Scanned Josephson Tunneling Microscopy

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Davis's group recently introduced nanometer resolution Scanned Josephson Tunneling Microscopy (***SJTM***), a technique allowing Cooper-pair tunneling from a superconducting STM tip to image the electron-pair condensate of a superconductor. The ***SJTM*** operates at millikelvin temperatures and sequentially forms an array of 65,500 nanoscale Josephson junctions, whose Josephson critical current I_c is then measured to form the condensate image (***Nature*** 532, 343 (2016)). For the first time in superconductivity research, one can visualize the Cooper-pair condensate itself (Fig. 1A).

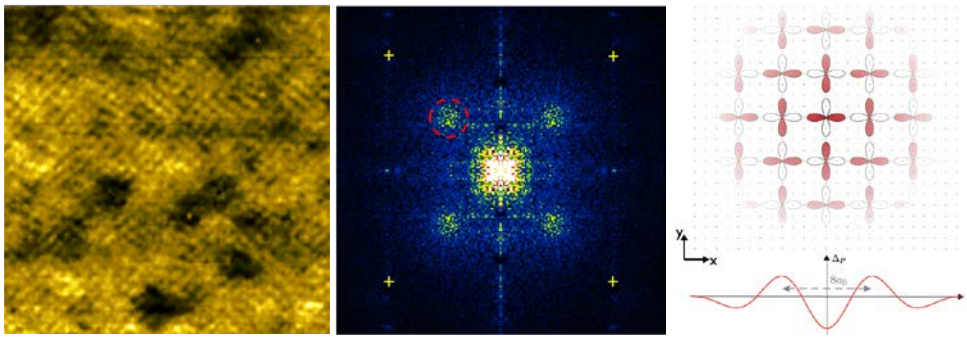

Fig. 1A Josephson critical current $I_c(r)$ images with atomic-resolution in 75nmX75nm FOV; B) Fourier transform of A shows the existence of PDW state; C) Schematic biaxial PDW.

SJTM is a very promising new approach to research into all kinds of heterogeneous superconductivity. For MPGSQM, our ***SJTM*** research will be in association with Bernhard Keimer and Andrew Mackenzie. Projects of immediate research focus include:

a) The pair density wave (PDW) state occurs when the density of Cooper-pairs modulates periodically in space at wavevector $\boldsymbol{Q_P}$. Only one instance has been detected (***Nature*** 532, 343 (2016)). Now we will search for new PDW states in several other classes of materials.
b) Other copper-based high temperature superconductors (CuHTS) materials, e.g. $YBa_2Cu_3O_7$ and La_2BaCuO_4, are also predicted to host a PDW state. We plan to develop new ***SJTM*** techniques to search for and study PDWs in these materials.
c) In CuHTS, a magnetic-field induced density wave phase appears at highest magnetic fields. Although generally referred to as a CDW, theory indicates that this could actually be a PDW state. Because this field-induced DW state is accessible in the "halo" surrounding quantized vortex cores (***Science 295***, 466 (2002)), we now plan to image this "halo" DW using ***SJTM*** to determine directly if it is a PDW.
d) The XRAY-scattering signature of a PDW has recently been predicted but has never been detected experimentally. In this project, we plan to study the same CuHTS crystal (e.g. $Bi_2Sr_2CaCu_2O_8$ or $YBa_2Cu_3O_7$ or La_2BaCuO_4) by SJTM and by XRAY techniques, to search for the XRAY-scattering signature that is definitely from a PDW. If detected, we will compare the physics information of the combined SJTM/XRAY results to improve understand of how a PDW generates a secondary charge density wave (CDW) state.