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Review of the PhD thesis „Classical Communication with displacement receivers via noisy channels" by Ludwig Kunz

The thesis of Ludwig Kunz studies classical communication by applying methods from quantum optics. The thesis analyses various communication scenarios, detectors, types of noise and develops a formalism to study those.

The thesis starts with a historical introduction and summary of the state of the art in Chapter 1.

The thesis continues with elaborating on the necessary background in the following chapters. These give a thorough introduction into the relevant topics and contain a carefully edited and long list of references.

Chapter 2 deals with an in-depth introduction into various quantum states of light and their representations. Starting with the basics of quantum mechanics and introducing classical electrodynamics, the thesis then focusses on introducing phase space representations. Mr Kunz then discusses the representation of particular quantum states, including Fock states, coherent states, squeezed states, and thermalized states. This chapter gives a very nice introduction into the topic.

Chapter 3 focusses on the theory of communication and starts with a detailed summary of the theory of error probabilities during the transmission of a signal. The chapter then continues with the theory of mutual information and the question of how much information can be transmitted through an erroneous channel. Important concepts such as the Shannon entropy and the von Neumann entropy are introduced. Mr Kunz next introduces the concept of a capacity of a channel and its limits in quantum theory. The chapter then finishes with different possible encodings of information, such as on-off keying, binary phase shifts, quadrature phase shifts, and pulse modulation.

Chapter 4 starts with various methods on how to measure the different encodings of information using certain types of detectors or receivers, such as photon counting or homodyne detection. Dependent on the encoding, a different detection method needs to be chosen in order to read out the information. A particular focus of this chapter is the displacement receiver. which can resolve binary coherent alphabets, and which can be seen as a special case of a universal coherent receiver. In particular, a method for detecting larger alphabets is introduced, which can be realized by splitting up the signal into multiple modes using arrays of beam splitters. From an experimental viewpoint, it is particularly interesting that the thesis also discusses the most common errors and imperfections that could occur in an experimental implementation of a displacement receiver. Further, the thesis discusses communication and, in particular, measurements in the limit of low energy. Mr Kunz derives the formalism for discussing mutual information and measurements for coherent states in different measurement scenarios, individual measurements as well as collective measurements.

Chapter 5 deals with noise in communication, e.g. induced through the channel or through the measurement. The thesis discusses first different types of noise, including thermal noise, linear and nonlinear phase noise. Master equations for the individual scenarios and their solutions are presented. Mr Kunz first focuses on coherent states and then generalises the derivations to arbitrary states. A particular focus also lies on the study of nonlinear phase noise in the context of squeezed states.

In Chapter 6, the noise models derived in the previous chapter are studied in specific communication settings. First, the case of thermal noise is considered and different types of detectors are studied. Second, the effects of a Kerr nonlinearity on a phase encoding. Here, coherent states with different phases are considered and the study is then extended to squeezed states. The third type of noise considered in this chapter is phase noise. Here, in particular two types of scenarios are considered, the case where the mean energy of the state is fixed as well as the case where the maximum energy for a single state is limited.

The thesis concludes in Chapter 7 with a summary of the most important results as well as an outlook.

The thesis is very carefully and well written and was very interesting to read. The theoretical background is introduced in detail and, in particular, the list of references is very carefully compiled. The thesis contains many nice and interesting results and lays the foundation for further studies in this direction. It would also be particularly interesting to apply the derived models to experiments and to compare the simulations to real transmission channels.

The thesis work has also led to multiple publications, which confirms the quality and novelty of the results - including multiple publications as first author. It will be interesting to see how future work will build on these publications.

Overall, I consider the thesis of Mr Kunz as very good.

Prof. Dr. Stefanie Barz