

**Rectification effect and spontaneous voltage generation  
in superconductor MoGe/ferromagnet NiFe bilayer**  
超伝導体 MoGe/磁性体 NiFe における整流効果と自発電圧生成

Dept. Appl. Phys., Univ. Tokyo<sup>1</sup>, RIKEN CEMS<sup>2</sup>,  
Inst. AI and Beyond, Univ. Tokyo<sup>3</sup>, AIMR Tohoku Univ.<sup>4</sup>,  
Koyomi Oshigane<sup>1</sup>, Hiroki Arisawa<sup>1,2</sup>, Eiji Saitoh<sup>1,2,3,4</sup>

東大工<sup>1</sup>, 理研 CEMS<sup>2</sup>, 東大 BAI<sup>3</sup>, 東北大 AIMR<sup>4</sup>

押金こよみ<sup>1</sup>, 有沢洋希<sup>1,2</sup>, 齊藤英治<sup>1,2,3,4</sup>

E-mail: oshigane-koyomi628@g.ecc.u-tokyo.ac.jp

The rectification effect, where the resistance differs depending on the forward or backward direction of the applied current, enables the conversion of a.c. electric fluctuations into d.c. voltage. In conductors without junctions, the rectification effect typically requires the breaking of spatial inversion symmetry in the atomic scale due to the short coherence length of electrons in solids.

In a type-II superconductor, topologically protected superconducting vortex strings are generated and annihilated only at the surface of the superconductor, and the broken spatial inversion symmetry at the superconductor's surface affects the transport properties of vortex strings, which does not require the breaking of spatial inversion symmetry inside the superconductor. In particular, it has been reported that a MoGe thin film fabricated on a ferrimagnetic insulator  $\text{Y}_3\text{Fe}_5\text{O}_{12}$  (YIG) exhibits nonreciprocal vortex motion due to the broken spatial inversion symmetry at the MoGe/YIG interface, resulting in the nonreciprocal resistance [1].

In this study, we demonstrated the rectification effect in a MoGe thin film on a ferromagnetic metal NiFe. By applying an in-plane magnetic field to the MoGe/NiFe bilayer and measuring the resistance of the MoGe layer (Fig.1), we found that finite nonreciprocal resistance appears in a magnetic field where vortex strings are mobile (Fig.2). We also demonstrated that d.c. voltage is spontaneously generated in the MoGe layer even without an input current (Fig.2), and revealed that the voltage originates from the vortex motion reflecting the asymmetric magnetic environment at the MoGe surfaces. Furthermore, by measuring the spontaneous d.c. voltage generation and nonreciprocal electrical response in three bilayer systems, MoGe/NiFe, MoGe/YIG, and MoGe/SiO<sub>2</sub>, we revealed that the spontaneous d.c. voltage generation is correlated to the nonreciprocal electrical response [2].

Fig.1. Schematic illustration of measurement

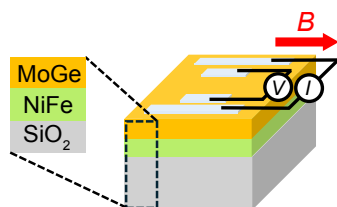
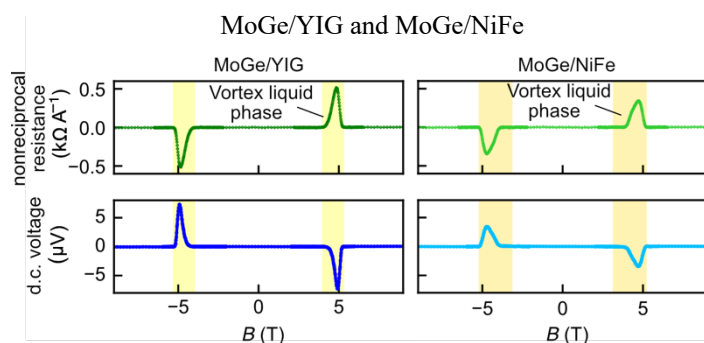


Fig.2. Nonreciprocal resistance and d.c. voltage in



[1] J. Lustikova et al., *Nature Communications* **9**, 4922 (2018).

[2] K. Oshigane et al., *Applied Physics Letters* (accepted, 2024).