U.S. Particle Accelerator School
Education in Beam Physics and Accelerator Technology

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Part 4 Linear Accelerator Magnets

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January 16, 2020

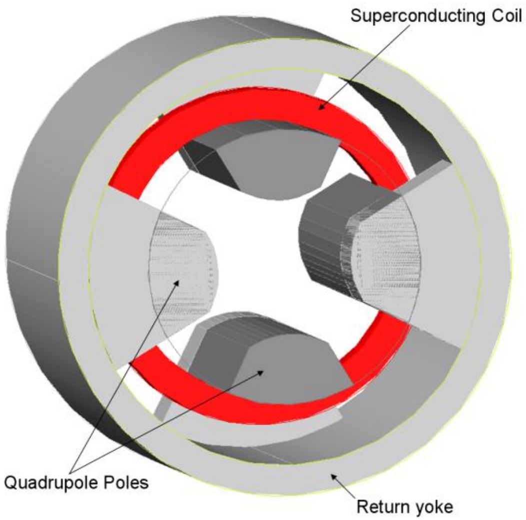
Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

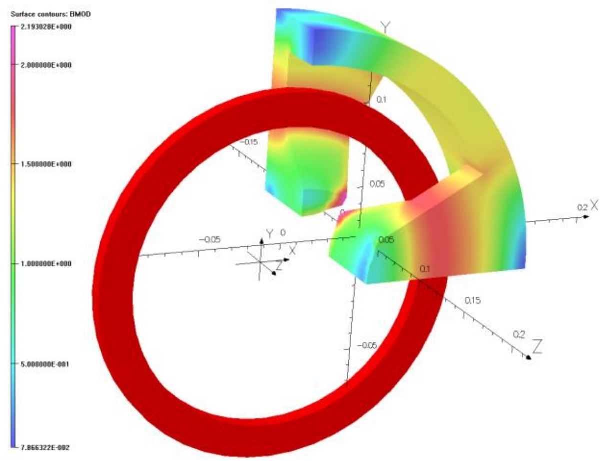
High Temperature Superconducting Quadrupoles with Circular Coils

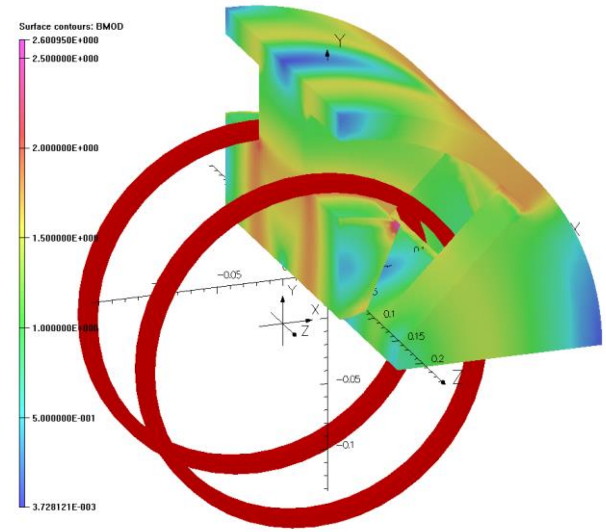
Outline

- *High Temperature Accelerator magnets*
- *Magnets Design*
- *Magnet Tests*

Novel Superconducting Accelerator Magnet Configuration

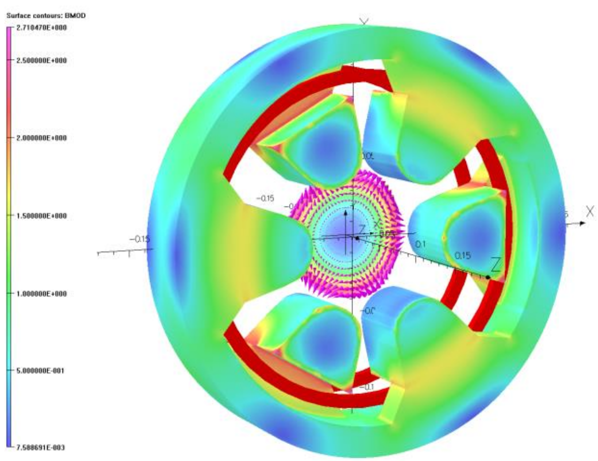






Single Coil Quadrupole

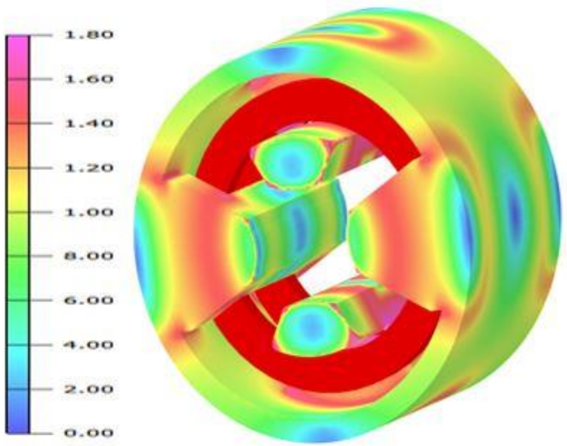
Double Coil Quadrupole



Double Coil Sextupole

- *Often new is forgotten old:*
- ***I.F.Malyshev, "Multipole Magnetic Lens", a.c. 1689890/26-25, published 12.10.1973, Bulletin 41, USSR.***
- ***V.S. Kashikhin, "A Novel Design of Iron Dominated Superconducting Multipole Magnets with Circular Coils", IEEE Trans. on Applied Superconductivity, 2010, Vol. 20, Issue 3, pp. 196-199.***

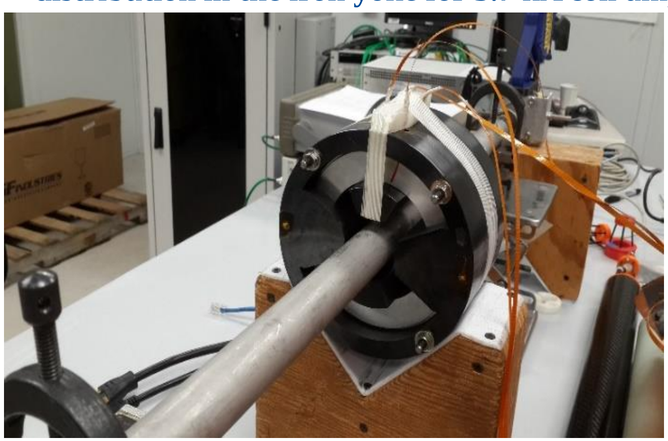
HTS Quadrupoles with Circular Coils



Double coil quadrupole geometry and flux density distribution in the iron yoke for 3.7 kA coil ampere-turns.

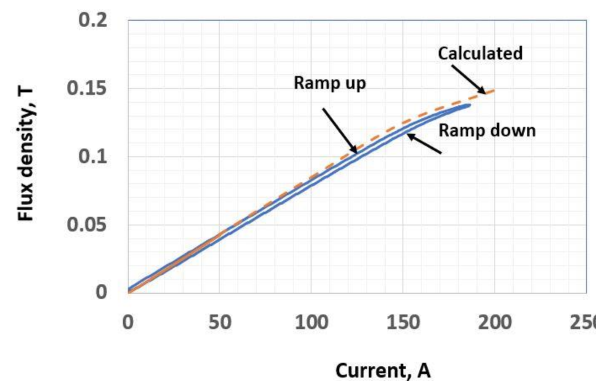
Quadrupole Parameters

Parameter	UNIT	Single coil	Double coil
Magnet aperture	mm	45	45
Coil number of turns		20	94
Superconductor		BTG*	SCS4050**
Coil peak current***	A	185	10
Coil ampere-turns***	kA	3.7	0.94
Peak field in the coil	T	0.25	0.07
Field gradient	T/m	8.7	2.4
Magnet length	mm	50	100
Outer yoke diameter	mm	170	170



Measurements at 20 C

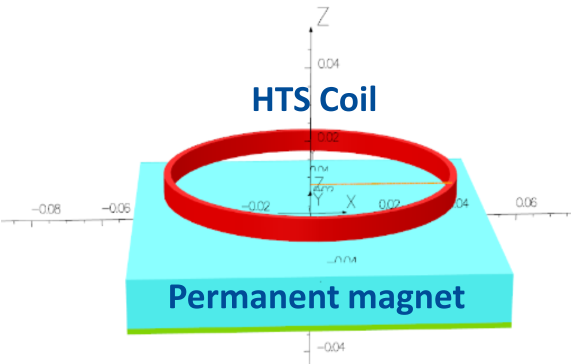
Cold test in LN2

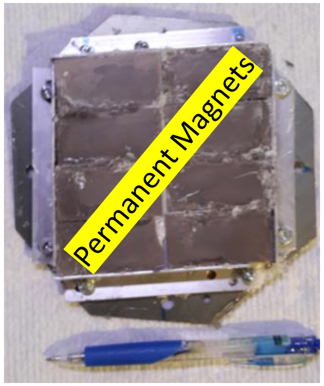


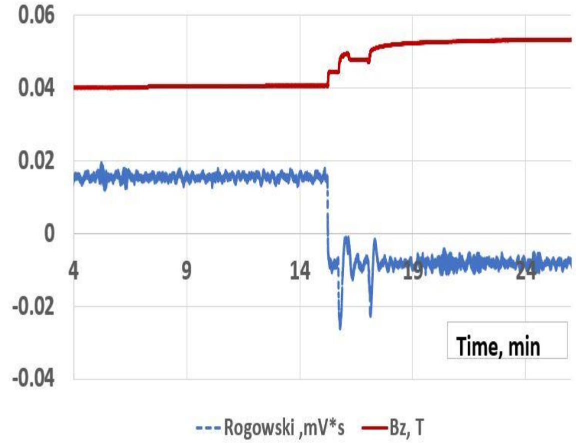
Peak current reached 185 A at 77K

V.S. Kashikhin, J. DiMarco, A. Makarov, Z. Mendelson, S. Rabbani, S. Solovyov, D. Turrioni, "High Temperature Superconducting Quadrupole Magnets with Circular Coils", IEEE Trans. on Applied Superconductivity, 2019, Vol. 29, Issue 5, 4002404.

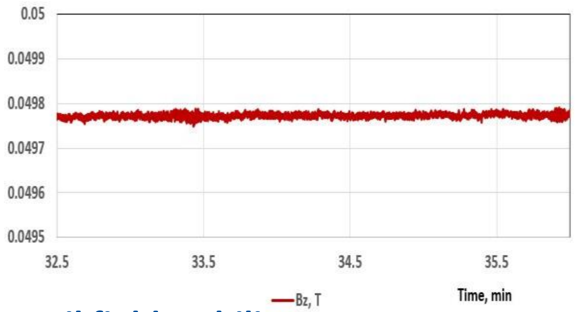
Short-Circuited HTS Coils Tests







HTS Coil test setup



HTS Coil field stability was ~0.5 Gauss

HTS Coil field under the weight of 1.2 kg and 2.4 kg

The coil stably levitated during 10 min having field 0.04 T on the surface where the Hall probe was positioned. At 15 min of the test the weight was doubled from 1.2 kg to 2.4 kg. It closed the gap between coil and permanent magnet block with corresponding field increasing to 0.053 T. The induced in HTS coil currents measured by Rogowski coil were 655 A and 1017 A correspondingly. It is promising that the magnetic field is very stable (better than 0.5 Gauss) for the fixed coil and Hall probe positions.

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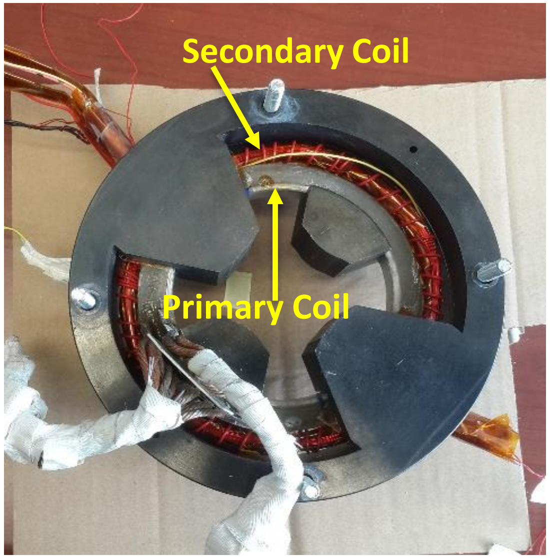
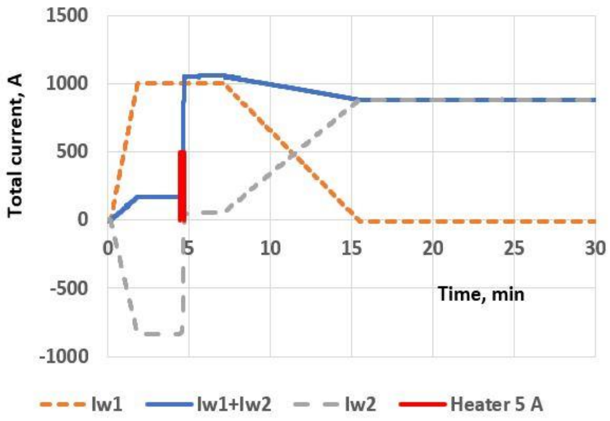
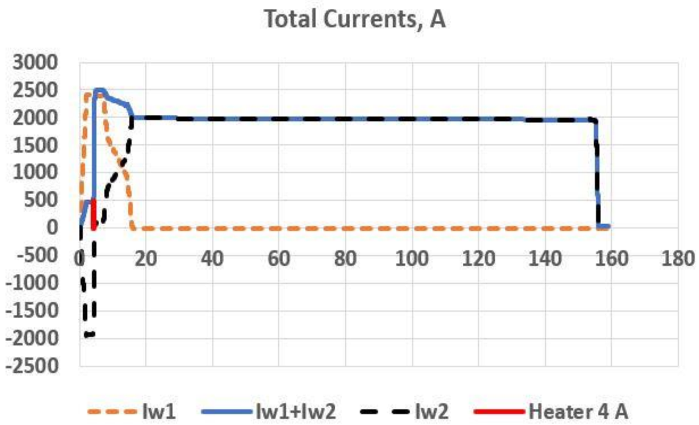
HTS Quadrupole with Short-Circuited Coil

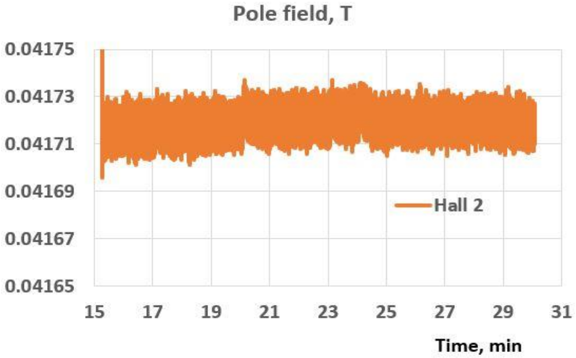




In secondary HTS Coil induced -833 A current



In secondary HTS Coil induced -1900 A stable current



Field stability is 0.2 Gauss

HTS Quadrupole Test Setup

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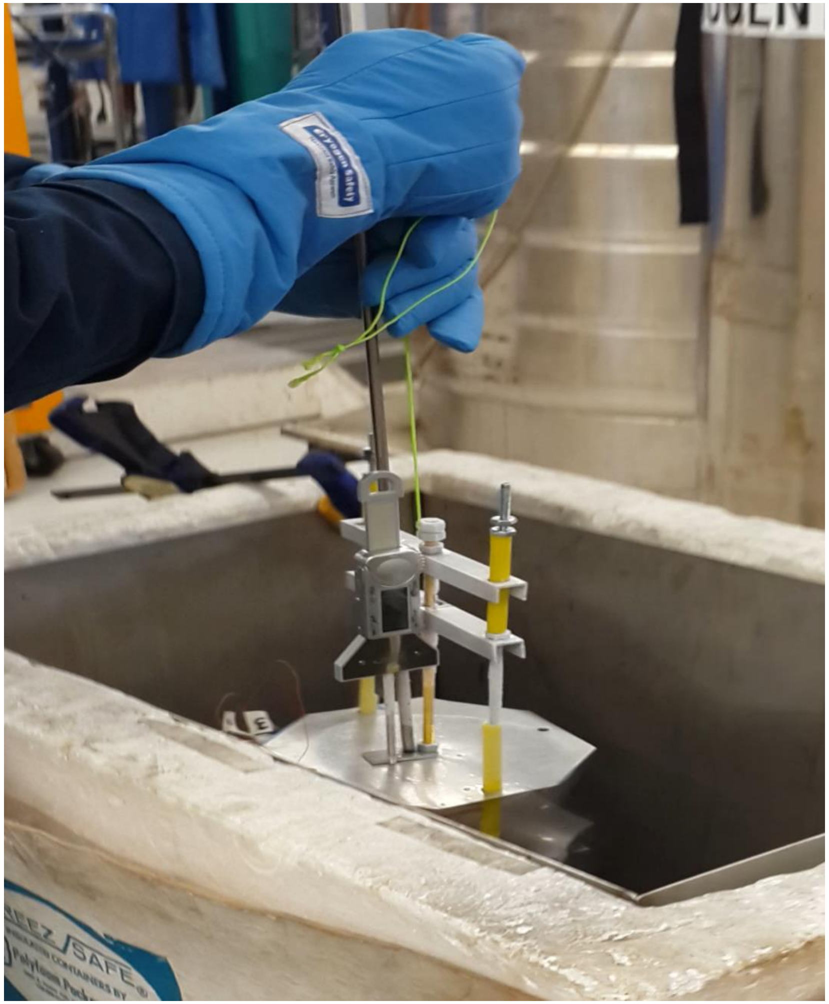
HTS Coil Levitation Test Setup



Test HTS Quadrupole with Circular Coil

Summary

- This LDRD activity opens the way to generate magnetic field using circular HTS coils in accelerator magnets.
- The permanent stable magnetic field could be generated by HTS short-circuited coils. The primary coil used only for the short period of time to pump energy in the secondary. The power source could be disconnected but the secondary coil continues generate the magnetic field.
- This type of magnet could be used in various applications where needed a permanent magnetic field.