Linear Dichroism in high temperature superconductors in THz range

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Abstract—**We measure as a function of sample orientation, doping, temperature, and energy, the Faraday rotation of linearly polarized THz light by high temperature cuprate thin film superconductors. We observe a linear dichroism signal which increases with decreasing frequency and may exhibit resonances in the THz (1-6 meV) range.**

I. INTRODUCTION

Optical anisotropies are reflections of the broken symmetries of the system and can yield valuable information about underlying physics and electronic states [1-3]. Optical symmetry breaking has been observed in cuprate high temperature superconductors [4, 5] and has been associated with the enigmatic pseudogap "phase." Here we have measured polarization anisotropies for the cuprate high temperature superconductor $YBa_2Cu_3O_{7-x}$ (YBCO) in the THz (1-6 meV) frequency range as a function of doping and temperature. We have detected linear dichroism (LD) which increases with decreasing frequency, similar to that which was observed in Ref [6], and exhibits possible resonances predicted by Ref [7] .

II. EXPERIMENT

The YBCO thin films used in this study were grown epitaxially on $LaSrAlO_4$ (LSAO) substrates using pulsed laser-ablated deposition. LSAO is transparent in the THz range and has tetragonal crystal symmetry, which eliminates any LD signals from the substrate. Polarization rotations were measured using three wire grid polarizers (WGP) placed in a THz time-domain spectroscopy (TDS) setup, similar to Ref [8]. WGP1 acts as a clean-up polarizer for the plane polarized THz pulses generated from the photoconductive antenna (PCA). WGP2 is placed on a rotation mount which is switched between +45° and -45° w.r.t to WGP1. WGP3 is fixed at +45°. THz pulses were recorded for perpendicular and parallel positions of WGP2 w.r.t. WGP3. FFT of the two pulses give the perpendicular and parallel THz electric field as function of frequency, the ratio of the real part gives the Faraday rotation. Sample was fixed on a rotation stage and polarization rotations were measured as a function of the sample orientation.

III. RESULTS

The polarization rotation is sinusoidal as a function of the angle between incident linear polarization with respect to the sample orientation and shows a 180° periodicity (see inset of Fig. 2), which identifies the rotation as arising from linear polarization anisotropy. The amplitude of the LD signal was obtained by a least-squares fit of $\frac{\Delta\theta_F}{2} sin(2\phi + \varphi)$ to the Faraday signal vs. sample orientation angle ϕ. The strongest LD signals tended to be found in mid-under-doped samples. The films in Fig. 2 are labeled as underdoped (UD), optimally-doped (OPD), and over-doped (OVD) followed by their superconducting transition temperature. $\Delta\theta_F$ is plotted as a function of energy in Fig. 1. The LD signal increases strongly as frequency decreases from 6 to 1 meV. This may be an indication that the origin of the LD signal could be 1D conducting "stripe" or nematic structures [6] or some other mechanism causing the enhancement of the LD signal at THz frequencies (e.g., Ref. [7]).

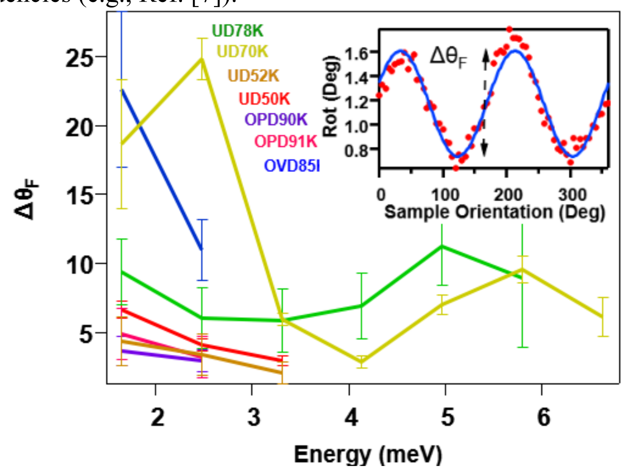

Fig. 1. $\Delta\theta_F$ plotted as a function of energy for a wide range of sample dopings at 300 K. Inset shows the Faraday rotation as a function of sample orientation for UD70K.

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