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Paderborn, June 2, 2026

Report on dissertation "Nonclassicality of measurement statistics of quantum electromagnetic radiation" by Vadym Kovtoniuk

In his thesis, the candidate, Vadym Kovtoniuk, presents his research on the sophisticated problem of characterizing the quantum nature of light under realistic conditions. This includes three main pillars to which the candidate significantly contributed: (i) deriving tight inequalities for detecting nonclassical features, (ii) advance and probe these inequalities under complex open-system conditions, and (iii) developing the new framework of "latent optical nonclassicality"—quantum effects which are not directly detectable but impact extended schemes. With his unified theoretical framework, demonstrating a great potential for applications, the candidate exquisitely shows that he independently and significantly contributed to a cutting-edge field of modern research.

During his PhD, the candidate achieved to produce five publications—all of which demonstrate substantial progress and are highly interesting for the general physics, quantum information, and quantum optics communities. Moreover, the candidate was accepted to present his research at six conferences. Overall, the depth and clarity of the candidate's research is impressive.

Concerning the thesis itself, in the introduction, the candidate provides an excellent overview on the topic under study, with a very clear embedding into contemporary research initiatives as well as with a coherent and diligent structuring.

Chapter 1 rigorously develops the theoretical foundation for the research carried out, covering vast topics ranging from phase-space descriptions, over quantum measurement theory (incl. nonclassical statistics), convex geometry (incl. Hahn–Banach separation), and Chebyshev systems (incl. Karlin's theorem). The rigorous, yet very accessible introduction to several complex topics demonstrates the candidate's ability to work with sophisticated, mathematical methodologies and communicate their relevance for physics in an understandable manner.

Chapter 2 pertains to nonclassicality conditions and their tightness. To this end, a broad framework for constructing necessary and sufficient criteria, which are related to measurements. Special emphasis is dedicated to (sub-)geometries of the set of classical states and polynomial witnesses.

Chapters 3 and 4 explore the highly relevant and broad family of photon-number-based statistics. Thereby, criteria for detection with finite number resolution are carefully constructed. Various experimentally relevant scenarios of detectors and states to be characterized are probed through the resulting nonclassicality criteria. Based on the prior considerations, the candidate further explores phase-sensitive measurement schemes. Relevant imperfections, such as mode mismatch and varying detection efficiency (e.g., via neutral-density filters), are considered in depth, which is again supplemented through relevant applications.

Chapter 5 covers the notion of latent optical nonclassicality. Motivated by conditional state preparation (steering), the impact of informationally incomplete measurement scenarios is deduced, highlighting the cases in which no single-mode characterization succeeds in verifying nonclassicality. In addition, relations to other models of quantum correlations are critically assessed, and nonclassicality inequalities for experiments are formulated.

In the conclusion, a summary and an outlook are presented. Therein, the candidate ties together all topics to which the candidate contributed, providing a great overview and outlining potential future works rendered accessible via the approaches devised throughout the thesis.

It was my pleasure to read the dissertation of Mr. Vadym Kovtoniuk. Throughout, the thesis is very well written and coherently structured structured, making it easy for the reader to follow the complex subject matter. The state of the art, incl. the existing literature, as well as the novelty of the candidate's contributions are clearly and thoroughly presented, without any identifiable gaps. I have no requests for any changes and recommend to accept the doctoral thesis as is.

Optional questions to be considered for the defense:

- Can a Chebyshev-system-based construction be related to known nonclassicality criteria that exploit the roots/zeros of the Husimi Q function?

- In Sec 2.3, the closure of complex set with the point at infinity is considered.

This might require an adjustment of the underlying topology; for example, the compactification of the complex plane to the Riemann sphere. What are the assumed properties of the map $\alpha \mapsto \Pi(\alpha)$ with respect to the point at infinity to ensure regularity?

- How does the notion of latent nonclassicality extend to multimode systems? (A simple concrete example would be helpful.) Is it possible to capture temporal nonclassical correlations (optionally including time-ordering, non-Markovian, and other effects) through this approach?

In general, the candidate demonstrates a deep understanding of mathematical quantum physics. Identifying the quantum nature of physical systems, here mostly light, is essential for emerging applications that harness such effects. The candidate made an outstanding contribution to move the field forward and to connect his mathematical framework to experimentally relevant scenarios. I hope that his contributions will receive the impact they deserve. On the supervision side, I believe that I can see the direct and positive impact of Dr. Andrii Semenov, guiding the candidate to and through cutting-edge topics worth studying, in which Mr. Kovtoniuk was then able to excel with his ideas.

Therefore, it is my pleasure recommending to accept the dissertation and award the grade **summa cum laude** (according to German/European grading standards). If applicable, I strongly support awarding an additional distinction/award to the candidate for his outstanding academic achievements.

If you have any questions, please do not hesitate to contact me.

Jan Sperling