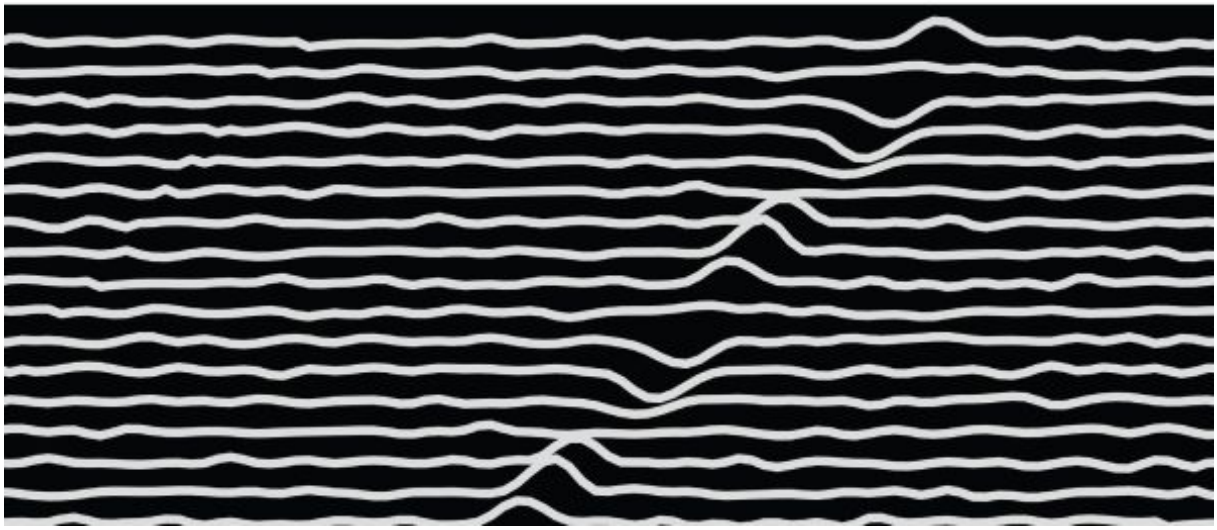
ICFO

FEDERICA A. BEDUINI
Advisor: Morgan W. Mitchell



PhD Thesis Defense FEDERICA BEDUINI 'Entanglement and State Characterisation from Two-Photon Interference'

FEDERICA BEDUINI

November 03, 2015

Tuesday, November 3, 11:00. ICFO Auditorium

FEDERICA BEDUINI

Quantum information with cold atoms and non-classical light

ICFO-The Institute of Photonic Sciences

This thesis analyses the effects of two-photon interference in a polarisation squeezed state under two different points of view: on one hand, it presents a new method to obtain the temporal wavefunction of a state of two photons; on the other hand, it studies the microscopic entanglement properties of a collective nonclassical polarisation state, such as

the polarisation squeezed state.

The complete characterisation of an unknown quantum state often requires complicated reconstruction methods due to its complex nature: in the first part of this thesis, we describe a new technique to completely recover the wavefunction of a state with two photons (a "biphoton") with just few simple measurements, thanks to the interference with a coherent reference. With this technique, we successfully reconstruct the wavefunction of single-mode biphotons from a low-intensity narrowband squeezed vacuum state.

Many large collective systems that feature nonclassical properties, e.g. superconductivity and squeezing, show entanglement among their components at their microscopic level. Here we report the first direct study of this kind of entanglement for light polarisation. In analogy with the spin-squeezing inequalities that connect squeezing to entanglement for atomic ensembles, we derive an inequality valid for states with classical polarisation correlations, whose violation implies pairwise entanglement among the photons in the state. We consider a polarisation squeezed state that results from the combination in the same spatial mode of a squeezed vacuum state, generated by an optical parametric oscillator (OPO), and a coherent state with orthogonal polarisations: we find that this kind of state always violates our inequality within the coherence time of the squeezed vacuum state. We also quantify the entanglement between the photon pairs by computing the concurrence of the two-photon reduced density matrix: we find that the states that exhibit higher entanglement satisfy the condition for higher visibility of the two-photon interference. We also find that the concurrence is larger for lower squeezing levels, in agreement with the monogamy of entanglement and in analogy to the atomic case. This translation of spin-squeezing inequalities to the optical domain enables us to test directly the squeezing-entanglement relationship.

We generate a squeezed vacuum state with an OPO and we combine it with a coherent state to generate a polarisation squeezed state and we measure the photon pair counts for different polarisation bases. We recover the density matrices corresponding to different realisations of the polarisation squeezed state via quantum tomography: all the density matrices that we reconstruct with this method are entangled, with concurrence up to 0.7.

Our measurements confirm several theoretical predictions, including entanglement of all photon pairs within the squeezing coherence time.

Tuesday November 3, 11.00 h. ICFO Auditorium

Thesis Advisor: Prof. Morgan W. Mitchell

