

**Christianne Beekman**  
Personal Gender Pronouns: She/Her/Hers

Associate Professor at Florida State University /  
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### Education/Training:

Institution and Location	Degree	Year(s)	Field of Study
Leiden University, Netherlands	PhD	2010	Physics
Leiden University, Netherlands	MSc	2005	Physics

### Research and Professional Experience:

August 2020 – present: **Associate Professor at Florida State University/NHMFL**

August 2014 – July 2020: **Assistant Professor at Florida State University/NHMFL**

In 2014, I established a research group that deals with strongly correlated electron systems in which the properties of the electrons (charge, orbital and spin) and the properties of the lattice are uniquely intertwined. Using the state-of-the-art thin film growth facility that I set up with my startup funds, my group grows thin films of transition metal oxides and frustrated antiferromagnets. I designed my laboratory at the NHMFL with a long-term vision, to build a sustainable and productive research program in engineering of spin textures (and associated functional properties) in thin films of emerging quantum materials, with a special focus on frustrated magnetism. Thin film growth allows control of the physical properties, such as the magnetism and the electrical properties, via small variations to the lattice structure, induced by epitaxial strain. One of the main research goals is to engineer novel noncollinear spin textures in thin films of frustrated magnets. The Beekman group studies these textures using neutron diffraction and magnetometry. The group has pioneered the use of capacitive torque magnetometry to study magnetism in thin films of strongly anisotropic and highly frustrated antiferromagnets. The Beekman group uses the technique to characterize the magnetic anisotropy of pyrochlore titanates and spinel vanadates, and to chart the presence and evolution of specific spin textures as a function of applied external perturbations. With these facilities, I established a robust research program that investigates spin ice materials exposed to structural perturbations and confinement. Furthermore, I am the first to use this technique to characterize the anisotropy associated with structurally engineered noncollinear spin textures in spinel vanadate thin films. This work could lead to the creation of spin ice states in 3d-electron systems and to new type II multiferroics. This has been made possible due to support of the State of Florida in the form of startup funds and by the National Science Foundation via an NSF CAREER award.

- **Publications since August 2014 (12):** Science (2020, Perspective), Phys. Rev. Mat. (2018 and 2019), Vacuum (2018), Nanolett. (2017), Adv. Func. Mat. (2016), Sci. Rep. (2016), Phys. Rev. B (2016), APL Materials (2016), Phys. Rev. Lett. (2015), Adv. Science (2015), and Appl. Phys. Lett. (2014).
- **Grants – Funded:** 2019 NSF CAREER Award totaling **\$545,649** (this award is on the TARU list and recognized by FSU as an extraordinary accomplishment); two FSU Grants (PI) totaling **\$65,500** and three FSU Equipment grants (Co-PI) totaling **\$139,092**.
- **Research Presentations (15):** 5 invited talks at R1 Universities, 10 invited talks at conferences/symposia/workshops.
- **Awards:** 2018-2019 PAI award for excellence in teaching and research; 2018 College of Arts & Sciences Dean's Faculty Travel award, 2019 Provost Travel Award.

March 2012 – August 2014: **Postdoctoral Researcher at Oak Ridge National Laboratory**

At ORNL I investigated how external perturbations like epitaxial strain and applied electric fields affect the intrinsic and functional properties of a variety of thin films. I have worked on BiFeO<sub>3</sub>, BiCrO<sub>3</sub>, La<sub>0.7</sub>Sr<sub>0.3</sub>MnO<sub>3</sub> and La<sub>0.4</sub>Sr<sub>0.6</sub>MnO<sub>3</sub> films, which were grown by pulsed laser deposition. I have constructed a phase diagram of BiFeO<sub>3</sub> when it is highly strained. I have used techniques such as synchrotron and lab-scale x-ray diffraction, scanning probe microscopy and neutron diffraction to measure the properties necessary to construct the phase diagram. This work has resulted in a better understanding of how strain affects the multiferroic properties of BiFeO<sub>3</sub>. This has resulted in various publications including a paper in Nanoletters (2017), Adv. Funct. Mater. (2016), Sci. Rep. (2016), Adv. Sci. (2015) and Adv. Mater. (2013).

March 2010 – February 2012: **Postdoctoral Researcher at University of Toronto**

At the University of Toronto I have investigated single crystals of multiferroic BiFeO<sub>3</sub> and the topological insulators Bi<sub>2</sub>Se<sub>3</sub> and Bi<sub>2</sub>Te<sub>3</sub> using various optical spectroscopy methods (micro-Raman, Fourier transform infrared spectroscopy and ellipsometry). This led to two publications, one on Raman spectroscopy on BiFeO<sub>3</sub> single crystals (Physical Review B (R) (2012)) in which I accomplished unambiguous assignment of phonon mode symmetries solving a long-standing controversy in literature. In the other publication I investigate the optical properties of exfoliated thin flakes of the topological insulator Bi<sub>2</sub>Se<sub>3</sub> (Applied Physics Letters (2011)).

### List of Publications:

C. Beekman *Science*, **368**, 32-33 (2020), “Straining quantum materials even further”

Barry, K., Zhang, B., Anand, N., Xin, Y., Vailionis, A., Neu, J., Heikes, C., Cochran, C., Zhou, H., Qiu, Y., Ratcliff, W., Siegrist, T., and Beekman, C. *Physical Review Materials*, **3**, 084412 (2019), “Modification of Spin Ice Physics in Ho<sub>2</sub>Ti<sub>2</sub>O<sub>7</sub> Thin Films”

C. Thompson, D. Reig-i-Plessis, L. Kish, A. A. Aczel, B. Zhang, E. Karapetrova, G. J. MacDougall, and C. Beekman, *Phys. Rev. Materials* **2**, 104411 (2018) “Spin Canting and Orbital Order in Spinel Vanadate Thin Films” DOI: 10.1103/PhysRevMaterials.2.104411

Dildar, I. M., Boltje, D. B., Hesselberth, M. B. S., Beekman, C., & Aarts, J. *Vacuum*, **148**, 131-135. (2018) “Mitigating target degradation in sputtering manganite thin films.”

L. Li, Y. Zhang, L. Xie, J. R. Jokisaari, C. Beekman, J.-C. Yang, Y.-H. Chu, H. M. Christen, and X. Pan, *Nanoletters* **17**, 3556 (2017) “Atomic-Scale Mechanisms of Defect-Induced Retention Failure in Ferroelectrics”

J. Holleman, M. M. Bishop, C. Garcia, J. S. R. Vellore Winfred, S. Lee, H. N. Lee, C. Beekman, E. Manousakis, and S. A. McGill, *Phys. Rev. B* **94**, 155129 (2016) “Evidence for impact ionization in vanadium dioxide”

C. Beekman, W. Siemons, M. Chi, N. Balke, J. Y. Howe, T. Z. Ward, P. Maksymovych, J. D. Budai, J. Z. Tischler, R. Xu, W. Liu, H. M. Christen, *Adv. Funct. Mater.*, **26**, 5166 (2016) “Ferroelectric Self-Poling, Switching, and Monoclinic Domain Configuration in BiFeO<sub>3</sub> Thin Films”

S. Jesse, M. Chi, A. Belianinov, C. Beekman, S. V. Kalinin, A. Y. Borisevich and A. R. Lupini, *Sci. Rep.* **6**, 26348 (2016) “Big Data Analytics for Scanning Transmission Electron Microscopy Ptychography”

Yongsoo Yang, Christianne Beekman, Wolter Siemons, Christian M. Schlepütz, Nancy Senabulya, Roy Clarke, and Hans M. Christen *APL Materials* **4**, 036106 (2016) “Origin of thickness dependence of structural phase transition temperatures in highly strained BiFeO<sub>3</sub> thin films”

H. Dixit, C. Beekman, C.M. Schlepütz, W. Siemons, Y. Yang, N. Senabulya, R. Clarke, M. Chi, H.M. Christen, and V.R. Cooper, *Adv. Sci.* **2**, 1500041 (2015), “Understanding Strain-Induced Phase Transformations in BiFeO<sub>3</sub> Thin Films”

A. T. Wong, C. Beekman, H. Guo, W. Siemons, Z. Gai, E. Arenholz, Y. Takamura and T. Z. Ward, *Appl. Phys. Lett.* **105**, 052401 (2014) “Strain driven anisotropic magnetoresistance in antiferromagnetic La<sub>0.4</sub>Sr<sub>0.6</sub>MnO<sub>3</sub>”

W. Siemons, C. Beekman, J. D. Fowlkes, N. Balke, J. Z. Tischler, R. Xu, W. Liu, C. M. Gonzales, J. D. Budai, and H. M. Christen, *APL Materials* **2**, 022109 (2014) “Focused-ion-beam induced damage in thin films of complex oxide BiFeO<sub>3</sub>”

W. Siemons, C. Beekman, G.J. MacDougall, J.L. Zarestky, S.E. Nagler and H.M. Christen, *J. Phys. D: Appl. Phys.* **47** 034011 (2014) “A complete strain–temperature phase diagram for BiFeO<sub>3</sub> films on SrTiO<sub>3</sub> and LaAlO<sub>3</sub> (0 0 1) substrates”

C. Beekman, W. Siemons, T. Z. Ward, M. Chi, J. Howe, M. D. Biegalski, N. Balke, P. Maksymovych, A. K. Farrar, J. B. Romero, P. Gao, X. Q. Pan, D. A. Tenne, and H. M. Christen, *Adv. Mater.* **25**, 5561 (2013) “Phase Transitions, Phase Coexistence, and Piezoelectric Switching Behavior in Highly Strained BiFeO<sub>3</sub> Films”

C. Beekman, A. A. Reijnders, Y. S. Oh, S. W. Cheong, and K. S. Burch, *Phys. Rev. B* **86**, 020403(R) (2012) “Raman study of the phonon symmetries in BiFeO<sub>3</sub> single crystals”

C. Beekman, I. Komissarov and J. Aarts, *Phys. Rev. B* **85**, 245115 (2012) “Large electric-field effects on the resistance of La<sub>0.67</sub>Ca<sub>0.33</sub>MnO<sub>3</sub> microstructures”

S. Y. F. Zhao, C. Beekman, L. J. Sandilands, J. E. J. Bashucky, D. Kwok, N. Lee, A. D. LaForge, S. W. Cheong, and K. S. Burch, *Appl. Phys. Lett.* **98**, 141911 (2011) “Fabrication and characterization of topological insulator Bi<sub>2</sub>Se<sub>3</sub> nanocrystals”

C. Beekman, J. Zaanen and J. Aarts, *Phys. Rev. B* **83**, 235128 (2011) “Nonlinear mesoscopic transport in a strongly cooperative electron system: the La<sub>0.67</sub>Ca<sub>0.33</sub>MnO<sub>3</sub> microbridge”

C. Beekman, I. Komissarov, M. Hesselberth, and J. Aarts, *Appl. Phys. Lett.* **91**, 062101 (2007) “Transport properties of microstructured ultrathin films of La<sub>0.67</sub>Ca<sub>0.33</sub>MnO<sub>3</sub> on SrTiO<sub>3</sub>”

### **Invited Talks:**

Beekman, C. (presented 2020, October) The highly anisotropic phase diagram of the spin ice Ho<sub>2</sub>Ti<sub>2</sub>O<sub>7</sub> Seminar at University of Minnesota (virtual, national)

Beekman, C. (presented 2019, November) Characterization of noncollinear spin textures in spin ice materials using capacitive torque magnetometry. Presentation at 64th Annual Conference on Magnetism and Magnetic Materials, Las Vegas (international).

Beekman, C. (presented 2019, August) Magnetic Crystallography in Thin Films of Frustrated Magnets. Colloquium at Florida State University (local).

Beekman, C. (presented 2019, August) Torque Magnetometry, a Tool for Magnetic Crystallography in Thin Films of Frustrated Magnets. Presentation at 32nd European Crystallographic Meeting (ECM 32) in Vienna, Austria (international).

Beekman, C. (presented 2019, January). Structural Tuning of Orbital and Spin Order in Frustrated Antiferromagnets. Presentation at Joint MMM-Intermag conference, IEEE, Washington DC. (International)

Beekman, C. (presented 2018, June). Neutron Studies on thin films of frustrated magnets. Plenary presentation at the meeting of ORNL, ORNL. (National)

Beekman, C. (presented 2018, March). Structural Tuning of Orbital and Spin Order in Frustrated Antiferromagnets. Delivered at University of Alabama, Tuscaloosa. (Regional)

Beekman, C. (presented 2017, August). Growth and characterization of strained  $\text{Ho}_2\text{Ti}_2\text{O}_7$  spin ice thin films. Delivered at Leiden University, Netherlands. (International)

Beekman, C. (presented 2017, June). Neutron Studies on thin films of frustrated magnets. Plenary presentation at the meeting of ORNL, ORNL. (National)

Beekman, C. (presented 2016, December). Structure-property relationship in strained and doped orthovanadates. Plenary presentation at EMN meeting transparent conductive oxides, EMN, Orlando. (International)

Beekman, C. (presented 2016, August). Neutron studies on thin films of frustrated magnets. Plenary presentation at QCMD Young Investigators Meeting, ORNL, ORNL. (National)

Beekman, C. (presented 2016, March). Phase Coexistence and Piezoelectric Switching in Highly Strained  $\text{BiFeO}_3$  Thin Films. Plenary presentation at FL-AVS, AVS, UCF Orlando. (Regional)

Beekman, C. (2016, February). Controlling the Functional Properties of Complex Oxides with Epitaxial Strain. Delivered at University of Florida, Gainesville. (Regional)

Beekman, C. (presented 2016, February). Phase Coexistence and Piezoelectric Switching in Highly Strained  $\text{BiFeO}_3$  Thin Films. Plenary presentation in *In-situ heating in Aberration-Corrected STEM Workshop and Educational Symposium*. Symposium conducted at the meeting of Hitachi Inc, Georgia Tech Atlanta. (National)

Beekman, C. (presented 2013, November) From Undergraduate Student to Independent Researcher . Plenary presentation and panel discussion, conducted at 80th Annual Meeting of the APS Southeastern Section, Bowling Green KY (Regional)

### **Contributed Talks:**

Zhang, B., Xin, Y., Holleman, J., McGill, S., and Beekman, C. (accepted, 2021, January) Stoichiometry-Dependence of Electronic Properties in  $\text{LaVO}_3$  Thin Films. Presentation at the Virtual Electronic Materials and Applications 2021 (EMA 2021) (virtual, international)

Zhang, B., Xin, Y., Holleman, J., McGill, S., and Beekman, C. (presented 2020, November) Stoichiometry-Dependence of Electronic Properties in  $\text{LaVO}_3$  Thin Films. Presentation at The 87th Annual Meeting of the Southeastern Section of the APS (virtual, regional)

Zhang, B., Xin, Y., Holleman, J., McGill, S., and Beekman, C. (accepted 2020, March) Stoichiometry-Dependence of Electronic Properties in  $\text{LaVO}_3$  Thin Films. March Meeting, American Physical Society. (international, cancelled)

Barry, K., Anand, N., Neu, J., Zhou, H., Graf, D., Siegrist, T., & Beekman, C. (presented 2019, March). Capacitive Torque Magnetometry: Study of field-induced magnetic transitions and transient states in the Spin-Ice Material Ho<sub>2</sub>Ti<sub>2</sub>O<sub>7</sub>. Presentation at March Meeting, American Physical Society. (International)

Thompson, C. J., & Beekman, C. (presented 2019, March). Magnetic phase transitions in thin films of the near-itinerant spinel CoV<sub>2</sub>O<sub>4</sub>. Presentation at March Meeting, American Physical Society, Boston. (International)

Barry, K., Anand, N., Zhou, H., Park, J. H., & Beekman, C. (presented 2018, March). Utilizing Torque Magnetometry to Measure Thin Films of Frustrated Magnets. Presentation at March Meeting, American Physical Society, Los Angeles. (International)

Ratcliff, W., Heikes, C., Barry, K., & Beekman, C. (presented 2018, March). Neutron Investigations of Thin Film Ho<sub>2</sub>Ti<sub>2</sub>O<sub>7</sub>. Presentation at March Meeting, American Physical Society. (International)

Thompson, C. J., Reig-i-Plessis, D., Kish, L., Aczel, A. A., Zhang, B., Karapetrova, E., MacDougall, G. J., & Beekman, C. (presented 2018, March). Structural and Magnetic Properties of CoV<sub>2</sub>O<sub>4</sub> Thin Films. Presentation at March Meeting, American Physical Society. (International)

Thompson, C. J., Reig-i-Plessis, D., Kish, L., Aczel, A. A., Zhang, B., MacDougall, G. J., & Beekman, C. (presented 2017, November). Structural and Magnetic Properties of CoV<sub>2</sub>O<sub>4</sub> Thin Films. Presentation at MMM, IEEE, Pittsburgh. (International)

### **Awards:**

PAI Award (2019): Departmental award for excellence in teaching and in research.

Dean Travel award (2019): For travel to the IEEE Joint MMM-Intermag conference

Provost Travel award (2019): For travel to the ECM32 conference in Vienna

### **Funding:**

Christianne Beekman (PI) (Feb. 15 2019 – Jan 31 2024) CAREER: Study of Degeneracy Breaking Effects and Emergent Phenomena in Heterostructures of Frustrated Antiferromagnets. **\$545,649**

Christianne Beekman (PI) (Jan 2018- Jan 2019) EIEG: Acquisition of a Vantec 500 to upgrade General Area Detector Diffraction System (GADDS). Co-PI's: Theo Siegrist, Eric Hellstrom, Tanya Peres, Lance Cooley, Rufina Alamo, Jeff Whalen **\$45,500**

Christianne Beekman (PI) (May 2015–Aug 2015). FYAP: Frustration in Strained Pyrochlore Thin Films. Funded by FSU CRC. Total award **\$20,000**.

Christianne Beekman (Co-PI). (Jan 2021- Dec. 2022) Pending with FSU-CRC-EIEG. Alpha-SE ellipsometer for thin film characterization Program Equipment and Infrastructure Enhancement Grant. Lu, Jun (PI), Lenhart, Steven (Co-PI), Schlenoff, Joseph (Co-PI). **\$40,000**

Christianne Beekman (Co-PI). (May 2019–May 2020). Acquisition of an Inert Atmosphere Glove Box to Synthesize and Handle Materials in a Low-Oxygen, Low-Water Content Environment. Hellstrom, Eric (PI), Funded by FSU-CRC-EIEG. Total award **\$36,064**.

Christianne Beekman (Co-PI) (May 2019–May 2020). Acquisition of a New General Purpose Benchtop X-ray Diffractometer for Enhancing Material Researches at the FSU Southwest Campus. Funded by FSU-CRC-EIEG.

Kametani, Fumitake (PI), Cooley, Lance (Co-PI), Lee, Peter (Co-PI), Liang, Zhiyong (Co-PI), Yu, Zhibin (Co-PI), Balicas, Luis (Co-PI), Han, Ke (Co-PI), Ramakrishnan, Subramanian (Co-PI), & Thirunavukkuarasu, Komalavalli (Co-PI). Total award **\$63,028**.

Student tech fee award (2018): x-ray diffraction lab setup for materials education, Total Award: **\$21,727**

### **Pending grants:**

Christianne Beekman (PI). Pending with NSF. Study of Magneto-elastic Properties of Spinel Vanadates using Spectroscopic Techniques. Co-PIs: Chikara, Shalinee (NHMFL), Kattel, Shyam (FAMU), Thirunavukkuarasu, Komalavalli (FAMU/NHMFL). **\$539,145**

Christianne Beekman (Co-PI). Pending with NSF-MRI. Acquisition of a Multi-User Single-Crystal X-ray Diffractometer with High Temperature and High Pressure Capabilities. Siegrist, Theo (PI), Wei, Kaya (Co-PI), Thirunavukkuarasu, Komalavalli (Co-PI), Baumbach, Ryan (Co-PI), Ozerov, Mykhaylo (Co-PI). **\$395,500**

### **Courses Taught:**

Phenomena in Condensed matter (PHZ3400)  
Materials Synthesis and Applications (PHY4471)  
Directed Independent Study-MS&E (ISC5905)  
Directed Individual Study (PHY5909)  
Planets, Stars, and Galaxies (AST1002)  
College Physics B (PHY2054C)  
College Physics B Labs (PHY2054L)  
College Physics A (PHY2053C)  
College Physics A: Labs (PHY 2053L)

### **Curriculum Development:**

Along with several others in the physics department I have been very involved with the development of the new Physics and Materials major. This major caters to an identified national need to educate the materials scientists of tomorrow. I have worked on developing a new course and on the addition of a lab experiment to the Intermediate/advanced Laboratory course.

PHY4471: “Materials Synthesis and Applications” course, the course will introduce undergraduate students to materials synthesis techniques, with a special focus on thin film synthesis. I will teach it for the first time in the Fall of 2019.

PHY3802L/PHY4822L: Development, implementation, and supervision of the x-ray diffraction lab (available since Fall 2018)

### **Service to the department:**

Advisor, Undergraduate Student Advising, Physics and Materials majors (2019–present).

Chair, Evelyn and John Baugh Research Presentation Scholarship Committee (2016–present).

Member, Laser Safety Committee (NHMFL, 2017 - present)

Member, Undergraduate Affairs committee (2014–present).

Member, Saturday Morning Physics committee (2014–present).

Member, Wyatt/Green endowed chair committee (2016–2019).

Member, preeminence search committee (2015–2016).

### **Service to the Profession:**

Elected as “Member at Large” in the executive committee of the GMAG topical group on magnetism of the American Physical Society. She will serve from 4/2020 – 3/2023.

### Program committees:

Joint MMM-Intermag conference. Sub-group: Fundamental Properties and Cooperative Phenomena.

### Symposium Organization:

Joint MMM-Intermag conference held in Washington DC Jan 2019 (Organizer)  
“EA: 3D Magnetic Frustration: Pyrochlore, Spinel and FCC Lattices”

MRS Spring 2020 (Co-organizer, accepted) “NM07: Two-Dimensional Quantum Materials Out of Equilibrium” (serves as principal editor for MRS Advances for NM07 symposium submissions).

### Proposal Review:

Proposal review for US based and international funding agencies:

French National Research Agency (2019)

ACS Petroleum Research Fund (2019)

Kentucky Science and Engineering Foundation (2016)

Proposal review for NHMFL user facilities

### **Outreach:**

Classroom activity development: Crystal growth demo, using sodium acetate (ongoing)

“Ask the Scientist” at First Friday community event (ongoing)

Classroom activity on magnetism in 8<sup>th</sup> grade classroom in Wakulla middle school. (Jan. 2018)

Physics Open House (2019)

Judge at Science Fair Apalachee Tapestry Magnet School of the Arts, Tallahassee (Jan. 2017)

NHMFL Open House (2015 - 2019)

FSU day at the Capitol (2015, 2017)

Public lecture on waves, Saturday Morning Physics (2015 - 2018)

### **Graduate Student Supervision (Major Professor):**

Barry, K. T., graduate Dec 2020 (Title: The Highly Anisotropic Phase Diagram of  $\text{Ho}_2\text{Ti}_2\text{O}_7$ : Bulk Single Crystals and Thin Films)

Thompson, C. J., graduate May 2020 (Title: Magnetic Anisotropy and Noncollinear Spin Textures in  $\text{CoV}_2\text{O}_4$  Thin Films)

Zhang, B., doctoral candidate (graduation expected in Summer 2021)

Sangsoo Kim, doctoral candidate

### **Doctoral Committees:**

#### Doctoral Committee Chair:

Zhang, B., doctoral candidate.

Kim, S., doctoral candidate.

#### Doctoral Committee Co-Chair:

Holleman, J., doctoral candidate.

Neu, J. N., doctoral candidate.

Henderson, A., graduate 2020 (Title: Geometric Frustration In Magnetic Systems: A Path To Quantum Materials)

#### Doctoral Committee Member:

Ho, David, doctoral candidate

Temidayo Oloye, Abiola, doctoral candidate

Barua, Shaon, doctoral candidate

Hu, X., graduate. (2017). "Studies on the origins and nature of critical current variations in rare earth barium copper oxide coated conductors"

Benjamin, S., graduate. (2016). "Magnetothermal transport and elastoresistive properties of low-dimensional magneto-electrics and dichalcogenides."

Coulter, J. E., graduate. (2015). "Photo-excited multiple excitons in strongly correlated insulators."

Kiswandhi, A. O., graduate. (2014). "Physical and chemical pressure effects on magnetic spinels"

#### Master Thesis Committee Member:

Mejia Marin, Juan (2020) Thesis title: Ferromagnetism in the hexagonal cage-like compounds :

$\text{Sm}_6(\text{Mo,W})_4\text{Al}_{13}$

Crawford-Goss, Ian (2020) Thesis Title: Superconductivity in Cerium containing High-entropy Alloys

### **Graduate and Postdoctoral Advisors:**

Graduate student advisor: Prof. Dr. J. Aarts (Leiden University)

Postdoctoral advisor: Prof. K.S. Burch (University of Toronto)

Postdoctoral advisor: Dr. H.M. Christen (Oak Ridge National Laboratory)

Postdoctoral advisor: Dr. T.Z. Ward (Oak Ridge National Laboratory)