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Making Quantum Matter from Light

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In this talk I will discuss ongoing efforts at UChicago to explore matter made of light. I will begin with a broad introduction to the challenges associated with making matter from photons, focusing specifically on (1) how to trap photons and imbue them with synthetic mass and charge; (2) how to induce photons to collide with one another; and (3) how to drive photons to order, by cooling or otherwise. I will then provide as examples two state-of-the-art photonic quantum matter platforms: microwave photons coupled to superconducting resonators and transmon qubits, and optical photons trapped in multimode optical cavities and made to interact through Rydberg-dressing. In each case I will describe a synthetic material created in that platform: a Mott insulator of microwave photons, stabilized by coupling to an engineered, non-Markovian reservoir, and a Laughlin molecule of optical photons prepared by scattering photons through the optical cavity. I will conclude with a teaser to a superconducting microwave Chern insulator coupled to a Transmon qubit, where we explore topological circuit QED. Building materials photon-by-photon provides us with a unique opportunity to learn both what all of the above words mean, and why they are important for quantum-materials science.