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Generation of non-classical light in a nonlinear crystalline whispering gallery mode resonator

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Crystalline whispering gallery mode resonators (WGMR) [1] made out of LiNbO3 have proven to be a versatile source for non-classical states of light via optical parametric down conversion (PDC). During this process, one photon is split into two photons of lower frequency called signal and idler. These two photons are correlated due to energy conservation and can hereby influence certain measurement statistics. In particular, we have shown efficient generation of twin beam squeezing, intensity squeezing [2], and tunable narrowband single photons [3]. The superior efficiency is based on strong nonlinear optical second order interaction, high Q-factors and small mode volumes.

Here, we report on the generation of squeezed vacuum states of light. This subclass of non-classical light finds application in different fields such as quantum state preparation [4] and quantum enhanced metrology [5] with the detection of gravitational waves [6,7] as it's most eminent application. By now, there are also commercial efforts to deploy squeezed vacuum states of light for continuous variable quantum computing as pursued by the Canadian company Xanadu.

We use a millimeter-sized crystalline WGMR and operate it as a degenerate optical parametric oscillator (OPO), which means that the two generated signal and idler photons have exactly the same wavelength. For that, the phasematching has to be stabilized on the MHz-scale, which favors millimeter-sized resonators compared to micrometer-sized ones as they are sensitive to thermorefractive noise [8]. We operate the system below the parametric oscillation threshold in order to generate squeezed vacuum states of light. The threshold is determined by the coupling conditions, which depend on the two prism couplers. One prism is used for coupling the 532 nm pump beam evanescently to the resonator. The squeezed vacuum mode is detected after the second prism via homodyne detection.

To the best of our knowledge, we were able to show the generation of squeezed vacuum states of light in a crystalline whispering gallery mode resonator for the first time. We achieved a reduction of the noise variance up to 1.2 dB at a sideband frequency of 500 kHz for a total system input power of only 300 µW. The noise reduction highly depends on the coupling conditions and there are different ways to improve the reduction further as implementing polarization dependent coupling [9] and changing the resonator design. The current results show that the crystalline WGMR platform might be a future candidate not only for a low power source of non-classical light, which would be needed for real world applications, but also for future fundamental research on the regime around the parametric oscillation threshold as it is tunable and in a low power regime.

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