

Graduate Program in Spintronics Seminar

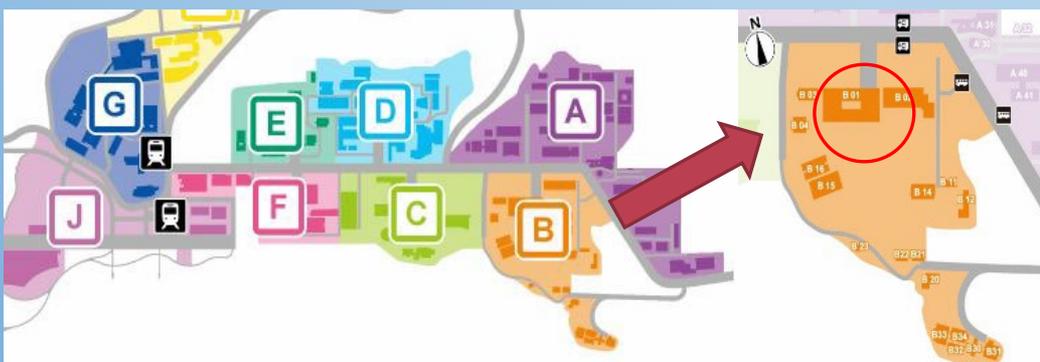


Prof. Dr. Dominik Zumbühl
Department of Physics, University of Basel
Director, NCCR SPIN



Lecture Title
"Spin-orbit coupling in 2D and 0D semiconductors"

Date: Tuesday, November 7, 2023, 4:00 p.m.
Place: Materials Development Education and Research Bldg.
Lecture Room 2 (Room 102)



Materials Science and Engineering
Education and Research Building (B01)

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Spin-orbit coupling in 2D and 0D semiconductors

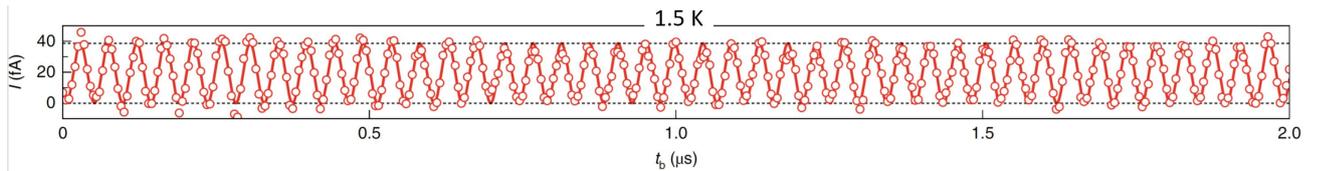
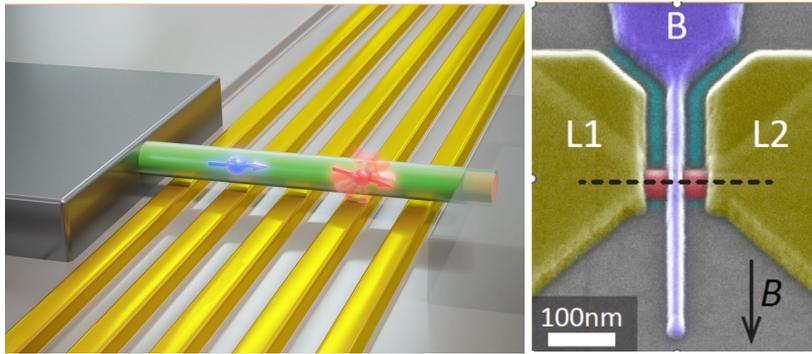
Dominik Zumbühl, University of Basel and NCCR SPIN

The spin-orbit interaction (SOI) arises from the relativistic physics of semiconductor charges, creating magnetic out of electric fields when performing a Lorentz boost into the rest frame of a charge. The SOI is at the heart of key phenomena in condensed matter physics and conveniently gives access to magnetic degrees of freedom via electric fields. This makes possible all-electrical coherent spin manipulation while simultaneously opening the door for dephasing by charge noise. In this presentation, I will present aspects of the 2D physics of the quantum oscillations of resistivity, and then turn to the fully confined 0D structures of hole spins qubits in Si and Ge quantum dots.

Shubnikov-de Haas (SdH) oscillations are the fingerprint of the Landau and Zeeman splitting on the resistivity, serving as paradigmatic experimental probe. So far, no analytical description could be found for the vast majority of parameter space with Rashba, Dresselhaus and Zeeman terms all present. We bridge this gap by providing an analytical formulation [Candido et al., arXiv:2304.14327], and derive a simple condition for beating-free SdH oscillations, notably different from the persistent spin helix for materials with large $g^* m^*$ such as InAs or InSb.

Semiconductor spins are leading contenders for highly scalable qubits. I will present recent progress from the [NCCR SPIN](#), the Swiss National Program on Quantum Computation. Highlights incl. ultrafast qubits, taking only 1 ns to coherently rotate a spin from pointing up to down; operation of spin qubits up to 5 K, where vast cooling power becomes available, making possible integration of the classical control electronics; operation of a 2-qubit gate with highly anisotropic exchange, allowing for high fidelity gate operation while operating at high speeds; and finally a sweet spot combining *both* qubit coherence *and* speed, thus opening new avenues for ultrafast and highly coherent hole spin qubits

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[Bio:](#) Dominik received his PhD at Harvard University in 2004 on quantum coherence and spin in semiconductor quantum dots after receiving a diploma from ETH Zürich in 1998 and a MSc in 2000 from Stanford University. After a 2-year postdoc at MIT, Dominik started his own group in 2006 at the University of Basel where he has been working since. In 2008, he received a starting grant in the first ERC call. He was promoted to associate professor in 2012 and to full professor in 2023. He served as Department Chair from 2015-2019 and since 2021, he is the director of the NCCR SPIN, the Swiss National Program on Quantum Computing with Si and Ge spins. He was elected as a fellow of the American Physical Society (APS) in 2023.

Dominik's research interests are in quantum transport experiments in semiconductor nanostructures, focusing on quantum computation with spins, coherence, interactions, quantum condensed matter at ultralow temperatures and machine learning for quantum devices.