OPTOMECHANICS

Squeezing hots up

Squeezed light is useful for metrology and quantum information. An optomechanical squeezed light source that works at room temperature will facilitate the technological applications of quantum light.

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Noise is inescapable in the quantum world. Quantum optics allows for squeezed states of light, where this noise is suppressed at certain times at the cost of increased noise at other times (Fig. 1). Squeezed light has been shown to improve the performance of interferometric gravitational-wave detectors[1], but compact sources suppressing low-frequency noise over a broad range of frequencies remain an outstanding challenge. Now, writing in *Nature Physics*, Nancy Aggarwal and colleagues report a device that uses the optomechanical interaction to create broadband squeezed light at room temperature[2]. This is a major step towards the practical application of squeezed light.

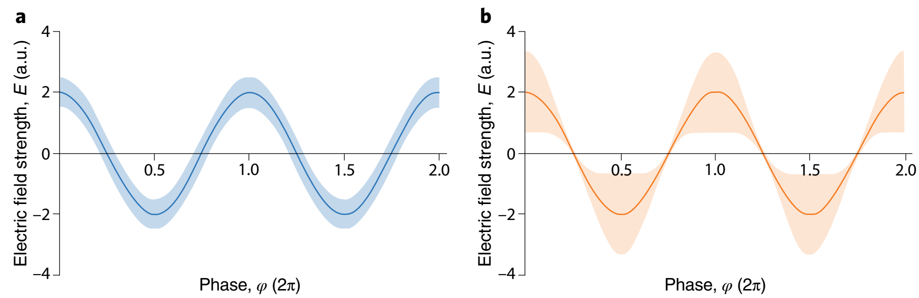

Fig. 1 | Quantum noise in squeezed light. Electromagnetic fields (electric field strength E pictured) all have a certain amount of quantum noise, shaded region. **a**, In classical light, this noise is the same for all phases (φ). **b**, Squeezing allows the noise to be reduced for certain phases, in this case allowing more precise determination of the frequency. This conveys a metrological advantage.

The most common type of squeezed light source uses nonlinear processes in materials that exhibit a strong second-order optical nonlinearity. In a typical scenario[3], a lithium niobate or potassium titanyl phosphate crystal is pumped at some frequency $2f$ by a strong optical field. Placing the crystal in an optical cavity that is resonant with frequency f results in a device called an optical parametric oscillator. Inside an optical parametric oscillator, the electromagnetic field is squeezed such that noise is suppressed by up to 3 dB for certain phases. Destructive interference between the noise in the light exiting the cavity and that in the field outside it results in squeezing that can, in principle, be arbitrarily strong: the largest observed squeezing value is approximately 15 dB (ref. [4]).

The field of optomechanics, whose workhorse is a moving mirror interacting with light inside an optical cavity[5], has made several significant advances recently, including the observation of non-classical states of motion[6] and entanglement between two mechanical oscillators[7]. This same interaction gives rise to an effective nonlinearity in the electromagnetic field that mimics the second-order nonlinearity used in optical parametric oscillators. This makes it possible for optomechanical devices to produce squeezed light, but the thermal noise that plagues mechanical systems in the quantum regime typically masks the squeezing. Aggarwal and colleagues have demonstrated a device that uses the optomechanical interaction to produce squeezed light and that works at room temperature. By contrast, previous optomechanical squeezed light sources all operated at cryogenic temperatures.

The authors employed a set-up widely used in the field of optomechanics to conduct their investigation: their optical cavity consisted of a massive motionless mirror on one end and a micromirror on the other, suspended from a substrate so that it may oscillate with a frequency of 876 Hz. The cavity was driven optically at a frequency slightly above its resonance. Under these conditions the radiation pressure interaction created an additional trapping force on the micromirror. This force increased the oscillation frequency of the micromirror to 145 kHz by means of the optical spring effect and gave the cavity a Young's modulus equal to that of cork[8].

Since radiation pressure is key to its effectiveness, the authors had to engineer the device such that the radiation-pressure-driven motion was comparable to or larger than the thermally induced motion. The optical spring could yield a bandwidth of potentially hundreds of kilohertz over which the squeezing is constant. To equal the performance without an optical spring, the authors would have had to use a micromirror with a prohibitively large vibrational quality factor, precluding operation at room temperature. Using a version of a clever locking technique the group developed previously[9], they could deal with instabilities introduced by operating in this regime.

The radiation pressure interaction is also responsible for the squeezing created by the device. The quantum noise in the optical field shakes the micromirror, whose motion is imprinted on the light field inside the cavity. Interference between the light leaking out from the cavity and that reflected from it produces squeezed light.

The work by Aggarwal and colleagues is particularly significant in two respects. The first is combining all the characteristics required of a practical and flexible squeezed light source into a single device. Using an optomechanical system required state-of-the-art techniques and materials to overcome the deleterious effects of thermal noise. The net result was a source of squeezed light operating at room temperature suppressing quantum noise over a broad range of frequencies, between 33 and 62 kHz.

Second, this experiment built on earlier work and presented a technique based on photocurrent correlations to directly measure the squeezing in a light beam without the need to calibrate the shot noise level. As such calibration requires temporarily changing the operating parameters of the device, it cannot be used while the source is operating. The correlation technique, which was shown to work just as well, will thus prove useful in the deployment of squeezed light sources.

The amount of squeezing produced by the demonstrated device is of the order of 0.7 dB. This is admittedly far from the 15 dB that other squeezed light sources have managed to produce, but there is ample scope to improve the performance of the device. Cavity feedback noise and differential phase noise between the local oscillator and squeezed beam are currently the limiting factors at high and low frequencies, respectively. On the other hand, reducing optical losses inside and outside the cavity would improve the squeezing performance at all frequencies.

Optomechanical squeezed light sources possess advantages beyond the frequency-independent and broadband nature of the squeezed light they produce. Optomechanical devices that are compatible with on-chip operation already exist[10]; this work opens the door to the possibility of developing miniature on-chip sources of broadband squeezed light. Potential applications of these sources include precise metrology, gravitational-wave detection and continuous-variable quantum information. ❐

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