

Quantum light sources, such as single photon emitters (SPEs) are the key enabling technology for the future of quantum communications. SPEs may also play a key role when integrated with photonic systems to develop optical quantum computing. Indeed, these technologies are one of the strategic research agendas recognized by the European Quantum Flagship. Successful realization of these goals in a rapidly developing field is thus an availability of robust and scalable production of bright sources of indistinguishable photons with precisely defined properties and novel tools for manipulations and control of photonic qubits. Such control can be realized by utilizing controllable, tunable, high-quality nanoscale cavities. However, present cavities, such as ring resonators or photonic crystals when used as sources of individual photons are limited by low repetition frequencies.

We propose a solution that extends beyond a single material limitation and move towards hybrid plasmonic-dielectric platforms. These have several advantages, including deep-subwavelength sizes or the possibility of significantly slowing down decoherence processes. Such photonic platforms combine high refractive index dielectrics with a metallic component that supports surface plasmon polaritons. The freedom to use both types of materials in various sizes and geometries allows achieving ultra-small mode volumes and strong confinement of the electromagnetic field, leading to enhanced light-matter interactions and increased single photon emission rates. Examples of such are hyperbolic metamaterials (HMMs), where alternating layers of metals and dielectric lead to strong enhancements of spontaneous emission rates by many-orders-of-magnitude, or a broad class of photonic environments of epsilon-near-zero (ENZ) (meta)materials. However, despite these possibilities once fabricated, these materials are fixed in functionality.

The goal of the project is to utilize both HMM and ENZ materials as promising components of advanced quantum light sources in the form of nanophotonic structural devices for light manipulation and enable dynamic tunability in these platforms. Specifically, emission rates, mode profiles, directivity and polarization are some of the key parameters that need to be controlled with high fidelity in a dynamic fashion. A natural answer to this challenge is incorporation of tunable materials based on e.g. phase change, change of charge, or application of external field, into these platforms to achieve post-fabrication trimming or even dynamic control over their optical properties. Such tunable cavities and environments could find applications in enhanced sensing and imaging, thermal management via modified scattering, and especially in quantum technologies.