

## **Master in Photonics – “PHOTONICS BCN” Master ERASMUS Mundus “EuroPhotonics”**

### **MASTER THESIS PROPOSAL**

**Dates: April 2021 - September 2022**

**Laboratory: Departament de Física Quàntica i Astrofísica  
Institution: Universitat de Barcelona  
City, Country: Barcelona, Spain**

**Title of the master thesis: Ultracold dipolar bosons trapped in atomtronic circuits**

**Name of the master thesis supervisor and co-supervisor: Montserrat Guilleumas and  
Bruno Juliá**

(for external proposals a co-supervisor from the Master program in needed)

Email address: [munsa@fqa.ub.edu](mailto:munsa@fqa.ub.edu)

Phone number: 934039182

Mail address: Martí i Franquès 1, 08028-Barcelona

**Keywords: Atomtronics, dipolar interactions, quantum tunneling**

#### **Summary of the subject (maximum 1 page):**

The recent advances in the preparation and control of ultracold atomic gases have fostered the appearance of a specific subfield termed atomtronics, which is aimed at the development of technological applications based on atomic matter waves [1–3]. Its first steps are mainly pursuing successfully applied theories from the fields of quantum optics and electronics.

In the current project, we would like to extend our previous work within the Bose-Hubbard framework, on tunneling dynamics with contact interacting atoms [4,5], to atoms with dipole-dipole interaction. The latter is characterized by a long range and anisotropic nature. We will consider a sample of polarized ultracold dipolar atoms confined in three spatially separated traps. By solving the extended Bose-Hubbard Hamiltonian [6] we will explore the ground state and the phase diagram of the system for different dipole orientations, depending on the strength of the interactions. The main aim is to characterize ultracold dipolar bosons in quantum circuits for different polarization directions, starting with the smallest unit circuit, a trimer. We will investigate the entanglement properties and the role played by the anisotropic character of the dipolar interaction [6]. Dynamical effects such as vortex states can be also investigated.

[1] L. Amico, G. Birkel, M. Boshier, and L.-C. Kwek, New J. Phys. 19, 020201 (2017).

- [2] M. K. Olsen and A. S. Bradley, Phys. Rev. A 91, 043635 (2015).  
[3] B. T. Seaman, M. Krämer, D. Z. Anderson, and M. J. Holland, Phys. Rev. A 75, 023615 (2007).  
[4] A. Escrivà, A. Muñoz Mateo, M. Guilleumas, and B. Juliá-Díaz, Phys. Rev. A 100, 063621 (2019).  
[5] A. Escrivà, A. Richaud, M. Guilleumas, and B. Juliá-Díaz, J. Phys. B: At. Mol. Opt. Phys. 54, 115301 (2021).  
[6] A. Gallemí, M. Guilleumas, R. Mayol and A. Sanpera, Phys. Rev. A 88, 063545 (2013).

**Additional information (if needed):**

\* Required skills: Programming skills (python or fortran), Knowledge of quantum many-body (preferable)

\* Miscellaneous :