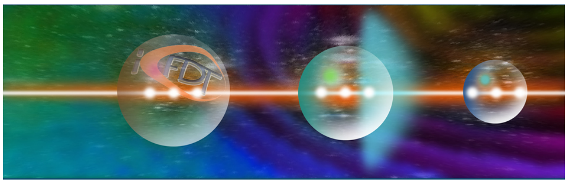

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# Quantum spectroscopy approach for novel diagnostics

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Quantum Sensing is a rapidly growing branch of research within the area of quantum science and technology offering key resources, beyond classical ones, with clear potential for commercialisation of novel (quantum) sensors. Their physical implementation can vary and each approach has specific advantages/limitations and varying levels of TRL for different applications.

The activity of our lab is focused on the exploitation of quantum resources offered by photons to boost the performance of novel quantum sensors, drawing an innovative programme of challenging applications. We are building on the idea of the Quantum Ghost Spectroscopy (QGS), i.e. the counterpart in the frequency domain of Quantum Ghost Imaging (QGI), and we are addressing challenges in basic research, targeting novel applications. Ghost imaging (GI) is a sophisticated method to image an object without analysing the light that passed through it.

The framework of QGI extends such possibility to the quantum domain usually through the use of spatial quantum correlations of pairs of photons generated via Spontaneous Parametric Down Conversion (SPDC). However, focusing on spatial correlations only is quite restrictive, as such correlations can be in the spectral or polarization domain as well. In fact, each photon is in a superposition of several possible modes (spatial, frequency or polarization), all of which arrive on the object, and are then measured by a mode-insensitive bucket detector. Due to the correlations intrinsic to the pair-production process, the analysis of one of the correlated photons provides information on what has occurred to its twin [Fig.1]. Therefore, if the SPDC source generates pairs of photons in a nondegenerate configuration, i.e. belonging to different wavelength ranges (the first in the VIS and the second in the IR range), it could be possible to link IR and VIS components of the emission in such a way that spectral information in the former range can be assessed by looking only at the latter. This means that the requirements for accurate measurements are shifted from the IR to the VIS domain, for which much more solid, reliable and cost-effective solutions are available. Hence, the time-frequency domain reveals a huge potential for several applications and frequency correlations represent a versatile tool that can be exploited to enable the spectral analysis of objects where a direct measurement would not be feasible.

This approach has been employed by the HADES project [1] for the detection of several possible harmful threats showing optical properties in the NIR spectral regions. The obtained results and the future developments of our work will be presented and discussed.

[1] https://www.hades-sps.it/

[2] A. Chiuri, et al. Ghost imaging as loss estimation: Quantum versus classical schemes, PRA, 105, 013506 (2022)

[3] A. Chiuri, et al Fast remote spectral discrimination through ghost spectrometry, PRA 109, 042617 (2024)

[4] A. Chiuri, et al. Quantum Ghost Imaging Spectrometer, ACS Photonics, 10, 12, 4299–4304 (2023)

**Primary author:** CHIURI, Andrea (ENEA)

**Presenter:** CHIURI, Andrea (ENEA)

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