RELAZIONE ATTIVITA’ ANNUALE DEI PERFEZIONANDI/DOTTORANDI – PRIMO ANNO

REPORT ON THE PHD ACTIVITY – FIRST YEAR

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| **NOME E COGNOME**  **NAME AND SURNAME** | Federico Belliardo |
| **DISCIPLINA/PHD COURSE** | Nanoscienze |

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| **CORSI FREQUENTATI CON SOSTENIMENTO DI ESAME FINALE**  **ATTENDED COURSES (WITH FINAL EXAM)** | **VOTAZIONE RIPORTATA**  **MARK** | **NUMERO DI ORE**  **HOURS** |
| Numerical Analysis and Optimization | 30 | 40 |
| Stability of Matter in Quantum Mechanics | 30L | 40 |
| Theory of Many-Body System | 30 | 30 |
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| **CORSI FREQUENTATI SENZA SOSTENIMENTO DI ESAME FINALE**  **ATTENDED COURSES (ATTENDANCE ONLY)** | **NUMERO DI ORE**  **HOURS** |
| Elements of Probability Theory and Mathematical Statistics | 40 |
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| **ALTRE ATTIVITÀ FORMATIVE (SEMINARI, WORKSHOP, SCUOLE ESTIVE, ECC.) – DESCRIZIONE**  **OTHER PHD ORIENTED ACTIVITIES (SEMINARS, WORKSHOPS, SUMMER SCHOOLS, ETC) – DESCRIPTION** | **NUMERO DI ORE**  **HOURS** |
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| **ATTIVITÀ DI RICERCA EVENTUALMENTE SVOLTA (MAX. 3.000 CARATTERI)**  **RESEARCH ACTIVITY (MAX. 3000 CHARACTERS)** |
| In the published paper I have explored the possibility of performing Heisenberg limited quantum metrology of a phase, without any prior, by employing only maximally entangled states of the used quantum system (atoms or photons for example). They are universal resources for quantum information and in the literature are often thought to be the the optimal states to perform phase measurement (for example in a Mach-Zehnder interferometer). In particular they are shown to reach Heisenberg scaling, a regime in which the measurement error decreases quadratically faster with respect to the prediction of the central limit theorem. This effect is amenable to the entanglement between the probes. This is all straightforward in the context of sensing, where we measure small deviations from a known reference phase, but if we have no prior information it is not obvious that the maximally entangled states are still useful at all in phase estimation. In the literature some scattered results can be found that address this issue and the proposed solution is to use entangled states of growing sizes and appropriately postprocess the measurement outcome. In our paper the origin of this issue is presented clearly and an analytical upper bound on the precision is proposed (showing Heisenberg scaling) which comes from a detailed optimization of the resources. Together with other technical extensions of the algorithm (yet to be published) we plan to perform an experiment on this protocol. Even if maximally entangled states of medium to high sizes are not yet available the algorithm can be simulated with opportunely engineered single photon states. This is per se already a practical application of possible interest. For the experimental part we plan to rely on the group of prof. Sciarrino at the University La Sapienza in Rome. They have developed a quantum optic platform using special components called Q-plates that can simulate the phase accumulation of the maximally entangled state. What we add to their metrological technique is the "software" part (how many estimation stages should there be, which Q-plates should be activated at each stage, how many photons use at each stage) that aims to make the best out of their apparatus. We also performed our optimization in the case a photon loss or phase fluctuation noise acts on the system. Which means that we can calibrate the procedure according to the details of the experiment (once it has been characterized). If noise is present the Heisenberg scaling disappears asymptotically, surviving only up to a certain precision, this cannot be changed by the calibration. I am currently unsure about the practical effects of this calibration, I will evaluate them in the future through simulations or in the actual experiment. |

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| **EVENTUALI PUBBLICAZIONI**  **PUBLICATIONS (IF AVAILABLE)** |
| Achieving Heisenberg scaling with maximally entangled states: an analytic upper bound for the attainable mean square error (arxiv.org/abs/2007.02994). Accepted for Physical Review A. |
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| **DATA**  **DATE** | 16/10/2020 | **FIRMA**  **SIGNATURE** | Federico Belliardo |