Rydberg Photonics with Thin-Film Cuprous Oxide

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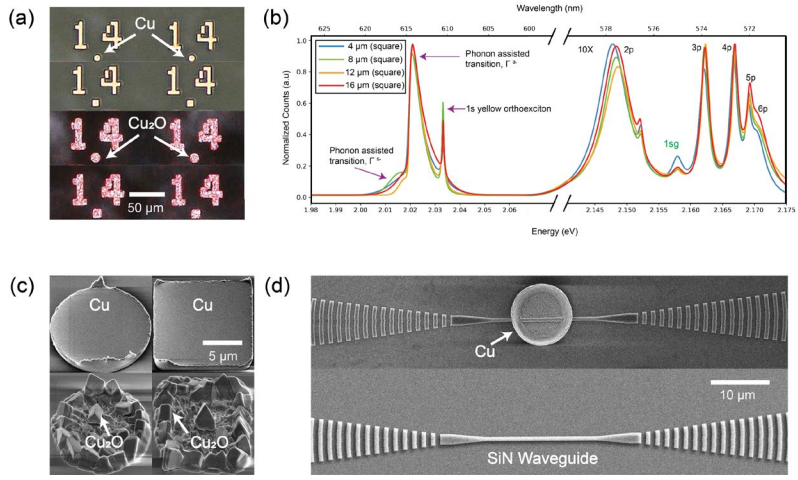
Cuprous oxide (Cu_2O) has gained attention as a solid-state material with the potential for hosting excitonic Rydberg states. These states are defined by high principal quantum numbers (n), leading to significantly larger wavefunctions. As a result, Cu_2O exhibits strong dipole-dipole ($\propto n^4$) and van der Waals ($\propto n^{11}$) interactions, making it an attractive platform for solid-state quantum technologies. Thin-film Cu_2O samples are of particular interest as they can be meticulously fabricated to reduce defects, allowing for the observation of extreme single-photon nonlinearities via the Rydberg blockade.

In this presentation, I share our recent findings on the spectroscopic absorption and photoluminescence of Rydberg excitons in synthetic Cu_2O thin films. Our results show a series of yellow excitons extending up to a principal quantum number of n = 7. I discuss our progress in the bottom-up assembly of 2D arrays of Rydberg excitons, which could make a platform for simulating lattice models. Furthermore, I present promising results from coupling Rydberg excitons with silicon nitride photonic circuitry, marking a significant advancement in Rydberg photonics. Finally, I will cover our theoretical results on open quantum system phase transitions that can be explored using strongly interacting Rydberg polaritons. These discoveries pave the way for the development of scalable and integrated on-chip quantum devices based on Rydberg states in Cu_2O.



(a) site-selective growth of Cu_2O thin films. (b) PL spectrum of the fabricated array. (c) SEM image of the site-selective grown films. (d) Fabricated SiN waveguide integrated with Cu_2O.

References

[1] J. DeLange et al, Scientific Reports 13, 16881 (2023)
[2] H. Alaeian and V. Walther, arXiv 2311.15091 (2023)

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