PHYS 404/690 Quantum and Nonlinear Optics

Problem set # 7 *(due April, 3)*

Each problem is 10 points. The problems marked with $*$ are required for graduate students only, and are extra credit problems for undergraduates.

P1 Consider a Mach-Zender interferometer and assume that one input mode is in a coherent state and that the other is in a squeezed vacuum state. Show that the phase fluctuations at the output are reduced below the standard quantum limit ($\Delta\phi_{SQL} = 1/\sqrt{\bar{n}}$) to $\Delta\phi = e^{-r}/\sqrt{\bar{n}}$.

P2 The experimenters reported 5 dB intensity squeezed vacuum. Help theorists to write the squeezing operator to produce that amount of squeezing.

P3 In class we discussed that optical losses degrade squeezing. To qualitatively estimate this effectd it is common to model optical losses as a beam slpitter. for example, a 10% loss is modeled as a 90/10 beam splitter, such that 90% of photons are transmitted, and ten per cent are reflected. Assume that the 5 dB squeezed vacuum field from the previous problem falls into one input of such beam splitter, and the regular coherent vacuum - into the other. Calculate the amount of squeezing after the beam splitter.

P4 Consider a positive cat state: $|\psi\rangle \simeq (|\alpha\rangle + |-\alpha\rangle)/\sqrt{2}$. Calculate average electric field of this state, and average photon number. Do these answers make sense to you?

P5* Consider the superposition of the vacuum and 10 photon number state: $|\psi\rangle \simeq (|0\rangle + |10\rangle)/\sqrt{2}$. Calculate the average photon number. Next assume that a single photon is absorbed and recalculate the average photon number. Does your result seem sensible in comparison with your answer to the previous question?