CORE RESEARCH AREA

Paul-Drude-Institut für Festkörperelektronik

Leibniz-Gemeinschaft

Leibniz Forschungsverbund Berlin e.V.

Control of Elementary Excitations by Acoustic Fields

Motivation / Mission / Approach

Our curiosity and efforts are driven by the rapidly developing areas of solid state quantum communication, computations and sensing, while the emerging interdisciplinary challenges motivate us.

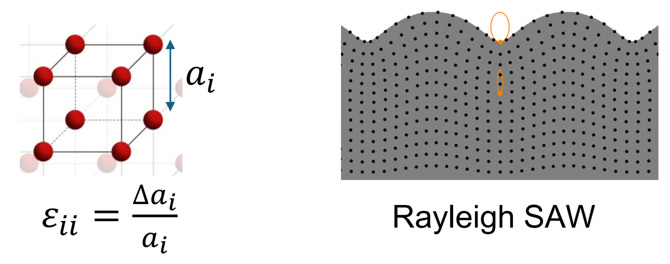
We explore new fundamental ways for coherent manipulation of solid state quantum excitations at ultra-high frequencies, micro- and nano-meter spatial scales and demonstrate key proof-of-principle devices.

We create complex nanostructures comprising materials supporting spins, excitons, polaritons and magnetic excitations and actuate on those using GHz-frequency acoustic strain, which we generate by converting microwave signals into phonons.

Research Topics

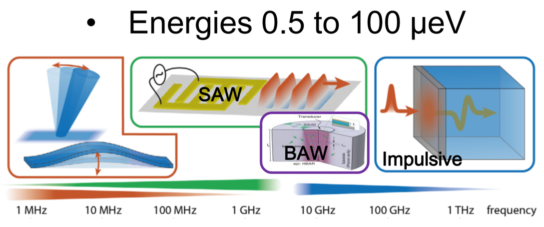
Surface (SAWs) and bulk (BAWs) acoustic waves

Acoustic phonons are a source of dynamic lattice deformation and piezoelectric fields at the nanoscale.

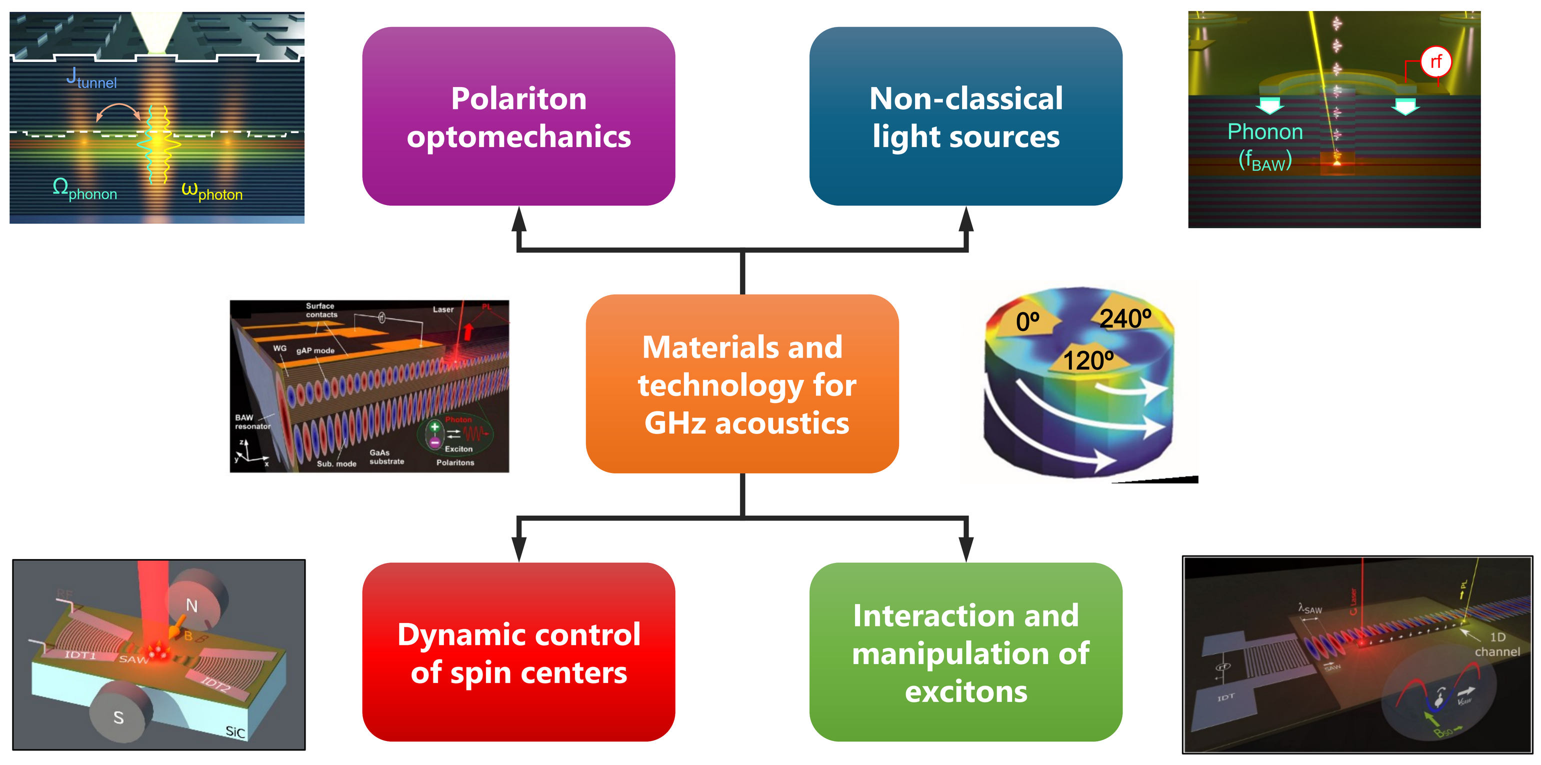


Lattice constant: a_i {i = x,y,z}
- Energy bandgap
- Electrical conduction
- Optical anisotropy
- Magnetic properties
- Quasiparticles
- Defects
- Spins

Acoustic strain
- Freq. 100 MHz to 20 GHz
- Wavelengths 0.5 to 20 µm
- Energies 0.5 to 100 µeV



Wigger et al., Adv. Quantum Technol. 4, 2000128 (2021)



Facts and Numbers

Members in 2025

Senior Scientists: A. Hernández-Mínguez, K. Biermann, P. V. Santos

Scientists: A. S. Kuznetsov, M. Yuan

PhD Students: M. Saeedi, N. Ashurbekov

Visiting scientists: P. W. Matrone (PhD), R. Rachmandran (PhD), J. Gordon, I. Carraro Haddad (PhD), Prof. M. Msall, Prof. A. Pitanti

Main Internal Collaborations

❖ CReA Nitride Semiconductors
- metal-doped AlN films (O. Brandt, V. D. Dihn)

❖ CReA Quantum Cascade Lasers
- BAW modulation of QCLs (V. Pistore)

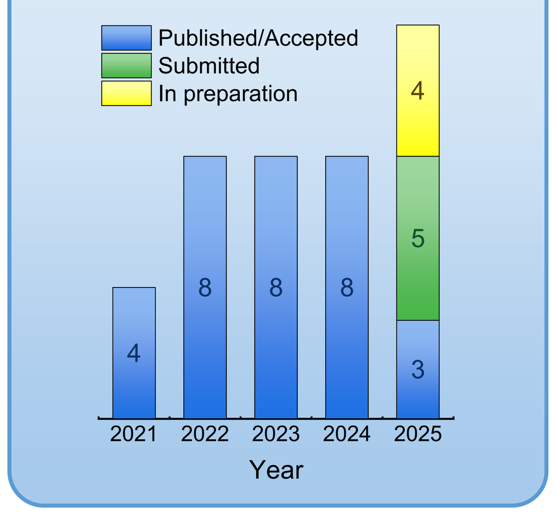
❖ CReA Disordered Semiconductors
- Exciton-polaritons in organic semiconductors (S. Shoaee)

❖ Technology & Transfer
- Clean room facilities

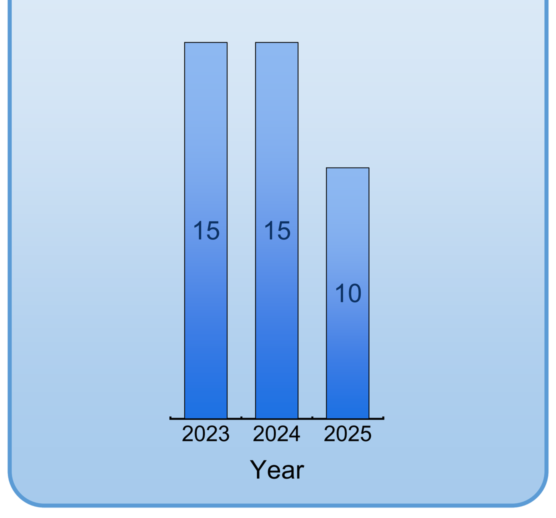
Main External Collaborations

- Helmholtz-Zentrum Dresden-Rossendorf, Germany
- Hochshule für Technik und Wirtschaft, Germany
- Nat. Inst. of Standards and Technology, USA
- University of San Luís Potosí, Mexico
- Institute of Photonic Sciences, Spain
- Universität Münster, Germany
- University of Campinas, Brazil
- Instituto Balseiro, Argentina
- TU München, Germany
- University of Pisa, Italy

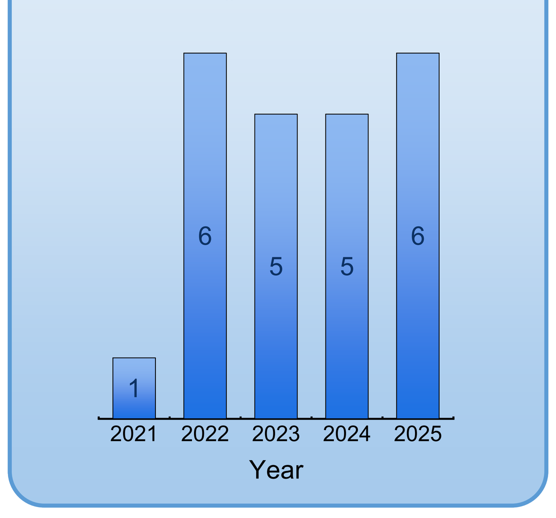
Publications



Talks and Seminars



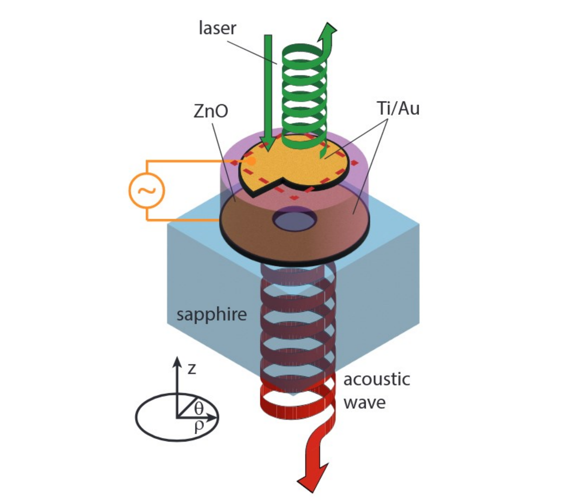
Visiting Scientists



Third Party Funding

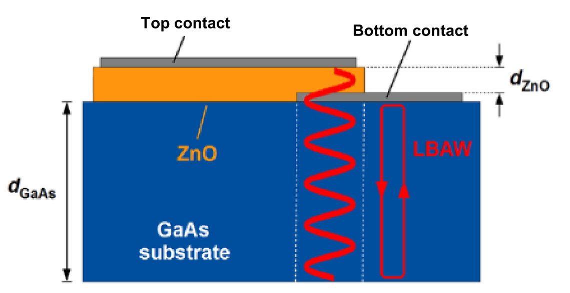
Agency	Starting – Ending Year	Title	Principal Investigator	Amount
DFG	2021 – 2025	Nanoscale optomechanical interactions in semiconductor microcavities	Dr. Paulo V. Santos	216 k€
DFG	2022 – 2025	Coherent GHz electro-optomechanics with polaromechanical crystals	Dr. Paulo V. Santos Dr. Alexander Kuznetsov	289 k€
EU	2024 – 2028	High-frequency SAW resonators on SiC for applications in quantum technology, within MSCA Doctoral Network "HINA"	Dr. Alberto Hernández-Mínguez	217 k€
DFG	2025 – 2028	Integrated acousto-NEMS on monolithic new-nitride thin films, within SPP "Nitrides4Future''	Dr. Mingyun Yuan	178 k€
Leibniz Society	submitted	Leibniz Professorship	Dr. Mingyun Yuan	2200 k€

Current Work and Prospects



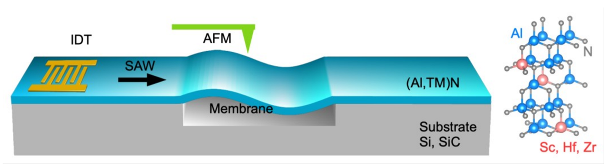
GHz helical optomechanics (poster by N. Ashurbekov)

❖Design, excitation and characterization of helical fields
❖Modulation of photon orbital angular momentum
❖Non-reciprocal coupling to spin transitions



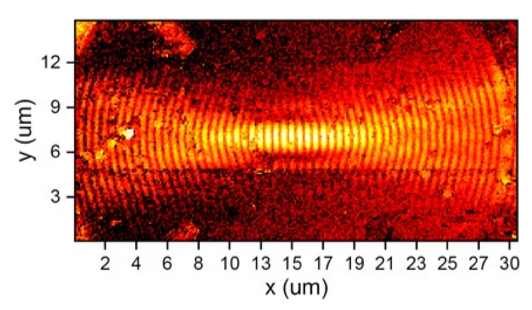
New materials for future-generation SAW and BAW technology

❖ Hybrid integration of (K,Na)(Nb,Ta)O_3 thin films
❖ Sc-doped AlN films
❖Frequencies reaching up to 20 GHz



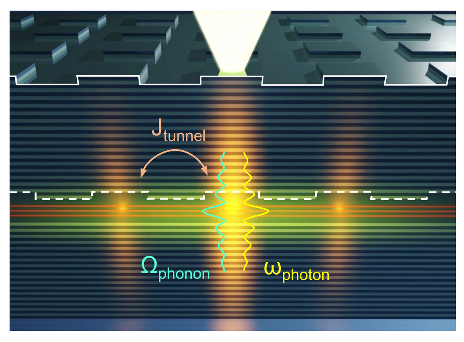
Integrated acousto-NEMS on new-nitride thin films

❖Synthesis and study of new nitride compounds for GHz SAWs
❖Acousto-NEMS phononic platforms for quantum technology
❖Applications as sensors in harsh environments



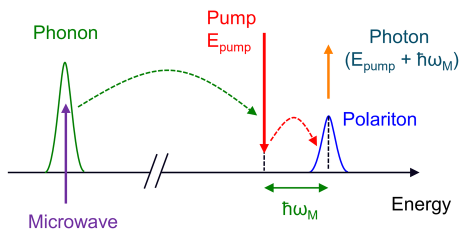
Spatial mapping of acoustic fields (poster by M. Yuan)

❖Characterization of helical acoustic waves
❖Efficiency of SAW coupling to van der Waals materials



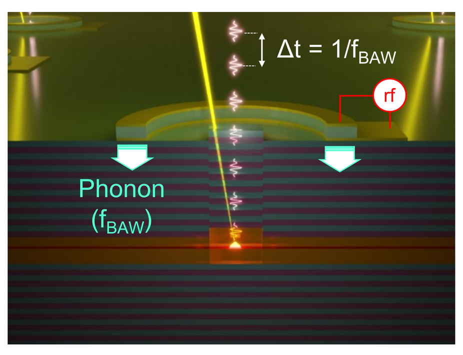
Polariton lattices + (chiral) phonons

❖Floquet engineering of topology
❖Non-reciprocity of polariton tunneling



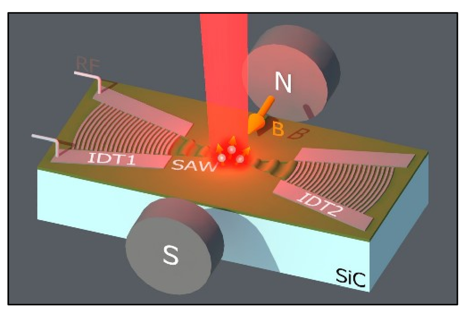
Microwave-to-optical conversion

❖Conversion between GHz qubits and optical photons
❖Development of high-Q MCs for polaritons



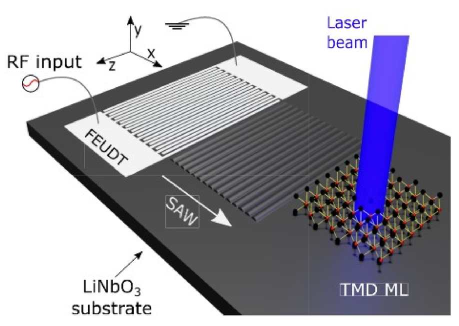
GHz-triggered non-classical light sources (poster by. A. S. Kuznetsov)

❖Sub-micron traps – quantum polaritons
❖QDs embedded in patterned optical cavities
❖Color centers in epitaxial AlN films



Acoustic control of spin centers

❖SAW resonators in (K,Na)(Nb,Ta)O_3 /SiC hybrid systems
❖Non-reciprocal spin manipulation by helical SAWs



Acoustic exciton control in van der Waals materials

❖SAW-driven excitonic dynamics in TMDs
❖SAW-modulated single-photon emission of TMDs on nanopillars
❖Exciton-polaritons in TMDs embedded in optical cavities

Acknowledgements

PDI is part of the Forschungsverbund Berlin and a member of the Leibniz Association.

Our research is funded by the Federal Ministry of Research, Technology, and Space (BMFTR) and the Berlin Senate. Additional funding from the EU, DFG, DAAD, and Humboldt Foundation is gratefully acknowledged.

Contact: Dr. Alberto Hernández-Mínguez, hernandez-minguez@pdi-berlin.de

Federal Ministry of Research, Technology and Space

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