# Yu HE

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## Research Interests

Magnetism and superconductivity are two inherently exclusive order parameters in nature; however, at the nanoscale, they are anticipated to coexist and interact synergistically. My research focuses on investigating novel spin-related transport properties at two-dimensional magnetic/superconducting nanointerfaces through thin film material growth and nanofabrication. This includes the generation, injection, and detection of supercurrent without energy dissipation, as well as the magnetic modulation of the superconducting phase. In particular, I try to develop innovative spin-related low-temperature storage devices, such as superconducting magnetic tunnel junctions and magnetic Josephson junctions, hoping to further drive the evolution of traditional spintronic devices toward extremely low power consumption (aJ/bit).

## Education

**Beihang University** *Beijing, China*

PhD student in Electronic Science and Technology *Sept 2023 - Current*

- **Supervisors: A.P. Guang Yang**
- **Courses:** Introduction to Low Temperature Storage and Quantum Computing

**Beihang University** *Beijing, China*

M.E. in Electronic Science and Technology *Sept 2021 - Sept 2023*

- **Supervisors: Prof. Haiming Yu** and A.P. Guang Yang
- **Courses:** Matrix Theory, Introduction to Solid State Physics, Modern Semiconductor Device Physics, Theory of Magnetism, Magnetic Property Measurement Technologies, Introduction To Micro-Nano Fabrication Technology, Spin Dynamics(**Jean-Philippe Ansermet, EPFL**)

**Northwestern Polytechnical University** *Xi'an, China*

B.E. in Electronics and Information Engineering *Sept 2017 - July 2021*

- **Supervisors: Prof. Ping Kwan Johnny Wong**
- Won the Outstanding Student Scholarship of the School of Electronics and Information of Northwestern Polytechnical University in 2019-2020 academic year

## Research Projects

**Emergent Nonlinear Effects in 2D Superconducting Spintronics: From Symmetry Breaking to Functional Transport** *Beijing, China*

Leading project affiliated at Beihang University *April 2025 - Ongoing*

- **Project Description**: This project investigates nonlinear transport phenomena in two-dimensional superconducting spintronic heterostructures, focusing on the profound impact of symmetry breaking on emergent functionalities. We achieve this by integrating superconducting $NbSe_2$ with layered magnetic semiconductors (FGaT, FGeT), spin-orbit-coupled materials ($WS_2$, graphene), etc. The core objective is to reveal how the breakdown of time-reversal, spatial-inversion, and crystalline symmetries leads to novel effects like nonreciprocal charge transport and diode-like behavior. Our work seeks to establish a unifying symmetry-based framework that connects these fundamental transport signatures to the heterostructure's intrinsic properties. This research is set to advance nonlinear transport knowledge and accelerate the development of next-generation superconducting spintronic devices offering field-free and geometry-tunable control.
- **My Tasks**: The early phase of this project will focus on learning and exploring the exfoliation and transfer techniques of two-dimensional superconducting and magnetic materials, aiming to characterize low-dimensional superconductivity and the transport properties of corresponding heterostructures. In parallel, a comprehensive review of existing theoretical and experimental studies on the impact of symmetry-breaking mechanisms on transport phenomena will be conducted to identify potential directions for breakthrough research.
- **Supervisor: A.P. Guang Yang**. and A.P. Haozhe Yang

**Quantitative Study of Geometry-Dependent Superconducting Diode Effect in Nb Nanowires** *Beijing, China*

Leading project affiliated at Beihang University *June 2024 - March 2025*

- **Project Description**: This project focused on investigating the nonreciprocal transport phenomenon in asymmetric structured Nb nanowires. Unlike conventional s-wave bulk superconductors, these constricted nanowires can function in a nonreciprocal manner under a perpendicular magnetic field, with the superconducting-to-normal metallic phase transition depending on the polarity of the bias current. Our research aimed to characterize the superconducting diode effect (SDE) through second harmonic measurements. Additionally, by designing experiments and proposing phenomenological interpretation, we have quantitatively analyzed the impact of asymmetric geometric constraints on SDE effects and explore potential underlying physical mechanisms.
- **My Tasks**: Based on existing published work, I derived a theory of nonlinear resistance for harmonic measurements. For device fabrication, a Nb layer was deposited onto $SiO_2$ ( 300 nm)/Si substrates using DC magnetron sputtering. Electron-beam lithography was then employed to pattern Hall bar devices, incorporating asymmetric structures with various geometric extensions along the current channel. Cryogenic measurements were performed using a Physical Properties Measurement System (ColdTUBE from MultiFields Technology), along with external Keithley 6221 and Keithley 2182 instruments for DC measurements, and an SR830 for AC measurements. This project has now been completed, and its results have been published in Advanced Functional Materials. Meanwhile, a parallel project on the field-free superconducting diode effect based on geometric extensions has also been concluded, and the related manuscript is currently being prepared for publication.
- **Supervisor: A.P. Guang Yang** and A.P. Le Wang.

**Novel Magnetoresistance in EuS/Au/EuS Switches: From Localisation to Spin Scattering Crossover** *Beijing, China*

Collaboration project with University of Cambridge *May 2023 - Aug 2023*

- **Project Description**: This project investigates the emergence of novel magnetoresistance phenomena in EuS/Au/EuS spin-switch structures, focusing on the transition from localization to spin scattering regimes. By varying the Au spacer thickness, we observe a crossover from quantum localization to giant magnetoresistance (GMR) driven by spin-dependent scattering. Additionally, the enhanced spin Hall magnetoresistance (SMR) further underscores the role of spin-dependent transport. Through detailed analysis of electrical transport in these heterostructures, where over 99% of current flows through the central Au interlayer, we demonstrate that the thickness of the Au spacer directly influences the system's crossover from localization to GMR. The research opens pathways to leveraging interfacial magnetic exchange fields for novel magnetoresistance effects, with significant implications for spintronic applications.
- **My Tasks**: In this project, I collaborated with Dr. Hisakazu Matsuki from Prof. Jason Robinson's group to conduct cryogenic measurements of angular-dependent magnetoresistance (ADMR) and Hall measurements on EuS/Au/EuS structures provided by Dr. Matsuki. After a series of discussions and a thorough literature review, particularly focusing on the work by Juan M. Gomez-Perez et al. in Nano Letters (2020), we demonstrated that the uniquely large $G_i$ at the EuS/Au interfaces significantly modifies electronic transport, allowing for a crossover to GMR as the thickness of the Au layer increases. In addition to the cryogenic measurements, I took the lead in enhancing the measurement system, which involved developing LabVIEW programs to automate the process, resulting in high efficiency in data collection. This collaborative work had deepened my understanding of low-temperature transport measurements while gaining insights into the theory of low-temperature transport in magnetic superconducting material systems through relevant literature research.
- **Supervisor: A.P. Guang Yang** and Prof. Jason W. A. Robinson; cooperated with Dr. Hisakazu Matsuki.

**Molecular Regulation of Two-dimensional Ferromagnetic Crystals** *Xi'an, China*

Leading project affiliated at Northwestern Polytechnical University *Oct 2020 - June 2021*

- Funded by the Natural Science Foundation of Chongqing (General Program)
- **Project Description**: This project aimed to study the structure, electronic states, and magnetism of organic/two-dimensional material systems, in order to obtain their basic characteristics and regulate their interface design schemes. Part of the research had been incorporated into my undergraduate thesis
- **My Tasks**: As a graduation thesis research project for undergraduate students under the funding framework of the Natural Science Foundation of Chongqing (General Program), A first-principles study of the structural, electronic and magnetic properties of the pristine bulk CoRhCrAl quaternary Heusler alloy and its (111), (001) and (110)-oriented thin films were performed by using VASP based on the density functional theory.
- **Supervisor: Prof. Ping Kwan Johnny Wong** and Prof. Wen Zhang; under the direct guidance of Dr. Iltaf Muhammad.

# Skills

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| **Programming** | Python, Matlab, LabView. |
| **Laboratory skills** | Thin Film Deposition, Nano-fabrication, Vacuum Technology, Material Characterization, Cryogenic Transport Measurement, Exfoliation and Flake Transfer |
| **Miscellaneous** | Linux, Shell (Bash/Zsh), LaTeX(Overleaf/VS Code), Data Analysis. |

# Publications

## Journal Articles


Geometric Asymmetry-Enhanced Nonreciprocal Supercurrent Transport Revealed by Second-Harmonic Response
Yu He, Zifeng Wang, Jiaxu Li, Fenglin Zhong, Haozhe Yang, Kewen Shi, Le Wang, Guang Yang, Weisheng Zhao
*Advanced Functional Materials* (Apr. 2025)

Novel magnetoresistance in EuS/Au/EuS sandwich structures: from localisation to spin scattering crossover
Hisakazu Matsuki, Guang Yang, Vitaly Golovach, Jiahui Xu, Yu He, Jiaxu Li, Alberto Hijano, Niladri Banerjee, Nadia Stelmashenko, F. Sebastian Bergeret, Jason W.A. Robinson

*In preparation for submission* (2024)

Spin-Related Superconducting Devices for Logic and Memory Applications
Yu He, Jiaxu Li, Qiusha Wang, Hisakazu Matsuki, Guang Yang
*ADVANCED DEVICES & INSTRUMENTATION* (Dec. 2023)

First-principles prediction of the half-metallicity in quaternary Heusler CoRhCrAl thin films
Iltaf Muhammad, Yu He, Anwar Ali, Wen Zhang, Ping Kwan Johnny Wong
*Physica Scripta* (June 2022)

### Conference Proceedings

Yu He, Iltaf Muhammad, Wen Zhang, Ping Kwan Johnny Wong. *First-principles Prediction of the Half-metallicity in Quaternary Heusler CoRhCrAl Thin Films*. The 2021 Around-the-Clock Around-the-Globe Magnetics Conference. 2021.

## Languages

**English** Professional proficiency
**Chinese** Native proficiency