PhD Thesis Defense FABIAN STEINLECHNER 'Sources of Photonic Entanglement for Applications in Space'

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Monday December 14, 11:00. ICFO Auditorium

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Optoelectronics

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The nonlocal correlations of entangled systems are a feature inherent to quantum theory that is fundamentally at odds with our common-sense notions of realism and locality. Additionally, entanglement is an essential resource for numerous quantum communication protocols such as quantum teleportation and quantum dense coding, quantum cryptography, as well as quantum-enhanced metrological schemes and quantum computation. These quantum schemes allow for significant gains in performance over their classical counterparts, and a commercial implementation of protocols utilizing entangled photons thus seems likely in the foreseeable future. A key challenge to be addressed, in order to achieve a global-scale implementation of quantum-enhanced protocols, is the distribution of entanglement over long distances.

While photons are in many ways ideal carriers of quantum information, their distribution over long distances is significantly impeded by losses. At present, loss in optical fiber links or atmospheric attenuation and obstructions of the line of sight in terrestrial free-space links limit the distribution of photonic entanglement to several hundred kilometers. Installing sources of photons with quantum correlations on space platforms would allow such distance limitations to be overcome. This would not only lead to the first global-scale implementation of quantum communication protocols, but would also create the opportunity for a completely new class of quantum experiments in a general relativistic framework.

State-of-the-art laboratory sources of entangled photons are generally ill-suited for applications in harsh environments such as space, either owing to the use of bulky lasers, the requirement for active interferometric stabilization, or insufficient photon-pair-generation efficiency. Thus, an integral milestone for the experimental implementation of quantum communication protocols over satellite links is the development of robust, space-proof sources of entangled photons with high brightness and entanglement visibility. This thesis is intended to bridge laboratory experiments and real-world applications of quantum entanglement in harsh operational conditions. To this end, the main results of this thesis are:

Highly efficient sources of polarization-entangled photons for the distribution of entanglement via long-distance free-space links. The sources are very robust and compact, and incorporate only components which are compliant with the severe requirements of space flight and operation.

Optimization of spectral properties and fiber-coupling efficiency of photon pairs generated via spontaneous parametric down-conversion in bulk periodically poled potassium titanyl phosphate. The results of these studies are of great practical relevance for the development of an ultra-stable and efficient entangled photon source.

Engineering and characterization of field-deployable polarization-entangled photon sources with high visibility (>99%) and record pair-detection rates (>3 million detected pairs per mW of pump power). As a result of the performance demonstrated, the sources developed have been incorporated into ongoing experiments, for example in quantum nanophotonics and quantum communications, and will provide an enabling tool for future real-world applications.

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