In this project, we develop an interface for photons with incompatible spectral properties to enable their interference in a hybrid quantum network. This will be achieved via active time-frequency shaping of photon wave packets with advanced electro-optic as well as nonlinear optical methods.

A quantum network interconnects different quantum systems to allow for more advanced quantum information processing than a single system could perform on its own. The links in such a network are provided by photons propagating over optical channels (usually fibers), which carry the information from node to node. A hybrid quantum network consists of nodes of different types, e.g. quantum memories, single-photon sources or trapped-ion-based quantum processors, which all carry out their dedicated tasks. In such a hybrid network, these various node types will naturally emit and absorb photons at different wavelengths and with different spectral bandwidths.

In order to perform advanced quantum information processing tasks, it is required that the photons from the various nodes interfere with each other, in a so-called two-photon interference. This is only effective, however, if the spectra of the photons match, in central wavelength as well as in bandwidth. It is, therefore, a key challenge for hybrid quantum networks to match the spectral properties of photons from dissimilar sources and allow for high-visibility two-photon interference between these photons.

In this project we develop and demonstrate tools to achieve precisely this matching. In particular, we aim to demonstrate high-visibility interference between photons emitted by two very different, yet both widely used, types of photon sources: quantum dots and spontaneous parametric down-conversion. In the first part of our project, we will match photons with initially compatible central wavelengths, but mismatched spectral bandwidths via electro-optic time-frequency shaping of the down-conversion photons. In a second step, we will apply this technique to demonstrate quantum teleportation, a fundamental protocol of quantum information processing, between these photons. Finally, we will go one step further and employ nonlinear optical time-frequency shaping methods to match photons of initially different central wavelengths and bandwidths. In addition, we will match both photons to an established telecommunication standard, which is designed for resource-efficient long-distance communication.

Existing approaches towards such a spectral matching of photons from dissimilar sources rely either on passive filtering, which is very inefficient due to large photon losses, or nonlinear conversion without spectral shaping, which is effective only for emitters with initially compatible bandwidths. Our approach will be the first to allow the simultaneous matching of central wavelength and bandwidth. At the same time, the active bandwidth shaping produces substantially lower loss than exclusively passive filtering. Thus, we anticipate that the results of this project can form key building blocks of future quantum networks.

Primary researchers involved

• Michał Karpiński, University of Warsaw, Poland

• Robert Keil, University of Innsbruck, Austria