Shaped pulses enable robust coherent control of quantum dots

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The future of photonic quantum technologies relies on bright, photostable, and on-demand sources of single and indistinguishable photons. Semiconductor quantum dots have emerged as a promising platform with excellent performance characteristics such as photostability, near Fourier limited emission linewidth, and growth technologies that allow easy integration into nanoscale devices. To operate as an on-demand photon source, the quantum dot must be prepared in its exciton state, which recombine to emit a single photon. In this talk, I will navigate through our recent works exploiting pulse shaping techniques including the pioneering off-resonant, below-band-edge coherent control of quantum dots [1], and accessing dark excitons in quantum dots for advanced entanglement generation [2].

In the second part, i will address the issue of scalability. To realize a scalable quantum photonic architecture based on quantum dots, it is beneficial to have an ensemble of quantum emitters that can be collectively excited with high efficiency.

Chirped pulse excitation is the most efficient scheme to excite a quantum dot ensemble due to its immunity to individual quantum dot parameters. This well-known method relies on the so-called adiabatic rapid passage, which ensures a robust transition to excited state, provided the t the temporal profile of the laser field is a slow function of time during the population transfer. Yet, the existing methods of generating chirped laser pulses to excite a quantum emitter are bulky, lossy, and mechanically unstable, which severely hampers the prospects of a quantum dot photon source. Here, we demonstrate a compact, high-efficiency, plug-and-play alternative for chirped pulse excitation of solid-state quantum emitters. Our technique is based on chirped fiber Bragg gratings developed around 800 nm -for the first time to the best of our knowledge- enables precise control of the dispersion characteristics of the laser pulses and couple them to a GaAs quantum dot [3]. We establish the versatility of our method by demonstrating a high-fidelity, frequency-multiplexed single-photon generation. Our work is a significant breakthrough toward realizing a practical quantum dot photonic device.

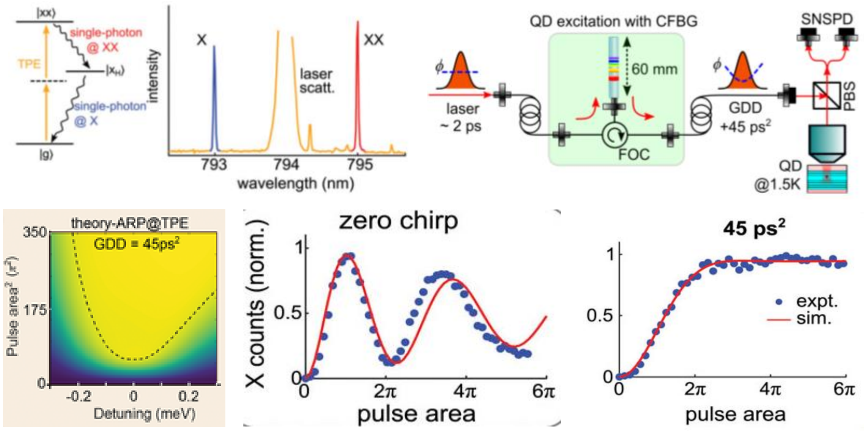

Figure 1: Robust excitation of quantum dots enabled by chirped laser pulses. Top panel: two photon excitation of a quantum dot biexciton state (see the level diagram), along with the emission spectrum with distinct peaks at exciton and biexciton energies. The schematic shows our compact fiber-integrated technique for chirped excitation using chirped fiber Bragg gratings engineered for 795 nm. Bottom panel: simulation of adiabatic passage, which shows that for higher positive chirp, population is invariant with respect to laser power and resonance variations- facilitating a collective excitation of multiple QDs. Bottom right panel shows a line plot of Rabi rotation for unchirped pulses and its disappearance at high chirp.

References

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