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From Rydberg Array Quantum Simulators to Inverse-Designed Photonics for Quantum Applications

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Abstract

My talk is divided into two main parts that reflect key areas of my recent research. In the first part, I will discuss quantum simulations of frustrated spin systems using Rydberg atom array quantum simulators. In particular, I will present the results of our investigation of the quantum phases of Rydberg atoms arranged in a frustrated Shastry–Sutherland lattice. This study, conducted both theoretically and experimentally, on QuEra's Rydberg atom array quantum simulators, revealed a variety of classical and quantum phases, including novel quantum critical points.

In the second part, I will highlight my ongoing experimental efforts to engineer light–matter interactions through photonic inverse design. I will demonstrate how inverse design enables precise control of optical states in the near field, opening up a wide range of applications for light–matter interaction, sensing, and enhanced spectroscopy. As a concrete example, I will describe how topology-optimized dielectric cavities can be coupled to excitonic systems, allowing us to control both their linear and nonlinear properties.

I will conclude by offering perspectives on future directions, including probing excitations in topological quantum materials and exploring light-induced physics in two-dimensional materials.

Bio

Dr. Vahagn Mkhitaryan is a Senior Research Scientist at Purdue University. He earned both his bachelor's degree in electrical engineering (2006–2010) and his master's degree in Plasmonics and Photonics (2010–2012) from Yerevan State University in Armenia. In 2013, he began his doctoral studies at ICFO – The Institute of Photonic Sciences in Barcelona, Spain, under the supervision of Valerio Pruneri and Javier García de Abajo and received his PhD from UPC – Universitat Politècnica de Catalunya in 2018. His dissertation focused on designing and characterizing active nanophotonic structures and devices—particularly periodic structures and multilayer thin films in combination with phase-change materials—using both experimental and theoretical approaches.

After completing his PhD, Dr. Mkhitaryan continued at ICFO (2017–2021) as a Postdoctoral Researcher in the Nanophotonics Theory group led by Prof. García de Abajo. During that time, he developed theoretical methods to investigate optical excitations in materials using electron beams as probes and carried out experiments to demonstrate plasmons in atomically thin metals. Following the global pandemic, he moved to the United States in 2021, joining Prof. Vladimir Shalaev's group at Purdue University—initially as a Postdoctoral Researcher and later as a Research Scientist. His current research interests include using photonic inverse design to enhance light–matter interactions, light-induced physics and control of quantum states of matter, spectroscopy of topological quantum materials, and investigating quantum many-body physics through Rydberg atom array-based quantum simulators.

Host

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