fully modular on one hand, using a repetitive structure of many elementary parts with joints between racetracks, to a more traditional single-piece yoke with uninterrupted windings. Both approaches are under consideration.

Experimental and Analytical Results

A candidate Internal-Tin conductor was heat treated and characterized at 4K using SQUID and VSM, revealing a field dependence of magnetization J_c that is well described with standard flux pinning models. ITER-barrel measurements of transport I_c will complete the characterization and indicate whether the observed high RRR values lead to sufficient stability.

A modular assembly approach allows selective application of iron and non-magnetic materials in the yoke, unlike the single piece yoke approach. An ANSYS analysis pointed out that there are at least two practical material allocations that are more efficient than a fully iron yoke. Iron plates stacked axially between racetracks combined with stainless steel cores within a racetrack require 10% less current for the same field on the beam. It is equally efficient when only the part of such plate closest to the beam is of iron, and the design becomes more efficient if holmium is used, but these options are less practical.

Discussion

It remains to be seen if the stability of the candidate Internal-Tin conductor is sufficient in this relatively low-field application. Adjustment of the heat treatment schedule to maximize RRR, at the cost of a somewhat reduced J_c, is the available tool to enhance the stability. Alternately Powder-in-Tube conductor can be considered, which has shown sufficient current density (at 12 T) albeit somewhat lower than the best Internal-Tin conductors, and is generally more stable since the effective diameter of the superconducting elements is typically smaller. It may therefore achieve a larger fraction of its extrapolated potential at 4-5 T.

A modular approach allows for the selective application of iron and non-magnetic materials in the yoke, which allows for more efficient designs. However, the large number of individual racetracks must be connected with joints that are better than simple solder joints although they do not need to be persistent. A simplified NMR-style joint should be sufficient.

Conclusions

The development of a short period Nb_3Sn undulator demonstration magnet is underway. The focus has been on conductor characterization and assembly approaches.

References

Weijers, H.W., *et al.*, MT-19, Genoa, Italy (2005).
Weijers, H.W., *et al.*, internal report NHMFL-MST-04-OPM-066-001.