

# Networks of liquid light

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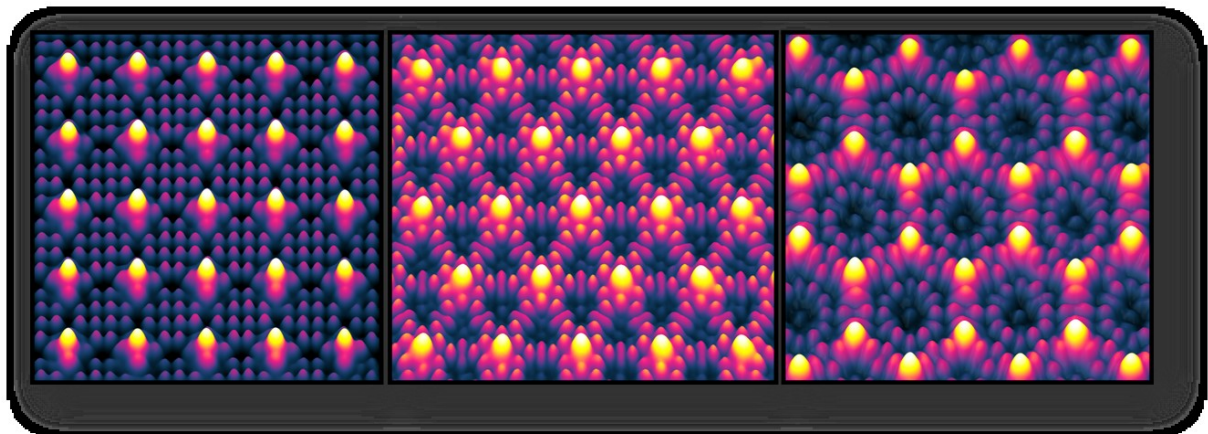
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Recent years have seen a surge of advancements in optical manipulation over bosonic light-matter quasiparticles known as exciton-polaritons in semiconductor microcavities. These particles appear under strong-coupling conditions between cavity photons and embedded quantum-well excitons. Characterised by very high interaction strengths, nonlinearities, and picosecond timescales, these coherent light sources provide an exciting testbed to explore room-temperature nonequilibrium Bose-Einstein condensation in the optical regime.

In this talk, I will present results on all-optically engineered macroscopic networks of connected exciton-polariton condensates, which permit studies on fundamental emergent behaviours in complex nonequilibrium dynamical systems while subject to a drive and bosonic final-state stimulation. I will explain how a uniquely polaritonic feature gives rise to so-called “ballistic condensates” which, when spatially coupled, form a bosonic condensed matter analog of time-delay coupled oscillators that are ubiquitous in nature. I will present experimental and theoretical results on large-scale condensate networks displaying aforementioned emergent behaviors, including: spontaneous synchronization with unprecedented long-range spatial and temporal correlations [1,2], strong polarization buildup and control [2], geometric frustration and formation of persistent superfluid currents [3], non-invasive optical control of the network coupling weights [4], and synthesis of artificial lattices with non-Hermitian flatband and topological properties [5,6].

Lastly, I will discuss recent developments on the role of polariton condensate networks as nonlinear information processing elements in the optical computing paradigm. I will address three examples: room-temperature optical logic, analog



simulators of spin-glass Hamiltonians, and as neuromorphic computing hardware.

## References

- [1] Töpfer et al., *Communication Physics* 3, 2 (2020).
- [2] Töpfer et al., *Optica* 8, 106 (2021).
- [3] Gnusov et al., *Physical Review B* 102, 125419 (2020).
- [4] Cookson et al., *Nature Communications* 12, 2120 (2021).
- [5] Alyatkin et al., *Physical Review Letters* 124, 207402 (2020).
- [6] Pickup et al., *Nature Communications* 11, 4431 (2020).
- [7] Alyatkin et al., *Nature Communications* 12, 5571 (2021).