

# Two-dimensional Coherent Optical Photocurrent Spectroscopy of a Semiconductor Microcavity

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Optical multidimensional coherent spectroscopy is a powerful technique for observing many-body interactions among excitons [1,2]. I will present a form of two-dimensional coherent spectroscopy that uses photocurrent as the observable [3], rather than an optical signal. This method is used to study a semiconductor microcavity and reveals the collective quantum ladder for the exciton-polaritons [4]. This ladder is known as the Tavis-Cummings ladder, and is a generalization of the better known Jaynes-Cummings ladder. Two-dimensional coherent photocurrent spectroscopy enables the direct observation of the Tavis-Cummings ladder up to the third rung in a solid-state exciton-polariton system. The Tavis-Cummings Hamiltonian describes the light-matter interaction when multiple oscillators are collectively coupled to a cavity. The resulting ladder of quantized states is a signature of the quantum mechanical nature of light-matter interaction. This quantum ladder exhibits mixing of the exciton-photon system in a manner analogous to a quantum beam splitter.

[1] X. Li, T. Zhang, C.N. Borca and S.T. Cundiff, "Many-Body Interactions in Semiconductors Probed by Optical Two-dimensional Fourier Transform Spectroscopy," *Phys. Rev. Lett.* **96**, 057406 (2006)

[2] T. Zhang, I. Kuznetsova, T. Meier, X. Li, R.P. Mirin, P. Thomas and S.T. Cundiff, "Polarization-dependent optical two-dimensional Fourier transform spectroscopy of semiconductors," *Proc. Nat. Acad. Sci.* **104**, 14227-14232 (2007).

[3] 11) G. Nardin, T.M. Autry, K.L. Silverman, and S.T. Cundiff, "Multidimensional Coherent Photocurrent Spectroscopy of a Semiconductor Nanostructure," *Opt. Express* **21**, 28617-28627 (2013).

[4] 1) T.M. Autry, G. Nardin, D. Bajoni, A. Lemaître, S. Bouchoule, J. Bloch, S. T. Cundiff, "Observation of the Collective Quantum Ladder for Polaritons in a Semiconductor Microcavity," submitted for publication (2015).