Temporal Stabilization of Magnetic Flux Focused by Superconducting Magnetic Lens

Akihisa Miyazoe[1], Ryoji Nakagawa[1], Chishin Hori[1], Hideki Tanaka[1], and Yukinobu Imamura[1]

HITACHI Inspire the Next

1. Hitachi Ltd., Research & Development Group, Center for Technology Innovation – Energy

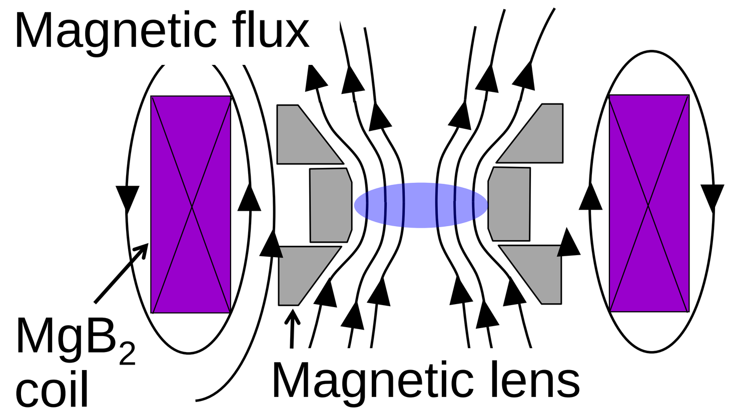
Program ID: MT25-Wed-Af-Po3.03-01

1. Background

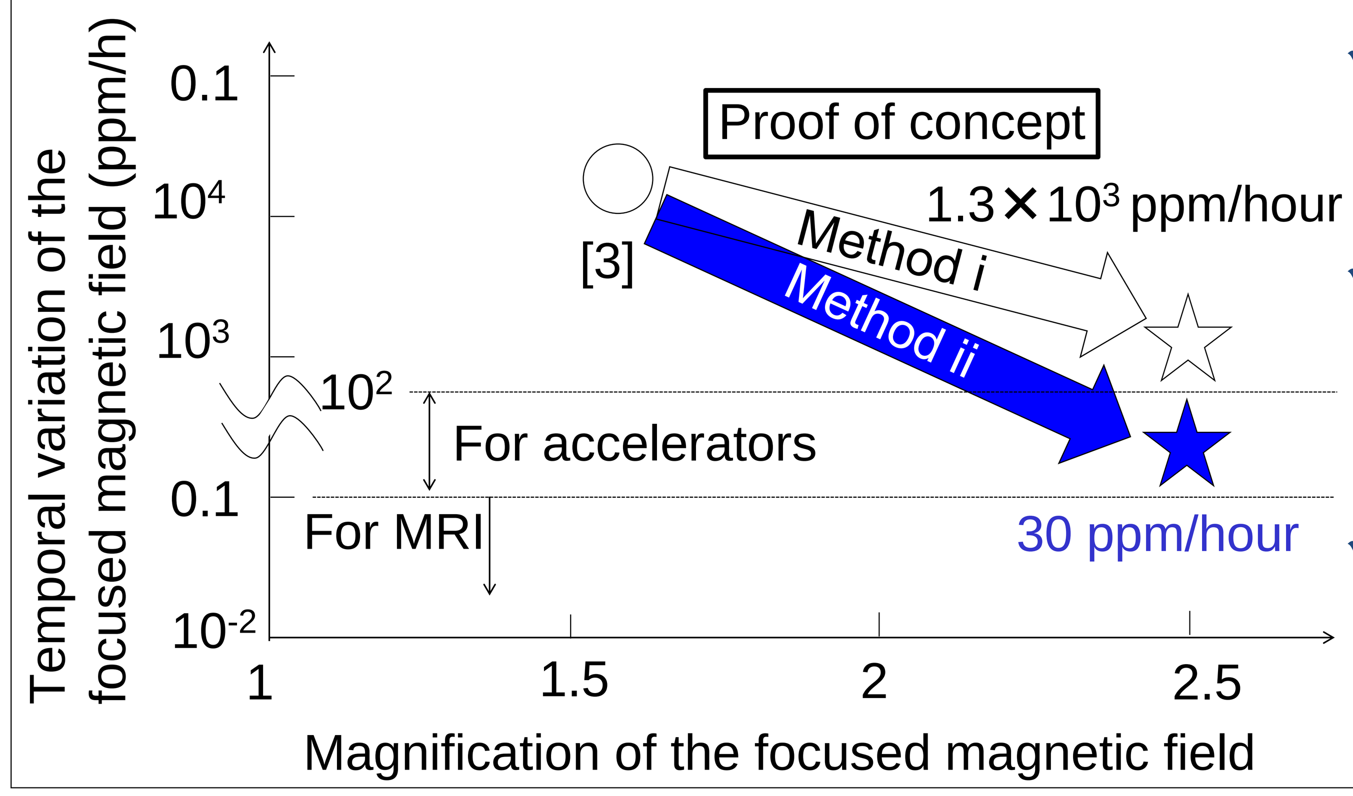
Higher-field magnets are becoming larger and less accessible and spend more energy in energizations. As a solution for generating higher magnetic field compactly, Kiyoshi and Zhang *et al.* [1]-[3] suggested a magnetic lens using high-temperature superconducting (HTS) bulks with properties of diamagnetism. The focused magnetic field was increased a background magnetic field of 7 T to 13 T with at 20 K. However, the fields kept reducing at a rate of -1.3×10^4 ppm/hour proportional to logarithm of time. The decay rate was high for applications, which is required to be below 10^{-3} ppm/hour.

2. Purpose of this study

- ✓ Experimental verification of effects by **two following methods** for stabilizing the **focused magnetic fields**.
  - i. Temperature reduction of the HTS magnetic lens in the energization of the surrounding coil generating a background magnetic field.
  - ii. Combination of the temperature reduction method and a method for overshooting the background magnetic field.



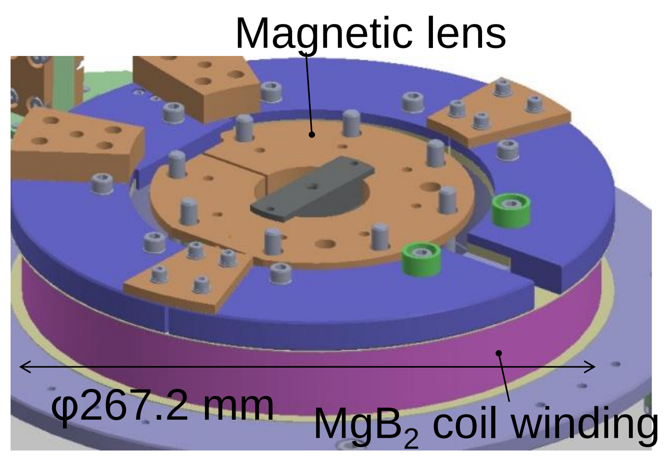
5. Conclusion

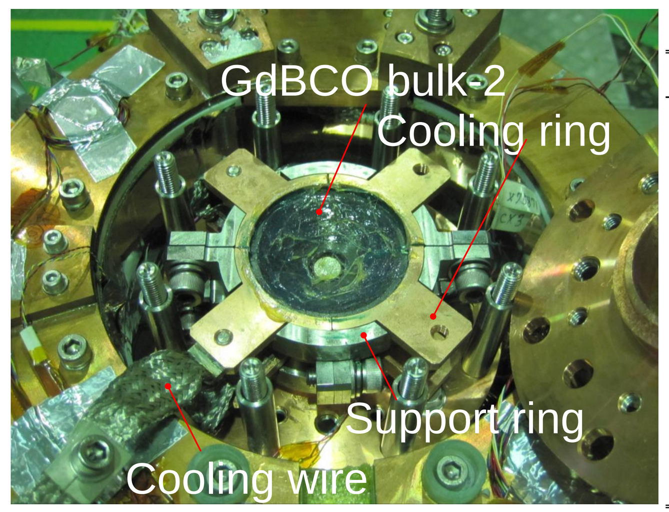


- ✓ Effect of the two methods for stabilizing magnetic fields focused by a magnetic lens using high-temperature bulks were verified experimentally.
- ✓ The temperature reduction method and the combination method reduced a decay rate of -6500ppm/hour to -1300ppm/hour and -30ppm/hour, respectively.
- ✓ This rate is small enough for some accelerator applications, but further studies are needed to expand applications of magnetic lenses.

3. Experimental procedure

Magnetic lens made from GdBCO bulks and MgB_2 coil generating background magnetic field

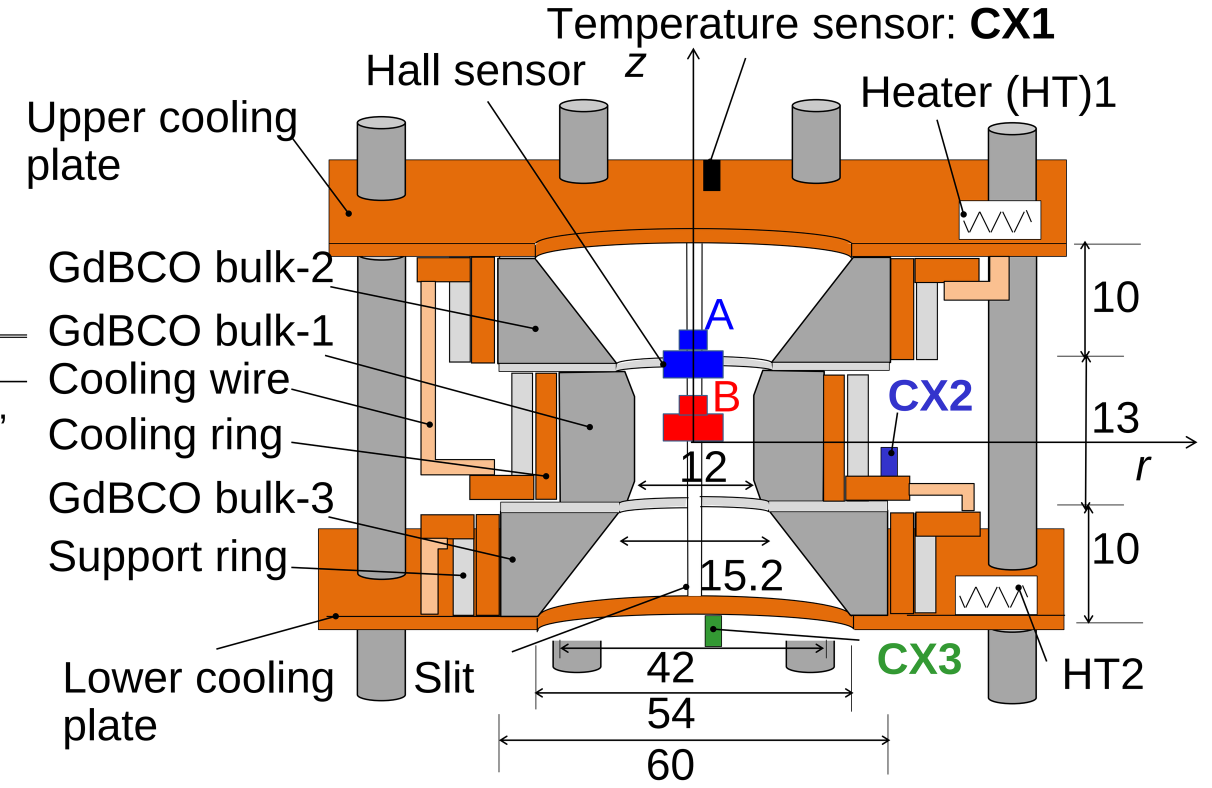




- ✓ The coil and the upper and lower cooling plates of the magnetic lens were connected in parallel to the cold head of the second stage of a Gifford-McMahon (GM) cryocooler attached to a cryostat.
- ✓ The temperatures of CX1 and CX3 were controlled with a PID method by using HT1 and HT2.

Specifications of MgB_2 coil

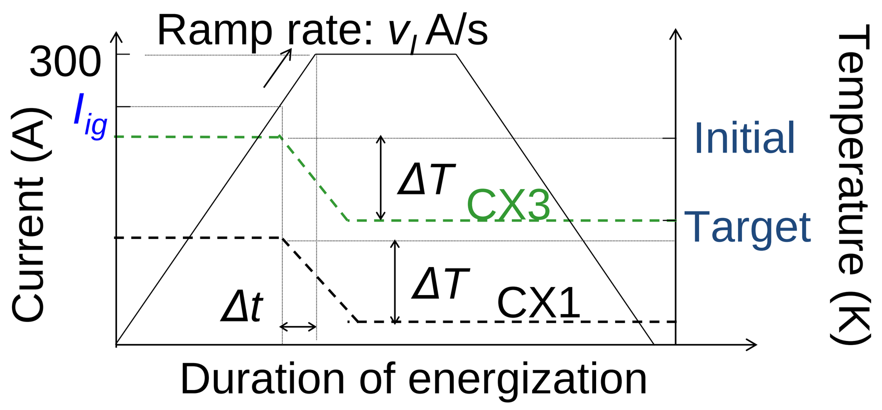
Parameter	Specification
Superconducting wire	Monocore-round wire, by Hitachi Ltd.
Wire diameter (mm)	φ1.3
Number of turns	439
Coil inner diameter (mm)	219
Coil outer diameter (mm)	267.2
Load factor at 20 K and 300 A (%)	94
Magnetic flux density at the center at 300 A (T)	0.681



Operation conditions for verifying the two methods, i and ii

- ✓ Nos.1 to 4 employed the method i with different ignition currents (I_{ig}).
- ✓ Nos.5 to 8 employed the method i and ii to compare the effects.
- ✓ Decay rates of the temporal variations in magnetic flux densities were approximated on the basis of

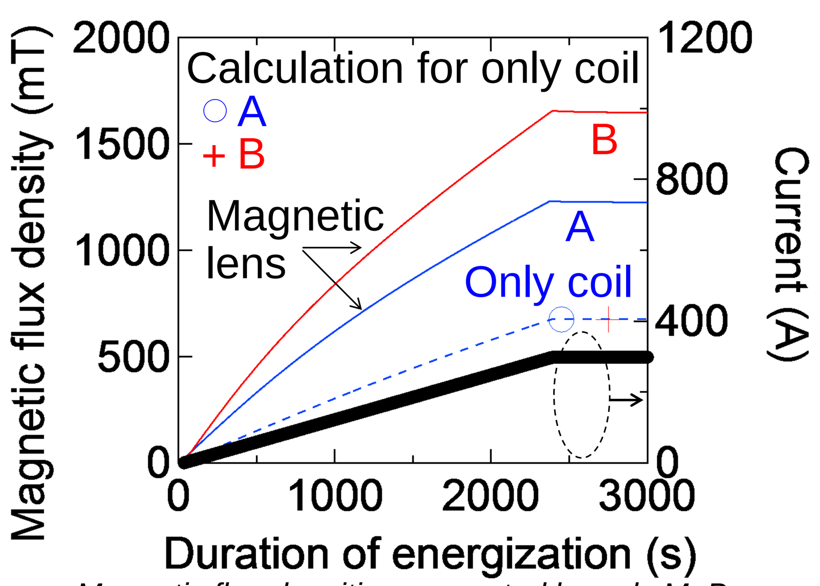
$$y = 1 - C_1 ln\left(1 + {}^{t}/_{C_2}\right) \qquad (1)$$



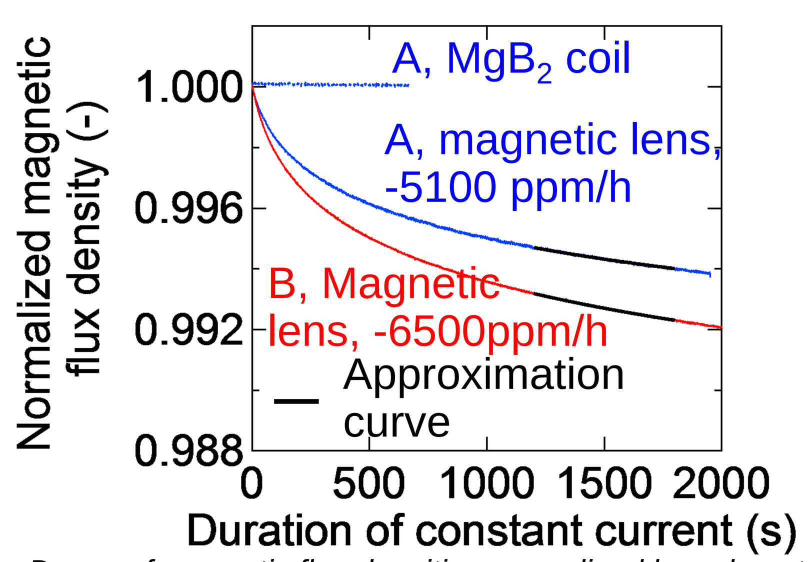
No.	Ramp rate: v_l (A/s)	Initial temperature of CX1	Initial temperature of CX3	Target temperature of CX1	Target temperature of CX3	Ignition current: I_{ig} (A)	Current reversal operation
1	0.48	18.3	21.7	-	-	-	-
2	0.48	24.4	28.0	18.3	21.7	285	-
3	0.48	24.4	28.0	18.3	21.7	276	-
4	0.48	24.4	28.0	18.3	21.7	250	-
5	4.8	18.2	21.5	-	-	-	-
6	4.8	18.2	21.5	13.3	18.2	10	-
7	4.8	18.2	21.5	-	-	-	300 to 285A
8	4.8	18.2	21.5	13.3	18.2	10	300 to 285A

4. Results and discussion

Temporal stabilities at different positions: The temporal variation at position B is higher

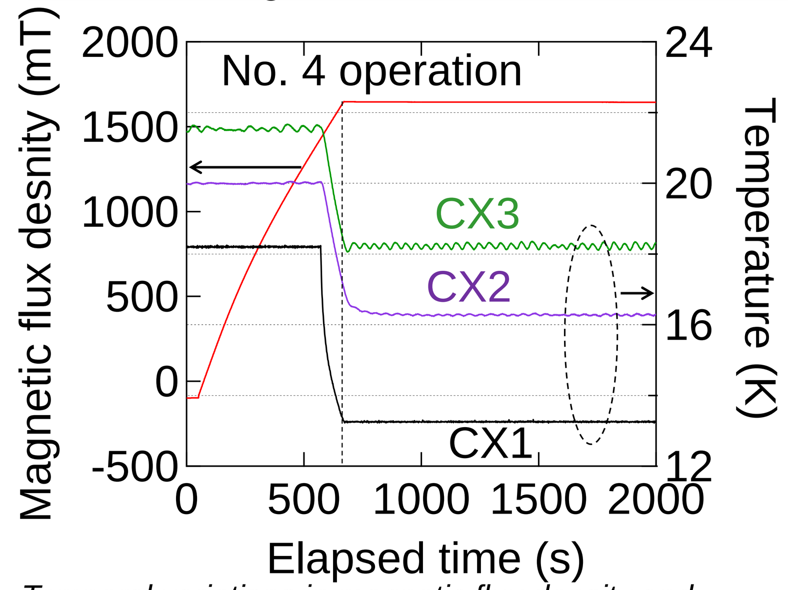


Magnetic flux densities generated by only MgB_2 coil and combinations of MgB_2 coil and magnetic lens at 20 K.

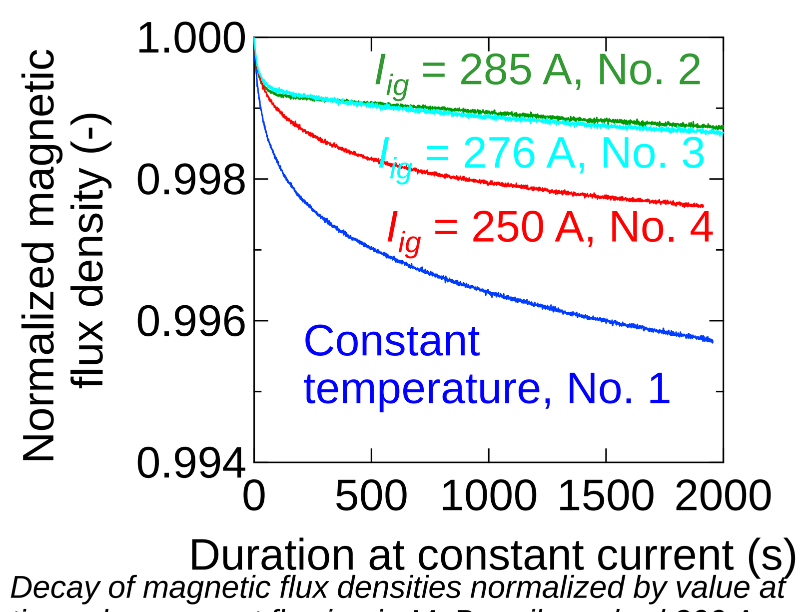


Decay of magnetic flux densities normalized by value at time when current flowing in MgB_2 coil reached 300 A. Approximation curve was drawn on basis of (1).

Effect of the method i: As the I_{ig} become large, the decays become slower.

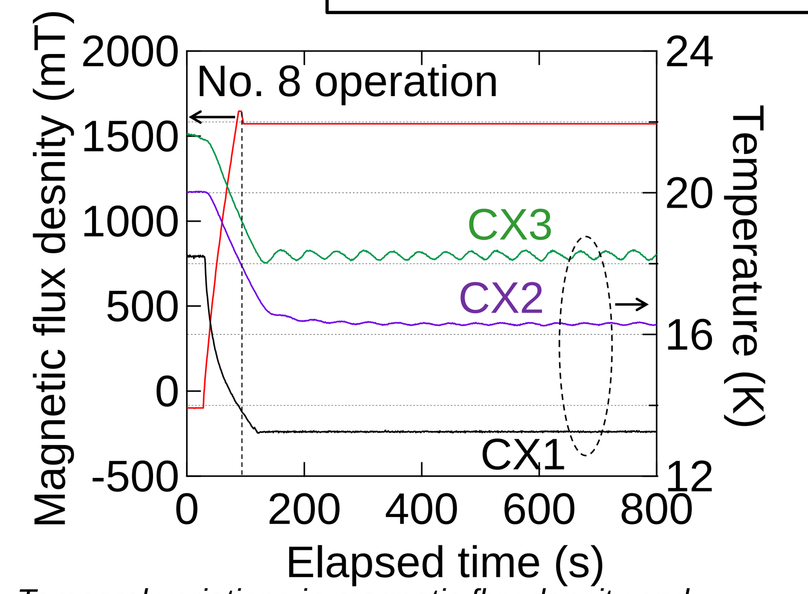


Temporal variations in magnetic flux density and temperatures of CX1, CX2, and CX3 for No.4.

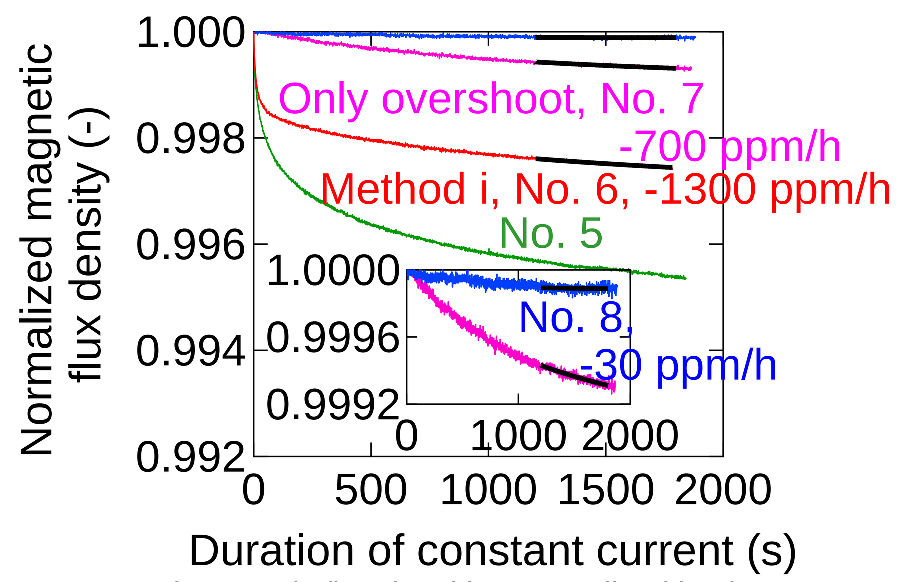


Decay of magnetic flux densities normalized by value at time when current flowing in MgB_2 coil reached 300 A. Curves are drawn using measurement values at position B in for Nos. 1, 2, 3, and 4.

Effect of the method i and ii: The method ii was more effective.



Temporal variations in magnetic flux density and temperatures of CX1, CX2, and CX3 for No.8.



Decay of magnetic flux densities normalized by the value at a time when current flowing in the MgB_2 coil reached 300 A. The curves are drawn using measurement values at the position B in operations of Nos. 5, 6, 7, and 8.

Hitachi Ltd.

References
[1] T. Kiyoshi, S. Choi, S. Matsumoto, T. Asano, and D. Uglietti, "Magnetic flux concentrator using Gd-Ba-Cu-O bulk superconductor", *IEEE Trans. Appl. Supercond.*, vol. 19, 2009, pp. 2174-2177.
[2] Z. Y. Zhang, S. Choi, S. Matsumoto, R. Teranishi, G. Giunchi, A. Figini Albisetti, and T. Kiyoshi, "Magnetic lenses using different MgB_2 bulk superconductors," *Supercond. Sci. Technol.* vol. 25, 2012, 025009.
[3] Z. Y. Zhang, S. Matsumoto, R. Teranishi, and T. Kiyoshi, "Improving the properties of GdBCO magnetic lenses by adopting a new design and resin impregnation, "*Supercond. Sci. Technol.*, vol. 26, 2013, 045001.