THE GENERAL APPEARANCE OF THE SUPERCONDUCTING MAGNET SYSTEM FOR THE GAS-DYNAMIC MULTI-MIRROR TRAP

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Background

The goal of the Gas-Dynamic Multimirror Trap (GDMT) project is to create a multi-functional experimental facility and lay the groundwork for future development of fusion applications of open-ended magnetic plasma confinement systems with linear axisymmetric configuration. Among the most promising plasma confinement concepts to be studied on this facility are the diamagnetic plasma confinement mode and plasma flux suppression by multimirror and helical magnetic sections.

The conceptual design of the GDMT installation is under development and assumes a modular construction principle, which allows the installation to satisfy the requirements of the experimental program. Regarding the magnetic system of GDMT, this means that it must be built from several types of universal modules, which could be assembled in a particular order according to demands of the experiment. By utilizing this approach and controlling the current in each of superconducting coils, which make up the modules, it is possible to facilitate a transition from one magnetic configuration to another. The confinement region of the magnetic system is a several meters long solenoid with diameter of magnetic coils ~ 1.3m and axially uniform magnetic field. A certain experimental scenario requires that the magnetic field be ramped up from 0.3 to 3 T within 5 seconds, which implies than a special low AC-loss superconducting cable must be chosen for this part of the installation. In this paper we present the requirements for magnetic field distribution, preliminary calculations and a general appearance of the superconducting magnet system, along with an assessment of the parameters of superconducting materials necessary to create such a system.

Conclusion

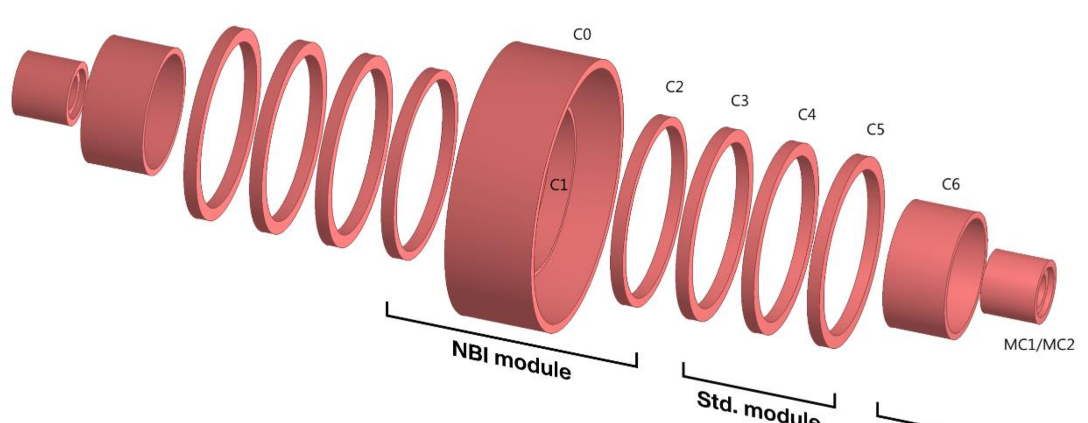
In the framework of the project to built the Gas-Dynamic Multimirror Trap in the Budker Institute of Nuclear Physics we evaluated basic parameters and general appearance of the superconducting magnetic system for this machine. The major requirements are that the magnetic field would be ramped up from 0.3 to 3 T within 5 seconds, which implies that a special low AC-loss superconducting cable must be chosen for this part of the facility. The mirror coils should have the field not less than 10 T.

In accordance with these demands, the windings of the GDMT were optimized in order to obtain the necessary magnitude and uniformity of the magnetic field in the aperture. The central coils could be made of NbTi superconductors with fine filaments like those used for superconducting magnets in accelerators in high energy physics. The 10 T mirror coils could be made of Nb3Sn superconductors, similar to used in the ITER toroidal field coils. The modular design of with three coils in each module has been suggested that will permit to change the magnetic field configuration in accordance with experiments required.

A preliminary substantiation of the choice of a superconducting current-carrying elements (cables) and initial superconductors for the windings of the GDMT has been made. The estimation of stability margins for all coils demonstrated that both NbTi and Nb3Sn coils have enough stability margins, including operation of NbTi coils at fast changing current.

The study demonstrated that the optimized superconducting magnet system for the Gas-Dynamic Multimirror Trap is feasible with use of modern low Tc superconductors and state of art in superconducting magnets.

Optimized coils configuration



Possible configuration of the GDMT magnetic system and coils labeling.

OPTIMIZED parameters of the coils

N	Coils	Z_{center}, m	R_{inner}, m	N turns	ΔZ, m	ΔR, m	Curr., A
1	C0	0	1.	3154	0.70135	0.0746	1630
2	C1	0	0.65	456	0.2028	0.0423	–1630
3	C2	0.93	0.673	600	0.1014	0.095	1630
4	C3	1.4633	0.65	768	0.1014	0.1188	1554
5	C4	1.9967	0.65	768	0.1014	0.1188	1662
6	C5	2.53	0.65	768	0.1014	0.1188	1855
7	C6	3.255	0.45	1003	0.49855	0.0289	3224
8	MC1	3.93	0.207	880	0.44	0.0605	3972
9	MC2	3.93	0.135	704	0.352	0.0605	2367

Parameters of SC strands and cables

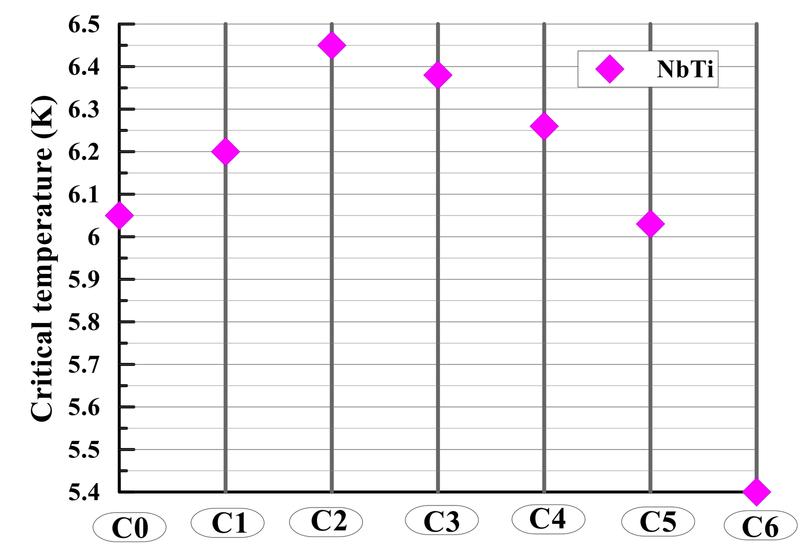
Main parameters of superconducting strands

Parameters	NbTi for C0-C5	NbTi for C6	Nb_3Sn for MC1-MC2
Diameter, mm	0.825	0.825	0.82
Diameter of filaments, µm	3.5	6	3
Twist pitch, mm	5	12	16.2
J_c(4.2K;5T), kA/mm²	2.5	2.3	-
I_c(4.2K;12T), A	-	-	>190
Copper/Supercond. Ratio	1.4	1.4	0.92
RRR	>70	>70	>100

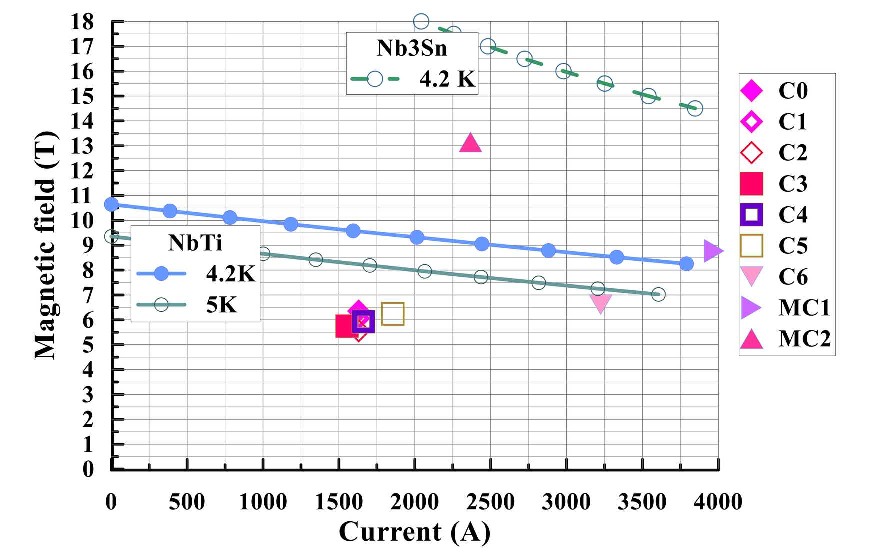
Main parameters of superconducting cables

NbTi superconducting cable	
Cable type	Rutherford cable with the stainless steel core
Number of strands	19
Twist pitch, mm	60
Size of the cable without insulation, mm²	1.5×8.5
Insulation thickness, µm	100
Nb_3Sn superconducting cable	
Cable type	Round, multiple twisted
Number of strands	24 Nb_3Sn+13 Cu
Twisting sequence	1+6+12+18=37
Copper/Supercond. Ratio	1.96
Size of the cable without insulation, mm²	4.5×4.5
Insulation thickness,mm	0.5

Stability evaluation

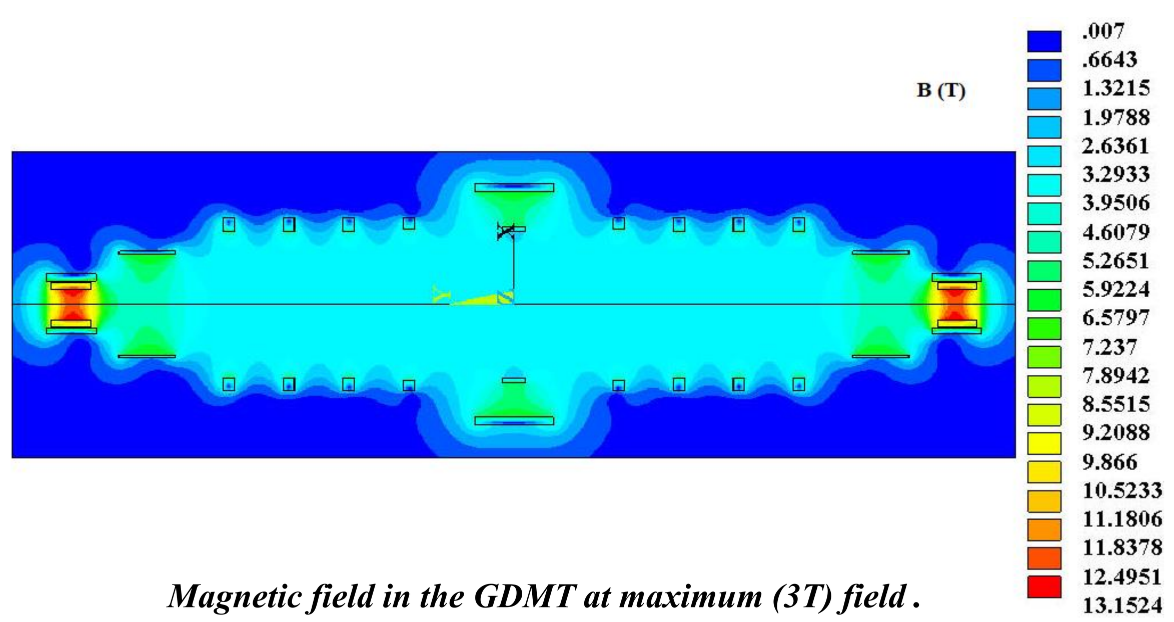


The minimum critical temperatures of NbTi coils at maximum operating field.



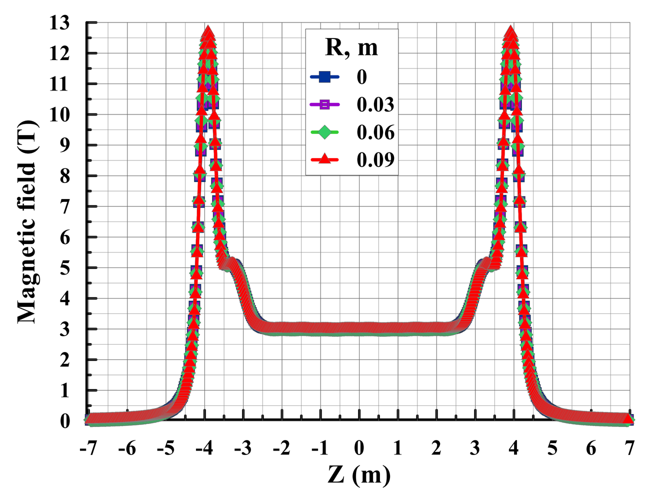
Dependencies of critical magnet field on the current at temperatures 5 K and 4.2 K for NbTi coils and at temperatures 4.2 K for Nb3Sn coils, by single symbols the quench currents along the load line for each coils are shown.

Magnetic field analysis

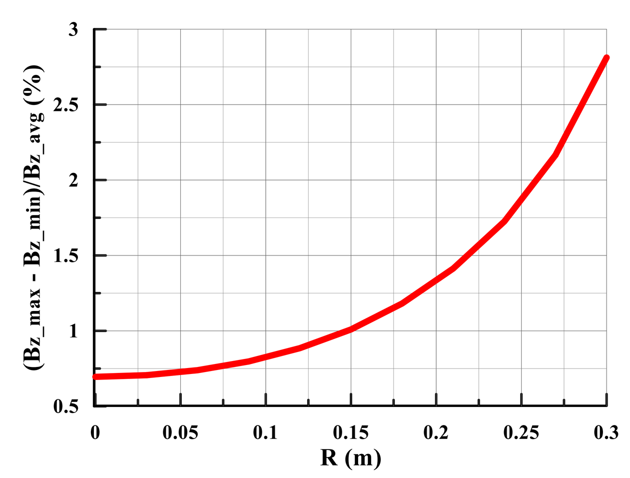


Magnetic field in the GDMT at maximum (3T) field .

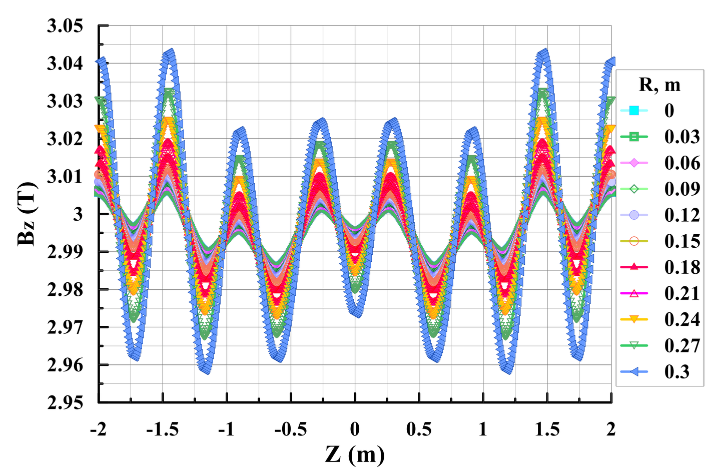
Uniformity of the magnetic field



The profile of magnetic field at different radii for the mode with the maximum (3 T) magnitude of the magnetic field in the central part of the GDMT.

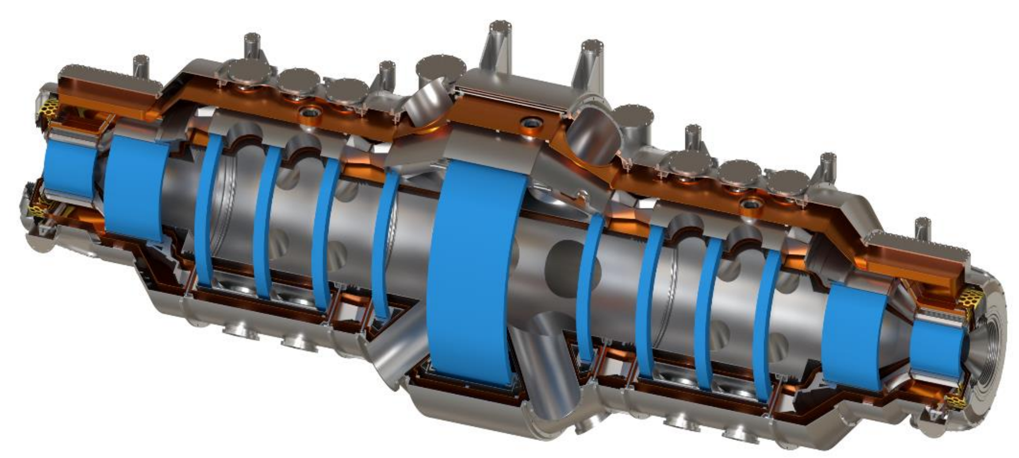


The non-uniformity of the field (Bz_max-Bz_min)/Bz_avg.

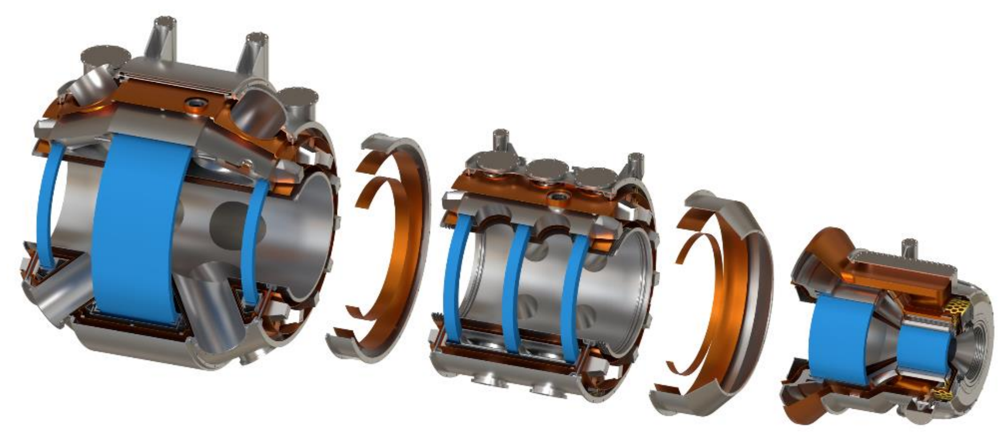


The longitudinal profile at different radii of the magnetic field Bz.

Cryostat assembling



Artistic view of the GDMT magnet system in the cryostat.



Artistic view of the possible modular design of magnet system of GDMT.

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