Report on the Habilitation Thesis

From light to knowledge: Sensing with photonic and neural networks

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The Habilitation Thesis by M. Ježek is devoted to various aspects of the detection of light on the photonic level and the processing of the resulting signal. The Thesis is based on 8 main plus 4 auxiliary scientific papers of the group supervised by the author published in impacted international journals in the period 2018–2025. It covers a wide range of topics, including single-photon detection, efficient determination of photon statistics, entanglement properties and polarization of light, and development of super-resolution methods of imaging.

The Thesis is prepared in the form of the main text, introducing in a user-friendly way the whole area, specific topics and summarizing the main results and open problems, and an appendix, reprinting the 8 main publications. The content of individual parts of the Thesis is as follows:

- Nonlinearity of single-photon detection: The presentation is based on 1 publication in *Applied Physics Reviews* (IF>10) from 2023, reporting a measurement of nonlinear effects in a single-photon detector. This work discovers so far unknown features of single-photon avalanche diodes.
- Determination of photon statistics and nonclassical properties of light: This part is based on 2 main publications in *Physical Review Letters* (IF>9) from 2019 *and Physical Review Applied* (IF>4) from 2024, and on 2 auxiliary publications in *npj Quantum Information* (IF>8) from 2018 and *Physical Review Letters* from 2019. Here the authors develop new experimental methods capable of detection photon number distributions and nonclassical correlations in photon counting.
- Control and measurement of polarization states of light: This part follows 3 publications in *Optics Express* (IF>3) from 2021, *Physical Review Applied* from 2022 and *Laser Photonics Reviews* (IF>9) from 2025. These papers describe efficient techniques of preparation and measurement of polarization states of light on a single-photon level and introduce machine-learning-based methods of polarization control.
- Evaluation of quantum entanglement: This part is based on a single publication in *Science Advances* (IF>13) from 2023. A general machine-learning method is developed and experimentally tested, which allows for a reliable quantification of quantum entanglement from incomplete measurements.
- High-resolution device-independent imaging and sensing: The presentation makes use of 1 preprint from 2025, already published in *Nature Communications* (IF>18), and on 2 auxiliary preprints from 2025. These works use modern methods of machine learning to improve resolution of imaging techniques beyond the standard diffraction limit.

The area of the habilitation is extremely important for advancing modern optical technologies in various directions. The presented set of publications shows that the Olomouc group under the supervision of M. Ježek brings substantial contributions to this quickly developing area. Indeed, it is clear that the Olomouc team belongs to the top groups worldwide. This is witnessed by high quality and high international reputation of the journals in which their results are published, and also by a high citation rate of some of these publications. In addition to the coherent set of results included in the Habilitation Thesis, M. Ježek appears as a coauthor of many other closely related papers published in prestigious journals which also show very high citation scores. So, in my opinion, there is no doubt about the high quality and relevance of the results presented in the Thesis in the context of present-day research. It is great that the students of optics at the Palacký University participate in this cutting-edge research.

I want to also emphasize great versatility of the approaches applied in various parts of this Thesis. The authors working under M. Ježek combine complex physical devices based on the most advanced current technologies of light detection on the single-photon level with highly sophisticated modern evaluation schemes using the deep-learning neural network methods. This approach represents an efficient strategy to overcome conventional limits and push the relevant methods to a higher level of performance. The authors are aware of potential drawbacks of these approaches and discuss their further improvements.

On a formal level, the Habilitation Thesis, as well as all contributing papers are well written, clearly structured and accompanied by perfectly designed and illustrative figures. The interplay between the summarizing main text of the Thesis and individual contributions works well – the Thesis provides an overall guidance in the complicated field, while the papers show detailed information on specific matters.

Overall, I have no objection against the successful habilitation of the applicant. I believe that his contribution to the field of quantum optics is substantial and already outperforms standard requirements for the associate-professor degree. I fully support awarding the scientific-pedagogical title *docent* to Dr. M. Ježek.

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