Dynamic fluctuations and static speckle in critical X-ray scattering from $SrTiO_3$

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Introduction

The antiferrodistortive (AFD) structural phase transition in $SrTiO_3$ results in a commensurate (2x2x2) superlattice at temperatures below ~105K and involves the frequency softening of a zone-boundary R_{25} phonon mode [1]. We report a detailed measurement of X-ray scattering from $SrTiO_3$ at the R point in reciprocal space over a wide temperature range above the phase transition, analyzing both the broad thermal diffuse scattering (TDS) component and the narrow central component of the critical scattering. Criticality of the phonon frequency softening was observed in agreement with modern theories of phase transitions, and the role of defect-pinned transition precursors in the central component was confirmed by the first-ever observation of static speckle in X-ray critical scattering from $SrTiO_3$.

Methods and Materials

The TDS experiment was performed at the undulator beamline of Sector 33 (UNICAT), and the coherent diffraction images were taken at Sector 8 (IMM/XOR CAT) at the Advanced Photon Source, Argonne National Laboratory.

Results and Discussion

The intensity of critical scattering from $SrTiO_3$ at the R-point as a function of temperature is shown in Fig. 1. These data were fit with a standard two-component line shape [2]. Constituent phonon frequency softening extracted from the broad TDS component is shown in Fig. 1(c), and the criticality of both components is shown in Fig. 2. The critical behavior of the broad component agrees with mean field predictions away from the transition, and agrees with renormalization group predictions within the Ginzburg interval of this system [3]. The criticality of the central component agrees with no available model and is sample dependent. When illuminated coherently

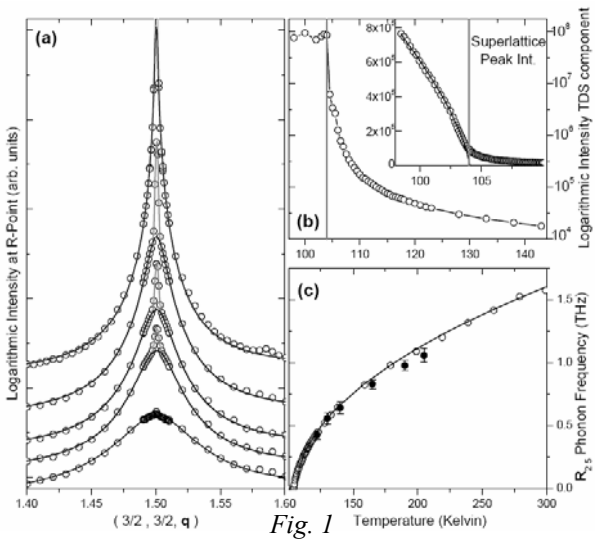

Fig. 1

FIGURE 1: Critical X-ray scattering from $SrTiO_3$ R-point

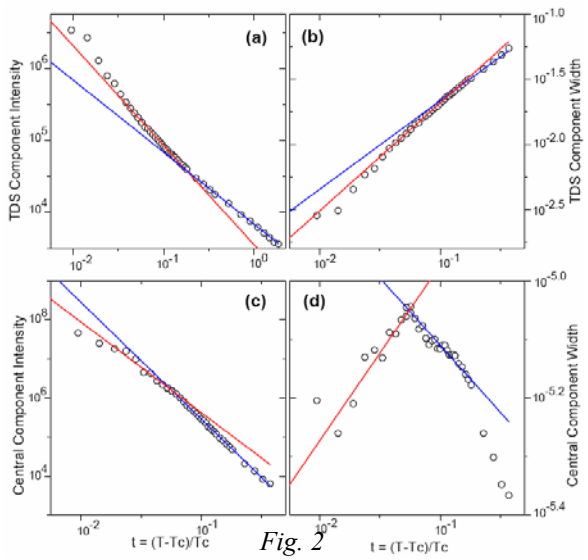

Fig. 2

FIGURE 2: Critical behavior of line shape components

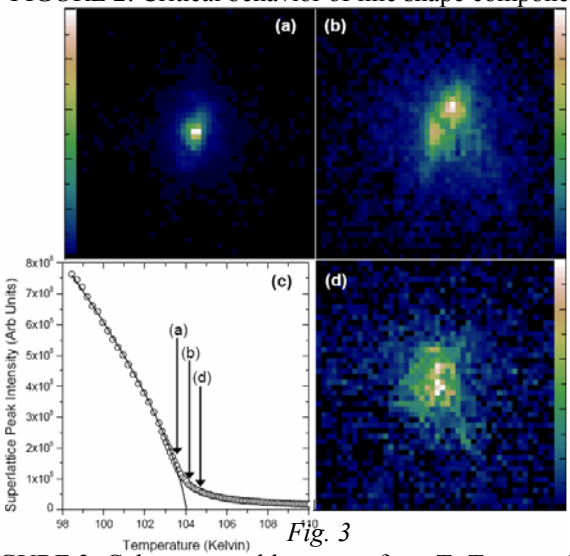

Fig. 3

FIGURE 3: Coherent speckle pattern from T>Tc central peak

the central component produces the static speckle patterns shown in Fig. 3. Phase contrast is observed immediately above Tc, and disappears abruptly at the bulk transition temperature. This indicates the anomalous central component is in fact due to a static distribution of low-T symmetric transition precursors, presumably accreting around defects above the phase transition.

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