BORIS KIEFER

Quantum Solutions Architecture | Computational Materials Science | Quantum Photonics

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PROFESSIONAL PROFILE

Quantum computing, photonics, and computational-science researcher and technical leader with 20+ years of experience turning complex physical models into simulation workflows, benchmarks, decision-support tools, and stakeholder-facing technical assets. Current work combines quantum photonics, quantum networking, unitary decomposition, fault-tolerance intuition, and resource-aware quantum assessment with deep electronic-structure and materials expertise using VASP, Quantum ESPRESSO, SeqQuest, and ABACUS. Solution-architecture focus: move from problem discovery to bounded technical scope, transparent assumptions, reproducible POCs, verification, and decision-ready recommendations.

SOLUTION ARCHITECTURE STRENGTHS

- **Discovery & scoping:** translate loosely defined scientific or customer problems into bounded requirements, constraints, evaluation metrics, and next-step decisions.
- **POC & workflow design:** build transparent simulators, notebooks, benchmarks, and technical briefs that expose assumptions and tradeoffs rather than hide them.
- **Quantum + classical assessment:** compare quantum, classical, and classical+AI approaches; identify computational kernels, resource drivers, scaling limits, and credible crossover conditions.
- **Quantum hardware translation:** connect algorithmic requirements to architecture-aware constraints across trapped-ion, superconducting, and photonic platforms.
- **Materials & chemistry integration:** connect DFT and materials workflows to quantum-ready formulations while retaining experimental, synthesis, phase-stability, defect, and property constraints.
- **Technical communication:** support mixed technical/non-technical audiences with reproducible demonstrations, implementation guides, roadmaps, briefs, and stakeholder-facing recommendations.

SELECTED SOLUTION-ARCHITECTURE ASSETS

Public simulator and research-software portfolio. Developed a rapidly growing set of public Jupyter/Python tools spanning quantum state preparation, superposition, Hong-Ou-Mandel interference, squeezed states, multimode photonics, Bell-state measurement, entanglement swapping, quantum networking, neutral-atom Rydberg blockade, fault tolerance, materials analysis, and applied photonics. Repositories are paired where appropriate with technical briefs, guided exercises, and citable releases.

Quantum opportunity and resource-assessment framework. Developed a modality-neutral framework for deciding whether industrial computational problems warrant quantum development, reformulation, monitoring, or continued classical investment based on classical tractability, resource requirements, noise, precision, and implementation constraints.

Cross-architecture entanglement-swapping benchmark. Implemented a common primitive across Python, QuTiP, Qiskit, IonQ-native, Quantinuum-native, and Strawberry Fields continuous-variable stacks to make abstraction-layer and architecture tradeoffs visible.

Photonic mesh and unitary-decomposition workflows. Developed QuTiP- and matrix-based workflows for programmable interferometers including decomposition/completion, degeneracy, boundary phases, MZI control, loss/noise, failure compensation, and hardware-aware constraints.

Agentic-AI scientific workflow prototype. Developed structured, human-guided, validation-gated scientific software workflows with prompt contracts, modular artifacts, automated checks, and checker-based repair for reproducible code and analysis.

Materials simulation for quantum and AI-enabled discovery. Built DFT and machine-learning-assisted workflows for bandgaps, phase stability, defect chemistry, magnetic states, and optical/electronic properties; use the classical baseline to identify where quantum treatment could add real value.

PROFESSIONAL EXPERIENCE

Full Professor, Department of Physics — New Mexico State University **2016-Present**

- Lead research and application development across quantum computing, quantum photonics, computational materials science, scientific simulation, and application-facing quantum assessment.
- Conduct NQVL-QCAP quantum-photonics research on programmable interferometers, unitary decomposition, MZI control, Gaussian/non-Gaussian resources, hardware constraints, and deployment-minded algorithms.
- Develop electronic-structure workflows for bandgap engineering, defects, phase stability, magnetic states, and optical/electronic properties; academic partner in an ongoing funded Sandia National Laboratories collaboration on narrow-gap infrared detector materials.

- Develop public research simulators that expose assumptions, quantify tradeoffs, and make quantum and materials workflows understandable to mixed technical audiences.
- Program Director, Engineering Physics/ABET: led successful ABET reaccreditation through 2031 with zero weaknesses or deficiencies, coordinating evidence, outcomes, reporting, faculty, administrators, and external evaluators.

Associate Professor, Department of Physics — New Mexico State University **2009-2016**

- Expanded research into quantum information, computational physics, materials modeling, and cross-disciplinary simulation workflows.
- Co-PI, NSF GOALI project with the University of New Mexico and General Motors, connecting computational modeling, materials science, and automotive-relevant technical challenges.
- Developed implementation-oriented research assets linking simulation results to cross-sector technical decisions.

Assistant Professor, Department of Physics — New Mexico State University **2003-2009**

- Established an independent computational and applied-physics research program spanning materials science, geoscience, complex physical systems, numerical modeling, and scientific computing.

INDUSTRY, NATIONAL-LAB & CROSS-SECTOR ENGAGEMENT

- Sandia National Laboratories - ongoing funded computational-materials collaboration: DFT-based bandgap engineering, phase stability, defect chemistry, and narrow-gap IR detector materials.
- General Motors - NSF GOALI collaboration: multi-institution computational modeling and stakeholder coordination for automotive-relevant materials challenges.
- Scion/Toyota-related research engagement (2010-2011): computational materials modeling through UNM Chemical Engineering.
- S3 / AFRL software spin-off - consultant (2016): applied quantum and computational-physics expertise in a commercial software context.
- Selected collaboration network also includes Los Alamos National Laboratory and quantum-industry partners through QCAP/NQVL activities.

TECHNICAL TOOLKIT

Quantum & simulation: Qiskit, QuTiP, Strawberry Fields, quantum circuits, photonic meshes, DV/CV protocols, entanglement, quantum networking, NISQ benchmarking, hardware-aware resource analysis.
Materials & DFT: VASP, Quantum ESPRESSO, SeqQuest, ABACUS, electronic structure, phase stability, defect chemistry, magnetism, bandgap engineering, optical/electronic properties.
AI & scientific software: Python, Jupyter, NumPy, SciPy, Matplotlib, LLM-assisted scientific computing, agentic workflows, validation-gated code generation, reproducible pipelines.
Decision support: design-space exploration, sensitivity analysis, classical/quantum comparison, technical briefs, demos, implementation guides, POC scoping, technical roadmaps.

SELECTED QUANTUM & COMPUTATIONAL PUBLICATIONS

- Kiefer, B. & Pfister, O. Photon-Conditioned Squeezed States for Directional Displacement Response in Continuous-Variable Photonics. arXiv:2605.27660 (2026).
- Coronado-Arrieta, M. & Kiefer, B. Beyond the HOM Dip: A Multi-Metric Module for Teaching Two-Mode Quantum Optical Interference. arXiv:2605.27751 (2026).
- Kiefer, B. A Research-Informed Module on Quantum Superposition for Rapid Classroom Adoption. arXiv:2605.23976 (2026).
- Pelofske, E., Bärtschi, A., Eidenbenz, S., Garcia, B. & Kiefer, B. Probing quantum telecloning on superconducting quantum processors. IEEE Transactions on Quantum Engineering 5, 1-19 (2024).
- Pelofske, E., Bärtschi, A., Garcia, B., Kiefer, B. & Eidenbenz, S. Quantum telecloning on NISQ computers. IEEE QCE, 605-616 (2022).

EDUCATION

- Ph.D., Geological Sciences - University of Michigan, Ann Arbor (computational modeling and simulation in complex physical systems).
- M.S., Geological Sciences - University of Michigan, Ann Arbor.
- Diplom, Physics - Georg-August-Universität Göttingen, Germany.