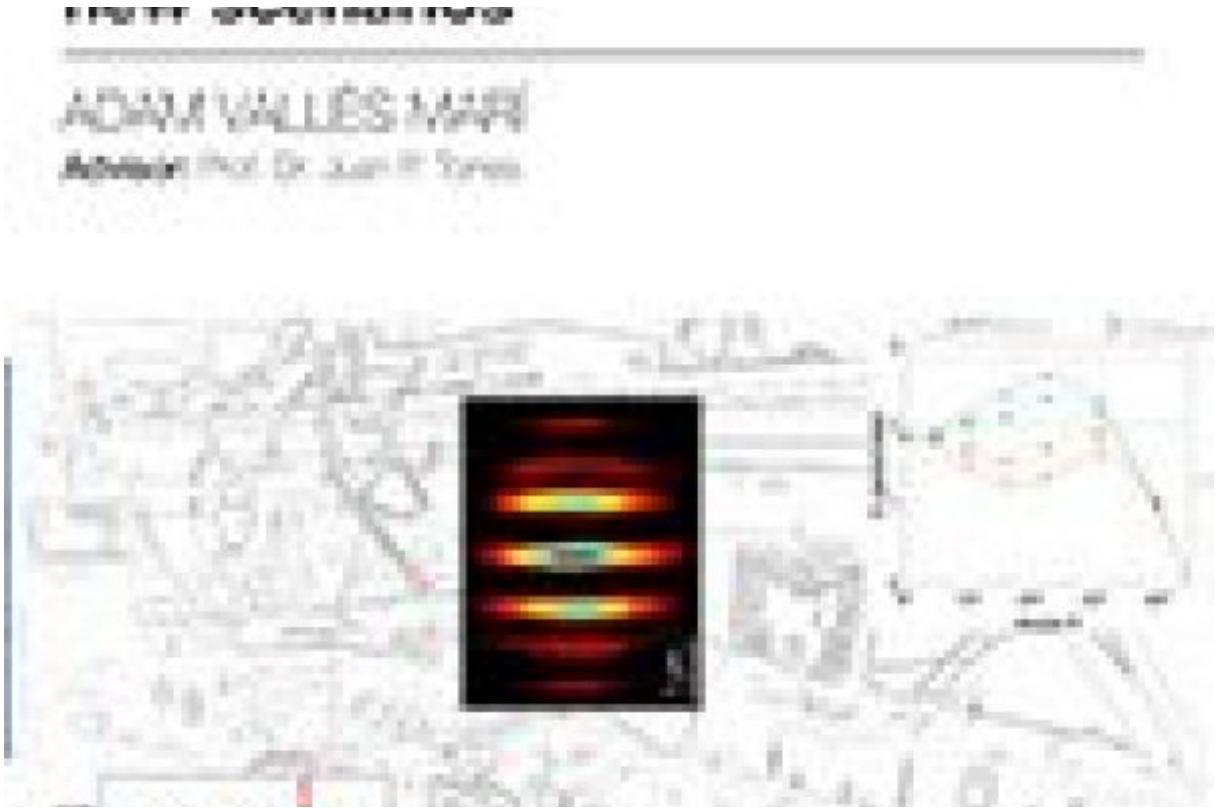

PhD Thesis Defense ADAM VALLES 'Entanglement, Bell?s Inequalities and Coherence: New Ideas and New Scenarios'

ADAM VALLES

February 14, 2017

Tuesday, February 14, 11:30. ICFO Auditorium

ADAM VALLES

Quantum engineering of light

ICFO-The Institute of Photonic Sciences

The work presented in this thesis, mostly experimental, is based on three main pillars: the concepts of entanglement, Bell?s inequalities and coherence. Entanglement is a very special type of correlation that can exist between two systems, even if these systems are physically separated by a large distance. Bell?s inequalities are a window to inquiry fundamental

questions about how Nature works at its fundamental level, and it turns out that they can also become tools with practical relevance. Coherence is a fundamental trait of electromagnetic theory, in the classical as well as in the quantum regimes, and it is closely linked to the concept of entanglement.

In this thesis we study different platforms aimed at generating entangled states. We control its properties, measure the quality of the entanglement and search for links with concepts such as coherence.

In certain cases of practical interest, the generation of entanglement can become a great challenge due to technical difficulties of the experiments. From a fundamental point of view, the concept of entanglement still poses questions about what it really means and where it can manifest.

In the different experiments presented in this thesis, we have generated different kinds of entanglement capable of being used in various environments. For instance, this is the case of the generation of polarization entangled paired photons at the telecom band in a semiconductor Bragg reflection waveguide. This represents a significant step towards the realization of efficient and versatile sources of entangled photon pairs, that could be integrated in a microchip. In another experimental scheme we have proved, also by measuring the violation of the Clauser, Horne, Shimony and Holt (CHSH) Bell-like inequality, the generation of non-coherent and coherent correlations between different degrees of freedom of a single photon, finding a close analogy with the entanglement that can exist between twodistant photons. These types of experiment can help in discussions aimed at illuminating what is the true meaning of entanglement.

Lastly, in a third experiment we make use of frequency-entangled photons to demonstrate a new type of optical coherence tomography (OCT) scheme, where the reflectivity of the sample translates in a change of coherence. We call this new approach induced Optical coherence tomography (iOCT). This new scheme allows probing the sample with one wavelength and measuring light with another wavelength.

As a result, we can gain penetration depth into the sample by using longer wavelengths, while still using the optimum wavelength for detection. Finally, from a theoretical perspective, we study how coherence and correlations represent two related properties of a compound system. We derive an expression that determine the relationship between the degree of coherence of each subsystem, and the type and degree of the correlation present between the subsystems. We also demonstrate that the degree of violation of the CHSH inequality is the appropriate measure that quantifies how much correlations can be turned

into coherence, and how much coherence can be extracted.

Tuesday, February 14, 11:30. ICFO Auditorium

Thesis Director: Prof . Dr. Juan Perez Torres