

Report on the PhD thesis of Vadym S. Kovtoniuk
“Nonclassicality of measurement statistics
of quantum electromagnetic radiation”
in the field of 104 – Physics and Astronomy

The thesis of Vadym Kovtoniuk is devoted to the construction of theoretical methods for identifying genuinely quantum features in the statistics of electromagnetic radiation measured under realistic experimental conditions. The work focuses on situations where only partial information about the quantum state is accessible and where imperfections of the detection process play an essential role.

The study addresses three closely connected tasks. The first is the establishment of a mathematically consistent framework for tight classicality inequalities, understood as a complete and nonredundant set of linear constraints characterizing classical measurement statistics for a specified detection configuration. The second task is the derivation of such inequalities for experimentally relevant measurement schemes while explicitly incorporating nonideal effects including optical losses, finite detector resolution, and imperfect mode overlap. The third objective is the investigation of hidden forms of optical nonclassicality that remain inaccessible at the level of individual measurements but can nevertheless be uncovered by analyzing correlations and structural relations between connected quantum states, in particular in conditionally prepared bipartite systems.

The dissertation is written in English and consists of an introduction, followed by a background section, four chapters based on four publications and a preprint (also published in the journal on 16 June 2026) devoted to the aforementioned issues, and conclusions. At the very beginning of the dissertation, the summary of the results and a list of the author’s publications are provided. The total length of the dissertation is 135 pages, and the list of references includes 161 titles.

In Chapter 3 based on one article and preprint a general framework for constructing tight inequalities is established for convex sets that are not necessarily polytopes. The corresponding set of optimal witnesses is shown to admit a complete description as a union of continuously parameterized families associated with coherent-state amplitudes. For the important class of problems in which the classical set is represented by a curve whose components constitute an extended Chebyshev system, explicit analytical expressions for all tight witnesses are derived. Furthermore, the resulting structure significantly simplifies the optimization procedure, reducing the effective search space to approximately one-half of its original dimension.

In Chapter 4 based on the two articles and preprint the developed theoretical framework was applied to a variety of experimentally relevant quantum-optical measurement schemes such as photon number resolving detectors, array detectors,

and Josephson photomultipliers. For photon counting experiments employing either photon-number-resolving detectors or detector arrays, explicit analytical forms of the corresponding tight nonclassicality criteria were derived. In the case of detector arrays, a complete hierarchy of determinant-based conditions was obtained for arbitrary array sizes.

In Chapter 5 based on one article and preprint, it is shown how introducing measurement parameters allows us to confirm non-classicality using detection schemes for which a single observable is insufficient. This conclusion is supported by a thorough examination of two important examples: unbalanced homodyne detection and on-off photodetection with adjustable efficiency.

In Chapter 6 a method for detecting latent optical nonclassicality in conditionally prepared quantum states has been developed based on a local hidden classical states model. The approach establishes a link between latent nonclassicality and nonclassical steering, extending previous results beyond Gaussian states and measurements to arbitrary quantum states and detection schemes.

It should be particularly noted that four (at the moment of thesis defence five) of the candidate's papers have been published in high-impact journals such as Physical Review A, which are ranked in the first quartile. All of this attests to the proper validation of the work's main findings.

At the same time, the following comments may be made regarding the dissertation:

1) The section Background is written primarily for specialists in a narrow field rather than for a broader audience of theorists. However, the fundamental distinction between classical and quantum physics is of general interest to the wider physics community. The notion of "optical nonclassicality" turns out to differ significantly from the way the term "nonclassicality" is used in other areas of theoretical physics. In my opinion, it would therefore be worthwhile to make the introduction more accessible to a broader readership and to discuss the concept of nonclassicality in a wider context, including its connection to the notion of nonclassicality in quantum optics.

2) Another small remark is that the list of the used in the thesis notations would be useful. In particular, as I understood Planck's constant is set to one which is not mentioned.

However, these remarks by no means fundamental and does not affect the high evaluation of the main results of Vadym Kovtoniuk's dissertation. The author has solved a series of important and timely problems, and the above comment may be taken into account in the author's future work.

The topics addressed in the dissertation are highly relevant to contemporary research. The thesis presents an impressive body of original results, supported by a thorough and convincing validation of the proposed methods and conclusions.

In my opinion, Vadym Kovtoniuk's dissertation, *"Nonclassicality of Measurement Statistics of Quantum Electromagnetic Radiation"*, fully satisfies all

the requirements established by the Ministry of Education and Science of Ukraine for doctoral dissertations. I therefore believe that its author, Vadym S. Kovtoniuk, fully deserves to be awarded the degree of Doctor of Philosophy in Specialty 104 – Physics and Astronomy.

Reviewer

Doctor of Sciences in Physics and Mathematics,

Senior researcher

Head of the laboratory of Strongly Correlated

Low-dimensional Systems

Sergei SHARAPOV

Bogolyubov Institute for Theoretical Physics

of the NASU