SU(1,1) interferometry and enhanced sub-shot-noise imaging

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The sensitivity of an interferometric measurement on a phase shift depends on the state of light used as a probe and the measurement scheme. A ‘standard’ precision is provided by a coherent state fed into a Mach-Zender interferometer, the so-called shot noise limit (SNL). A measurement beating this limit is said to be supersensitive. In order to make super-sensitive phase measurements, quantum resources can be used. For example, squeezed light is now implemented in gravitational wave detectors. Besides the input state and the detection scheme, one can also modify the interferometer. Two optical parametric amplifiers (OPAs) can be used instead of the passive beam-splitters of conventional interferometric setups, the phase sensitive response of the OPAs giving rise to interference patterns. Such interferometers, usually called SU(1,1) interferometers, can display phase super-sensitivity.

Using an SU(1,1) interferometer composed of two degenerate parametric amplifiers, see fig.1, we demonstrate a phase sensitivity overcoming the shot noise limit by 2.3 dB \cite{1}. The interferometer is strongly unbalanced, with the parametric gain of the second amplifier exceeding the gain of the first one by a factor of 2, which makes the scheme extremely tolerant to detection losses. We show that by increasing the gain of the second amplifier, the phase supersensitivity of the interferometer can be preserved, see fig.2, even with detection losses as high as 80%.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{Figure_1.png}
\caption{SU(1,1) interferometer composed of two cascaded parametric amplifiers with different gains $r_1$ and $r_2$.}
\end{figure}

It is to be noted that this active detection strategy involving parametric amplification before detection can also be implemented at the output of more common SU(2) interferometers \cite{2} (Mach-Zender, Michelson, Sagnac etc.). This is especially important in gravitational wave detectors where the detection losses limit the sensitivity. The tolerance of the interferometer to detection losses can be applied for experiments at frequency ranges where the efficiency of detectors is low (infrared, terahertz). As an example of this powerful detection technique, I will present a protocol in order to overcome inefficient detection in sub-shot-noise imaging using phase sensitive amplification prior to the detection of twin-beams.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{Figure_2.png}
\caption{Phase sensitivity of an unseeded SU(1,1) interferometer normalized to the shot noise limited phase sensitivity against the detection transmission for various ratio of gain unbalancing of the interferometer.}
\end{figure}