ID: 1280

The Gas-Dynamic Multimirror Trap Project

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Abstract

- The Gas-Dynamic Multimirror Trap (GDMT) project developed by BINP aims to advance linear magnetic plasma confinement systems and demonstrate their maturity for fusion applications.
- Updated version of GDMT developed since 2018 expands the experimental program to include studies of high-β plasma confinement [1] and make broader application of ECRH plasma heating methods [2].
- The reported version of the machine features continuously operating magnet system based on second generation high temperature superconductor (HTS) and long-pulse (up to 5 s) plasma heating systems.

[1]. A. D. Beklemishev 2016 Physics of Plasmas 23 082506

[2]. P. A. Bagryansky, A. G. Shalashov et al 2015 Phys. Rev. Lett. 114 205001

Background

Linear magnetic plasma confinements systems have a number of potential applications that can range from high-intensity (10^{18} n/s) fusion neutron sources for industrial and research purposes [1,2] to fusion-fission hybrid systems [3]. Implementation of advanced concepts such as multi-mirror and diamagnetic confinement [4] promises further improvement in power gain factor that can pave way to fusion energy applications of linear machines.

The goals of GDMT project are to expand the experimental database of gas-dynamic traps in support of their near-term fusion applications and to study new promising confinement concepts. In order to meet these goals, GDMT is being designed as a modular complex that can host a broad range of studies. The paper focuses on the most advanced version of magnet system that in its basic configuration features single magnetic mirrors and short central confinement solenoid made of HTS superconductor.

[1]. P.A. Bagryansky, Z. Chen, I.A. Kotelnikov et al 2020 Nucl. Fusion 60 036005

[2]. B.V. Kuteev, P.R. Goncharov, V.Yu. Sergeev et al 2010 Plasma Phys. Rep. 36 281–317

[3]. D.V. Yurov and V.V. Prikhodko 2016 Nucl. Fusion 56 126003

[4]. P.A. Bagryansky, A.D. Beklemishev, V.V. Postupaev 2019 J. Fusion Energ. 38 162–181

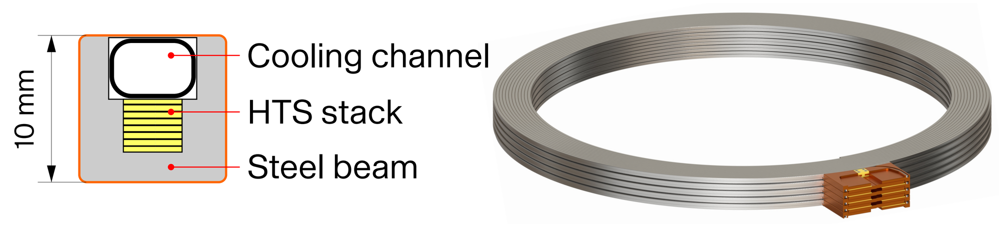
Features and scope

Short version of GDMT with single mirrors will be able to facilitate two classes of studies: beam-driven neutron sources and high-β confinement modes. Neutron source studies are characterized by hot plasma with sloshing ions produced by NBI, moderate β < 0.5 and aim to expand the experimental database of GDT and work out technologies necessary for continuous operation of a neutron source. Second class of studies is dedicated to exploration of high-β confinement modes, which will require highly uniform and precisely controlled magnetic field distribution that can be quickly ramped up to its maximum value. Ramp up to 3 T is one of the most strict requirements for the magnet system that necessitates the use of superconductors tailored for pulsed operation.

Central cell magnets

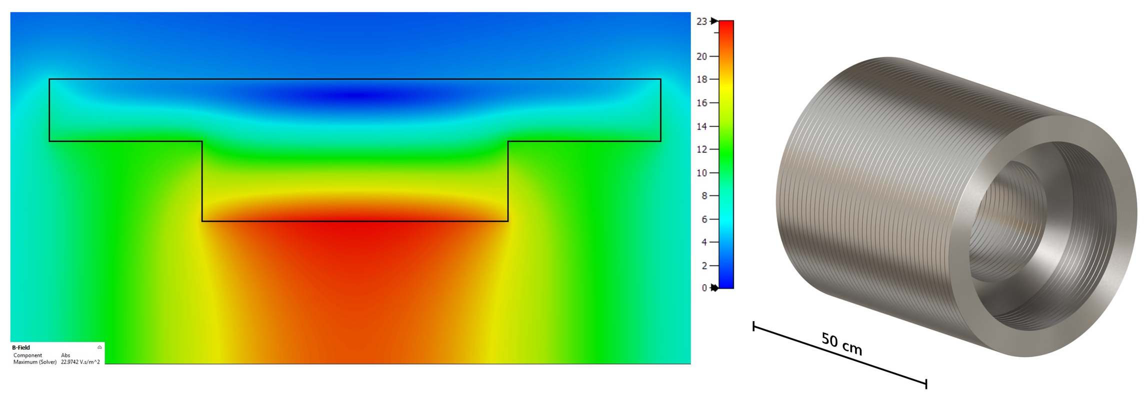
Internal diameter of central cell coils ranges from 0.9 m (transition coils) to 2.1 m (NBI coils). The transition coils generate constant magnetic field of 3 T in the near-mirror region for second-harmonic ECRH at 170 GHz. Larger NBI magnets provide space for round 400 mm ports, through which the neutral beam enters and exits plasma confinement vessel. The cable used in all central coils is a square cable-in-channel conductor with embedded cooling tube.

Coils are stacks of double pancakes with current and coolant terminals placed at external diameter and connected by resistive buses.



Magnetic mirror solenoids

One of the key features of the magnet system is the mirror solenoid with magnetic field of > 20 T in a 170 mm bore. The solenoid is a stack of double-pancakes with varying internal diameter would from a 12 mm REBCO tape reinforced by soldered-on steel tape. Solenoid is would without turn insulation which is expected to help with managing quenches.



Turns	8728
Tape length	9.8 km
Current	975 A
Bore diam.	240 mm
Energy	6.5 MJ
T_{oper}	20 K

Cryogenics and power supply

During pulsed operation the superconducting windings are expected to heat below their maximum operating temperature of 20 K. The cryoplant considered for the project is a 250 kW-class cryorefrigirator supplying supercritical helium at 4.5 K to magnets and cryosorption pumps.

Current sources for pulsed operation are based on supercapacitor batteries with total stored energy of 200 - 300 MJ.

Summary

GDMT is a next-generation magnetic mirror research facility that aims to validate and develop technologies necessary for fusion applications of linear confinement systems. The most advanced version of the magnet system enables exploration of high-β modes of plasma confinement, while extending the discharge duration by three orders of magnitude compared to existing GDT experiment.

Length (B/T mirrors)	9.6 m
Plasma vessel diam.	0.17 - 1.78 m
Mirror field	20 T
Central cell field	0.3 - 3 T
Central field ramp-up	0.54 T/s
Field energy	80 MJ
NBI energy	30 - 40 keV
NBI power	10 MW
NBI duration	2 - 5 s
NBI angle	45°
ECRH power	2 - 6 MW
ECRH frequency	170 GHz