Spin Coherence in the vortex core of $HgBa_2CuO_{4+\delta}$ as measured in the MagLab's 32T Superconducting Magnet

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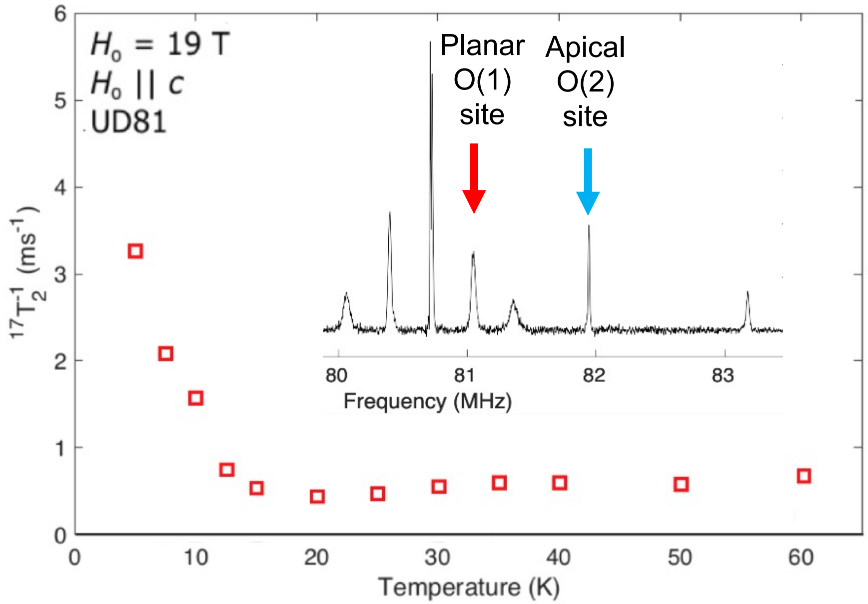
Funding Grants: G.S. Boebinger (NSF DMR-1644779); W.P. Halperin (DOE DE-FG02-05ER46248)

Achieving quantum phase coherence in devices and materials is a key aspect of the technology of quantum information processing which underlies progress toward a quantum computer. A paradigm for this coherence is achieved with nuclear spin systems using nuclear magnetic resonance (NMR). *Applications of coherent nuclear spin states are at the very heart of chemical, physical, and biological analysis of materials*. This experiment identifies an important milestone in the application of NMR spin coherence at high magnetic fields.

NMR resolution improves dramatically with increasing magnetic field; however, achieving spin coherence restricts most experiments to superconducting magnets. *The 32T all superconducting magnet recently developed at the MagLab increases the potential for realizing the improved spectral resolution afforded by high magnetic fields, while maintaining spin coherence*. Here, MagLab users show the first demonstration of an NMR spin coherence experiment in this magnet. [1]

The application involves ^{17}O NMR in a single crystal of the cuprate superconductor, $HgBa_2CuO_{4+\delta}$. The multi-pulse experiment records a spin coherence time, T_2. *The data discover spin dynamics in the vortices of magnetic flux in this superconducting compound that are most likely associated with the electronic bound states in the vortex cores*. [1]



The underdoped cuprate crystal has a superconducting transition at 81K. The exponential spin-spin relaxation rate is shown in the figure above. The data suggest that the vortices freeze from their liquid state near 15K. The inset shows first quadrupolar satellite spectra for both planar O(1) and apical O(2) oxygen sites. The data T_2^{-1}, is the decoherence rate for the O(1). The line width of O(2) is temperature and magnetic field independent up to H = 30T, showing that the vortices do not form a lattice detectable by NMR linewidth down to 5K. However, the increase in the relaxation rate at low temperatures signals a new type of spin dynamic state.

Facilities and instrumentation used: DC Field Facility, 32T superconducting magnet and condensed matter NMR group.

[1] I. Stolt, PhD thesis Northwestern University, 2021