# "What can nanophotonics do for ML, and what can ML do for quantum computing/simulation?"

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***Bio:*** Avik Dutt (MS/PhD ECE, Cornell University '17, B.Tech IIT Kharagpur '11), is an Assistant Professor and a National Quantum Lab (QLab) Fellow at the University of Maryland, College Park, with joint appointments in the Department of Mechanical Engineering and the multidisciplinary Institute for Physical Science and Technology (IPST). His doctoral dissertation about on-chip quantum and nonlinear optics was partially supported by a Jacobs Fellowship and received the Zurich Instruments thesis award in 2017. Subsequently he acquired postdoctoral training on quantum Hall effects and topology at Stanford. Dutt has a broad background in quantum and nonlinear nanophotonics and topological photonics. He has also proposed theoretical schemes for analog and digital quantum simulation. He is a recipient of an NSF CAREER award (2024), the inaugural SURA Early Career Scientist Award (2024), a 2020 Rising Star of Light award, and a 2020 Outstanding Reviewer recognition by the journal Light: Science & Applications. He has more than 100 journal articles and peer-reviewed conference publications garnering close to 5000 citations, and has presented 40 invited talks.

***Abstract:***
Scaling up next-generation nanophotonic systems is a prime goal for emerging applications in classical and quantum technologies, and for fundamental explorations into topological and non-Hermitian physics. However, current approaches to photonic technologies quickly run into issues of large spatial footprint and electro-optic interconnect density when massively scaled up to many modes. From a fundamental perspective, there is significant interest in studying high-dimensional physical systems, since richer topological phenomena and emergent phases can be expected in higher dimensions. However, experimentally realizing such high-dimensional systems is challenging because it requires complicated spatial structures.

To address these issues, I will discuss how nanoscale photonic devices augmented by "synthetic dimensions" can lead to disruptive architectures both for fundamental physics explorations into analog quantum simulation and for machine learning hardware accelerators, in terms of favorable scalability, high dimensionality, better controllability/ reconfigurability, and high-bandwidth operation. A combination of gradient-based inverse design and analytical techniques have recently enabled the creation of fully connected layers and convolutional layers for artificial neural network architectures in such synthetic dimensions – such as frequency and temporal modes, which harness internal degrees of freedom of photons. We will also elucidate the applicability of advanced gradient-based optimizers originally introduced in the ML community, but now generalized to digital quantum simulation on current state-of-the-art NISQ-era quantum processing units.