A High-Frequency Silicon Optomechanical Oscillator

CNF Project Number: 1997-11
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Primary Source of Research Funding: Private Funding
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Abstract:
We demonstrate a compact silicon optomechanical oscillator with a large intrinsic mechanical frequency-Q product of $4.32 \times 10^{12}$ Hz. It is able to operate at a high frequency of 1.294 GHz in the air.

Summary of Research:
Recently, self-sustaining optomechanical oscillators — realized by taking advantage of strong dynamic back-actions in micro-/nano-optomechanical cavities — have attracted a great deal of research interest [1-3]. In this work, we successfully demonstrate a high-frequency optomechanical oscillator on silicon-on-insulator (SOI) platform by combining strong optomechanical coupling, tiny effective motional mass, high optical and mechanical qualities into a single compact device.

The device is tested in the air environment. The employed optical TE mode at 1502.03 nm exhibits an intrinsic optical $Q$ factor of $3.5 \times 10^{5}$ (Figure 2). By locking laser frequency half-way into the cavity resonance at the blue-detuned side, we measure the RF spectrum of the cavity transmission, and clearly observe the fundamental RSMM at 1.294 GHz with a mechanical $Q$ factor of $3.34 \times 10^{3}$. Consequently, the mechanical mode exhibits a frequency-quality product of $4.32 \times 10^{12}$ Hz. To enhance the dynamic back-action for exciting optomechanical oscillation, we increase the laser-cavity detuning at the blue-detuned side to about 1.6 times the linewidth of the loaded cavity, so that the created Stokes sideband falls into the cavity resonance.

Figure 3 clearly shows that the mechanical mode is excited into coherent oscillation and the peak value of the mechanical spectral intensity is dramatically enhanced by more than 50 dB when the dropped optical power is increased to 4 $\mu$W. Detailed analysis of the mechanical spectrum (inset of Figure 3) shows that the mechanical linewidth is drastically suppressed down to 854 Hz, corresponding to an effective mechanical $Q$ factor as high as $1.52 \times 10^{6}$.
Figure 2: Experimentally recorded (blue) cavity transmission for a TE optical mode with an intrinsic Q factor of $3.5 \times 10^5$, together with a theoretical fitting (red). The cavity resonance is located at 1502.03 nm. The inset shows the optical field profile. (See full color version on inside front cover.)

Figure 3: RF spectrum of the optomechanical oscillator. The red and blue traces show the cases with dropped optical power of 0.63 and 4.0 µW, respectively. The inset shows the detailed spectrum of the oscillator, where the red curve shows a Lorentzian fitting. (See full color version on inside front cover.)

References:


