Measurements of photo-induced orbital angular momentum dynamics of superconductor

Y. Toda[1], S. Tsuchiya[1], T. Kurosawa[2], M. Oda[2], T. Mertelj[3], I. Madan[3], D. Mihailovic[3],
[1] Department of Applied Physics, Hokkaido University, [2]Department of Physics, Hokkaido University, [3]Complex Matter Department, Jozef Stefan Institute, Slovenia

The elucidation of the normal state above T_c is believed to be a key for understanding the mechanism of the high-T_c superconductivity. Various spectroscopic studies have been carried out and revealed that a pseudogap (PG) state and/or fluctuating superconducting (FSC) state exist above T_c and have unique properties different from SC. Optical time-resolved spectroscopy using femtosecond pulse laser has been shown to be a powerful tool for the investigation of the quasiparticle (QP) dynamics in the PG, FSC and SC gap states, and provided their bulk properties as complementary information to the well-established spectroscopy. In addition, high flexibility of modulating the spatio-temporal parameters of lightwaves in the UV-NIR region can provide various ways to resolve the features of QP dynamics associated with individual gap states, offering new and improved insights into the high-T_c superconductivity.

In this work, we will present several optical pump-probe studies of Bi-based high-T_c cuprates (Bi2212) by means of femtosecond optical pulses (UV-NIR pulses with 100 fs durations); polarization resolved spectroscopy for symmetry analysis, coherent quench spectroscopy for gap formation dynamics, and optical orbital angular momentum (OAM) resolved spectroscopy for phase coherence dynamics. In the standard pump-probe spectroscopy, the QP dynamics has revealed relaxation components associated with SC, PG, and electron-phonon relaxation through the continuum. The results of the hole-doping dependence, including the systematic variations of the gap energies, agreed well with those obtained from other spectroscopies. The polarization analysis of the dynamics has addressed the rotational symmetry breakings, which are suppressed at room temperature and appear below T^*, implying that the underlying rotational symmetry is spontaneously broken below T^* [1]. Under photodestruction conditions of the SC and PG states induced by an intense prepulse, we can investigate recovery dynamics of gaps (coherent quench spectroscopy) without the limitation of spatial inhomogeneity. The result of the PG recovery shows no critical behavior of coherent gap formation, indicating an absence of long-range order beyond a few coherence lengths [2]. The technique also allowed us to resolve the SC dynamics above T_c (FSC dynamics) with a critical slowing down of the relaxation, indicating that the pairing gap amplitude extends well beyond T_c [3]. On the other hand, the temperature dependence of the OAM dynamics shows virtually no pairing fluctuation above T_c. The result can be interpreted as a reduction of the phase coherence of the pairing because optical OAM appears only when the rotational momentum flow exists within the photoexcited volume. In another words, phase coherence of the pairing gap is suggested to be lost in the FSC. The observation of the OAM dynamics below T_c indicates that the photo-excitation with OAM enhances the SC with opposite chirality and/or suppress the SC with equal chirality although the details of such a photo-induced chiral symmetry breaking has not been clear yet [4].

*Email: toda@eng.hokudai.ac.jp

References

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