Comment on "Electronic Raman Scattering in High-T_c Superconductors: A Probe of $d_{x^2-y^2}$ Pairing"

Devereaux *et al.* [1] calculated electronic Raman scattering in a superconductor [2,3] for a gap function of $d_{x^2-y^2}$ symmetry. Strong anisotropies in the spectra of the superconducting gap excitations were predicted. "Quantitative agreement" with Raman data for Bi-2212 in B_{1g} and B_{2g} polarization configurations is claimed. Since the data are taken as evidence for $d_{x^2-y^2}$ pairing we point out flaws in [1] which invalidate its conclusions.

While the data presented for Bi-2212 in Figs. 2 and 3 of [1] agree with the calculation, no data for the A_{1g} component are presented. This is attributed in Ref. [13] of [1] to the impossibility of obtaining A_{1g} data from experiments involving a single polarization configuration. However, provided A_{1g} is large, its extraction from measurements for two polarization configurations is standard procedure of Raman spectroscopy. A_{1g} is large in literature data for Bi-2122 [4], Y-123 [5], and Tl-2223 [6]. In Fig. 1 we show that the A_{1g} spectrum of a single domain Y-123 crystal, obtained by us from the xx, yy, and $x'y'$ (i.e., x^2-y^2) polarization configurations is stronger than the B_{1g} and B_{2g} spectra. Its shape is the same as that of the measured xx and yy spectra.

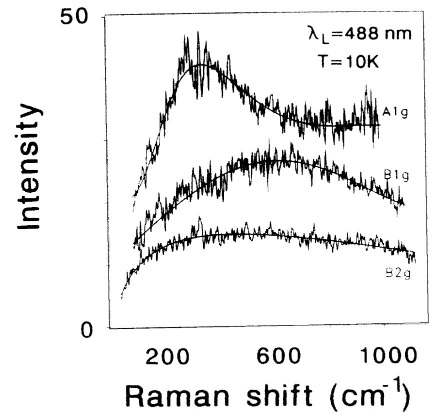

FIG. 1. A_{1g}, B_{1g}, and B_{2g} Raman response of a single domain Y-123 crystal determined from the xx, yy, and $x'y'$ (i.e., x^2-y^2) spectra displayed on the same scale. To compare with A_{1g} calculations of [1], which assume tetragonal symmetry, we have averaged xx and yy polarizations. This is not essential to our conclusions [9]. Phonons have been removed from the data.

Within the standard theory of scattering by normal carriers [7] in the range of Fig. 1 only unscreened scattering, related to mass fluctuations around and among the various sheets of the Fermi surface, should be observable well below the plasma frequency [8]. It has been shown [9] that the mass fluctuations obtained from the band structure [10] without resonance factors, account well for the normal state data in single domain Y-123. The A_{1g} mass fluctuations are actually several times larger than the average mass since the latter reverses sign around the Fermi surface (see Fig. 30 of [11]). Since the mass fluctuations also determine the γ of Eq. (4) of [1] we expect the A_{1g} scattering to be mostly unscreened while the curve in Fig. 1 of [1] corresponds to screened scattering.

The unscreened A_{1g} scattering, in particular that part due to fluctuations among various sheets of the Fermi surface, should have a maximum at $\omega = 2\Delta_0$, since it samples equally all values of $\Delta(\mathbf{k},T)$ which have a stationary point for $\Delta = \Delta_0$. This has been confirmed in Fig. 3 of [12] and contradicts the experiments of Fig. 1: A_{1g} peaks well below $2\Delta_0$ if, as required in [1], $2\Delta_0$ is given by the peak in B_{1g}. This results from the fact that the only spectrum which should peak well below $2\Delta_0$ is that for xy polarization, which has a well defined orthorhombic symmetry ($\neq A_g$) and samples the Fermi surface regions around zero gap.

Last, but not least, in Raman spectroscopy, like in many measurements which are not sensitive to the phase of the order parameter, there is no way to distinguish between $d_{x^2-y^2}$ and a strongly anisotropic s-wave gap (e.g., $|x^2-y^2|^2$).

In conclusion, the electronic scattering observed in high-T_c superconductors below T_c disagrees with the theoretical expectations based on $d_{x^2-y^2}$ pairing.

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