Review Report: dissertation Thesis Classical Communication With Displacement Receivers via Noisy Quantum Channels (Ludwig KUNZ) 0000-DR-335587

The Thesis broadly presents details of the capabilities of a generalised version of the displacement receiver (DR) classical optical communication with coherent states over different lossy and noisy channels. The displacement receiver is a feasible coherent detection strategy used predominantly in quantum optics for various purposes, including direct detection of the Wigner function. A typical arrangement consists of a linear optical network with coherent local oscillator beams and multiplexed single-photon detectors. Recently, high efficiency (reaching 90%), low dark counts and almost no imperfections have been achieved for single-photon detectors. The first versions of partial photon-number resolving detectors have also been considered. Therefore, it is expected that technological development will follow an open path for broader use of DR in quantum optics and optical communication and optical sensing.

The Thesis is based on four high-quality candidate peer-reviewed publications, including high impact npj Quantum Information with an experimental test, and in two papers (New J. Phys and JOSA B), the candidate is the first author. The results have also been presented at distinguished international conferences. Chapters 2, 3 and 4 smoothly and comprehensively introduce the basic concepts needed for the following chapter about research results. Especially, an overview of detection strategies and imperfections is helpful and well done as the central figure of merit photon information efficiency (PIE), i.e. mutual information or capacity per mean output photon number, is used. It determines the evaluation of protocols resented in the Thesis. Chapter 4 also analyses a particular optical communication measurement strategy with coherence in a low-energy limit (related to one candidate's publication). It shows that all considered detection strategies converge to PIE=2 nats for coherent states, whereas structured receivers slightly overcome this limit. Chapter 5 introduces channel noises, including nonlinear noise from Kerr effects in single-mode fibers without any multiplexing related to another candidate's publication. Section 6 considers all subjects and analyses PD receiver applicability in optical links with thermal and phase noise. It shows that PD can overcome homodyne detection in a low-energy limit and small thermal noise (PPM scheme). As thermal noise grows, homodyne detection becomes better. It is a result worth testing more experimentally. Also, analysis of phase noise and Kerr effect is included. The Thesis is concluded and emphasises: (i) PD receiver is sensitive to non-unit visibility, (ii) PNR helps against small channel noise after displacement optimisation (for thermal noise, PNR is not so needed), (iii) for strong phase noise, PD receiver approaches Helstrom bound and other results.

The Thesis is well written, clear, organised, and pedagogically written correspondingly to the levels of dissertations I typically review in Europe. Most research results were already peer-reviewed; they seem consistent and correct at the declared level of description, approximations and figure of merits used to evaluate them. The Thesis is theoretical; therefore, probably an analysis of an experimental range of parameters from recent laboratories will come at the next stage. It will be essential to convince experimentalists for further tests of the predictions.

The doctoral Thesis presents the general candidate's theoretical knowledge in quantum optics and optical communication and ability to conduct scientific work independently. The research results included in the Thesis and published are original solutions to current scientific problems in quantum optical communication.

My conclusion about the Thesis is positive. I suggest the Thesis for defence, and after this successful step, I believe Ludwig Kunz should be awarded a doctoral degree.

Based on the research results and submitted Thesis, the candidate deserves a distinction. The results are well published, stimulating for the theory and experiments and necessary for further developing classical optical communication with quantum states. They reflect modern technological steps, including upcoming photon-number resolving detectors.

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