Transcribing Quantum Information Using Quantum Dynamics of Coherent Materials

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Quantum information science stands to benefit immensely from real-world implementation of simple quantum algorithms at the device level. We will create a new blueprint for quantum information science by designing and synthesizing polymeric materials decorated with chromophores that support coherent relaxation dynamics, and examining how Laguerre-Gauss modes are processed by the relaxation dynamics. By exploiting the analogy to coherent relaxation dynamics evident in photosynthetic systems, these materials will permit direct detection of the quantum state of the incident photon. We will create theoretical models both to feedback into the design process and to provide an interface to quantum information science. Two dimensional electronic spectroscopy will be used to characterize the coherent dynamics and relaxation pathways within the functionalized polymers. The relaxation dynamics within the material can be customized and programmed for specific applications. The goal of this project is to create new materials for quantum information science that can exploit information channels beyond the “classical” regime without attempting to build a universal quantum computer.

This project exploits excitations in semi-ordered supermolecular arrays of coupled chromophores attached to polymers; excitations in this material will delocalize across many chromophores, allowing different relaxation paths to interfere and be resolved. This intermediate regime presents a fascinating compromise between semiconductor systems, in which exciton localization due to disorder prohibits chemical control of dynamics, and molecular excited states where coupling between molecules is random. With our proposed polymer systems, we have enough chemical control to manipulate the structure, coupling, and detuning amongst chromophores while still exploiting some aspects of solid state physics that arise from coherent delocalization of excited states. If successful, this effort will generate materials for optical undersea communication, ultrasensitive detection, and quantum encryption.