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Programmable linear quantum networks with a multimode fibre

High-speed data transfer through optical fibres using spatial multiplexing is practically limited by modal crosstalk. Instead of considering this modal crosstalk as a limitation, we here harness its mode mixing to process quantum optical information. We implement a programmable linear optical network based on the concept of inverse photonic design exploiting the technology of wavefront shaping. We demonstrate manipulation of two-photon quantum interference on various linear networks across both spatial and polarization degrees of freedom. In particular, we experimentally show the *zero-transmission law* in Fourier and Sylvester interferometers, which are used to certificate the degree of indistinguishability of an input state. Moreover, thanks to the ability to implement a non-unitary network, we observe the photon anti-coalescence effect in all output configurations, as well as the realization of a tunable coherent absorption experiment. Therefore, we demonstrate the reconfigurability, accuracy, and scalability of the implemented linear optical networks for quantum information processing. Furthermore, we study the statistical properties of one- and two-photon speckles generated from various ground-truth states after propagating through a multimode fibre. These statistical properties of speckles can be used to extract information about the dimensionality, purity, and indistinguishability of an unknown input state of light, therefore allowing for state classification. Our results highlight the potential of complex media combined with wavefront shaping for quantum information processing.

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