

Enhorabona al nou graduat de doctorat de l'ICFO

El Dr. Alexander Demuth s'ha doctorat amb una tesi titulada i¿½ Quantum imaging with optical fibre structures"

December 02, 2025

Felicitem el Dr. Alexander Demuth que ha defensat la seva tesi aquest mati a l'Auditori de l'ICFO.
El Dr. Demuth va obtenir el seu Master en Fisica a la RWTH Aachen University a Alemanya, abans d'incorporar-se al grup de recerca de Optoelectronics dirigit pel professor ICREA d'ICFO el Dr. Valerio Pruneri. La seva tesi titulada " Quantum imaging with optical fibre structures" ha estat dirigida pel prof. Dr. Valerio Pruneri.

RESUMEN:
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 transport.
We develop a protocol that measures the waveguide point-spread function via coincide ce imaging with a time-tagging SPAD array and timestamp post-processing.
Using these tools, we define metrics to certify and quantify correlation transport thro gh waveguides, and map its dependence on waveguide parameters.
- Waveguide-based transport of SPDC correlations
We validate transmission of SPDC spatiotemporal correlations through a custom-fabrica ed transverse Anderson localization optical fibre and a commercially available multicore fi re (MCF), showing high-dimensional, mode-parallel delivery of correlations necessary or coincidence imaging protocols. We inject position anticorrelated photon pairs into the fibr s, extract coincidences from SPAD array timestamps, characterize the waveguide point-spr ad function through the coincidence-imaging protocol and quantify preservation of correlations.
- Waveguided quantum ghost imaging.
Building on the established quantum correlation distribution, we implement wavegui ed quantum ghost imaging (QGI) through a MCF using a non-degenerate signal-idler photon p ir SPDC source. The idler illuminates the sample through the waveguide and is detected wit a single SPAD, while the signal, which has not interacted with the sample, is imaged w th spatial resolution on a SPAD array camera. We report image quality and imaging rates, nd identify limits of optical resolution.
- Real-time quantum ghost imaging.
We realize real-time, low-latency QGI (free-space and waveguided) by leveraging in-pi el asynchronous coincidence extraction in the SPAD array camera, eliminating exter al post-processing latency. Coincidence image frames are produced continuously, support ng live alignment and use.
Together, these results provide methods for waveguided, mode-parallel 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 constrained environments, low photon flux regimes, and imaging at unusual wavelengths, potentially enabling new use-cases for quantum imaging, for example in the life sciences.

Tribunal de Tesi:

Prof. Dr. Milena d'Angelo, Universita degli Studi di Bari

Prof. Dr. Pablo Loza Alvarez, ICFO

Prof. Dr. Bruno Julia Diaz, Universitat de Barcelona



Tribunal de Tesi