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THz and Mid-Infrared Linear Dichroism in the High T_c Superconductor $La_{2-x}Sr_xCuO_4$

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***Abstract*—We measure the rotation of the linear polarization of light that is transmitted through a high T_c superconductor film as a function of sample orientation. We observe a linear dichroism signal over the entire probing range from 2 to 230 meV, which is consistent with anisotropic in-plane conductivity. The $La_{2-x}Sr_xCuO_4$ thin film sample is epitaxially constrained to be tetragonal, so the symmetry breaking is purely electronic.**

I. INTRODUCTION

Symmetry breaking in cuprate high Tc superconductors (HTS) has been predicted long ago [1, 2] and has been observed more recently in THz [3, 4], mid-infrared (MIR) [4] and near-infrared [5, 6] polarization-sensitive measurements. Symmetry breaking has also been observed in dc angle-resolved transverse resistivity measurements [7, 8]. Most of the measurements have observed a twofold rotational symmetry breaking that is consistent with anisotropic conductivity in the plane of the HTS film. The origin of this nematicity is still unresolved.

II. RESULTS

In this work we explore an underdoped $La_{2-x}Sr_xCuO_4$ (LSCO) film with a T_c of 12 K. The film was 26 nm thick (20 unit cells) and was grown by molecular beam epitaxy as described in Ref. [8]. The film was probed in the THz and MIR

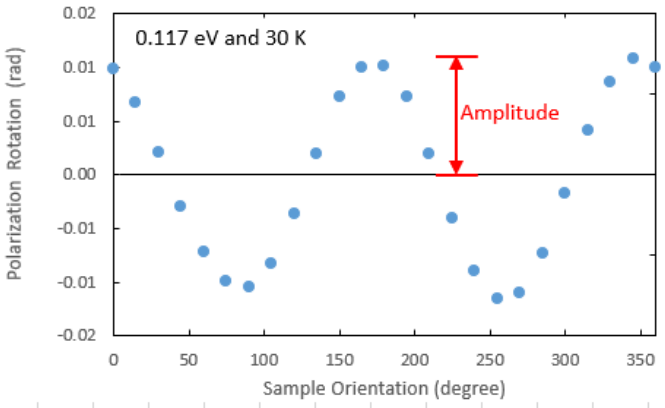

Fig. 1. Polarization rotation of transmitted light at 0.117 meV as the sample orientation is rotated at 30 K.

using techniques that are described in Ref. [4]. Figure 1 shows how the polarization of transmitted light with an energy of 0.117 eV (wavelength of 10.6 μm) is rotated as the sample orientation is changed at 30 K. This signal is consistent with linear dichroism (LD), where light polarized along one axis of the film is absorbed more strongly than light polarized in the perpendicular direction in the plane of the film. The amplitude of the LD signal is indicated by the red arrow. The LD signal decreases monotonically with increasing temperature but is still observable at room temperature. Figure 2 shows the frequency dependence of the LD signal amplitude. The LD signal amplitude strongly decreases with increasing probe energy up to 0.23 eV. This contrasts with our measurements on underdoped $YBa_2Cu_3O_{6+x}$ HTS films [4], where we observed a broad resonant enhancement of the LD signal near 0.1-0.6 eV.

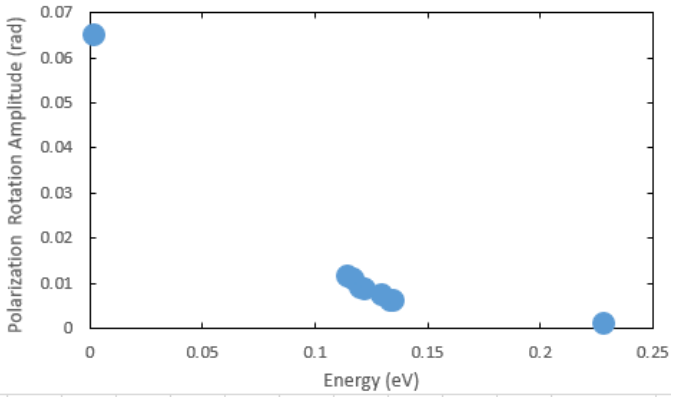

Fig. 2. Polarization rotation amplitude as a function of photon energy at 30 K.

III. SUMMARY

These are the first THz and MIR polarization-sensitive measurements in a tetragonal LSCO film. We observe a strong LD signal over the entire frequency range and up to room temperature. Future measurements that explore the doping, temperature, and frequency dependence of the LD signal will provide further insight into the mechanism responsible for this symmetry breaking.

REFERENCES

[1]. C. M. Varma, Non-fermi-liquid states and pairing instability of a general model of copper oxide metals, Phys. Rev. B **55**, 14554 (1997).
[2]. M. E. Simon and C. M. Varma, Detection and Implications of a Time-Reversal Breaking State in Underdoped Cuprates, Phys. Rev. Lett. **89**, 247003 (2002).
[3]. Y. Lubashevsky, L. Pan, T. Kirzhner, G. Koren, and N. P. Armitage, Optical Birefringence and Dichroism of Cuprate Superconductors in the THz Regime, Phys. Rev. Lett. **112**, 147001 (2014).
[4]. A. Mukherjee, J. Seo, M.M. Arik, H. Zhang, C. Zhang, T. Kirzhner, D.K. George, A.G. Markelz, N.P. Armitage, G. Koren, J.Y.T. Wei, and J. Cerne, "Linear dichroism infrared resonance in overdoped, underdoped, and optimally doped cuprate superconductors," Phys. Rev. B **102**, 054520 (2020).
[5] J. Xia, E. Schemm, G. Deutscher, S. Kivelson, D. Bonn, W. Hardy, R. Liang, W. Siemons, G. Koster, M. Fejer, and A. Kapitulnik, Polar Kerr-Effect Measurements of the High-Temperature $YBa_2Cu_3O_{6+x}$ Superconductor: Evidence for Broken Symmetry near the Pseudogap Temperature, Phys. Rev. Lett. **100**, 127002 (2008).
[6] L. Zhao, C. A. Belvin, R. Liang, D. A. Bonn,W. N. Hardy, N. P. Armitage, and D. Hsieh, A global inversion-symmetry-broken phase inside the pseudogap region of YBa2Cu3Oy, Nat. Phys. **13**, 250 (2017).
[7] J. Wu, A. Bollinger, X. He, and I. Božović, "Spontaneous breaking of rotational symmetry in copper oxide superconductors," Nature (London) **547**, 432 (2017).
[8] I. Božović, X. He, A.T. Bollinger and R. Caruso, "Is Nematicity in Cuprates Real?" Condensed Matter **8**, 7 (2023).