MASTER IN PHOTONICS – "PHOTONICS BCN"
ERASMUS+ "EUROPHOTONICS-POESII"

MASTER THESIS PROPOSAL

Dates: April - September 2018

Laboratory : ICFO – The Institute of Photonic Sciences
Institution: ICFO – The Institute of Photonic Sciences
City, Country : Castelldefels, Barcelona, Spain

Title of the master thesis: Application of a quantum random number generator to simulations in condense matter physics

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Keywords : quantum random number generators; FPGA; condense matter systems; Randomness in physics. Machine learning.

Summary of the subject (maximum 1 page) : Random numbers are central to fundamental research and technology developments, with applications in computation, simulations, cryptography, etc. Quantum mechanics has inherent randomness (ontic or intrinsic), as it persists even if we completely know the state of the system in consideration [1]. As it is a crucial resource for quantum technologies, a lot of scientific effort has been devoted recently to the development of quantum random generators (QRG) [2]. The goal of this project is to develop simulations (algorithms or observables) of condense matter systems that best reveal the benefit of current cutting-edge technological developments on QRGs, as opposed to conventional approach to use more and more optimized pseudo-random number generators. As a first example we study the determination of dynamical (relaxation) critical exponent of a 2D Ising model [3]. For this we use simulations in ICFO's developed Field programmable gate arrays (FPGA), which are appropriate for paralelized Monte Carlo simulations of this model. As a random number generator we use the ICFO's developed QRGs [4]. As a second example we will attempt to calculate the disordered Ising models phase diagrams, which can be seen as Ising

models with random coefficients. We finally will explore the possibility to implement machine learning strategies to optimization problems by means our FPGA and the QRG.

To undertake this program one requires knowledge of condense matter systems and quantum mechanics. We will focus on the theoretical side, as the FPGA and QRG are already developed and ready to use at ICFO. It will require management of a large amount of data produced by the FPGA simulations, and it will be useful, but not crucial, some knowledge on programming FPGAs. Expected impact is to produce a proof of the technological applicability of quantum random numbers in practical problems and to set up a machine (the FPGA plus the QRG) ready to be applied to a variety of interesting open problems in condense matter and optimization problems with machine learning.

[1] *Randomness in Quantum Mechanics: Philosophy, Physics and Technology*, M.N. Bera, A. Acín, M. Kuś, M. Mitchell, and M. Lewenstein, Accepted in Reports on Progress in Physics. arXiv:1611.02176 (2016).
[2] *Quantum random number generators*, M. Herrero-Collantes and J.C. Garcia-Escartin, Rev. Mod. Phys. 89, 015004 (2017)
[3] *Linear relaxation in large two-dimensional Ising models*, Y. Lin and F. Wang, Phys. Rev. E 93, 022113 (2016).
[4] *Ultra-fast quantum randomness generation by accelerated phase diffusion in a pulsed laser diode*, C. Abellán, W. Amaya, M. Jofre, M. Curty, A. Acín, J. Capmany, V. Pruneri, and M.W. Mitchell, Optics express 22, 1645 (2014); *Generation of Fresh and Pure Random Numbers for Loophole-Free Bell Tests*, C. Abellán, W. Amaya, D. Mitrani, V. Pruneri, and M.W. Mitchell, Phys. Rev. Lett. 115, 250403 (2015).

Additional information :

* Required skills : quantum physics; quantum information; statistical physics; simulation and computation skills.

* Miscellaneous :