



## Light that Talks: Interacting Photons and the Future of Quantum-AI Photonics

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**Wednesday, April 30<sup>th</sup> @ 2:00 pm in BRK 1001**

*Coffee and snacks served before seminar*

also on [MS Teams link](#)

**Abstract:** Photons lie at the heart of both foundational quantum science and next-generation quantum technologies, owing to their resilience against environmental decoherence and their unique role as carriers of quantum information. While advances in classical photonics have empowered remarkable control over photons, the absence of strong photon-photon interactions remains a central obstacle to realizing scalable quantum systems. A promising frontier in addressing this challenge is many-body quantum optics—an emerging paradigm that enables the exploration of strongly correlated quantum states of light and paves the way for quantum simulation, nonlinear quantum photonics, and complex information processing.

In this talk, first, I will present our recent efforts to establish solid-state platforms that enable and harness photon-photon interactions through excitonic intermediaries. We focus on cuprous oxide ( $\text{Cu}_2\text{O}$ ), a material that uniquely hosts excitonic Rydberg states characterized by large principal quantum numbers and dramatically enhanced interaction strengths. I will share the first spectroscopic observations of Rydberg excitons in synthetic  $\text{Cu}_2\text{O}$  thin films and describe our bottom-up approach to assembling 2D arrays of these excitons, laying the groundwork for solid-state quantum simulators of lattice models. I will also highlight our progress in integrating these highly interacting excitonic states with silicon nitride photonic circuits, representing a critical step toward scalable Rydberg photonics. Building on this foundation, the second part of the talk explores a complementary solid-state platform based on a novel class of GaAs quantum dots (QDs). By engineering properties of individual emitters as well as coherent interactions between multiple QDs, we propose a novel approach to realize and study collective quantum effects, followed by the controlled generation of non-classical light, emergent many-body correlations, and access to synthetic quantum phases—further expanding the landscape of many-body quantum optics in semiconductor systems. Finally, I will briefly introduce our latest development: an all-optical neural network architecture powered by the intrinsic nonlinearity of atomic systems. This initiative merges quantum photonics with neuromorphic computing, offering a path toward analog quantum information processing with unprecedented scalability.

Together, these advances reflect a unified vision: to develop practical, scalable, and highly interactive photonic systems that leverage solid-state quantum materials and atomic vapors to unlock the full potential of quantum technologies.

**Bio:** Hadiseh Alaeian received her Ph.D. from Stanford University in 2015, where her dissertation on non-Hermitian and active photonics earned her the Silver Medal from the Materials Research Society. Following her doctoral studies, she continued her research in Germany—first as a Humboldt Postdoctoral Fellow, and later as a Junior Group Leader at the University of Stuttgart. Her work on quantum dynamics and phase transitions in photonic systems—including photon Bose-Einstein condensation and atom-induced photon-photon interactions—was recognized with the Young Investigator Award from the Stuttgart-Ulm-MPI Quantum Hub and the Eliteprogramm of the Baden-Württemberg Foundation. In August 2020, Hadiseh joined Purdue University as an Assistant Professor of Electrical and Computer Engineering and Physics and Astronomy. Her research combines theoretical and experimental approaches to explore quantum collective phenomena in strongly interacting and non-Markovian quantum photonic systems.