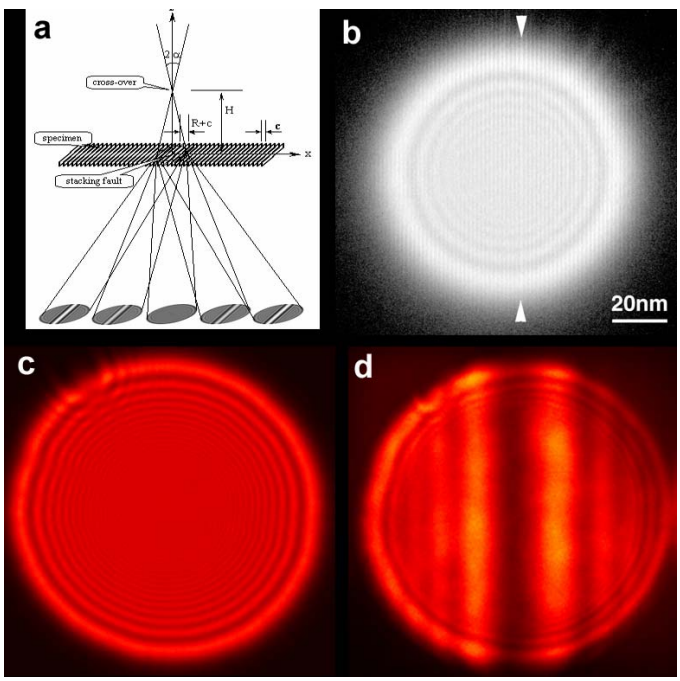
Picometer accuracy in measuring lattice displacements by coherent electron diffraction

The presence of defects strongly influences the properties of the high-temperature superconductors, in particular their current carrying capacities. Thus a major challenge we face is to identify the factors that limit the current density. Here, we report a novel technique, using a coherent electron beam, to measure stacking faults and grain boundaries to an accuracy of a trillionth of a meter (1 pm), ten times better than previous techniques. Taking advantage of the purity of a coherent electron beam, we detected the interference of electrons transmitted through large regions of crystal on each side of the defect. The technique may improve understanding of crystal interfaces and their relationship with material properties.

The displacements of the extrinsic and intrinsic faults for $Bi_2Sr_2CaCu_2O_8$ superconductor, are measured as: R=0.320 ± 0.002 nm and R=-0.319 ± 0.001 nm, respectively. At twist boundaries we observed rigid body translation normal to the boundaries as large as 0.03 ± 0.01 nm, and determined the displacement vector associated with the addition or subtraction of one bilayer of (CuO_2 + Ca) to be 0.320 ± 0.002 nm for the intrinsic and extrinsic layers in $Bi_2Sr_2CaCu_2O_8$, as well as for the intrinsic layer in $Bi_2Sr_2Ca_2Cu_3O_{10}$.



(a) Schematic of the experimental setup showing how the phase of the electrons that are scattered into a particular direction 2α changes for different paths from the crossover through the specimen. The vertical planes represent atom planes separated by a spacing c. H is the distance from the source or crossover to the specimen, R the horizontal displacement at the fault that is placed at the vertical mirror in the figure. (b) Lattice image of $Bi_2Sr_2CaCu_2O_8$ superconductor with a stacking-faults in the middle. (c) Coherent parallel recording of dark field images (PARODI) for crystal without defect. (d) Coherent PARODI for crystal with a stacking fault in the middle, showing interference fringes.

Lijun Wu, Yimei Zhu, D. O. Welch, and M. Suenaga (Brookhaven National Laboratory)
J. Tafto (University of Oslo, Norway)

Phys. Rev. Lett. **85**, 5126 (2000)
Phys. Rev. B **66**, 104517 (2002)