Title of Project : **Development of ultralow temperature and ultrahigh-resolution laser-based photoemission spectroscopy and investigation of the mechanism of exotic superconductors**

Shik Shin
(The University of Tokyo, Institute for Solid State Physics, Professor)

Research Area : Condensed matter physics I
Keyword : Optical properties

【Purpose and Background of the Research】

Realization of room-temperature superconductivity is one of the ultimate goals in the field of materials science. In order to achieve a high critical transition temperature (T_c), one needs to elucidate how materials can overcome T_c ~ 40 K, a so-called BCS limit predicted from a conventional theory of phonon-mediated superconductivity. To this end, it is important to learn from a variety of exotic superconductors, wherein the mechanism of Cooper-pairing is unconventional.

Angle-resolved photoemission spectroscopy (ARPES) is a powerful tool to investigate the mechanism of superconductivity, because the energy-and-angular distribution of photoelectrons released from Cooper-pair breaking is a direct reflection of the pairing symmetry. In fact, ARPES studies on high-T_c copper- and iron-based superconductors revealed the symmetry and anisotropy of superconducting gaps as well as novel electronic structures such as pseudogaps and kinks in band dispersions. On the other hand, exotic superconductors exhibiting low T_c' are less studied by ARPES because of the insufficient energy resolution and cooling power.

Recently, we achieved the energy resolution of 70 μeV and lowest temperature of 1.5 K in ARPES by developing a 7-eV quasi-CW laser harmonics, a He^4 cryostat, and an electron energy analyzer. We succeeded to revealed an octet-line node structure of the superconducting order parameter in an iron-based superconductor KFe_2As_2 (T_c = 3.4 K; Okazaki *et al.*, Science 2012), thus enabling access to the exotic low-T_c regime by laser-based ARPES.

【Research Methods】

In order to investigate a variety of exotic superconductors (Fig. 1), the development of an extreme ARPES apparatus is indispensable. In this project, we aim to achieve the lowest temperature of 500 mK and energy resolution of 50 μeV by extending the laser-based ARPES through developing a new He^3 cryostat and high-repetition or CW lasers. We also develop 8 eV laser harmonics by using nonlinear crystals KBBF and new harmonics laser using rare gas, so that we can survey a wide momentum region of the Brillouin zone.

【Expected Research Achievements and Scientific Significance】

Our research will reveal the pairing mechanism of various exotic superconductors, organic superconductors, and candidate topological superconductors that are expected to harbor Majorana fermions. The information would provide a guiding principle for the search of novel superconductors that may operate at room temperature. The developmental of monochromatic high-harmonic lasers would also open a new field of laser-based high energy spectroscopy.

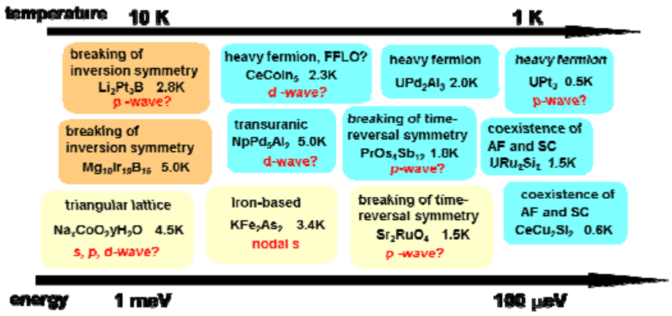

Figure 1: Exotic superconductors.

【Publications Relevant to the Project】

- Octet-line node structure of superconducting order parameter in KFe_2As_2, K. Okazaki, S. Shin *et al.*, Science **337** (2012) 1314-1319.
- Orbital independent superconducting gaps in iron pnictides, T. Shimojima, S. Shin *et al.*, Science 332 (2011) 564-567.

【Term of Project】 FY2013-2017

【Budget Allocation】 149,700 Thousand Yen

【Homepage Address and Other Contact Information】

http:// shin.issp.u-tokyo.ac.jp/
shin@issp.u-tokyo.ac.jp