Quantum physics is rapidly developing and finding its way into pop culture, presenting itself as a complex, yet interesting concept. However, you can intuitively understand many of its aspects, such as superposition – a particle in a superposition is in many states at once, not just one, as in the case of a classical description. The particle chooses one of these states during the measurement and stays in it. Thanks to superposition, very efficient quantum algorithms are possible, which operate on the principle of simultaneous checking of the entire space of solutions at once – this is how, for instance, Shor's algorithm for decomposing a number into prime factors works. Quantum computers will bring a qualitative leap in the processing speed of many algorithms. The quantum description of the world also allows for quantum entanglement, which is a particular type of superposition. Several particles or systems cannot then be described individually. There are correlations between them, for example, two particles may be either in the state 0 or in the state 1, but we will always measure both in the same state. Quantum entanglement allows us to exchange quantum information between systems. It can also be used for the so-called quantum state teleportation, which unfortunately is not the kind of teleportation we know from movies - only information is transmitted here, not a physical particle. Photons (individual light particles) are the go-to for transmitting quantum information. They have a number of interesting properties, but it is particularly important that they interact weakly with the environment and move at the speed of light – hence their name - flying qubits (quantum bits). Photons can therefore be used to interconnect quantum systems – such networks are often called quantum internet and allow to increase the prospects of existing quantum systems significantly. Unfortunately, different quantum systems require various different photons – for example, with a different color of light or time characteristic, so they cannot be easily integrated.

Our project will develop the technology of temporal and spectral transformations (changing the duration of the photon and its color) to enable quantum communication and connect mismatched quantum systems. We pay special attention to the preservation of quantum information carried by these photons in the process of their modification. The creation of efficient interfaces enables the connection of many systems and the dynamic development of quantum information processing. Such systems are especially needed to extend the possibilities of currently available measurements from other fields – for example, we can connect many optical telescopes to obtain a significant increase in resolution, as in the case of the famous photo of a black hole created using a combination of numerous radio-telescopes. In addition, quantum interfaces will enable long-distance communication by matching the requirements of “quantum repeaters” and existing fiber optic infrastructures. Based on this, it will be possible to create a vast quantum network, enabling the connection of distant research centres and companies for the further development and use of quantum technologies.