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Ultra-compact scanning tunneling microscope enables study of superconducting materials in high magnetic fields

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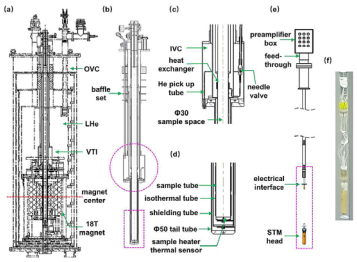
Instrument can capture atomic-level images of materials in magnetic fields up to 20 T and at sub 2K temperatures.



Scanning tunneling microscopy and spectroscopy are techniques for visualizing material structures at the atomic scale. The measurements taken by these methods can be used to learn more about emergent quantum properties of condensed matter, such as superconductivity, that require low temperatures and high magnetic fields. However, fitting an atomic-resolution scanning tunneling microscope (STM) inside a powerful — but small — magnet is difficult.

Zhang et al. developed an ultra-compact STM that can operate inside a 20 T superconducting magnet. Their microscope was made to fit inside a 10 mm diameter piezo tube nested within a 30 mm interior of the magnet.

In addition to the cramped conditions, the two other challenges to designing STMs inside powerful magnets include high-field compatibility and minimizing vibrations.

“The carefully cut outer piezo tube is responsible for the STM’s coarse positioning, overcoming the space restriction,” said author Qingyou Lu. “Sapphire is utilized for the mechanical structure of the STM, taking advantage of its high hardness and non-metallic nature to enhance high-field compatibility. Moreover, the small size leads to a higher resonant frequency, which means better vibration resistivity.”

In tests, the team’s STM captured atomic-scale images of highly oriented pyrolytic graphite in a 17 T magnetic field and resolved superconducting energy gaps of type-II superconductors $NbSe_2$ and $PdBi_2$ at temperatures below 2K.

Having demonstrated the capabilities of their microscope, the team plans to employ it to study superconducting materials within even more powerful magnetic fields.

“We are going to perform STM/S measurements on intriguing unconventional superconductors in world-class high-field facilities where the field can achieve 45.22 T,” said Lu.

Source: “An ultracompact scanning tunneling microscope within a Φ 10 piezo tube in a 20 T superconducting magnet,” by Min Zhang, Jihao Wang, Wenjie Meng, Jing Zhang, Qiyuan Feng, Ze Wang, Yalin Lu, Yubin Hou, and Qingyou Lu, *Review of Scientific Instruments* (2024). The article can be accessed at https://doi.org/10.1063/5.0191662.

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