

# KIPP J. VAN SCHOOTEN, PH.D.

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## RESEARCH INTERESTS

Investigating fundamental spin-spin interactions as a probe of the nano- and mesoscale physics governing macroscopic observables in material systems ranging from carbon-based materials to semiconductor dopants and defects. By coherently manipulating the spin identity of optically and electrically generated excited states via electron spin resonance (ESR), insight into the chemical nature, environmental interactions, and possible technological usefulness of such spin states can be gained.

Also of interest is the technological development of novel and unique experimental probes of spin dependent phenomena. Combining magnetic resonance techniques with modern advancements in the realms of electronics, optical spectroscopy, and radio frequency control opens new windows on accessing and controlling spin systems.

Current projects focus on expanding the parameter space over which electron spin states may be electrically addressed; in particular, from large magnetic fields ( $\sim 3.3$  Tesla, Larmor frequency of  $\sim 94$  GHz) down to very weak magnetic fields (1 mT with  $\sim 30$  MHz Larmor frequency). At each extreme of magnetic field, the spin-spin coupling mechanisms experienced by charge carriers at the microscopic level can be quite different and are currently poorly understood. Additional projects revolve around taking advantage of electron-nuclear hyperfine couplings in order to enhance nuclear polarization via dynamic nuclear polarization (DNP). This allows enhanced detection of nuclear magnetic resonance (NMR) for states ranging over phosphorus donor qubits in silicon, to chemical groups at 2D surfaces, and material-confirmation of topological insulator states.

## RESEARCH EXPERIENCE

**Postdoctoral Researcher**, Dartmouth College, Hanover, New Hampshire 2015–2017  
*Ramanathan Lab*

- Rather than popular optical methods, using electrically detected magnetic resonance (EDMR) to explore defect states in SiC as potential qubit systems with electronic readout.
- Exploring the cross-over of underlying mechanisms for spin-dependent dissociation/recombination in donor-defect spin-pairs within phosphorus-doped silicon (Si:P) between extremes in magnetic field.
- Investigating the dependence of spin-pair formation and enhanced DNP through resonant exciton formation in Si:P and SiC using narrow linewidth, tunable lasers.
- Enhancing DNP for highly sensitive chemical identification at 2D surfaces.
- Using DNP as an experimental confirmation of topological insulating states in material candidates.
- Testing graphene for the potential of exploiting electron-nuclear couplings with DNP.
- Advisor: Prof. Chandrasekhar Ramanathan

**Postdoctoral Researcher**, University of Utah, Salt Lake City, Utah 2013–2015  
*Materials Research, Science, and Engineering Center (MRSEC)*

- Develop powerful excitation and detection methods for the Inverse Spin Hall Effect.
- Explore spin-current injection schemes and spin- to charge-current conversion mechanisms in organic semiconductors.

- Design and implement a  $\sim$ \\$1.4M, 12.5 Tesla, 330 GHz electro-optical spin resonance facility. [PDF] (*project canceled due to budget cuts*)
- Advisors: Profs. Christoph Boehme, Z. Valy Vardeny, Brian Saam

#### *The Spin Electronics Group*

- Measuring and numerically modeling spin-spin interaction energies and pair separations within organic semiconductors via electrical detection of Rabi oscillations under resonance detuning.
- Correlating morphology and magnetic order/disorder in organic semiconductors.
- Develop and refine the measurement and excitation techniques required for observation of exceedingly small electrical and optical signals.
- Advisor: Prof. Christoph Boehme

#### *The Organic Semiconductors and Optical Nanostructures Group*

- Spent 4 weeks at the University of Regensburg, Regensburg, Germany to retrofit a wide-field, optical microscopy setup with single-molecule spin-resonance capabilities.
- This work was sponsored by Prof. John M. Lupton, Chair of the Institute of Experimental and Applied Physics at the University of Regensburg.

### EDUCATION

**University of Utah**, Salt Lake City, Utah 2006–2012

*Ph.D. in Condensed Matter Physics, Dept. of Physics & Astronomy*

- Thesis: *Optically Active Charge Traps and Chemical Defects in Semiconducting Nanocrystals Probed by Pulsed Optically Detected Magnetic Resonance* [PDF]
- Ph.D. dissertation published in 2013 Springer Theses Series, ISBN:9783319005898
- Advisors: Prof. John M. Lupton & Prof. Christoph Boehme

**Southern Polytechnic State University**, Marietta, Georgia 2000–2005

*B.Sc in Physics, Dept. of Physics*

- Minor (non-traditional) in Electrical Engineering Technology
- Senior Project: *Development of a Wireless Geophone System for Subsurface Depth Seismology*
- Advisors: Dr. James B. Whitenton, Dr. Russel S. Patrick, Dr. Michael G. Thackston

### TECHNICAL PROFICIENCIES

#### *Techniques*

- Electron Spin Resonance (electrical, optical, and absorption detected ESR, both at high and low fields)
- Optical techniques (optics bench design, pulsed electrical/optical excitation for time-gated electroluminescence/photoluminescence spectroscopy)
- Organic semiconductor device fabrication, glovebox procedures, and thermal evaporation of metals
- Chemical handling, wetlab, and basic cleanroom procedures
- Electronic methods of small-signal detection, signal conditioning, and noise analysis
- Analog/digital electronics, microcontroller programming/interfacing, RF electronics, PCB design, and associated test equipment

#### *Software*

- Building quantum mechanical numerical simulations
- Python, MATLAB, LabVIEW, OriginLab, Xepi/PulseSPEL,  $\LaTeX$
- Working experience with C/C++, Assembly, AutoCAD/Inventor

### REFEREED JOURNAL PUBLICATIONS

(\*) *denotes shared authorship.*

- [1] Zhu, L., **van Schooten, K. J.**, Guy, M. L., Ramanathan, C. Optical dependence of electrically detected magnetic resonance in lightly doped Si:P devices. *Phys. Rev. Appl.* **7**, 064028 (2017). doi:[10.1103/PhysRevApplied.7.064028](https://doi.org/10.1103/PhysRevApplied.7.064028)
- [2] Guy, M. L., **van Schooten, K. J.**, Zhu, L., Ramanathan, C. Chemisorption of water on the surface of silicon microparticles measured by dynamic nuclear polarization enhanced NMR *J. Phys. Chem. C* **121**, 2748–2754 (2017). doi:[10.1021/acs.jpcc.6b11065](https://doi.org/10.1021/acs.jpcc.6b11065)
- [3] Sun, D., Kareis, C. M., **van Schooten, K. J.**, Jiang, W., Kavand, M., Davidson, R. A., Shum, W. W., Zhang, C., Tiwari, A., Boehme, C., Liu, F., Stephens, P. W., Miller, J. S., Vardeny, Z. V. Spintronic detection of interfacial magnetic switching in a paramagnetic thin film of tris(8-hydroxyquinoline)iron(III). *Phys. Rev. B* **95**, 054423 (2017). doi:[10.1103/PhysRevB.95.054423](https://doi.org/10.1103/PhysRevB.95.054423)
- [4] Sun, D., Zhang, C., Kavand, M., **van Schooten, K. J.**, Malissa, H., Groesbeck, M., McLaughlin, R., Boehme, C., Vardeny, Z. V. Spintronics of organometal trihalide perovskites. (2016) [*under review*] arXiv:[1608.00993](https://arxiv.org/abs/1608.00993)
- [5] Miller, R., **van Schooten, K. J.**, Malissa, H., Joshi, G., Jamali, S., Lupton, J. M., Boehme, C., Morphology effects on spin-dependent transport and recombination in polyfluorene thin films. *Phys. Rev. B* **94**, 214202 (2016). doi:[10.1103/PhysRevB.94.214202](https://doi.org/10.1103/PhysRevB.94.214202)
- [6] Kavand, M., Baird, M., **van Schooten, K. J.**, Malissa, H., Lupton, J. M., Boehme, C., Discrimination between spin-dependent charge transport and spin dependent recombination in  $\pi$ -conjugated polymers by correlated current and electroluminescence-detected magnetic resonance. *Phys. Rev. B* **94**, 075209 (2016). doi:[10.1103/PhysRevB.94.075209](https://doi.org/10.1103/PhysRevB.94.075209)
- [7] Hao, J., Davidson, R. A., Kavand, M., **van Schooten, K. J.**, Boehme, C., Miller, J. S., Hexacyanobutadienide-based frustrated and weak ferrimagnets:  $M(\text{HCBD})_2 \cdot z\text{CH}_2\text{Cl}_2$  ( $M = \text{V}, \text{Fe}$ ). *Inorg. Chem.* **55**, 9393–9399 (2016). doi:[10.1021/acs.inorgchem.6b01565](https://doi.org/10.1021/acs.inorgchem.6b01565)
- [8] Hao, J., Rheingold, A. L., Kavand, M., **van Schooten, K. J.**, Boehme, C., Capdevila-Cortada, M., Novoa, J. J., Wöß, E., Knör, G., Miller, J. S., Characterization of tetracyanopyridine (TCNPy)-based magnets:  $\text{V}[\text{TCNPy}]_2 \cdot z(\text{CH}_2\text{Cl}_2)$  ( $T_c = 111 \text{ K}$ ) and  $\text{V}[\text{TCNPy}]_3 \cdot z(\text{CH}_2\text{Cl}_2)$  ( $T_c = 90 \text{ K}$ ). *Chem. Eur. J.* **22**, 14273–14278 (2016). doi:[10.1002/chem.201602385](https://doi.org/10.1002/chem.201602385)
- [9] Hao, J., Rheingold, A. L., Kavand, M., **van Schooten, K. J.**, Boehme, C., Capdevila-Cortada, M., Novoa, J. J., Wöß, E., Knör, G., Miller, J. S., The tetracyanopyridinide dimer dianion,  $\sigma\text{-}[\text{TCNPy}]_2^{2-}$ . *Chem. Eur. J.* **22**, 12312–12315 (2016). doi:[10.1002/chem.201603071](https://doi.org/10.1002/chem.201603071)
- [10] \*Sun, D., \***van Schooten, K. J.**, Kavand, M., Malissa, H., Zhang, C., Groesbeck, M., Boehme, C., Vardeny, Z. V., Inverse spin Hall effect from pulsed spin current in organic semiconductors with tunable spin–orbit coupling. *Nat. Mater.* **15** 863–869 (2016). doi:[10.1038/nmat4618](https://doi.org/10.1038/nmat4618)
- [11] **van Schooten, K. J.**, Baird, D. L., Limes, M. E., Lupton, J. M., Boehme, C., Probing long-range carrier-pair spin-spin interactions in a conjugated polymer by detuning of electrically detected spin beatings. *Nat. Commun.* **6**, 6688 (2015). doi:[10.1038/ncomms7688](https://doi.org/10.1038/ncomms7688)
- [12] Malissa, H., Kavand, M., Waters, D. P., **van Schooten, K. J.**, Burn, P. L., Vardeny, Z. V., Saam, B., Lupton, J. M., Boehme, C., Room-temperature coupling between electrical current and nuclear spins in OLEDs. *Science* **345**, 1487–1490 (2014). doi:[10.1126/science.1255624](https://doi.org/10.1126/science.1255624)
- [13] **van Schooten, K. J.**, Boehme, C. & Lupton, J. M. Coherent magnetic resonance of nanocrystal quantum-dot luminescence as a window to blinking mechanisms. *ChemPhysChem*

15, 1737–46 (2014). doi:[10.1002/cphc.201400081](https://doi.org/10.1002/cphc.201400081)

- [14] Her, J. H., Stephens, P. W., Davidson, R. A., Min, K. S., Bagnato, J. D., **van Schooten, K. J.**, Boehme, C. & Miller, J. S. Weak ferromagnetic ordering of the  $\text{Li}^+[\text{TCNE}]^-$  (TCNE = tetracyanoethylene) organic magnet with an interpenetrating diamondoid structure. *J. Am. Chem. Soc.* **135**, 18060–3 (2013). doi:[10.1021/ja410818e](https://doi.org/10.1021/ja410818e)
- [15] **van Schooten, K. J.**, Huang, J., Talapin, D. V., Boehme, C. & Lupton, J. M. Spin-dependent electronic processes and long-lived spin coherence of deep-level trap sites in CdS nanocrystals. *Phys. Rev. B* **87**, 125412 (2013). doi:[10.1103/PhysRevB.87.125412](https://doi.org/10.1103/PhysRevB.87.125412)
- [16] **van Schooten, K. J.**, Huang, J., Baker, W. J., Talapin, D. V., Boehme, C. & Lupton, J. M. Spin-dependent exciton quenching and spin coherence in CdSe/CdS nanocrystals. *Nano Lett.* **13**, 65–71 (2013). doi:[10.1021/nl303459a](https://doi.org/10.1021/nl303459a)
- [17] Baker, W. J., Ambal, K., Waters, D. P., Baarda, R., Morishita, H., **van Schooten, K. J.**, McCamey, D. R., Lupton, J. M. & Boehme, C. Robust absolute magnetometry with organic thin-film devices. *Nat. Commun.* **3**, 898 (2012). doi:[10.1038/ncomms1895](https://doi.org/10.1038/ncomms1895)
- [18] Baker, W. J., McCamey, D. R., **van Schooten, K. J.**, Lupton, J. M. & Boehme, C. Differentiation between polaron-pair and triplet-exciton polaron spin-dependent mechanisms in organic light-emitting diodes by coherent spin beating. *Phys. Rev. B* **84**, 165205 (2011). doi:[10.1103/PhysRevB.84.165205](https://doi.org/10.1103/PhysRevB.84.165205)
- [19] Chaudhuri, D., Wettach, H., **van Schooten, K. J.**, Liu, S., Sigmund, E., Höger, S. & Lupton, J. M. Tuning the singlet-triplet gap in metal-free phosphorescent  $\pi$ -conjugated polymers. *Angew. Chem.* **49**, 7714–17 (2010). doi:[10.1002/anie.201003291](https://doi.org/10.1002/anie.201003291)
- [20] McCamey, D. R., **van Schooten, K. J.**, Baker, W. J., Lee, S.-Y., Paik, S.-Y., Lupton, J. M. & Boehme, C. Hyperfine-field-mediated spin beating in electrostatically bound charge carrier pairs. *Phys. Rev. Lett.* **104**, 017601 (2010). doi:[10.1103/PhysRevLett.104.017601](https://doi.org/10.1103/PhysRevLett.104.017601)
- [21] Boehme, C., McCamey, D. R., **van Schooten, K. J.**, Baker, W. J., Lee, S.-Y., Paik, S.-Y. & Lupton, J. M. Pulsed electrically detected magnetic resonance in organic semiconductors. *Phys. Status Solidi B* **246**, 2750–2755 (2009). doi:[10.1002/pssb.200982357](https://doi.org/10.1002/pssb.200982357)
- [22] Walter, M. J., Borys, N. J., **van Schooten, K. J.** & Lupton, J. M. Light-harvesting action spectroscopy of single conjugated polymer nanowires. *Nano Lett.* **8**, 3330–3335 (2008). doi:[10.1021/nl801757p](https://doi.org/10.1021/nl801757p)
- [23] **van Schooten, K. J.**, Baird, D. L., Limes, M., Lupton, J. M., & Boehme, C. Probing Carrier-Pair Spin-Spin Interactions in a Conjugated Polymer by Detuning of Electrically Detected Beating of Spin-Rabi Oscillations. *New England Section Meeting of the American Physical Society*. Hanover, New Hampshire, USA, November 06–07, 2015.
- [24] **van Schooten, K. J.**, Baird, D. L., Limes, M., Lupton, J. M., & Boehme, C. Probing Carrier-Pair Spin-Spin Interactions in a Conjugated Polymer by Detuning of Electrically Detected Beating of Spin-Rabi Oscillations. *Rocky Mountain Conference on Magnetic Resonance* (RMCAC 2015). Snowbird, Utah, USA, July 26–30, 2015.
- [25] **van Schooten, K. J.**, Sun, D., Vardeny, Z. V., & Boehme, C. Artifact free Inverse Spin Hall Effect Measurements in Organic Semiconductor Devices by Pulsed Ferromagnetic-Resonant Spin-Pumping. *Rocky Mountain Conference on Magnetic Resonance* (RMCAC 2014). Copper Mountain, Colorado, USA, July 13–17, 2014.

CONFERENCE  
TALKS

- [26] **van Schooten, K. J.**, Huang, J., Talapin, D. V., Boehme, C. & Lupton, J. M. Spin-Dependent Light-Harvesting in Nanotetrapods by Controlling Electronic Trap States with Optically Detected Magnetic Resonance. *Nanoscience with Nanocrystals* (NaNaX6). Bad Hofgastein, Austria, May 18–23, 2014.
- [27] **van Schooten, K. J.**, Huang, J., Talapin, D. V., Boehme, C. & Lupton, J. M. Spin-Dependent Light-Harvesting in Nanotetrapods by Controlling Electronic Trap States with Optically Detected Magnetic Resonance. *International Conference on Quantum Dots* (QD2014). Pisa, Italy, May 11–16, 2014.
- [28] **van Schooten, K. J.**, Huang, J., Talapin, D. V., Boehme, C. & Lupton, J. M. Spin-Dependent LightHarvesting in Colloidal Nanocrystals by Controlling Electronic Trap States with Optically Detected Magnetic Resonance. *American Physical Society March Meeting*. Baltimore, Maryland, USA, March 17–22, 2013.
- [29] **van Schooten, K. J.**, Huang, J., Baker, W. J., Talapin, D. V., Boehme, C. & Lupton, J. M. Probing Electronic Trap States in Colloidal Nanocrystals with Optically Detected Magnetic Resonance. *Rocky Mountain Conference on Analytical Chemistry* (RMCAC 2012). Copper Mountain, Colorado, USA, June 16–21, 2012.
- [30] **van Schooten, K. J.**, Baker, W. J., Huang, J., Talapin, D. V., Boehme, C. & Lupton, J. M. Observation of Long Spin Coherence Times in CdSe/CdS Colloidal Nanostructures. *American Physical Society March Meeting*. Dallas, TX, USA, March 22–25, 2011.

CONFERENCE  
POSTERS

- [31] **van Schooten, K. J.**, Guy, M. L., Zhu, L., Ramanathan, & C. Design Considerations for Frequency-Swept Electrically-Detected Magnetic Resonance at High Fields. *Gordon Research Conference: Defects in Semiconductors*. New London, New Hampshire, USA, August 14–19, 2016.
- [32] **van Schooten, K. J.**, Baker, W. J., Huang, J., Talapin, D. V., Boehme, C. & Lupton, J. M. Long Spin Coherence Lifetimes of Optically Generated Excitations in Colloidal CdS Nanorods. *Optical Probes of Conjugated Polymers and Organic Nanostructures* (OP2011) & *Excited State Processes on Electronic and Bio Nanomaterials* (ESP2011). Santa Fe, NM, USA, June 19–24, 2011
- [33] **van Schooten, K. J.**, Huang, J., Baker, W. J., Talapin, D. V., Boehme, C. & Lupton, J. M. Long Spin Coherence Lifetimes of Optically Generated Excitations in Colloidal CdS Nanorods. *Fundamental Optical Processes in Semiconductors* (FOPS2011). Lake Junaluska, NC, USA, August 1–5, 2011.
- [34] **van Schooten, K. J.**, Liu, S., Walter, M. J., McCamey, D. R., Scherf, U., Boehme, C., & Lupton, J. M. Time-Resolved Measurements of Spin-Dependent Carrier Recombination in Charge Transfer States of pi-Conjugated Polymers. *American Chemical Society National Meeting*. Salt Lake City, UT, USA, March 22–26, 2009.

COLLOQUIA &  
SEMINARS

- [35] Making Use of Trapped-Carrier Spins in Colloidal Nanocrystals, *Institute of Experimental and Applied Physics Colloquium*, University of Regensburg, Regensburg, Germany, June, 23, 2014.
- [36] Increasing Accessibility to the Inverse Spin Hall Effect by Pulsed Ferromagnetic-Resonant Spin-Pumping, *Materials Research, Science, and Engineering Center* (MRSEC) *Seminar*, University of Utah, Salt Lake City, UT, USA, April 8, 2014.



BOOKS	[37] <b>K. J. van Schooten</b> , <i>Optically Active Charge Traps and Chemical Defects in Semiconducting Nanocrystals Probed by Pulsed Optically Detected Magnetic Resonance</i> , Springer, Cham, Switzerland, 2013. ISBN:9783319005898	
TEACHING EXPERIENCE	<b>Dartmouth College</b> , Hanover, New Hampshire <i>Lecturer, Dept. of Physics &amp; Astronomy</i> - Course: Introduction to Optics	2017
	<b>Dartmouth College</b> , Hanover, New Hampshire <i>Lecturer, Dept. of Physics &amp; Astronomy</i> - Course: Methods of Experimental Physics	2017
	<b>University of Utah</b> , Salt Lake City, Utah <i>Graduate Teaching Assistant, Dept. of Physics &amp; Astronomy</i> - Courses: Modern Physics (grading, office hours, class 1 day/week), Electronics I (grading, office hours, practical lab), Solid State II (grading, office hours) - <i>Outstanding Teaching Assistant of the Year</i> award winner each year of TA duties	2006–2009
	<b>Southern Polytechnic State University</b> , Marietta, Georgia <i>University Staff Tutor, Campus-wide</i> - Courses: Physics (all levels), Calculus (I-III), Pre-Calculus - Hired as the only staff Physics tutor for the University, and one of two Calculus tutors	2003–2005
ACADEMIC SERVICE	<b>Graduate Student Advisory Council, Chair</b> Dept. of Physics & Astronomy, University of Utah, Salt Lake City, Utah	2011–2012
	<b>Graduate Student Advisory Council, Vice-Chair</b> Dept. of Physics & Astronomy, University of Utah, Salt Lake City, Utah	2010–2011
	<b>Academic Misconduct Committee, Graduate Representative</b> College of Science, University of Utah, Salt Lake City, Utah	2008–2010
	<b>Academic Appeals Committee, Graduate Representative</b> College of Science, University of Utah, Salt Lake City, Utah	2008–2010
	<b>IEEE Student Organization, Activities Director</b> Electrical and Computer Engineering Technology, Southern Polytechnic State University, Marietta, Georgia	2002–2003
HONORS & AWARDS	<b>Ph.D. dissertation published in Springer Theses Series</b> <i>Optically Active Charge Traps and Chemical Defects in Semiconducting Nanocrystals Probed by Pulsed Optically Detected Magnetic Resonance</i> , ISBN:9783319005898	SPRING 2013
	<b>2nd Place Best Graduate Student Oral Presentation</b> <i>Probing Electronic Trap States in Colloidal Nanocrystals with Optically Detected Magnetic Resonance</i> . Student Research Symposium, Dept. of Physics & Astronomy, University of Utah	AUGUST 4, 2012
	<b>1st Place Best Graduate Student Oral Presentation</b> <i>Long Spin Coherence Lifetimes of Optically Generated Excitations in Colloidal CdS Nanorods</i> . Student Research Symposium, Dept. of Physics & Astronomy, University of Utah	AUGUST 13, 2011
	<b>Outstanding Teaching Assistant</b> Course: Solid State Physics II (PHYS 5520). Taught by: Prof. John Lupton. Dept. of Physics & Astronomy, University of Utah	2008–2009

**Outstanding Teaching Assistant**

2007–2008

Course: Intro to Quantum and Relativity (PHYS 3740). Taught by: Prof. John Lupton.  
Dept. of Physics & Astronomy, University of Utah

**Outstanding Teaching Assistant**

2006–2007

Course: Intro to Quantum and Relativity (PHYS 3740). Taught by: Prof. John Lupton.  
Dept. of Physics & Astronomy, University of Utah

**Outstanding Teaching Assistant**

2005–2006

Course: Intro to Quantum and Relativity (PHYS 3740). Taught by: Prof. David Ailion.  
Dept. of Physics & Astronomy, University of Utah

**PROFESSIONAL  
AFFILIATIONS**

American Physical Society, Member

2008–PRESENT

American Chemical Society, Member

2006–PRESENT

Institute of Electrical and Electronics Engineers, Member

2002–2005, 2015–PRESENT

**PEER-REVIEW  
EXPERIENCE**

Physical Review Letters (PRL)

Physical Review B (PRB)

Applied Physics Letters (APL)

Journal of the American Chemical Society (JACS)