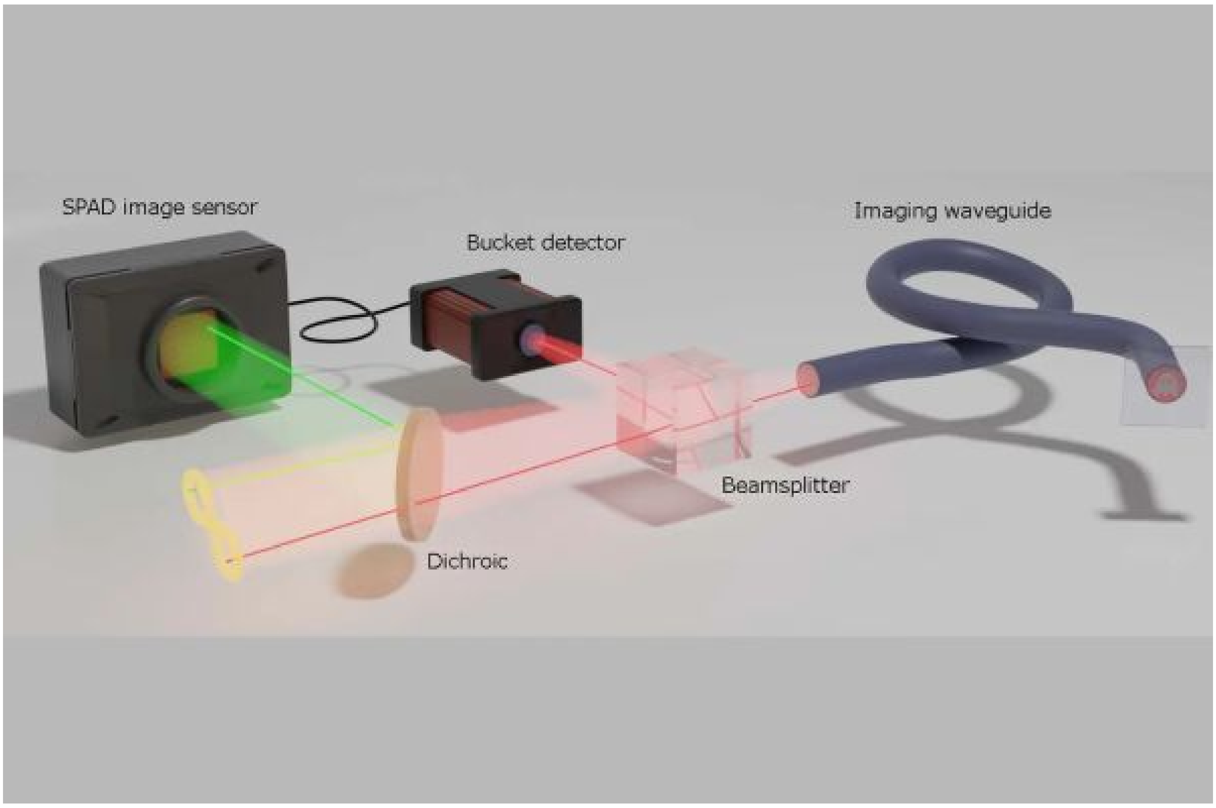

Quantum imaging reaches the inaccessible

ICFO researchers and collaborators have demonstrated real-time waveguided quantum ghost imaging. The technique, published in Optica, employs an optical fiber to illuminate otherwise inaccessible samples and a novel SPAD camera designed to perform real-time imaging without the need for external equipment.
This approach extends the benefits of quantum imaging to applications where direct access to the sample is impractical or potentially damaging, such as biomedical endoscopy or remote industrial inspection.

January 08, 2026

In recent years, quantum physicists have started to explore the potential of quantum light (for instance, entangled photons) to enhance optical imaging by improving optical resolution, the signal-to-noise ratio, and other key features.

One of the most striking examples is **quantum ghost imaging (QGI)**. In this technique, entangled photon pairs, whose positions and arrival times are correlated beyond the classical regime, are split into two paths: one of them (the idler) illuminates the sample and only the arrival time is recorded, while the other one (the signal) is directly imaged, capturing both position and time of arrival. By selecting only those measurements that exhibit the expected temporal correlations, an image solely based on the signal photons is reconstructed. Thus, the image emerges from photons that have never interacted with the sample, hence the name i¿½ghost imagingi?

½. In a recent Optica publication, ICFO researchers **Dr. Alexander Demuth** and **Dr. Robin Camphausen**, led by **ICREA Prof. Valerio Pruneri**, and collaborators from Fondazione Bruno Kessler, Trento (Italy) have expanded the capabilities of QGI by demonstrating, for the first time, **real-time waveguided quantum imaging (wQGI)**.

In a previous publication from Prof. Pruneri's group, the researchers had already employed an optical fiber to transmit spatial quantum correlations. In this case, however, the optical fiber not only transmits spatially correlated photon pairs, but also illuminates a distant sample with them, making it possible to **image otherwise inaccessible regions**. The presented method is thus **suitable for endoscopic imaging**, a minimally invasive technique where the object under study is occluded from direct view, such as by opaque biological tissue.

Moreover, the researchers developed a custom single-photon avalanche diode (SPAD) array camera specifically for QGI. Directly in the camera's pixels, signal photon detections can be correlated in time with idler arrival times. This ability to correlate measurements directly on-chip **eliminates the external post-processing step** which state-of-the-art techniques require, thereby removing latency and, thus, allowing **real-time quantum imaging** for the first time.

The researchers now look forward to improving the SPAD array camera for faster imaging and higher number of pixels, as well as to generating photon pairs of widely separated frequencies. i¿½A crucial advantage of quantum ghost imaging in general is that signal a d idler can have different frequencies,i¿½ shares Dr. Alexander Demuth, first author of the article. i¿½In our experiment, this separation was small, serving only as a proof of co cept. The natural next step is to broaden it. Ideally, one photon could be in the mid-infrared, where image sensors are not readily available, enabling minimally invasive mid-infrared endo copic imagi

Reference:

Alexander Demuth, Robin Camphausen, Massimo Gandola, Enrico Manuzzato, Alessandro Tontini, Leonardo Gasparini, Valerio Pruneri, Real-time waveguided quantum ghost imaging, Optica (2025).
DOI: https://doi.org/10.1364/OPTICA.574234

Acknowledgements:
Agencia Estatal de Investigacion (CEX2024-001490-S, MICIU/AEI/10.13039/501100011033, MCIN/AEI/10.13039/501100011033/FEDER); Fundacion Cellex (ICFO CELLEX PhD-fellowship); FUNDACIO Privada MIR-PUIG; Centres de Recerca de Catalunya; Ministerio de Economia y Competitividad (MAGICAL: PID2022-137952NB-I00); Ministerio de Ciencia, Innovacion y Universidades (PRTR-C17.I1); H2020 Future and Emerging Technologies (899580, H2020-FETOPEN-2018-2020); HORIZON EUROPE Digital, Industry and Space (101082596).