# Rail magnets arrangement for improving stability of a superconducting transport system

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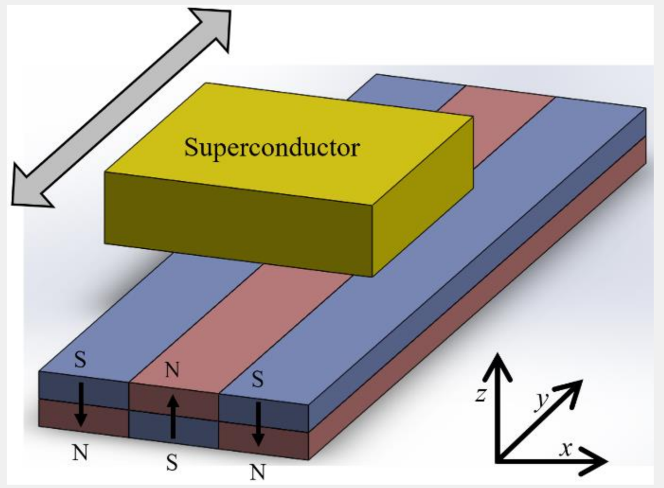
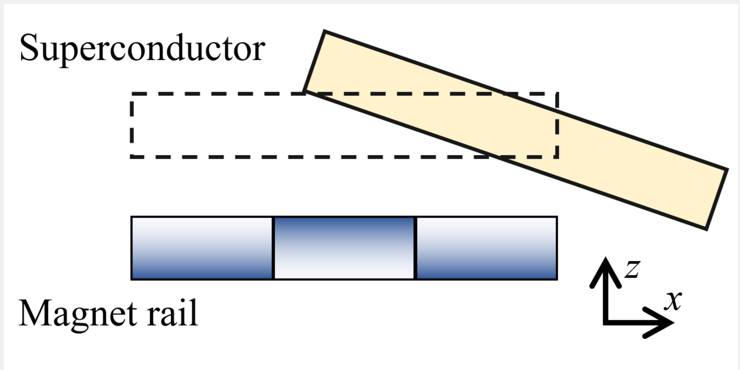
## 1. Introduction

High-temperature bulk superconducting transport system owns the capability of passive stabilization and operate at low energy consumption. In the standard superconducting transport system with the conventional magnet rail configuration, the levitation shuttle tilts to the reverse bank angle when it deviates laterally. In this study, the rail magnet arrangement was examined so that the levitation shuttle tilts to the bank angle. The roll angle of the shuttle was examined by measuring the magnetic levitation force acting on the left and right parts of the shuttle.

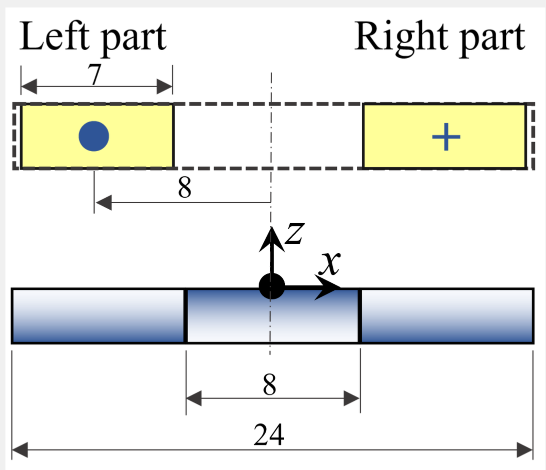



Schematic diagram of a superconducting magnetic levitation coaster.




Schematic diagram of the levitating superconductor with lateral shift. This is an undesirable roll angle.

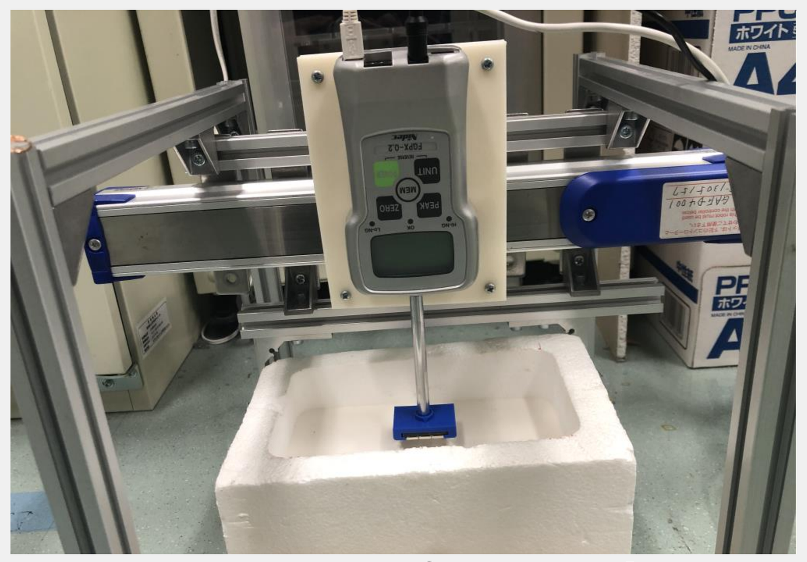
## 2. Measurement of magnetic force




The left part superconductor was cooled at $x$ = -8 and $z$ = 7. This initial position is the origin($x$=0) of the levitating shuttle. After cooling, the superconductor moves horizontally while vertical levitating force($F_z$) is measured.
In all measurements, the [8-8-8] rail was used for cooling. Since the width of the shuttle is assumed to be constant, the position of the superconductor is also constant at $x$ = ±8.

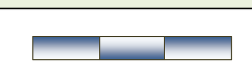
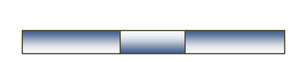
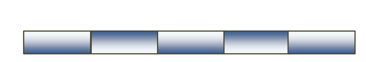
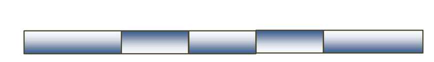
Bulk superconductor
(QMG-GdBaCuO, mass: 5.8 g);
width: 7 mm;
thickness: 5 mm;
length:25 mm; thickness: 5 mm

Rail magnets (NdFeB);
width: 8 or 14 mm *refer to the table*;
length:25 mm;
thickness: 2 mm



Measuring apparatus for vertical magnetic force $F_z$ of the levitating superconductor and a magnet rail.
In the measurement, A rail magnet moved horizontally quasi-statically above the superconductor in the liquid nitrogen pool. A force gauge is attached to the magnet rail. The rail magnet is attached to a force gauge and the x-axis stage.

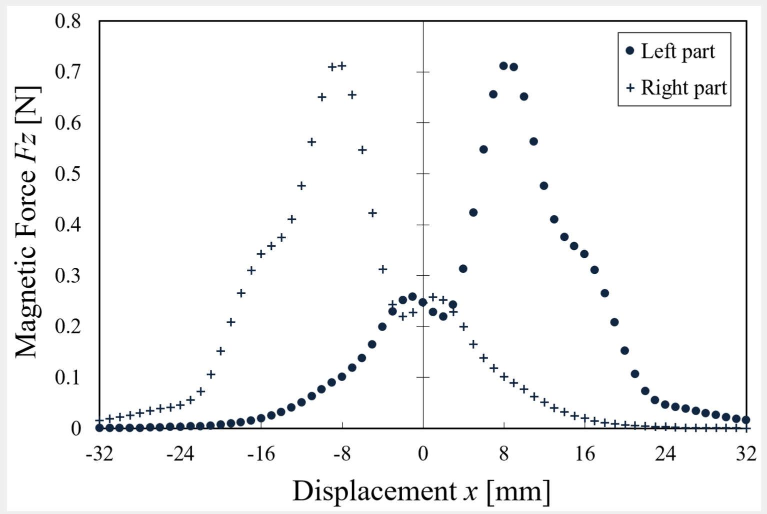
Table 1. Magnet arrangement used in the experiment. The magnets are arranged so that the vertical magnetic field alternates up and down.

| Abbreviation | Cross-sectional diagram of rail magnet arrangements |
|---|---|
| 8-8-8 |  |
| 14-8-14 |  |
| 8-8-8-8-8 |  |
| 14-8-8-8-14 |  |

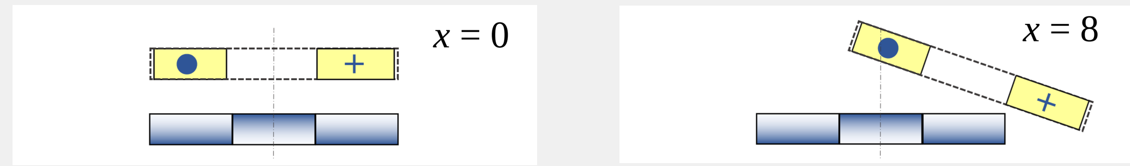
## 4. Conclusion

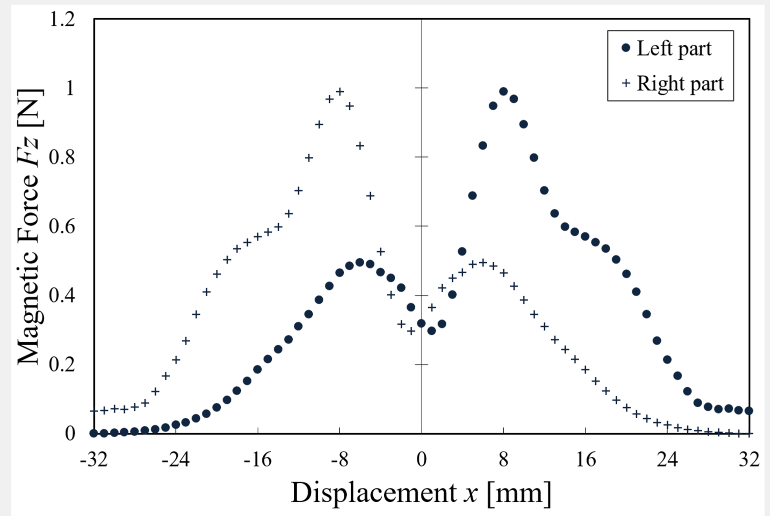
The inclination of the floating shuttle was estimated from the levitating force acting on the left and right superconductor parts of the shuttle.
In the arrangement([8-8-8-8-8], [14-8-8-8-14]) in which rail magnets were added outside the width of the shuttle, the shuttle tilted in the desired direction.

## 3. Measurement results and shuttle roll angle

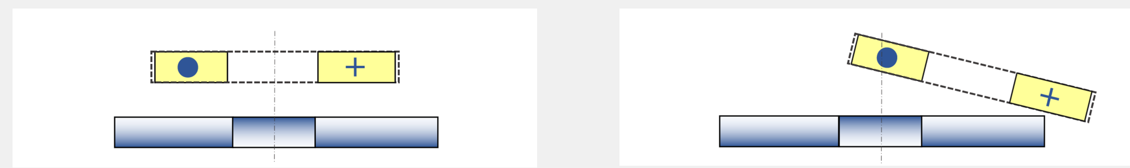


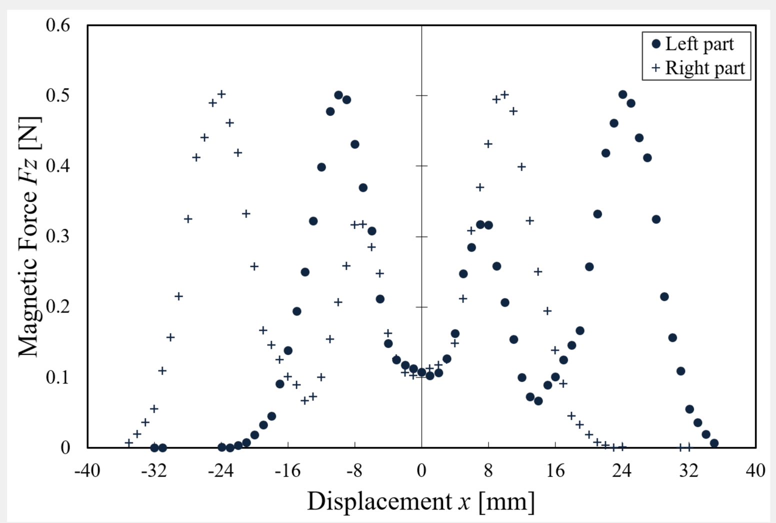

**[8-8-8]** arrangement rail
within $x$ = ± 4 mm, the shuttle is almost horizontal.
For $x$ > 5, the shuttle tilts in an undesired direction.



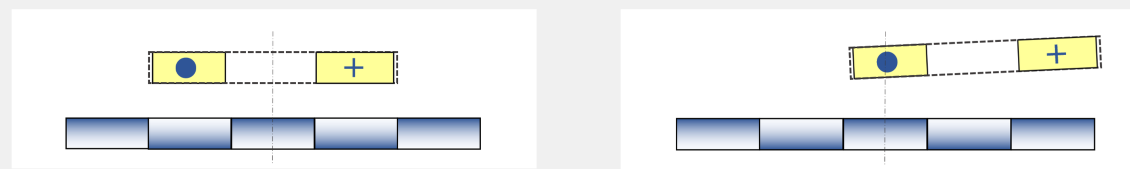



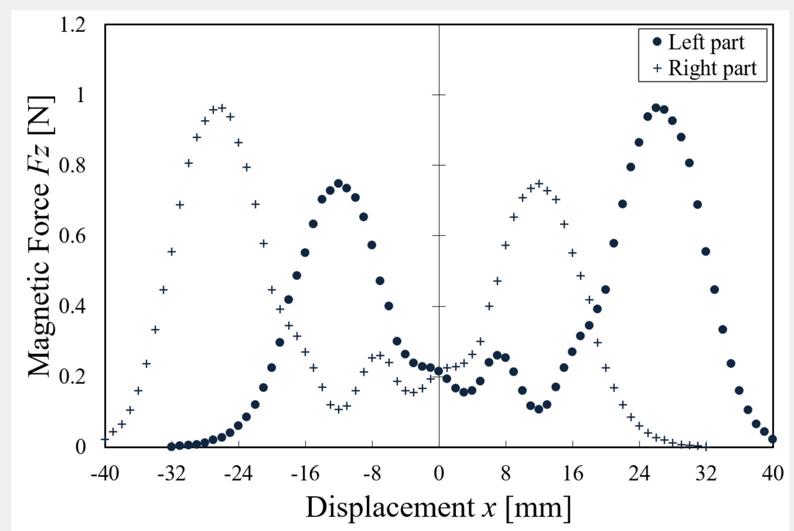

**[14-8-14]** arrangement rail
within $x$ = ± 4 mm, the shuttle is almost horizontal.
For $x$ > 5, the shuttle tilts in an undesired direction.






**[8-8-8-8-8]** arrangement rail
within $x$ = ± 7 mm, the shuttle is almost horizontal.
For $x$ > 7, the magnetic force increases in both the inner and outer parts, but the outer part force is larger.
7<$x$<16, the shuttle tilts in a desired direction.






**[14-8-8-8-14]** arrangement rail
within $x$ = ± 4 mm, the shuttle is almost horizontal.
For $x$ > 7, the levitating force in the outer part increases.
The magnetic force in the inner part does not increase so much.
7<$x$<17, the shuttle tilts in a desired direction.