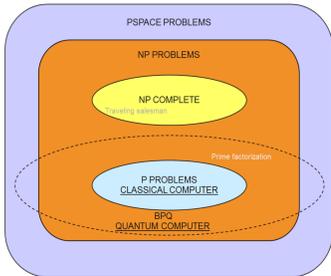
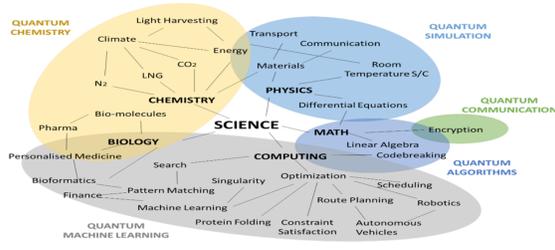


1. Motivation: Quantum simulation

There are many kind of problems which are not solvable not even with the most powerful super computer. Since many decades physicists know that a quantum computer (UNIVERSAL QUANTUM SIMULATOR) could solve those problems. The possibility of building the first quantum computer raised an huge interest which ultimately lead to a race among a bunch of companies and organizations (IBM, Microsoft, Google, etc.). An easier approach is to build a quantum simulator for solving a specific set problems. Those devices are called ANALOG QUANTUM SIMULATORS. The aim of our work is realizing a full-controllable quantum simulator working at ambient conditions.

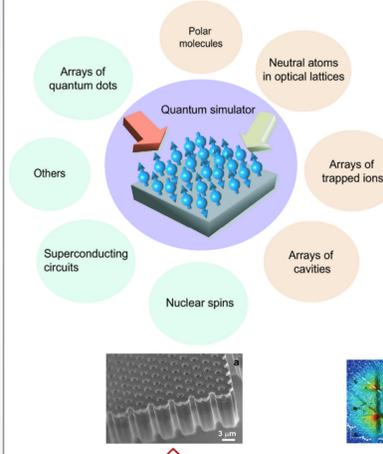


Classification of different types of problems



Areas affected by the advent of the quantum simulators era.

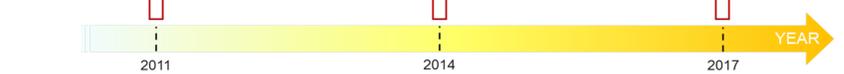
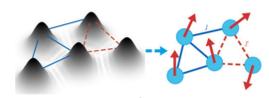
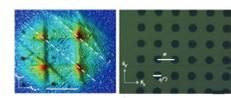
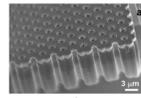
2. Experimental implementations



For realizing an analog quantum simulator we need two basic components: an ensemble of "quantum" particles and tunable interactions. In the past 15 years many experimental systems have been realized each one carrying some pros and cons. Our choice fell on the use of ARRAYS OF OPTICAL CAVITIES as platform and EXCITON-POLARITON CONDENSATES as quantum particles.



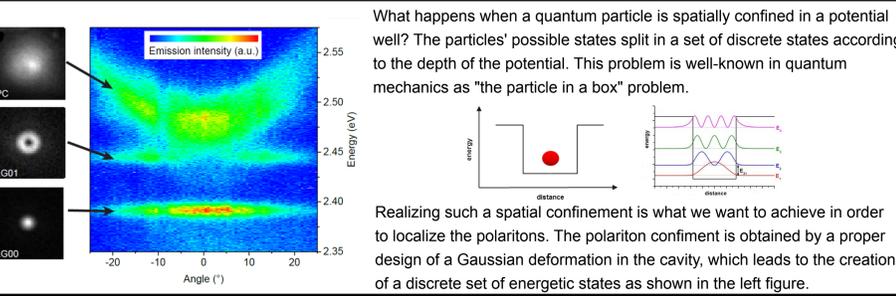
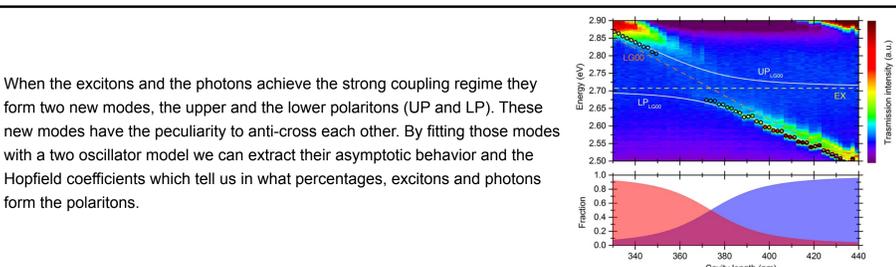
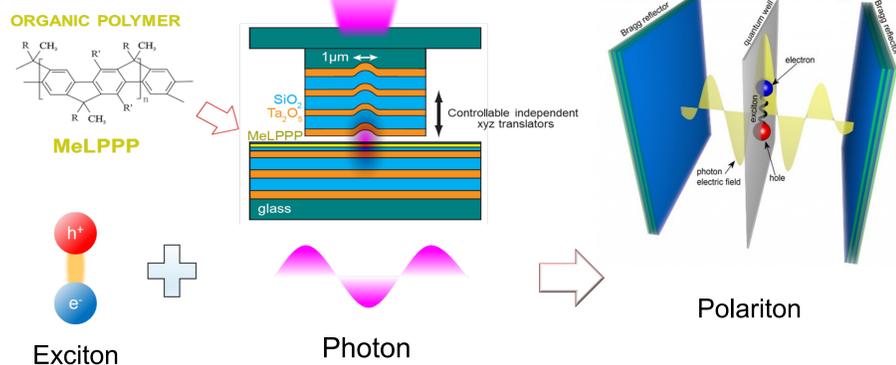
- PROS:
- Easier to generate
 - Working at higher T
 - Full optical approach
- CONS:
- Only for specific problems (analog)
 - Weak self-interactions



All the realizations of exciton-polaritons in arrays of optical cavities in the past years have required cryogenic temperatures to work.

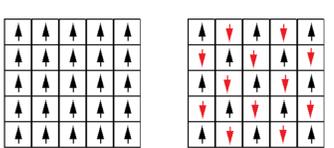
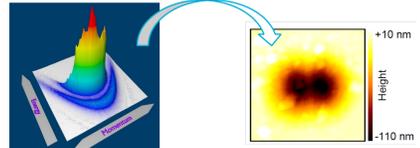
3. An exotic light-matter state: the exciton-polariton

In order to create the quantum particle we need an active material which provides EXCITONS (bound states of electrons and holes) inside an OPTICAL CAVITY which provides CAVITY PHOTONS (the light trapped in the optical cavity). Once they achieve the so called strong coupling condition (in other words, when they are strongly interacting) they form a new exotic state made of light and matter: the EXCITON-POLARITON (or simply the POLARITON).

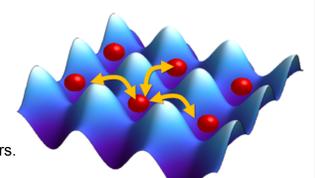


5. Future perspectives

First experimental observation of the Josephson Oscillation at ambient condition, i.d. an oscillation of the polariton population between two wells accompanied with a linear increase of the phase.



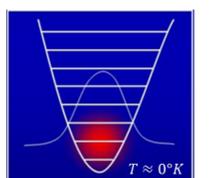
Study of different phase transitions. The creation of multiple coupled polariton condensates with a controllable phase can be used to study different phase transition such as magnetic transition.



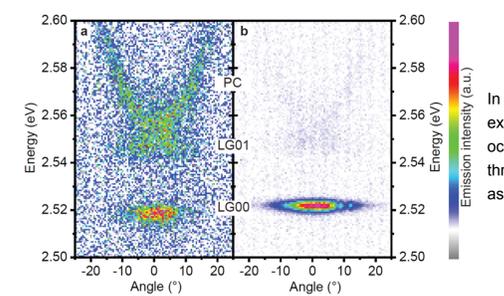
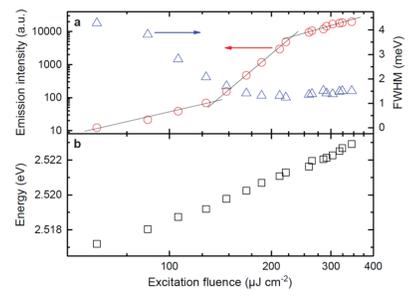
Ultimately, the realization of a tunable platform for interacting polariton condensates for tackling the field of many body physics, i.e. the field of physics in which multiple particles, each one treated individually, interact with all the others. This field of Physics represents one of the main challenge for the future of the quantum simulators.

4. 0D exciton-polariton condensate at ambient conditions

To be properly considered as quantum particles, the polaritons confined in the 0D microcavity have to become spatially and temporally coherent. This "status" can be achieved by realizing, with the polaritons (which belong to the special group of particle called bosons), the so called BOSE-EINSTEIN CONDENSATE. This condition has many peculiarities (Bose-Einstein statistics, extended spatial and temporal coherence, etc.) but one of the most evident is that all the particles forming the condensate "sit" on the lowest energetic state of the system (right figure). In order to generate the condensate we need to increase the density of polaritons, by exciting the system with a pulsed amplified laser, above a certain level which defines a certain power threshold.

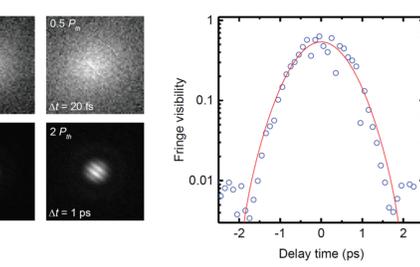


In the right plot, some of the features of the polariton condensate are shown through the study of the emission from the cavity when tuning the excitation power (i.d. the polariton density). Above the threshold the emission intensity (red circles) increases non linearly; the peak width, i.d. the full-width-half-maximum (FWHM), decreases and the energy of the peak shift toward higher energy (blueshift) due to the repulsive interaction among the polaritons and the excitons in the material.



In the left plot, k-space dispersions of the polaritons under different excitation powers are shown. Below threshold (a) the polaritons occupy all the discrete modes (LG00, LG01, PC) while above threshold (b) they "collapse" in the lowest energetic state (LG00) as expected.

In the right plot the temporal coherence is studied. In order to measure the first order coherence we send the emitted light in a Michelson interferometer and then we collect the light with a camera. By studying the interference patterns (fringe visibility) as a function of the delay time introduced in one arm of the interferometer, we can extract the coherence time of the polaritons. Below threshold the coherence time is very short, of the order of few femtoseconds (10^{-15}), while in the condensate regime the coherence extended up to few picoseconds (10^{-12}).



References

Georgescu et al., Rev. Mod. Phys. 86, 153 (2014)
Carusotto et al., Red. Mod. Phys. 85, 299 (2013)
N. Y. Kim et al., Nature Physics 7, 681-686 (2011)
Jacqmin et al., Phys. Rev. Lett. 112, 116402 (2014)
Berloff et al., Nature Materials (2017) online DOI: 16007.06065v1
Kasprzak et al., Nature 443, 409 (2006)
Plumhof et al., Nature Materials 13, 247-252 (2014)
Scafirimuto et al., ACS Photonics (2017) online DOI: 10.1021/acsp Photonics.6b00334

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Contatti

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