# Quantum optics and information science in multi-dimensional systems

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Photonic quantum systems, which comprise multiple optical modes as well as highly non-classical and sophisticated quantum states of light, have been investigated intensively in various theoretical proposals over the last decades. The ideas cover a large range of different applications in quantum technology, spanning from quantum communication and quantum metrology to quantum simulations and quantum computing. However, the experimental implementations require advanced setups of high complexity, which poses a considerable challenge. The successful realization of controlled quantum network structures is key for the future advancement of the field.

Here we present three differing approaches to overcome current limitations for the experimental implementation of multi-dimensional quantum networks: non-linear integrated quantum optics, pulsed temporal modes and time-multiplexing. Non-linear integrated quantum devices with multiple channels enable the combinations of different functionalities, such as sources and fast electro-optic modulations, on a single compact monolithic structure. Pulsed photon temporal modes are defined as field orthogonal superposition states, which span a high dimensional system. They occupy only a single spatial mode and thus they can be efficiently used in single-mode fibre communication networks. Finally, time-multiplexed quantum walks are a versatile tool for the implementation of a highly flexible simulation platform with dynamic control of the underlying graph structures and propagation properties.

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