

Polariton waveguides from chiral perovskites crystals

Exciton-polaritons (hereafter: polaritons) are unique quasiparticles that combine the properties of light and matter. They arise from the strong coupling of photons (light particles) with excitons—bound electron–hole pairs in a material. Thanks to this dual nature, polaritons can be used for optical information processing, and the creation of artificial neurons. To generate polaritons, optical microcavities - structures composed of two Bragg mirrors (DBRs) and an emitter in which excitons can be excited - are typically used. The structuring of such systems plays a key role, as it enables precise control over their properties and allows them to be tailored for photonic applications.

From a practical perspective, it is essential to use materials in which excitons can exist at room temperature. One such group of materials includes perovskites, which have gained popularity not only due to their favorable optical properties but also thanks to their facile synthesis (not requiring high temperatures or pressures) and the ability to tune their characteristics via compositional modification. These perovskites can adopt various dimensionalities—from quasi-2D to fully 3D—and within each group, their emission energy can be widely tuned.

In our project, we focus on perovskites with an additional intriguing feature: chirality—that is, their structure is not superimposable on its mirror image. Examples include compounds with the formula (R/S-MBA)₂PbX₄ (MBA = C₆H₅C₂H₄NH₃, X = iodine or bromine). These materials are not only intrinsically chiral but also emit light with chiral properties.

A novel aspect of our project is the fabrication of monocrystalline waveguides with defined geometry from such perovskites. We will achieve this using a microfluidically assisted pseudomorphic growth, unique technique developed at the University of Warsaw. This method enables the direct formation of complex structures—from simple waveguides to couplers, beam splitters, and interferometers—without the need for multiple processing steps. The entire structure is formed during the solution-based crystal growth process.

We have previously demonstrated that polaritons can form in achiral perovskite single crystals even without DBR mirrors. This significantly simplifies fabrication, reduces costs, and enhances the potential for practical applications. Our current goal is to extend this approach to chiral polaritons that emit light with a specific handedness. To enable integration with future photonic devices, we also plan to fabricate subwavelength polymer gratings directly on the crystal surface, which will serve as couplers. These elements will facilitate efficient light injection into the system, enable dispersion relation measurements, and improve the energy efficiency of experiments.

In the final stage of the project, we will couple the waveguides with a conventional DBR- or silver-mirror-based microcavity. In this hybrid system, strongly localized polaritonic states will emerge, resembling those found in quantum wires. This will allow for precise control over the emission energy of chiral light and the separation between consecutive emitted modes.

Our main experimental technique will be spatially and angularly resolved spectral tomography, which enables the analysis of reflectance, transmittance, and photoluminescence signals. We will perform experiments in both non-resonant mode (where polaritons are created indirectly using a laser pulse with higher energy than the emission energy) and resonant mode, where polaritons are directly injected using a properly tuned laser. This will allow us to control their properties—such as light polarization—already at the input stage.

The results of our research will contribute to the development of chiral photonics—demonstrating how to fabricate waveguides, couplers, beam splitters, and other components from chiral perovskites for precise light control in the strong coupling regime.