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Ph.D. DISSERTATION DEFENSE

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Time/Location:	12:00 PM – 2:00 PM / Zoom-- https://stevens.zoom.us/j/95405578346
Title:	Ultrafast Quantum Dynamics and Control of Multiphoton Processes
Chairperson:	Dr. Svetlana Malinovskaya, Department of Physics, School of Engineering and Science, Stevens Institute of Technology
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ABSTRACT

Quantum dynamics is the study of the time evolution of quantum observables with respect to a system, which in the context of this work, is a few-level atomic system interacting with a set of external EM fields. We study light-matter interaction in a number of interesting systems, with special focus on the occurrence of multiphoton processes on ultrafast timescales and how particular states of light can lead to desired dynamics of the atomic system and propagating light. Such an endeavor is the objective of quantum control, where we study the processes that underlie outcomes of interest for both the atomic system and light field, and seek to determine protocols that realize those outcomes. Such outcomes include selective population transfer in a manifold of atomic states or controlling the steady state response function of the atomic system to realize optical phenomena such as induced transparency and enhanced emission, all of which we study in this work.

A range of systems, of varying dimensionality and complexity, has been studied in this work, altogether demonstrating common principles that underlie light-matter interaction. The principle of quantum interference of multiple pathways for absorption/emission of quanta into an EM field, is responsible for the phenomena of induced transparency in conventionally studied systems, such as 3-level systems, as is in the case of the TLS, and the degenerate TLS. The interference of multiple pathways can additionally lead to phenomena such as optical gain and enhanced fluorescent emission, which can be very useful for generating lasing in samples that are optically pumped remotely, a topic we examine closely in this work. The combination of closed system dynamics of atoms driven coherently by an external light field, with the scattering processes generated by interacting with the vacuum, yields a rich set of novel phenomena that all circles back to this idea of quantum interference. In addition, we also consider the application of

multiphoton processes in population transfer, within a manifold of atomic states, and between manifold of few-atom states and few-cavity mode states.

The theoretical techniques we have considered, including the chirped STIRAP protocol, linear response theory, and the Floquet-Markov formalism have proven enormously useful in simplifying the problems considered in this work. They will prove similarly useful for our future research directions and for investigating other emerging problems in related fields of study. The results from this work have profound applications for quantum sensing and quantum information processing, especially in the development of quantum control protocols for remote sensing.