ICFO

PhD THESIS DEFENSE: Quantum imaging with optical fibre structures

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December 02, 2025

10:00

ICFO Auditorium

Two-photon quantum correlations are a resource for quantum communication, sensing, and imaging. Coincidence-based quantum imaging leverages spatiotemporal quantum correlations to form images from two-photon coincidences rather than intensity alone. To be useful beyond free-space laboratory setups, such as in access-constrained, realistic settings, quantum correlations must be distributed through compact waveguides while remaining usable after propagation across many spatial modes and at practical rates.

This thesis develops methods for waveguide-based quantum imaging by integrating and advancing three main technology components: engineered quantum light sources based on spontaneous parametric down-conversion (SPDC), optical waveguides (including disordered and multicore optical fibre), and detection with single-photon avalanche diode (SPAD) array cameras, through both time-tagging and rolling-delay compensation. We demonstrate and

quantify transport of quantum spatiotemporal correlations, and implement quantum imaging in a waveguided geometry using optical fibre. In addition, we show real-time operation with continuous coincidence image frames. The main specific achievements are:
- Foundations for correlation transport.
   We model the propagation of quantum correlated SPDC two-photon states in me
ia (continuous and discrete pictures), identifying measurable signatures of correlat
on conservation after transpo
t.   We develop a protocol that measures the waveguide point-spread function via coinc
dence imaging with a time-tagging SPAD array and timestamp post-proce
sing.   Using these tools, we define metrics to certify and quantify correlation transpor
 through waveguides, and map its dependence on waveguide pa
ameters. - Waveguide-based transport of SPDC cor
elations   We validate transmission of SPDC spatiotemporal correlations through a custo
-fabricated transverse Anderson localization optical fibre and a commercially available mul
icore fibre (MCF), showing high-dimensional, mode-parallel delivery of correlations n
cessary for coincidence imaging protocols. We inject position anticorrelated photon pairs into the fibres, extract coincidences from SPAD array timestamps, characterize the waveguide
oint-spread function through the coincidence-imaging protocol and quantify pre
ervation of c
rrelations. - Waveguided quantum gh
st imaging.   Building on the established quantum correlation distribution, we imple
ent waveguided quantum ghost imaging (QGI) through a MCF using a non-degenerate signal-id
er photon pair SPDC source. The idler illuminates the sample through the waveguide and is
etected with a single SPAD, while the signal, which has not interacted with the sample,
is imaged with spatial resolution on a SPAD array camera. We report image quality and ima
ing rates, and identify limits of opti
al resolution. - Real-time quantum
ghost imaging.   We realize real-time, low-latency QGI (free-space and waveguided) by l
veraging in-pixel asynchronous coincidence extraction in the SPAD array camera, el
minating external post-processing latency. Coincidence image frames are produced contin
ously, supporting live
lignment and use. Together, these results provide methods for waveguided, mode-par
llel delivery and measurement of quantum correlations using optical fibre transport and SPAD array camera coincidence imaging, and thus extend quantum imaging technology towards practical waveguided settings. This may outline routes to applications in constra
ned environments, low photon flux regimes, and imaging at unusual wavelengths, potent
ally enabling new use-cases for quantum imaging, for example in

Tuesday December 02, 10:00 h. ICFO Auditorium

Thesis Director: Prof. Dr. Valerio Pruneri

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