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REPORT ON THE HABILITATION THESIS BY DR. PETR MAREK

Dr. Petr Marek has shown an impressive and internationally-recognized scientific work over the last years. As a theoretician, he developed a variety of proposals in the field of quantum optics and quantum information processing. Importantly, this work took place in a strong international collaboration context that enabled seminal demonstrations by world-leader experimental groups. The challenging studies performed by Dr. Marek were instrumental in these realizations. His habilitation thesis provides an instructive overview of these achievements, which have been published in 12 peer-reviewed articles.

The general field of research of Dr. Marek is known as quantum optics, i.e. the investigation of the quantum properties of light and its interaction with matter. It also encompasses the fundamental study of measurement processes. In the last two decades, mostly based on the foundations of quantum optics, a new interdisciplinary line of research has strongly developed: the area of quantum information science and technology, including quantum communication, computing and metrology. The work of Dr. Marek enters specifically in this general framework and focuses on optical implementations. In this context, a key ingredient is to develop quantum nonlinearities: the research of Dr. Marek investigates this direction following different approaches at the single-photon level. The thesis is a very interesting and very-well written guide along this line.

The thesis is organized in 4 chapters, plus an introduction and a conclusion. The first chapter provides the general "nuts and bolts" of quantum optics. It introduces in particular the two traditionally-separated approaches in quantum information processing, the discrete- and the continuous-variable approaches, and summarizes the useful tools and concepts. Gaussian and non-Gaussian states and operations are discussed. The second chapter presents a first kind of quantum nonlinearity, the so-called noiseless amplification. Quantum information signal cannot be amplified to compensate for losses and therefore other techniques have to be developed. In the recent years, Dr. Marek proposed two probabilistic methods based on non-Gaussian operations. These theoretical approaches led to a seminal experimental demonstration in collaboration with the group of G. Leuchs and U. Andersen at the *Max Planck Institute for the Science of Light* in Germany. Chapter 4 then expands this probabilistic approach and details the work realized in order to extend the toolbox to manipulate a quantum state of light in an arbitrary way. Among other studies, an important work was to propose a feasible set of elementary logic gates. I consider this work as a very seminal contribution as it enabled to test the first principles of quantum computing based on coherent-state superpositions. It led to a first experimental demonstration in collaboration with the group of U. Andersen at the *Danish Technical Institute* in Denmark.

The last chapter of this thesis takes one step further and focuses on the realization of deterministic nonlinearities for quantum information processing. This is a daunting direction and the presented work is of the highest international level. Dr. Marek proposed a way to implement a nonlinear quantum gate

in a deterministic fashion. Specifically, he developed a cubic gate scheme, the lowest order nonlinear gate sufficient for universal processing of quantum information. This approach requires an ancilla state that provides the required nonlinearity in the protocol. Based on these ideas, Dr. Marek developed a strong collaboration with the group of A. Furusawa at the *University of Tokyo*. He participated to analyze the first quantum state engineering of such ancilla and contributed to the general concept of adaptive non-Gaussian measurements that will undoubtedly plays a central role in the future. I find this research line very creative and highly promising.

In conclusion, the work of Dr. Marek has been so far excellent and his research activities are ambitious and challenging. He is a highly skilled theoretician that knows very well how to interact with experimental groups. This ability gave him, and will give him again in the future, the ability to push new frontiers in his research field. I strongly recommend accepting this thesis for his habilitation.

Sincerely,
Prof. Julien Laurat