THESIS DEFENSE: Quantum nonlinear optics at the single-photon level with cold Rydberg atoms

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ICFO Auditorium and Online (Teams)

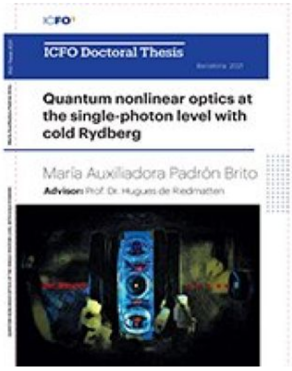
Photons are good candidates for carrying quantum information because they are very stable particles: they interact weakly with the medium and barely with each other. However, this has drawbacks when you want to process the information because, in this case, it is preferable to have photon-photon interactions. For example, for applications in quantum repeaters, such interactions would allow deterministic Bell state measurements, increasing the entanglement distribution rate between two remote nodes. Getting two photons to interact with each other efficiently requires mapping them into a nonlinear medium at the single-photon level, that is, a medium that reacts differently when it interacts with a single photon than when it does with two. Such strong nonlinearity has been demonstrated with Rydberg atoms, which are atoms excited to a state with a high principal quantum number.

In this thesis we have performed nonlinear quantum optics experiments using an ensemble of cold Rydberg atoms, where we have studied the properties of the quantum light emitted by these atoms. First, we demonstrated nonlinearities at the single-photon level. To reach this stage, we made several improvements to the previous experimental setup available in the group, of which the implementation of a dipole trap was especially relevant. We evidence quantum nonlinearity by measuring photon antibunching for the transmitted light after interacting with the Rydberg state under electromagnetically induced transparency (EIT). We also showed the generation of single photons on-demand after storing weak coherent states of light pulses as collective Rydberg excitations. Then, we studied the variation of the light statistic throughout the output pulse after propagating through the medium as Rydberg polaritons, which are superposition states of light and Rydberg excitations. We showed that the properties at the beginning and the end of the pulse were different from those of the steady state. In particular, the light detected after the input pulse was abruptly turned off gave much stronger suppression of two-photon events. Then, we investigated how to exploit this effect to generate single photons on demand. To do this, we analyzed the quality of the single photons detected at the end of the pulse as a function of the detection probability and compared the results with those obtained by storing the input pulse as collective Rydberg excitations. We showed that the photons were generated more efficiently when increasing the detection window at the cost of deteriorating the single photons statistics.
Finally, we investigated the indistinguishability of the photons emitted by our Rydberg atomic ensemble, a crucial property for using Rydberg atoms as nodes in quantum networks. We also compared the single photons generated after storage under EIT conditions with those obtained using a two-photon Raman excitation to the Rydberg state. We measured the indistinguishability by making them interfere with weak coherent states of light in a Hong-Ou-Mandel experiment. And we showed that, although we obtained better photon statistics under EIT conditions, the indistinguishability from those obtained with Raman excitation was significantly higher.

Due to recommendations in place to contribute containing the spreading of COVID-19, th defence will be carried out semi presencial with a maximum of 66 Icfonians in t e Auditorium, and partly remotely via MS Teams. This is the link to follow the Thesis Defe se online Click here to join the meeting

If you are interested in attending in person, please address your request to mery.gil@icfo.eu **by Tuesday April 6th .**

Hosted by: Prof Dr Hugues de Riedmatten



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