ICFO

PhD THESIS DEFENSE: Fundamentals of nonlinear interferometers and its use for optical coherence tomography

GERARD JIMENEZ MACHADO

December 02, 2022
11:00
ICFO Auditorium

This thesis, mostly experimental, is based on two fundamental pillars: nonlinear interferometers and Optical Coherence Tomography (OCT). Nonlinear interferometers are a class of interferometers that exhibit nonclassical phenomena brought on by nonlinear elements, such as optical parametric amplifiers and parametric down-conversion (PDC) nonlinear crystals. OCT is a non-invasive imaging technique that allows to obtain images with high axial and cross-sectional resolution of a wide variety of samples.
The first novel contribution of this thesis is an experimental scheme that combines the two ideas: an OCT scheme based on a nonlinear interferometer. In these new approach the reflectivity of the sample translates in a loss of first-order coherence between two beams, that is the variable that is measured. In addition, it allows probing the sample with a

wavelength different from the one that is measured. In this way, the penetration depth in the sample can be enhanced using longer wavelengths while using light at the optimal wavelength for detection.

We present and implement two different experimental configurations. The first is a nonlinear interferometer based on induced coherence, or Mandel-type interferometer, that works in the low parametric gain regime of parametric down-conversion (PDC). The results presented here are a proof-of-concept, that can potentially offer new applications for OCT, but that are not meant to substitute traditional OCT systems.?

The second OCT scheme overcomes some of the limitations of the first scheme discusse above. It is an SU(1,1), or Yurke-type interferometer, that operates in the high parametric gai regime of parametric down-conversion. In addition to taking advantage of the salutar features of this new approach, it also enables obtaining values of power and axial resolutio comparable to those of conventional OCT

The second novel contribution of this thesis is related to fundamental aspects at the heart o nonlinear interferometers. We discuss two experiments that study two important concept behind the idea of induced coherence: quantum distinguishability and parametri amplification (stimulated emission). In the first experiment we propose a new experimenta measure of quantum distinguishability and derive a complementarity relation betwee distinguishability and first-order coherence. In the second experiment, we contribute to th ongoing debate about the true role of quantum distinguishability and stimulated emission i explaining the induced coherence effect

Finally, we put forward theoretically a new scheme to retrieve transverse spatial informatio of a sample using a nonlinear interferometer, based on projecting the outgoing photons i selected spatial modes. We call this new proposal spatial spectroscopy, and it does no require a physical mechanical scan of the sample. We demonstrate the feasibility of th technique with a simple example. This last contribution constitutes a future proposal to b carried out with nonlinear interferometers, evidencing their great versatility and potentia applications in new areas

Thesis Director: Prof Dr. Juan Perez Torres

Hosted by: Prof. Dr. Juan P. Torres