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# RPPR Final Report

## as of 23-Mar-2023

Agency Code: 21XD

Proposal Number: 73945EMRIP

Agreement Number: W911NF-19-1-0390

### INVESTIGATOR(S):

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**Report Date:** 23-Sep-2022

Date Received: 23-Mar-2023

**Final Report** for Period Beginning 24-Jun-2019 and Ending 23-Jun-2022

**Title:** Ultra-low temperature magnetic imaging of topological quantum phenomena

**Begin Performance Period:** 24-Jun-2019

**End Performance Period:** 23-Jun-2022

**Report Term:** 0-Other

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**Distribution Statement:** 1-Approved for public release; distribution is unlimited.

**STEM Degrees:** 0

**STEM Participants:**

**Major Goals:** The objective of this DURIP proposal is to develop an ultra-low temperature magnetic force microscope (ULT-MFM) with high magnetic field (14 T) for visualizing topological or emergent quantum phenomena in condensed matter physics. The proposed microscope will allow exploration of various intriguing topological quantum phenomena such as dissipationless chiral edge states in quantum anomalous Hall (QAH) systems and devices, unconventional vortices in topological superconductors (TSC), and emergent non-collinear magnetism at oxide interfaces or heterostructures.

**Accomplishments:** The PI purchased a close-cycle helium-3 refrigerator with 14 T superconducting magnet. A dedicate lab with a pit was prepared for housing the cryogenic system with the microscope. Due to the disruption of in-person research and supply chain issue, the progress of design and construction of the microscope has been delayed. The PI and his student managed to finished the design of microscope. All necessary components and raw materials have been purchased. The most parts are made in the departmental machine shop. The student is assembling and testing performance of various modulus of the microscope. See attached figure for the design drawing and testing results of xy-walker. The PI expect fully assemble of the microscope in summer of 2023. Low temperature test and commission of the microscope are expected in the fall of 2023.

**Training Opportunities:** A Ph.D. student was trained to design and assemble the helium-3 MFM. The training of graduate students for future generation of materials scientists is a key component of this instrumentation proposal.

**Results Dissemination:** The results of our research efforts will be disseminated to the community via the usual channels of peer-reviewed journal articles and oral/poster presentations at scientific conferences and workshops. In addition, we will post pre-prints of unpublished work on online arXiv server.

**Honors and Awards:** Nothing to Report

**Protocol Activity Status:**

**Technology Transfer:** Nothing to Report

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as of 23-Mar-2023

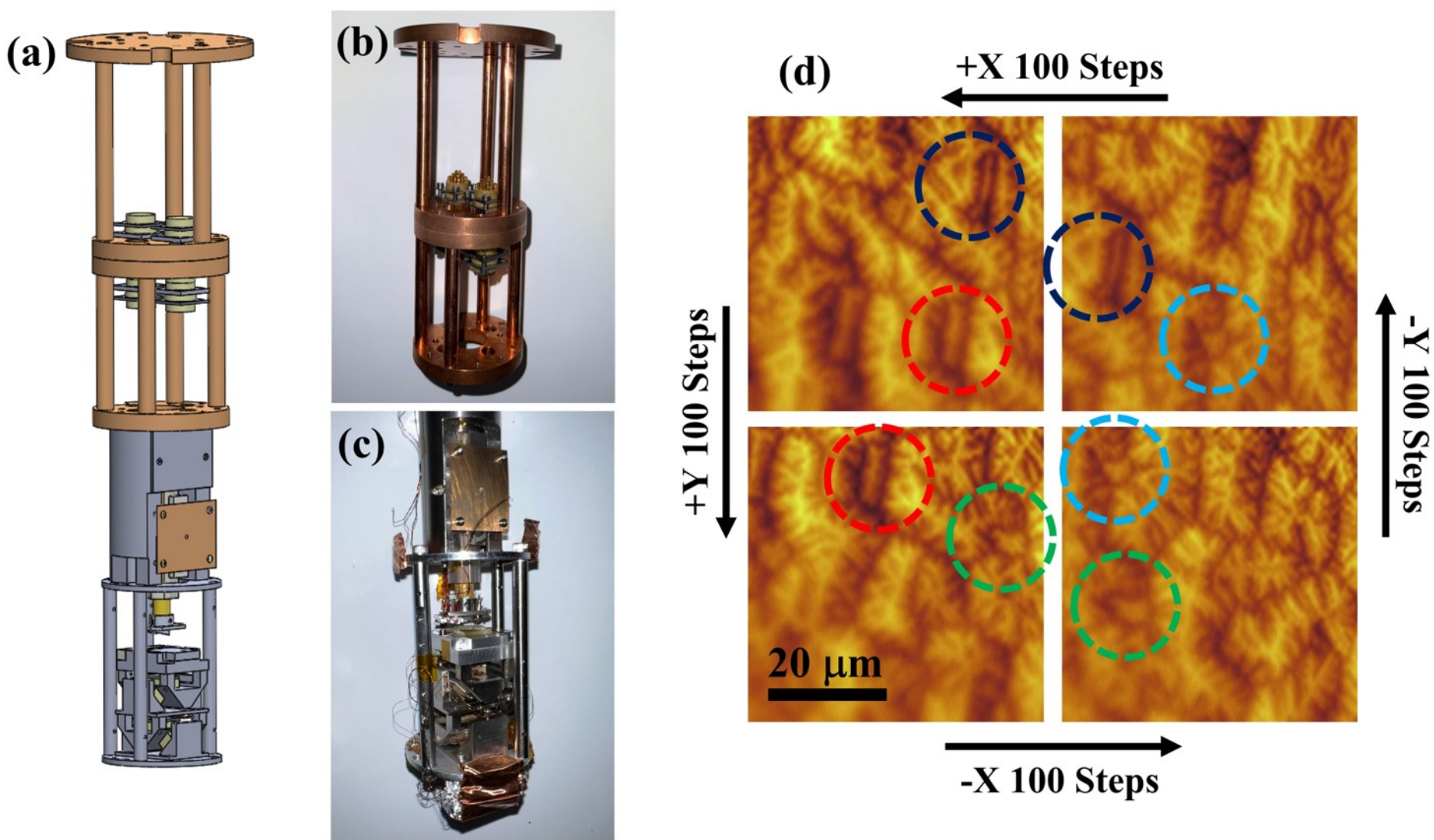
**Partners**

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I certify that the information in the report is complete and accurate:

Signature: Weida Wu

Signature Date: 3/23/23 10:58AM



**Figure. He3 MFM system** (a) A 3D CAD drawing of the He3 MFM system (b) A photo of assembled OFHC parts connecting from the He3 pot to MFM head. (c) A photo of assembled XY walkers on a test probe. (d) MFM images of the XY-walker test results on  $\text{Fe}_3\text{Sn}_2$  at 120 K. The dash circles of the same colors indicate the same locations on the surface.