One of the major technological challenges of the modern world is to develop efficient ways to process information. Computers, since their invention, have become faster and the smallest transistors reach atomic scales. However, further miniaturization of electronic devices and increase in information processing speed and efficiency are no longer possible due to fundamental physical limitations. One way to overcome these constraints is to use light as an information carrier instead of electrical current.

Photons have three major advantages over electrons. First, they are faster than electrons. Second, photons propagate at extremely long distances with much smaller losses. And third, the information can be encoded in light intensity, polarization, phase or energy. Importantly, analogue and digital computation schemes require nonlinear transformation of signals, as provided by transistors or logic gates in the case of electronics. Photons however, are weakly interacting particles, and photonic nonlinear phenomena occur mainly when the medium is illuminated with a high-power laser beam. For this reason, photons have so far been used to quickly transfer information via optical fibers, not finding any practical application in information processing.

The research so far suggests that the light-matter quasiparticles arising in optical cavities, so called exciton-polaritons, are the source of nonlinear phenomena occurring at very low excitation powers. For example, we recently demonstrated that exciton-polaritons can efficiently realize nonlinear XOR gate operation. We used this property to develop an artificial neural network and teach it to recognize images. Typically, exciton-polariton microcavities are based on semiconductor structures which require cryogenic temperatures to operate.

For practical application in photonic devices, we propose to develop a novel photonic platform based on exciton-polaritons working at room temperature. We strive to achieve the efficiency of the nonlinear transformation that exceeds the capabilities of the currently available silicon photonic devices and develop a new geometry of polariton waveguides or circuits with the possibility to propagate spin polarized polariton currents.

Our idea is based on the implementation of perovskites into an optical cavity filled with liquid crystals. Perovskites have excellent optical properties for light-matter coupled systems operating at room temperature. Our novel growth method allows for the fabrication of long-lived stable perovskite crystals that sustain pulsed excitation in wide range of pulse energies. The liquid-crystal component provides novel functionality, i.e. microcavity tunability through its high birefringence and spin-orbit coupling effects with cavity photons. Thus, one device will allow to control the energy, phase, intensity and polarization of the emitted light. We will use the optical nonlinear effects available in this system to achieve low threshold operation. This is particularly important for example in the photonic neuromorphic computing scheme, where the efficient data processing requires non-linear transformation of input data. We will also structure perovskite crystals into different geometries. The waveguide, splitter and photonic circuit geometry will allow us to test the utility of our system in photonic devices such as optical switches, or photonic accelerators. This, combined with birefringent liquid crystal will allow to reach the regime, where the spin polarized currents will propagate along our waveguide. We believe that our novel photonic system will allow in future for energy efficient and ultrafast all-optical information processing.