Plan Overview

A Data Management Plan created using DMPonline

Title: Using Quantum Material Josephson Junctions to explore Non-reciprocal Superconductivity

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Funder: Netherlands Organisation for Scientific Research (NWO)

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Project abstract:

Nonreciprocal electron conduction, fundamentally arising from broken symmetries and nonlinear responses, is an important phenomenon that is integral to modern technological applications. Integrated circuit technology, for example, takes advantage of nonreciprocity in the current-voltage response in semiconductor junctions, enabling semiconductor diodes, transistors, and other circuit elements. However, nonreciprocal superconductivity, where superconducting pairs of electrons have a directional response to applied voltage, has long been sought after for use in superconducting electronics. Being able to create and manipulate nonreciprocal superconducting current is a significant fundamental challenge and success may lead to breakthroughs enabling superconducting circuits in analogy to semiconducting ones, but with the added benefit of low power consumption and high speed operation.

Recently, my group realized the superconducting analog to the semiconductor diode, using a quantum material Josephson junction (QMJJ). In QMJJs, two superconductors are coupled via a non-superconducting quantum material barrier, materials where quantum effects manifest non-classical properties. Many of these materials contain tunable, symmetry breaking perturbations that, when integrated into Josephson junctions, provide controllable knobs for modulating superconductivity across the junction in new ways, including introducing nonreciprocity. Following initial experiments, several recent theories propose possible mechanisms for realizing non-reciprocal superconductivity in QMJJs using differing classes of materials, but a complete understanding remains elusive due to a paucity of experiments.

This project’s goal is to create, understand, and control nonreciprocal superconductivity using layered quantum materials, with specific symmetry breaking perturbations, in QMJJs with layered superconductors, focusing specifically on two proposed classes of QM (ferroelectrics and obstructed atomic insulators). We will explore how their particular symmetry breaking and intrinsic properties fundamentally affect superconductivity in the junction, how that is modulated by external fields, and how it can be controlled. This project straddles fundamental physics, material science, and device engineering, in an interdisciplinary effort with potential to impact next generation technologies.

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Using Quantum Material Josephson Junctions to explore Non-reciprocal Superconductivity

General Information

Name applicant and project number

Name: Mazhar N. Ali
Project Number: VI.Vidi.223.089

Name of data management support staff consulted during the preparation of this plan and date of consultation.

Name: Esther Plomp

1. What data will be collected or produced, and what existing data will be re-used?

1.1 Will you re-use existing data for this research?

If yes: explain which existing data you will re-use and under which terms of use.

- Yes

Yes, we will re-use existing data from the student Houssam El Mrabet Haje's Master's work with no constraints regarding said re-use.

1.2 If new data will be produced: describe the data you expect your research will generate and the format and volumes to be collected or produced.

Whenever possible, we will use file formats suitable for long-term preservation and re-use of research data. In our choices, we will adhere to the guidance provided by 4TU.ResearchData. The table below provides an overview of the types of data which will be collected and the associated file formats.

Type of data	Format
Quantitative measurement results	.csv format
Qualitative image data	.png/jpg/gif format
Metadata	.txt format

1.3. How much data storage will your project require in total?

- 100 – 1000 GB

2. What metadata and documentation will accompany the data?

2.1 Indicate what documentation will accompany the data.

All datasets will be accompanied by NOTE files providing the documentation necessary for data re-use data. Guidance provided by 4TU.ResearchData will be followed when preparing the NOTE files.

2.2 Indicate which metadata will be provided to help others identify and discover the data.

All data supporting publications will be made openly available through 4TU.ResearchData. 4TU.ResearchData is a trusted and certified research data repository (it has a Data Seal of Approval certification). All datasets will be accompanied by rich metadata (adhering to DataCite metadata standard) to ensure that they are findable. In addition, to further aid their discoverability, keywords describing the datasets will be added. 4TU.ResearchData is also using schema.org metadata, meaning that all datasets are indexed in Google Dataset Search. Every dataset will be also assigned a Digital Object Identifier (DOI), to make them citable and persistently available.

3. How will data and metadata be stored and backed up during the research?

3.1 Describe where the data and metadata will be stored and backed up during the project.

- Institution networked research storage

During the course of the research project, all data will be stored on local servers (Project Drive) maintained and automatically backed up by TU Delft ICT as well as locally on the instrument computers. Data can be recovered with the help of TU Delft ICT services in the event of an incident.
All code will be maintained in a dedicated GitLab version control system provided by TU Delft, which similarly to Project Drive, is backed up and maintained by TU Delft.

3.2 How will data security and protection of sensitive data be taken care of during the research?

- Not applicable (no sensitive data)

4. How will you handle issues regarding the processing of personal information and intellectual property rights and ownership?

4.1 Will you process and/or store personal data during your project?

If yes, how will compliance with legislation and (institutional) regulation on personal data be ensured?

- No

4.2 How will ownership of the data and intellectual property rights to the data be managed?

The datasets underlying the published papers will be publicly released following NWO's policies. During the active phase of research, the lead applicant from TU Delft will oversee the access rights to data (and other outputs), as well as any requests for access from external parties. They will be released publicly no later than at the time of publication of corresponding research papers.

5. How and when will data be shared and preserved for the long term?

5.1 How will data be selected for long-term preservation?

- All data resulting from the project will be preserved for at least 10 years

All data supporting publications will be made openly available through 4TU.ResearchData. 4TU.ResearchData is a trusted and certified research data repository (it has a Data Seal of Approval certification), and ensures that research data will be preserved for at least 15 years.

5.2 Are there any (legal, IP, privacy related, security related) reasons to restrict access to the data once made publicly available, to limit which data will be made publicly available, or to not make part of the data publicly available?

If yes, please explain.

- No

5.3 What data will be made available for re-use?

- All data resulting from the project will be made available

All raw data will be retained for at least ten years on TU Delft servers for the purposes of validation. The datasets underlying the figures and conclusions in academic papers will be made publicly available through 4TU.ResearchData, in line with the TU Delft Research Data Framework Policy.

5.4 When will the data be available for re-use, and for how long will the data be available?

- Data available as soon as article is published

All research data underpinning research papers will be made publicly available by depositing at 4TU.ResearchData no later than at the time of the publication of the corresponding research article.

5.5 In which repository will the data be archived and made available for re-use, and under which license?

The datasets underlying the published papers will be published at 4TU.ResearchData, which is a trusted and certified research data repository (Data Seal of Approval certification). All datasets will be licensed under a CC-BY licence which requires attribution/credit for the original creation, while at the same time ensures broadest possible re-use. All datasets will be accompanied by rich and descriptive metadata, compliant with DataCite metadata schema, to ensure that all datasets are findable and accessible online. https://data.4tu.nl/info/en/

5.6 Describe your strategy for publishing the analysis software that will be generated in this project.

The developed software and codes presented in academic papers will be shared on GitHub and those GitHub repositories will be published via 4TU.ResearchData. This way, they will be publicly available to anyone for re-use under an open licence. They will be also assigned a Digital Object Identifier (DOI), to make them citable and persistently available.

6. Data management costs

6.1 What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

4TU.ResearchData is able to archive 1TB of data per researcher per year free of charge for all TU Delft researchers. We do not expect to exceed this and therefore there are no additional costs of long term preservation.
The dedicated data managers in the project (see project contributers) will be responsible for data management in the project.