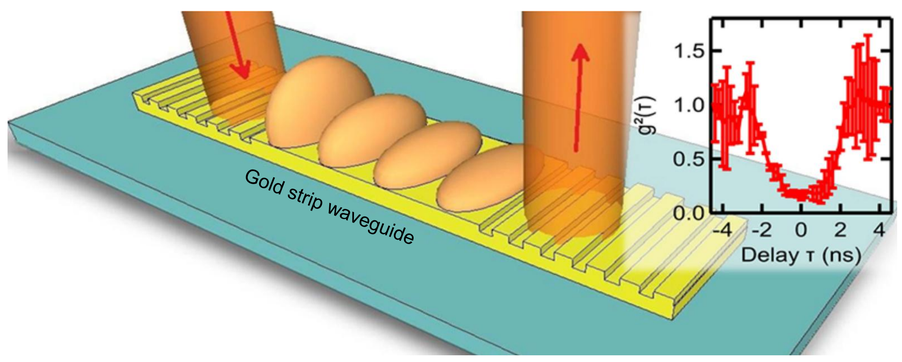
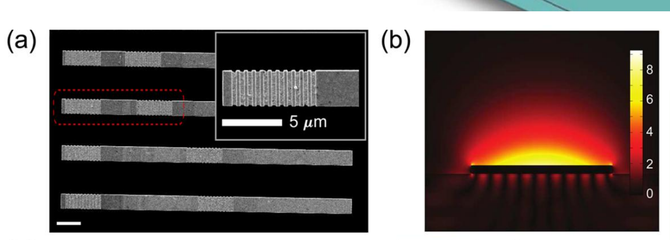
MONASH University

Integrating and Engineering of Quantum Light Sources

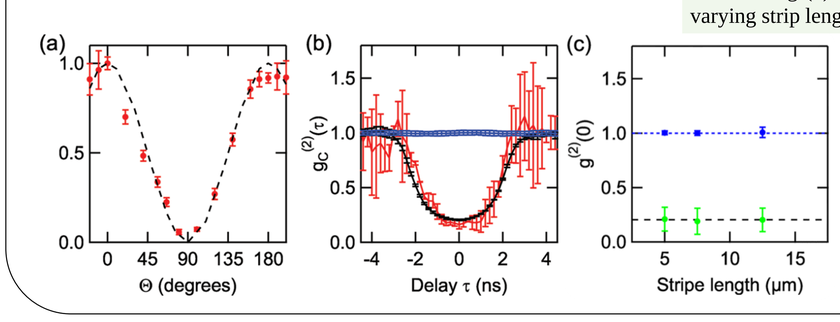
@ *Nanophotonics Lab*

Single surface plasmon polaritons



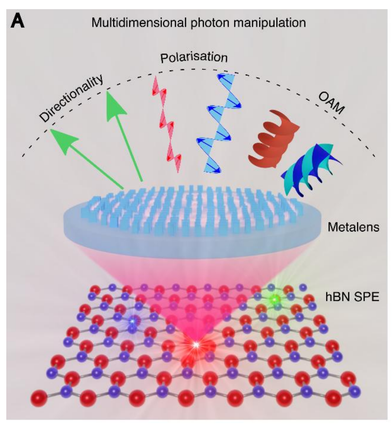


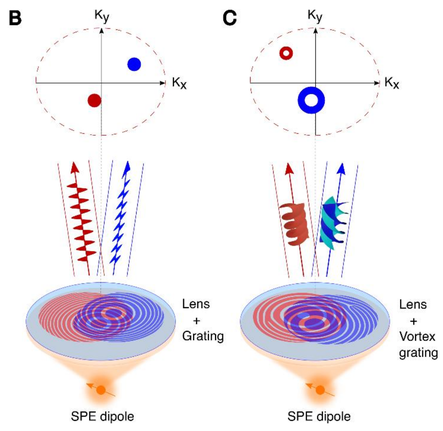
(a) SEM images of fabricated gold strip waveguides with lengths ranging from 5 to 20 μm. The grating couplers are zoomed for clarity. (**b**) Fundamental SPP mode supported in the stripe waveguide. (**c**) Schematic of the experimental setup, including a single-photon source stage, waveguide probing stage, and final analysis stage [1].



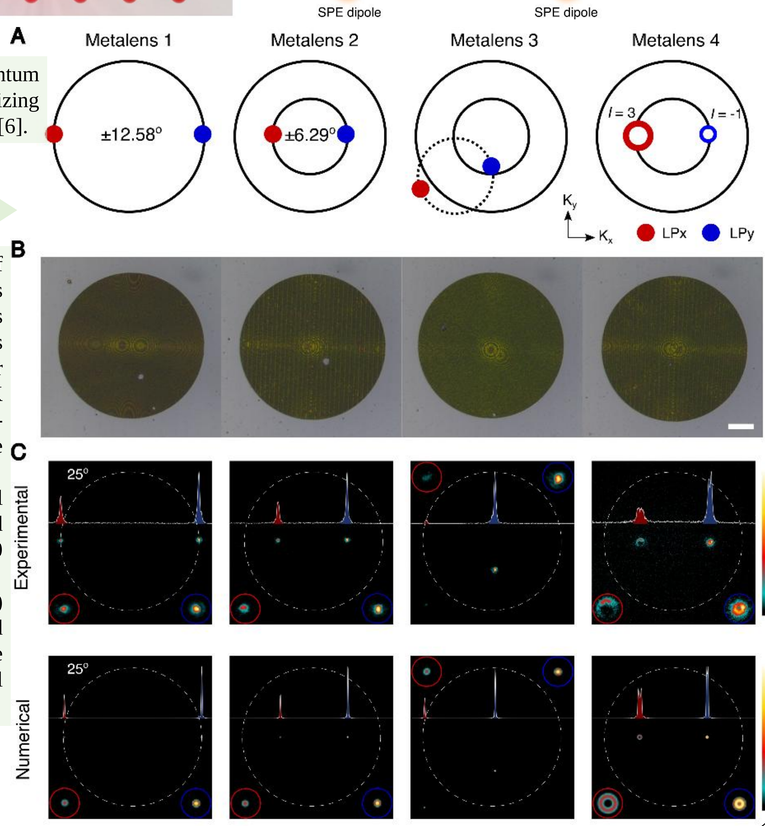
(a) Coincidence rate at the out-coupler as a function of incident polarization. (**b**) Conditional second-order quantum coherence function. (**c**) Measured $g^2(0)$ for waveguide with varying strip lengths.

Arbitrarily structured single photons



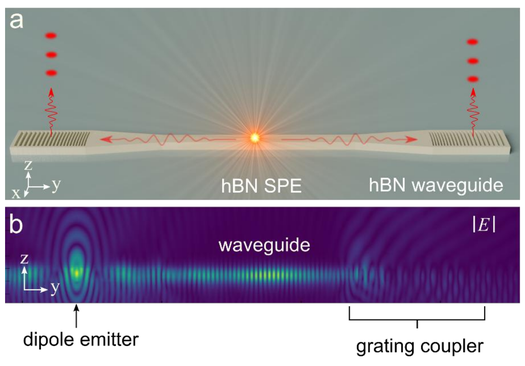


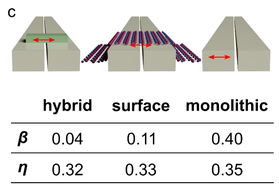
Arbitrarily structured quantum emission with polarizing beam-splitting metalenses [6].



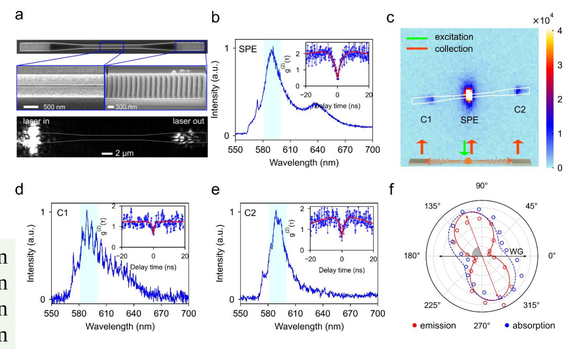
(**A**) Schematics of different metalens functionalities. The circles represent desired positions for orthogonal linear polarizations in the K space. The doughnut-shaped spots indicate the generation of OAM.
(**B**) Far-field optical images of the fabricated metalens. Scale bar is 30 μm.
(**C**) Experimental (top) and numerically calculated (bottom) results of the SPE far-field back focal imaging.

On-chip solid-state quantum emitters





	hybrid	surface	monolithic
β	0.04	0.11	0.40
η	0.32	0.33	0.35

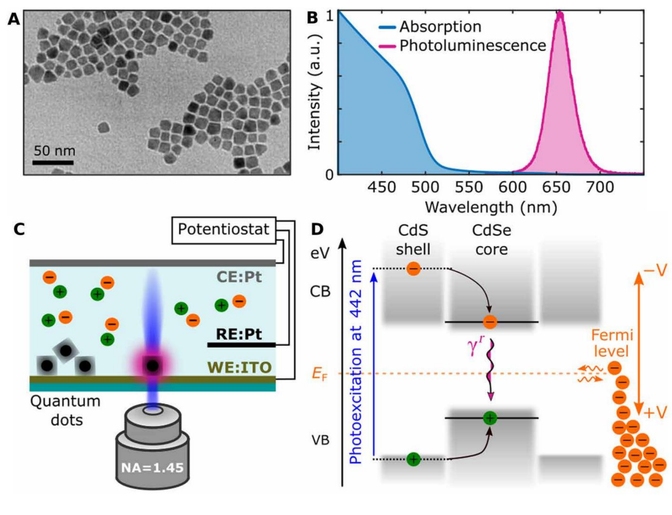


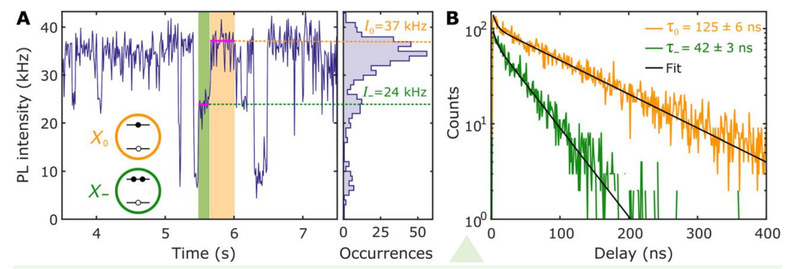
Left: Schematic illustration of a quantum emitter in a monolithic Hexagonal boron nitride waveguide. **Right**: Characterisation of a coupled quantum emitter at room temperature [2].

hBN is not only a bright, room-temperature host for quantum emitters but also a promising 2D dielectric material for photonic chip platforms. Demonstrations of hBN-based high-Q cavities—including resonant metasurfaces [3,4], suspended microdisk cavities [5], and one- and two-dimensional photonic crystal cavities [5]—as well as various integrated waveguide components [2,5], highlight its potential for integrated quantum photonics.

Electrically manipulated single photons

Charged colloidal giant-shell CdSe/CdS quantum dots [7]

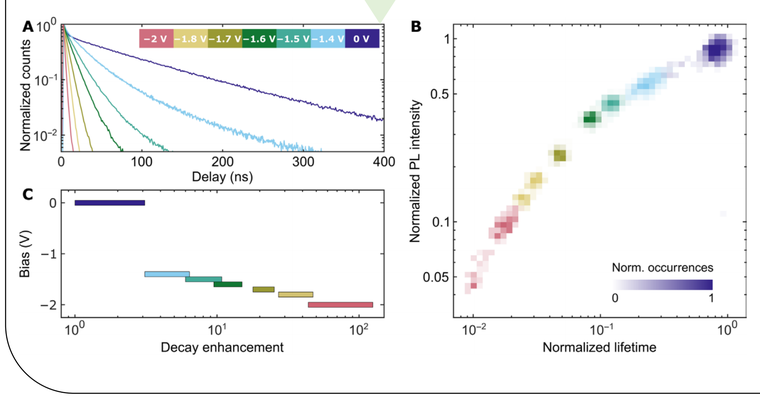


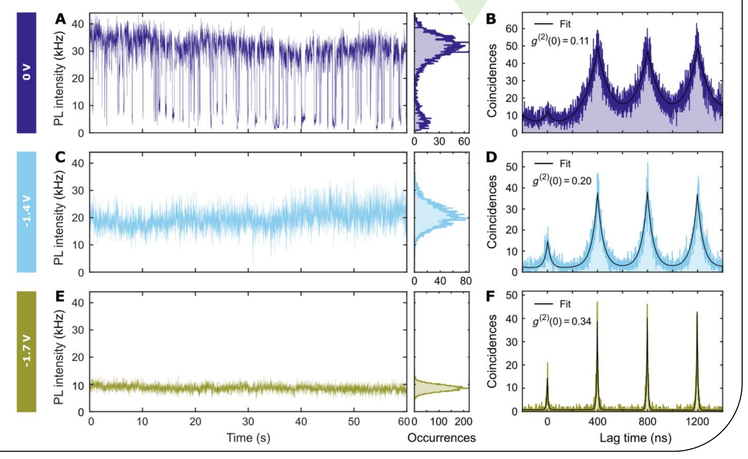


(**A**) Photoluminescence intensity time trace of an individual quantum dot measured at 0-V bias and 30-nW excitation power. Neutral exciton X_0 and negative trion X_- are highlighted by orange and green areas, respectively. The time bin is 10 ms. (**B**) Decay histograms of X_0 and X_- were acquired using the photon arrival times from the orange and green time windows in (A). The decay histograms are fitted with a biexponential function (black lines) to filter out the contribution of positive trion and multiexciton states characterized by short lifetimes.

(**A**, **C**, **and E**) Control of blinking and intensity via application of voltage bias. (**B**, **D**, **and F**) Intensity autocorrelation $g^{(2)}(t)$ histograms. The measured values of $g^{(2)}(0)$ confirm that the quantum dot remains a good single-photon source at negative bias.

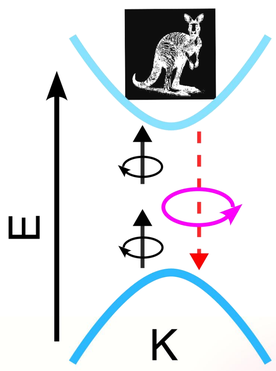
Active control of decay rate with voltage bias.



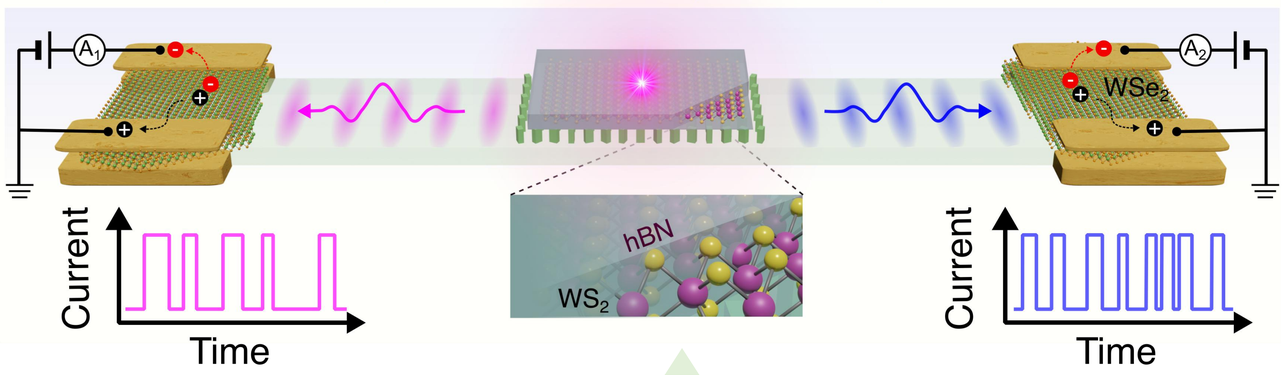


Emerging light-wave valleytronics

The valley degree of freedom of electrons in materials such as graphene and transition metal dichalcogenides (TMDCs) has emerged as a promising platform for quantum information processing.



In monolayer TMDCs, inversion symmetry breaking combined with strong spin–orbit coupling enables valley-selective excitation and population control using light. This intrinsic valley–photon coupling provides a pathway for optical initialization, manipulation, and readout of valley qubits.



Schematics of waveguide-routed photon detection and the proposed on-chip programmable valley optoelectronic nanocircuit. The energy diagram illustrates the nonlinear valley selection rule.

References

*[1] Di Martino, Giuliana, et al. "Quantum statistics of surface plasmon polaritons in metallic stripe waveguides." Nano Letters 12.5 (**2012**): 2504-2508.*

*[2] Li, Chi, et al. "Integration of hBN quantum emitters in monolithically fabricated waveguides." ACS Photonics 8.10 (**2021**): 2966-2972.*

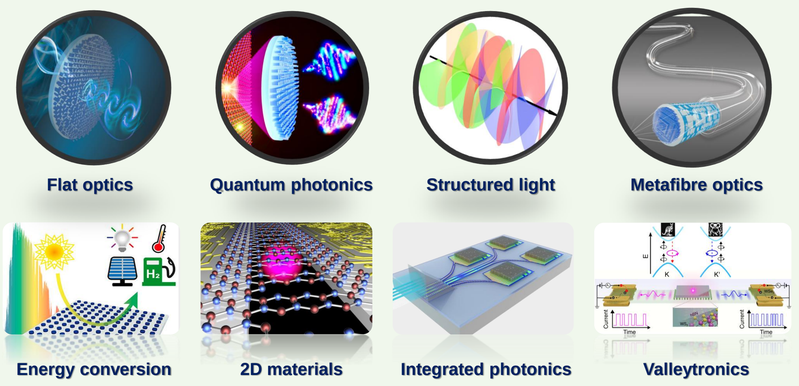
*[3] Sortino, Luca, et al. "Optically addressable spin defects coupled to bound states in the continuum metasurfaces." Nature Communications 15.1 (**2024**): 2008.*

*[4] Kühner, Lucca, et al. "High-Q nanophotonics over the full visible spectrum enabled by hexagonal boron nitride metasurfaces." Advanced Materials 35.13 (**2023**): 2209688.*

*[5] Nonahal, Milad, et al. "Engineering quantum nanophotonic components from hexagonal boron nitride." Laser & Photonics Reviews 17.8 (**2023**): 2300019.*

*[6] Li, Chi, et al. "Arbitrarily structured quantum emission with a multifunctional metalens." Elight 3.1 (**2023**): 19.*

*[7] Morozov, Sergii, et al. "Electrical control of single-photon emission in highly charged individual colloidal quantum dots." Science Advances 6.38 (**2020**): eabb1821.*



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