From Optical to Electrical Generation of Spin-Polarized Polaritons in Perovskite Metasurfaces

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The generation and control of spin-polarized ($\sigma = \pm 1$) exciton-polariton quasiparticles and their Bose-Einstein condensate (BEC) state holds strong promise for emerging applications in optics, spintronics, and quantum information. Here we report both optical and electrical generation of spin-polarized exciton-polaritons in a monolithic $MAPbI_3$ perovskite metasurface integrated into a light-emitting transistor (LET) – Fig. 1a [1].

The metasurface features a square lattice of isosceles triangular holes that support high-Q bound state in the continuum (BIC) resonances, which strongly couple to the perovskite excitons, enabling polariton condensation at threshold excitation fluence (Fig. 1b). The intentionally broken in-plane C_2 symmetry splits the polarization singularity of the Γ-point BICs into two distinct, oppositely circularly polarized states in momentum space [2], yielding a spin purity of 0.8 (Fig. 1c). The Rashba-split polariton LET emission shows momentum-entangled dispersion branches within the same mode, which can be electrically addressed by group velocity selection (Fig. 1d).

Our results demonstrate the feasibility of using polycrystalline perovskite metasurfaces for high-purity, electrically controlled spin-polarized polaritons and condensates - without the need for external magnetic fields or synthetic gauge potentials.

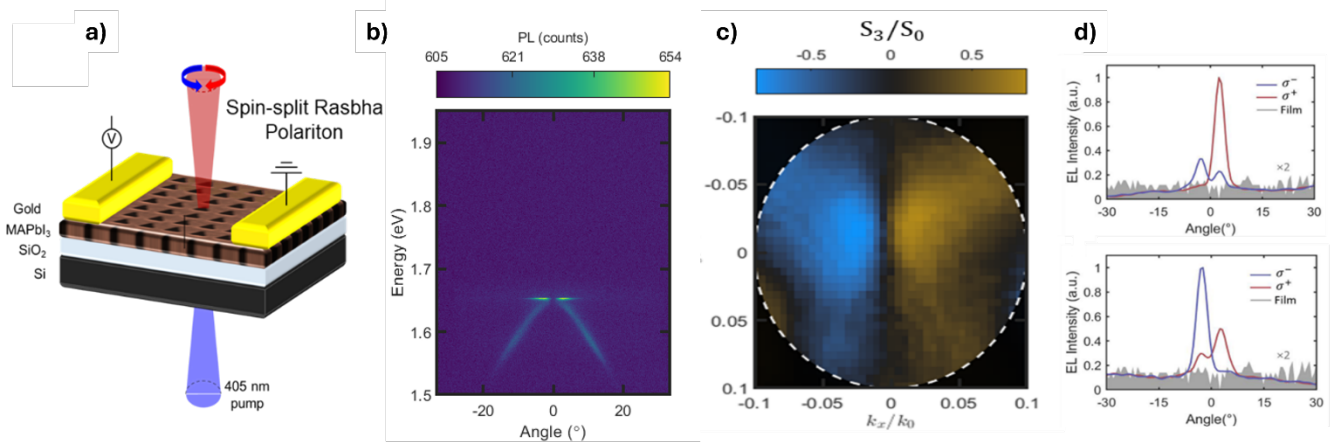

Figure 1: a) Schematic of the perovskite light-emitting *metatransistor* used for optical and electrical generation of spin-polarized exciton polaritons. b) Angle-resolved spectra showing polariton emission near the condensation threshold. c) Circularly polarized photoluminescence map of the normalized S_3 Stokes parameter, showing the spin-split states of the BEC in momentum space. d) Electrical control of spin-polarized polaritons in the light emitting transistor.

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References

[1] Y. Wang, G. Adamo, S.T. Ha, J. Tian, C. Soci, Electrically generated exciton polaritons with spin on-demand, Adv. Mat. 37, 2412952 (2025)

[2] J. Tian, G. Adamo, H. Liu, M. Klein, S. Han, H. Liu, C. Soci, Optical Rashba effect in a monolithic light-emitting perovskite metasurface, Adv. Mater. 34, 2109157 (2022)

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