Revisiting the electronic and structural properties of heavily underdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ high T_c cuprate superconductor by STM/STS

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Decades after the discovery of high T_c superconductors, there is still some scope to delve deeper into the physics of many poorly understood phenomena such as the pairing mechanism, pseudogap, ordered electronic phases, vortices, and quasiparticle interference present in these compounds. Here, we revisit some of these features in highly underdoped single crystals ($T_c \approx 50$ K) of $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) by STM/STS following recent findings in heavily overdoped specimen [1]. STM offers immense spatial and energy resolution for resolving structural and electronic features down to the atomic scale in real space.

The goal of our present work is to understand the ordered phases and the vortex core structures in Bi2212 in the heavily underdoped region. *Recent findings from low field vortex imaging studies in overdoped samples has revealed a d-wave electronic core structure with a zero-bias conductance peak at the vortex center which splits upon moving away from the core center* [1, 2]. These observations are clearly in contrast with vortex signatures at high fields where low energy checkerboard charge order is observed inside a vortex core and the zero-bias peak is absent. However, underdoped Bi2212 is known to be challenging for STM experiments due to strong local inhomogeneities and pseudogap related features. In our data, we observe some of the recently reported features such as the crystal stripe phase [3], and other well-known features like periodic $\approx 4a_0 \times 4a_0$ and $\approx (3/4)a_0 \times (3/4)a_0$ electronic modulations, where a_0 is the crystallographic unit cell. The major focus of our work is to study the intrinsic vortex core electronic structure and ordered phases at low fields in underdoped Bi2212 and possibly detect the pair density waves around the cores in real space from topographic imaging at very low energies close to the superconducting gap.

[1] Tim Gazdic et al. *arXiv:2103.05994 (2021)*, (To be published in PRX).
[2] Tim Gazdic. *Real Space Periodic Electron Density Modulations and Vortex Core Spectroscopy in Heavily Overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$*. PhD Thesis 2020.
[3] Zhao et al. *Nature Mater 18, 103—107 (2019)*.