

# Yun-Yi Pai

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**PRINCIPAL INTERESTS** Quantum Enhanced Sensing; Quantum Optical Sensing; Quantum Transport; Low Temperature Scanning Probe Microscopy; Low Temperature Optical Probe Microscopy and Spectroscopy

**ACADEMIC BACKGROUND** *Ph.D. in Physics* April 2020  
**University of Pittsburgh**, Pittsburgh, PA  
• Thesis: “Superconductivity of Strontium Titanate in Reduced Dimensions”  
• Supervisor: **Jeremy Levy**

*Master of Science in Applied Physics* May 2014  
**Cornell University** Ithaca, NY  
• Thesis: “Investigation and Perturbation of the Optical Properties of the Single Defects in Zinc Oxide”  
• Supervisor: **Gregory David Fuchs**

**EMPLOYMENT HISTORY** *Postdoctoral Research Associate* April 2020 - Present  
**Oak Ridge National Laboratory**, Oak Ridge, TN  
• Optically probe quantum materials at milli-Kelvins  
• Quantum transport of mesoscale devices  
• Hybrid quantum sensor development  
• Supervisor: **Benjamin J. Lawrie**

*Internship* Sep. 2019 - Mar. 2020  
**Oak Ridge National Laboratory**, Oak Ridge, TN  
• MilliKelvin optical characterization of SrTiO<sub>3</sub>  
• Supervisor: **Benjamin J. Lawrie** and **Ho-Nyung Lee**

*Internship* July. 2019 - Dec. 2019  
**Pennsylvania State University**, State College, PA  
• Modeled the ferroelastic morphology of SrTiO<sub>3</sub>, the interplay between charge, polar and octatilt degrees of freedom, using phase-field method with High-Performance Computing (HPC) system  
• Supervisor: **Long-Qing Chen**

**SPECIAL ACHIEVEMENTS** *Awards*  
• *Dean’s Tuition Scholarship*, Spring 2020  
• *Kenneth P. Dietrich School of Arts & Sciences Predoctoral Fellowship*, Fall 2019  
• *Andrew Mellon Predoctoral Fellowship*, 2018-2019  
• *Kenneth P. Dietrich School of Arts & Sciences Fellowship*, 2014-2015

*Invited Talk*  
• Andor, Oxford instrument, 2022, TBD

- Electronic Materials and Applications 2022. “Optically Probing Quantum Spin Liquid Candidates and Toward Quantum Enhanced Optical Sensing”, FL. 1/19/2022. (EMA-071-2022)
- Materials Science Seminar, Penn State University, State College, PA. 11/19/2019.
- Oak Ridge National Lab, Oak Ridge, TN. 8/29/2019.

#### *Professional Activities*

- Member of various professional societies (APS, 2015 - present, ACerS, 2022 - present).

#### *Chair*

- Electronic Materials and Applications 2022 (EMA 2022), *American Ceramic Society*.

#### *Refereed Publications*

- Nature Communications, ACS Nano Letters, ACS Materials Letters, Journal of the Optical Society of America B, Journal of Physics B: Atomic, Molecular and Optical Physics.

#### *Outreach*

- Lab tour For students from Taylor–Allerdice High School. 2015, 2016, 2017.
- *Investing Now!* Science demo for students from under-represented groups. 2017

#### *Booth Representative*

- Quantum Science Center at *InnovationXLab*, Oct. 7-8, 2020

#### *Leadership Team*

- Postdocs and Graduate Students of Quantum Science Center (QSC), Dec. 2020 - Dec. 2021
  - Meet a Quantum Information Science and Technology Expert - Seminar Series (organizer)
  - 1st QSC Poster Session (organizer, booklet), Mar. 4, 2021 ([ORNL News](#))
  - 1st QSC Summer School (Day 4 Moderator) ([Website](#))

## **TEACHING**

### *University of Pittsburgh, Pittsburgh, PA*

#### Teaching Assistant

- PHYS 0212 Introduction to Laboratory Physics, Jan. 2019 - Apr. 2019
- PHYS 1426 Modern Physics Laboratory, Jan. 2018 - Apr. 2018
- PHYS 0175 Basic Physics for Science and Engineering II, May 2015 - Jun. 2015

### *Cornell University, Ithaca, NY*

#### Lab Assistant

- AEP 2640 Computer Instrumentation Design, Aug. 2013 - Dec. 2013

## **Expertise**

### *Optical Microscopy and Quantum Optical Microscopy*

- Built a confocal microscope onto Asylum Research MFP-3D AFM. Used time-correlated single-photon counting to characterize single photon emitters in ZnO; Relaxometry in NV centers
- Polarization-, helicity-resolved milliKelvin magneto-Raman spectroscopy; milliKelvin magneto-optical microscopy, spin noise spectroscopy

- Theory and instrumentation of quantum enhanced microscopy with two mode squeezed light

#### *Quantum Transport*

- Fabricate (conductive-AFM lithography) and study (5 years): quantum dots, electron waveguides, superconducting nanowires

#### *Cryostats and Dilution Refrigerators: Troubleshooting and Maintenance*

- Dilution Refrigerators: Leiden CF900 (3 years as the superuser), Oxford Triton (2 years), Leiden CF 1500 (2 years). Quantum Design PPMS (4 years as the superuser) with Vibration Sampling Magnetometry (PPMS-VSM) and Quantum Design Dilution Refrigerator (PPMS-DR)
- Helium Leak Detection: Adixen ASM 340, Inficon UL 1000, UL 5000

#### *Scanning Probe Microscopy*

- Asylum Research MFP-3D (>1,000 hours of usage; 2 years as the superuser), Asylum Research Cypher. Nanomagnetism milliKelvin-Scanning Probe Microscope (mK-SPM) (> 3 years)
- C-AFM lithography; Implemented the c-AFM lithography for electron waveguides with mK-SPM

#### *Programming, Full Automation, Probabilistic Modeling, Computer Vision*

- GitHub: <https://github.com/yypai>
- I automated 3 labs at ORNL:
  - mK-confocal, polarization resolved, magnetic field dependent Raman, photoluminescence, MOKE, pulse sequence and time tagging with a free-space optical setup with Leiden CF
  - Quantum transport with Oxford Triton dilution refrigerator
  - Polarization resolved Raman, temperature control and auto-focus with Montana cryostat
- Python: data analysis and multi-index manipulation (Numpy, Scipy, Pandas, xarray), high-precision math (mpmath), visualization (matplotlib, plot.ly, BlenderPy), website (Django), instrument automation (pyvisa, nidaqmx-python, pythonnet, pywinauto), probabilistic modeling (pyMC3), machine learning (scikit-learn), deep learning (Keras, tensor flow 2.0), computer vision (opencv), quantum physics and quantum photonics (qutip, strawberry field)
- LabVIEW: NI-DAQmx, JKI state machine, etc; Mathematica; bash, zsh
- Google Script, JavaScript, HTML/CSS (my website <https://yypai.github.io/>)

#### *Lab Database Management*

- <https://yypai.github.io/database.html>
- I setup and managed (for 5 years) a lab-wide database in during my PhD. It collects more than 650 instrument time series. The database had successfully helped us troubleshoot our instruments numerous times.

#### *CAD, PCB, Mask, Scientific Art*

- AutoCAD, Blender (my gallery: <https://yypai.github.io/art.html>), Illustrator, Photoshop, InDesign, Lightroom
- DC and Microwave PCB design: KiCAD, FreeCAD. Mask design: KLayout
- machine shop

**PATENTS  
FILLED**

1. Benjamin J. Lawrie, **Yun-Yi Pai**, Chengyun Hua, Raphael C. Pooser, Claire E. Marvinney, *Quantum Enhanced Magneto-Optical Microscopy*.

**JOURNAL  
ARTICLES**

See also [my google scholar](#) page.

*Under review*

1. **Yun-Yi Pai**, Claire E. Marvinney, Liangbo Liang, Ganesh Pokharel, Jie Xing, Allen Scheie, Michael Chilcote, Athena S. Sefat, David Parker, Stephen Wilson, and Benjamin J. Lawrie, “Observation of Conjugate Helicity in Crystalline-Phononic Vibronic Bound State in Quantum Spin Liquid Candidates NaYbSe<sub>2</sub>”.  
<https://arxiv.org/abs/2203.13361>
2. David Curie, Jaron T. Krogel, Lukas Cavar, Abishek Solanki, PrameyUpadhyaya, Tongcang Li, **Yun-Yi Pai**, Michael Chilcote, Vasudevan Iyer, Ilia Ivanov, Mao-Hua Du, Fernando Reboledo, Benjamin Lawrie, “Correlative nanoscale imaging of strained hBN spin defects”.  
<https://arxiv.org/abs/2203.10075>
3. The Windchime Collaboration: Alaina Attanasio, Sunil A. Bhave, Carlos Blanco, Daniel Carney, Marcel Demarteau, Bahaa Elshimy, Michael Febbraro, Matthew A. Feldman, Sohriti Ghosh, Abby Hickin, Seongjin Hong, Rafael F. Lang, Benjamin Lawrie, Shengchao Li, Zhen Liu, Juan P. A. Maldonado, Claire Marvinney, Hein Zay Yar Oo, **Yun-Yi Pai**, Raphael Pooser, Juehang Qin, Tobias J. Sparmann, Jacob M. Taylor, Hao Tian, Christopher Tunnell, “Snowmass 2021 White Paper: The Windchime Project”.  
<https://arxiv.org/abs/2203.07242>
4. Alessandro R. Mazza, Jason Lapano, Harry Meyer, Christopher Nelson, Tyler Smith, **Yun-Yi Pai**, Benjamin J. Lawrie, Timothy R. Charlton, Robert G. Moore, T. Zac Ward, Gyula Eres, Mao-Hua Du, Matthew Brahlek, “Surface-induced even/odd reversal in the topological magnet MnBi<sub>2</sub>Te<sub>4</sub>: Implications for the quantized anomalous Hall effect”.
5. Michael A. McGuire, **Yun-Yi Pai**, Matthew Brahlek, Satoshi Okamoto, R. G. Moore, “Electronic and topological properties of the van der Waals layered superconductor PtTe.”  
<https://arxiv.org/abs/2203.06655>
6. Haoxiang Li, G Fabbri, AH Said, **YY Pai**, QW Yin, CS Gong, ZJ Tu, HC Lei, JP Sun, J-G Cheng, Ziqiang Wang, Binghai Yan, R Thomale, HN Lee, H Miao, “Conjoined Charge Density Waves in the Kagome Superconductor CsV<sub>3</sub>Sb<sub>5</sub>”.  
<https://arxiv.org/abs/2202.13530>
7. Haoxiang Li, Yu-Xiao Jiang, J. X. Yin, Sangmoon Yoon, Andrew R. Lupini, **Y. Y. Pai**, C. S. Nelson, A. H. Said, Y. M. Yang, Q. W. Yin, C. S. Gong, Z. J. Tu, H. C. Lei, Binghai Yan, Ziqiang Wang, M. Z. Hasan, H. N. Lee, and H. Miao, “Spatial symmetry constraint of charge-ordered kagome superconductor CsV<sub>3</sub>Sb<sub>5</sub>”.  
<https://arxiv.org/abs/2109.03418>

8. Muneer Alshowkan, Philip G. Evans, Brian P. Williams, Nageswara S. V. Rao, Claire E. Marvinney, **Yun-Yi Pai**, Benjamin J. Lawrie, Nicholas A. Peters, Joseph M. Lukens, “Advanced Architectures for High-Performance Quantum Networking”.  
<https://arxiv.org/abs/2111.15547>
9. Jie Zhang, T. Yilmaz, J. W. R. Meier, **J. Y. Pai** (typo), J. Lapano, H. X. Li, K. Kaznatcheev, E. Vescovo, A. Huon, M. Brahlek, T. Z. Ward, B. Lawrie, R. G. Moore, H. N. Lee, Y. L. Wang, H. Miao, B. Sales, “Flat Band Induced Negative Magnetoresistance in Multi-Orbital Kagome Metal”.  
<https://arxiv.org/abs/2105.08888>

*Published*

1. **Yun-Yi Pai**, Claire E. Marvinney, Liangbo Liang, Jie Xing, Allen Scheie, Alexander A. Puzhtov, Gabor Halasz, Xun Li, Athena S. Sefat, David Parker, Lucas Lindsay, Benjamin J. Lawrie, “Nearly-Resonant Crystalline-Phononic Coupling in Quantum Spin Liquid Candidate CsYbSe<sub>2</sub>”. *Journal of Materials Chemistry C* **10**, 4148 (2022).  
<https://doi.org/10.1039/D1TC05934C>  
Inner Cover
2. **Yun-Yi Pai**, Claire E. Marvinney, Chengyun Hua, Raphael C. Pooser, Benjamin J. Lawrie, “Magneto Optical Sensing beyond the Shot Noise Limit”. *Advanced Quantum Technologies* **5**, 2100107 (2022).  
<https://doi.org/10.1002/qute.202100107>  
Front Cover
3. **Yun-Yi Pai**, Claire E. Marvinney, Matthew A. Feldman, Brian Lerner, Yoong Sheng Phang, Kai Xiao, Jiaqiang Yan, Liangbo Liang, Jason Lapano, Matthew Brahlek, Benjamin J. Lawrie, “Magnetostriction of  $\alpha$ -RuCl<sub>3</sub> flakes in the zigzag phase”. *Journal of Physical Chemistry C* **125**, 46, 25687 (2021).  
<https://doi.org/10.1021/acs.jpcc.1c07472>  
Supplemental Cover
4. Jie Zhang, Jong Mok Ok, **Yun-Yi Pai**, Jason Lapano, Elizabeth Skoropata, Alessandro R. Mazza, Haoxiang Li, Amanda Huon, Sangmoon Yoon, Benjamin Lawrie, Matthew Brahlek, T. Zac Ward, Gyula Eres, H. Miao, and Ho Nyung Lee, “Extremely large magnetoresistance in high-mobility SrNbO<sub>3</sub>/SrTiO<sub>3</sub> heterostructures”. *Physical Review B* **104**, L161404 (2021).  
<https://doi.org/10.1103/PhysRevB.104.L161404>
5. Jie Zhang, **Yun-Yi Pai**, Jason Lapano, Alessandro R. Mazza, Ho Nyung Lee, Rob Moore, Benjamin J. Lawrie, T. Zac Ward, Gyula Eres, Valentino R. Cooper, Matthew Brahlek, “Design and realization of Ohmic and Schottky interfaces for oxide electronics”. *Small Science* **2**, 2100087 (2022).  
<http://doi.org/10.1002/smssc.202100087>
6. Haoxiang Li, T. T. Zhang, T. Yilmaz, **Y. Y. Pai**, C. E. Marvinney, A. Said, Q. W. Yin, C. S. Gong, Z. J. Tu, E. Vescovo, C. S. Nelson, R. G. Moore, S. Murakami, H. C. Lei, H. N. Lee, B. J. Lawrie, and H. Miao, “Observation of Unconventional Charge Density Wave without Acoustic Phonon Anomaly in Kagome Superconductors AV<sub>3</sub>Sb<sub>5</sub> (A=Rb, Cs)”. *Physical Review X* **11**, 031050 (2021).

<https://doi.org/10.1103/PhysRevX.11.031050>

7. Jong Mok Ok, Narayan Mohanta, Jie Zhang, Sangmoon Yoon, Satoshi Okamoto, Eun Sang Choi, Hua Zhou, Megan Briggeman, Patrick Irvin, Andrew R. Lupini, **Yun-Yi Pai**, Elizabeth Skoropata, Changhee Sohn, Haoxiang Li, Hu Miao, Benjamin Lawrie, Woo Seok Choi, Gyula Eres, Jeremy Levy, Ho Nyung Lee, “Correlated oxide Dirac semimetal in the extreme quantum limit”. *Science Advances* **7**, eabf9631 (2021).  
<https://doi.org/10.1126/sciadv.abf9631>
8. B. J. Lawrie, M. Feldman, C.E. Marvinney, **Y. Y. Pai**, “Free-space confocal magneto-optical spectroscopies at milliKelvin temperatures” *SPIE Proceedings Volume 11806, Quantum Nanophotonic Materials, Devices, and Systems 2021*; 1180604 (2021).  
<https://doi.org/10.1117/12.2595780>
9. Jason Lapano, **Yun-Yi Pai**, Alessandro Mazza, Jie Zhang, Tamara Isaacs-Smith, Patrick Gemperline, Lizhi Zhang, Haoxiang Li, Ho Nyung Lee, Hu Miao, Gyula Eres, Mina Yoon, Ryan Comes, T. Zac Ward, Benjamin J. Lawrie, Michael McGuire, Robert G. Moore, Christopher T. Nelson, Andrew May, Matthew Brahlek, “Self-regulated growth of candidate topological superconducting parkerite by molecular beam epitaxy”. *APL Materials* **9**, 101110 (2021).  
<https://doi.org/10.1063/5.0064746>
10. Muneer Alshowkan, Brian P. Williams, Philip G. Evans, Nageswara S. V. Rao, Emma M. Simmerman, Hsuan-Hao Lu, Navin B. Lingaraju, Andrew M. Weiner, Claire E. Marvinney, **Yun-Yi Pai**, Benjamin J. Lawrie, Nicholas A. Peters, Joseph M. Lukens, “A Reconfigurable Quantum Local Area Network Over Deployed Fiber”. *Physical Review X Quantum* **2**, 040304 (2021).  
<https://doi.org/10.1103/PRXQuantum.2.040304>
11. Jason Lapano, Lauren Nuckols, Alessandro R. Mazza, **Yun-Yi Pai**, Jie Zhang, Ben Lawrie, Rob G. Moore, Gyula Eres, Ho Nyung Lee, Mao-Hua Du, T. Zac Ward, Joon Sue Lee, William J. Weber, Yanwen Zhang, and Matthew Brahlek, “Adsorption-controlled growth of  $\text{MnTe}(\text{Bi}_2\text{Te}_3)_n$  by molecular beam epitaxy exhibiting stoichiometry-controlled magnetism”. *Physical Review Materials* **4**, 111201(R) (2020).  
<https://doi.org/10.1103/PhysRevMaterials.4.111201>
12. Benjamin J Lawrie, Claire E. Marvinney, **Yun-Yi Pai**, Matthew A. Feldman, Jie Zhang, Aaron J. Miller, Chengyun Hua, Eugene Dumitrescu, Gábor B. Halász, “Multifunctional Superconducting Nanowire Quantum Sensors”. *Physical Review Applied* **16**, 064059 (2021).  
<https://doi.org/10.1103/PhysRevApplied.16.064059>
13. **Yun-Yi Pai**, Hyungwoo Lee, Jung-Woo Lee, Anil Annadi, Guanglei Cheng, Shicheng Lu, Michelle Tomczyk, Mengchen Huang, Chang-Beom Eom, Patrick Irvin, Jeremy Levy, “One-Dimensional Nature of Pairing and Superconductivity at the  $\text{LaAlO}_3/\text{SrTiO}_3$  Interface.” *Physical Review Letters* **120**, 147001 (2018).  
<https://doi.org/10.1103/PhysRevLett.120.147001>

14. **Yun-Yi Pai**, Anthony Tylan-Tyler, Patrick Irvin, Jeremy Levy, “Physics of SrTiO<sub>3</sub>-based heterostructures and nanostructures: a review”. Reports on Progress in Physics **81** 036503 (2018).  
<https://doi.org/10.1088/1361-6633/aa892d>
15. L. Chen, J. Li, Y. Tang, **Y.-Y. Pai**, Y. Chen, N. Pryds, P. Irvin, J. Levy, “Extreme reconfigurable nanoelectronics at the CaZrO<sub>3</sub>/SrTiO<sub>3</sub> interface”. Advanced Materials **30**, 1801794. (2018)  
<https://doi.org/10.1002/adma.201801794>
16. **Yun-Yi Pai**, Anthony Tylan-Tyler, Patrick Irvin, Jeremy Levy, “LaAlO<sub>3</sub>/SrTiO<sub>3</sub>: a tale of two magnetisms.”, in Vol. 2, Sec. 5 of “Spintronics Handbook: Spin Transport and Magnetism”. 2nd ed” by CRC Press (2019).  
<https://www.taylorfrancis.com/chapters/edit/10.1201/9780429434235-14/laalo3-srtio3-yun-yi-pai-anthony-tylan-tyler-patrick-irvin-jeremy-levy>
17. N. R. Jungwirth, **Y. Y. Pai**, H. S. Chang, E. R. MacQuarrie, K. X. Nguyen, and G. D. Fuchs, “A single-molecule approach to ZnO defect studies: Single photons and single defects”. Journal of Applied Physics **116**, 043509 (2014).  
<https://doi.org/10.1063/1.4890979>

## CONFERENCE CONTRIBUTIONS

1. **Yun-Yi Pai**, Claire Marvinney, Chengyun Hua, Raphael Pooser, Benjamin Lawrie, “Magneto Optical Sensing beyond the Shot Noise Limit”, 2022 APS March Meeting, **Z55.11**.
2. **Yun-Yi Pai**, Claire Marvinney, Matthew Feldman, Kai Xiao, Jiaqiang Yan, Benjamin Lawrie, “Spin-Phonon Interactions in Quantum Spin Liquid Candidate  $\alpha$ -RuCl<sub>3</sub>”, CLEO: QELS Fundamental Science 2021, W4K.6.
3. **Yun-Yi Pai**, Claire Marvinney, Matthew Feldman, Chengyun Hua, Jong-Ryul Jeong, Benjamin Lawrie, “Optically Probing Quantum Materials at milliKelvin Temperatures”, 2021 APS March Meeting, **V36.11**.
4. **Yun-Yi Pai**, Megan Briggeman, Hyungwoo Lee, Jung-Woo Lee, Xiaoxing Cheng, Muqing Yu, Mengchen Huang, Jianan Li, Chang-Beom Eom, Long-Qing Chen, Patrick Irvin, Jeremy Levy, “Superconductivity at the LaAlO<sub>3</sub>/SrTiO<sub>3</sub> 1D Zigzag Nanowires”, 2020 APS March Meeting, **B48.11**. (**APS Online**, **Virtual Meeting**).
5. **Yun-Yi Pai**, Megan Briggeman, Hyungwoo Lee, Jung-Woo Lee, Mengchen Huang, Jianan Li, Chang-Beom Eom, Patrick Irvin, Jeremy Levy, “Superconductivity in 1D Zigzag Nanowires”, 2019 APS March Meeting, **P09.14**.
6. **Yun-Yi Pai**, Hyungwoo Lee, Jung-Woo Lee, Anil Annadi, Guanglei Cheng, Shicheng Lu, Michelle Tomczyk, Mengchen Huang, Chang-Beom Eom, Patrick Irvin, Jeremy Levy, “One-Dimensional Nature of Pairing and Superconductivity at the LaAlO<sub>3</sub>/SrTiO<sub>3</sub>”, 2018 Materials and Mechanisms of Superconductivity (M2S-2018), Beijing, Th-S48-05.
7. **Yun-Yi Pai**, Hyungwoo Lee, Jung-Woo Lee, Anil Annadi, Guanglei Cheng, Shicheng Lu, Michelle Tomczyk, Mengchen Huang, Chang-Beom Eom, Patrick Irvin, Jeremy Levy, “One-Dimensional Nature of Pairing and Superconductivity at the LaAlO<sub>3</sub>/SrTiO<sub>3</sub>”, 2018 APS March Meeting, **B30.12**.
8. **Yun-Yi Pai**, Anthony Tylan-Tyler, Patrick Irvin, Jeremy Levy, “LaAlO<sub>3</sub>/SrTiO<sub>3</sub>: a tale of two magnetisms”, 2017 APS March Meeting, **A37a.12**.

9. **Yun-Yi Pai**, Dong-Wook Park, Mengchen Huang, Anil Annadi, Hyungwoo Lee, Zhenqiang Ma, Chang-Beom Eom, Patrick Irvin, Jeremy Levy, “Vertical gating of sketched nanodevices”, 2016 APS March Meeting, [S24.3](#).
10. **Yun-Yi Pai**, Mengchen Huang, Hyungwoo Lee, Chang-Beom Eom, Patrick Irvin, Jeremy Levy, “LaAlO<sub>3</sub>/SrTiO<sub>3</sub> field-effect nanodevices using in-situ-grown Au top gates”, 2015 APS March Meeting, [G13.4](#).