Symmetry breaking and Optical property of high-temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$

Kun Zhang[1], Masataka Matsumoto[2], Kenta Nakagawa[3,4], Azusa Matsuda[1], Genki Shiro[5], Toru Asahi[1,6,7]

[1]Department of Advanced Science and Engineering, Waseda University, Tokyo, Japan;
[2]Department of Mathematics, Shanghai University, Shanghai, China;
[3]Kanagawa Institute of Industrial Science and Technology (KISTEC), Ebina, Japan;
[4]Department of Applied Physics and Physico-Informatics, Keio University, Yokohama, Japan;
[5]Department of Biophysics, Kyoto University, Kyoto, Japan;
[6]Waseda Research Institute for Science and Engineering, Waseda University, Tokyo, Japan;
[7]Global Consolidated Research Institute for Science Wisdom, Waseda University, Tokyo, Japan;

zk19941123@ruri.waseda.jp

The pseudogap state in high transition temperature copper oxide superconductors shows many unusual magnetic, electrical phenomenon. A principal issue is to understand the origin of the pseudogap phase in the high transition temperature copper oxide superconductors[1]. An important controversial problem is whether the pseudogap phase is a crossover from the superconducting phase or a distinct phase. If it is the latter, the symmetry changing which cause of magnetic/electric order will be observed by phase transition. There are several evidences from angle-resolved photoemission spectroscopy (ARPES)[2] and polarized neutron diffraction[3] show that the time-reversal symmetry is broken at the pseudogap phase. However, X-ray optical activity (XOA)[4] showed not time-reversal symmetry but mirror symmetry broken.

Here we report the persuasive evidence of spatial-inverse symmetry and time-reversal symmetry broken by using our original machine, the generalized-high accuracy universal polarimeter(G-HAUP)[5,6]. G-HAUP enables us to measure the optical rotation (OR) and the circular dichroism (CD) in addition to the linear birefringence (LB) and the linear dichroism (LD), simultaneously. When the spatial inversion symmetry is broken, *reciprocal* OR and CD, *i.e.*, optical activity (OA) and natural CD (NCD), can be observed. On the other hand, when the time reversal symmetry is broken, *non-reciprocal* OR and CD, *i.e.*, Faraday rotation (FR) and Magnetic-CD (MCD), can be observed.

[1] Norman, M. R., Pines, D. & Kallin, C. Adv. Phys. 54, 715–733 (2005).

[2] A. Kaminski et al., Nature, 416, 610 (2002)

[3] S. De Almeida-Didry et al., Phys. Rev. B, 86, 020504 (2012)

[4] M. Kubota et al., J. Phys. Jap., 75, 053760 (2006)

[5] J. Kobayashi, T. Asahi, M. Sakurai, M. Takahashi, K. Okubo, Y. Enomoto, *Phys. Rev. B*, 1996, *53*, 11784-11795.

[6] M. Tanaka, N. Nakamura, H. Koshima, T. Asahi, *J. Phys. D: Appl. Phys.*, 2012, *45*, 175303-175310

Keywords: High Tc superconductor, chiral, symmetry, optics, phase transitions