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**Talk Title:** Probing and controlling strongly correlated matter with few photons fields

**Abstract:** The experimental realization of a quantum-degenerate, strongly interacting Fermi gas coupled to a high-finesse cavity will be presented.

In addition to the direct photon-atom coupling, manifested in the spectrum of the coupled system, this system also shows strong photon-pair coupling. The latter arises through the coupling of Fermion-pairs to light via photo-association to long-range molecular states.

The cavity transmission spectrum close to these transitions exhibits the anti-crossing characteristic of strong light-matter coupling, signaling the onset of coherent ‘pair-polaritons’. I will describe the dependence of the optical spectrum on interaction strength and connect the optical spectrum of the cavity with Tan’s contact, a universal property of the many-body physics of the Fermi gas. This provides a new connection between quantum optics and strongly correlated matter.

Both the atom-photon and pair-photon strong coupling can be leveraged in the dispersive regime to perform weakly destructive, repeated measurements of an individual atomic sample, which opens perspective for the continuous measurement of currents and quantum dynamics in complex quantum systems.