Strong nanophotonic interaction for lasing and single-photon emission

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I will talk about two topics: advancing nanolasers based on photonic topological cavities and strain-induced single-photon emitters in atomically thin semiconductors.

(1) Advancing nanolasers based on photonic topological cavities [1]:
Optical vector vortex beams provide additional degrees of freedom for spatially distinguishable channels in data transmission. Although several coherent light sources carrying a topological singularity have been reported, it remains challenging to develop a general strategy for designing ultra-small, high-quality photonic nanocavities that generate and support optical vortex modes. Here, we demonstrate wavelength-scale, low-threshold, vortex and anti-vortex nanolasers in a C5 symmetric optical cavity formed by a topological disclination. Various photonic disclination cavities are designed and analyzed using the similarities between tight-binding models and optical simulations. Unique resonant modes are strongly confined in these cavities, which exhibit wavelength-scale mode volumes and retain topological charges in the disclination geometries. In the experiment, the optical vortices of the lasing modes are clearly identified by measuring polarization-resolved images, Stokes parameters and self-interference patterns. Demonstration of vortex nanolasers using our facile design procedure will pave the way towards next-generation optical communication systems.

(2) Strain-induced single-photon emitters in atomically thin semiconductors [2]:
Single-photon emitters, the basic building blocks of quantum communication and information, have been developed using atomically thin transition metal dichalcogenides (TMDCs). Although the bandgap of TMDCs was spatially engineered in artificially created defects for single-photon emitters, it remains a challenge to precisely align the emitter's dipole moment to optical cavities for the Purcell enhancement. Here, I will present the demonstration of position- and polarization-controlled single-photon emitters in monolayer WSe2 via optical pumping. We demonstrate single-photon emitters encoded with spin angular momentum in a strained WSe2 monolayer coupled with chiral plasmonic gold nanoparticles. Single-photon emissions are observed at the nanoparticle position, exhibiting photon antibunching behavior with a g(2) value of ~0.3 and circular polarization properties. We also demonstrate electrically driven single-photon emitters located at the positions where strains are induced by atomic-force-microscope indentation on a van der Waals heterostructure. Therefore, our approach is a unique way to develop next-generation, deterministic, controllable single-photon emitters based on TMDC materials.

References

1. Nature Photonics 18, 286-293 (2024); Nature Communications 12, 4135 (2021); Nature Communications 11, 5758 (2020).
2. Science Advances 10, eadn7210 (2024); Science Advances 7, eabj3176 (2021).