Quantum nanophotonics based on the solid-state system

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In this talk, I will present three topics, (1) Electrically driven nanobeam lasers, (2) Quantum emission from atomic defects in wide-bandgap semiconductors, and (3) Polarization control of deterministic single-photon emitters in 2D materials.

Electrically pumped nanolasers with high quality factors and small mode volumes were demonstrated as a practical coherent light source in an ultracompact photonic integrated circuit. However, to achieve ultralow lasing threshold at room temperature and high-density integration with other photonic devices, it is necessary to develop new nanolasers with simple geometry and small physical size. Here we report the demonstration of the smallest-possible nanolasers in one-dimensional photonic crystal nanobeam structures at room temperature [1, 2].

Single photon emitters play a central role in many photonic quantum technologies. A promising class of single photon emitters consists of atomic color centers in wide-bandgap crystals, such as diamond, silicon carbide and hexagonal boron nitride. However, it is currently not possible to grow these materials as sub-micron thick films on low-refractive index substrates, which is necessary for the most mature photonic integrated circuits technologies. Hence, there is great interest to identify quantum emitters in technologically mature semiconductors that are compatible with suitable heteroepitaxies. Here, we characterize new quantum emitters in wide-bandgap semiconductors such as gallium nitride (GaN) and aluminum nitride (AlN) [3]. And we demonstrate the integration of a single-photon emitter in a hexagonal boron nitride (h-BN) flake with a Ag plasmonic waveguide and measured its optical properties at room temperature [4].

In the last part, I will present the deterministic control of the position and polarization of single-photon sources formed in monolayer WSe_2. By applying a strain to monolayer WSe_2 using a Si_3N_4 rod structure with a nanogap, band engineering and single-photon generation were successfully achieved at a desired position. Additionally, we controlled the polarization of single photons by changing the nanogap size [5].

I believe that our progress in qauntum/nanophotonics represents an important step toward further miniaturization of coherent/quantum light sources as well as fast all-optical processing in an ultracompact photonic integrated circuit.

Reference

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[3] A. M. Berhane*, Kwang-Yong Jeong* et al., "Bright Room-Temperature Single Photon Emission from Defects in Gallium Nitride," *Advanced Materials*, 29, 1605092 (2017).

[4] Kwang-Yong Jeong et al., "Integration of single photon emitters in 2D materials with plasmonic waveguides at room temperature," *Nanomaterials,* 10(9), 1663 (2020).

[5] Jae-Pil So*, Kwang-Yong Jeong* et al., "Deterministic control of position and polarization of single photon emitters in monolayer WSe2," under review.