Kilohertz coupling rate between mechanical oscillators via optical cavity resonance

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Introduction: Coupling of mechanical oscillators is a crucial technology for constructing micro/nano-mechanical processors for RF signals. The coupling has been realized with structural [1], electrical [2,3] and optical [4] principles. All-optical coupling has advantage of compatibilities with large-scale fiber-optic networks, nanoscale PICs, and optical quantum information processors. Here, we first demonstrate the on-chip optical coupling of the nano-mechanical oscillators (Fig. 1).

Device and experiments: The mechanical oscillators are coupled via the optical resonance mode of the double-coupled nanobeam PhC cavities, which belong to different oscillators (Fig. 1(c)). The second and third order even modes ($TE_{e,2}$ and $TE_{e,3}$ in Fig. 2(a)) with the larger optomechanical coupling constants [5] are selected as probe and pump, respectively. Optical spring effect is proportional to the coupling rate [1,3] between the oscillators. Our device is optimized for this point and the strong optical spring effect [5] is varied in Figs. 2(b, c). With a modulation of pump power at around frequency difference of two oscillators, we observed avoided crossings of oscillators' resonances (Fig. 3(b,c)), which indicate the strong coupling.

Conclusion: Our device is the first on-chip integration of the optically coupled nano-mechanical oscillators. Its coupling rate of 4 kHz is three orders of magnitude larger than the previous free space (millimeter-scale) analog [4] and reaches the same level of electrical coupling [2,3].

Reference and acknowledgement: [1] H. Okamoto et. al., Nat. Phys. **9**, 480-484 (2013). [2] T. Faust et. al., Nat. Phys. **9**, 485-488 (2013). [3] H. Okamoto et. al., Appl. Phys. Lett. **108**, 153105 (2016). [4] M. J. Weaver et. al., Nat. Commun. **8**, 824 (2017). [5] M. Eichenfield et. al., Nature **459**, 550-555 (2009). This work was supported by JSPS KAKENHI Grant Number 15H05735.

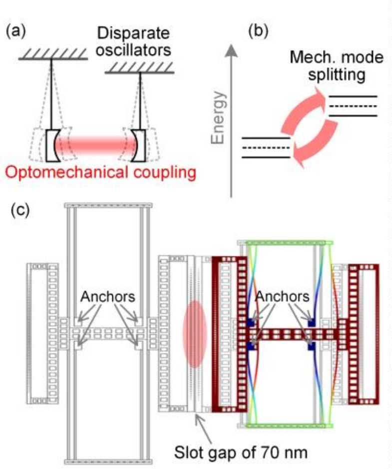

Figure 1

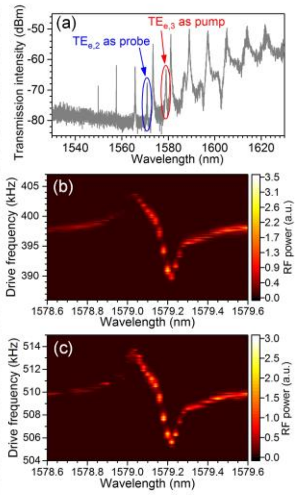

Figure 2

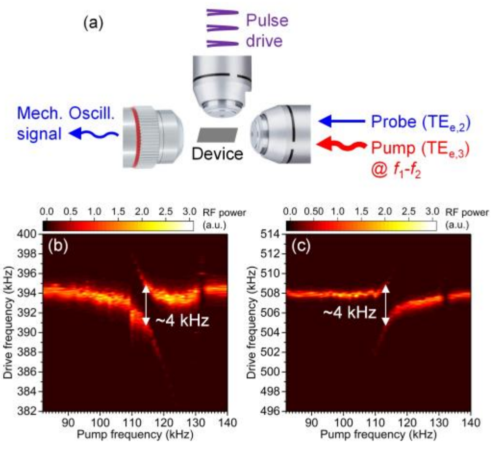

Figure 3

Fig. 1. (a) Schematic of the optomechanically coupled mechanical oscillators. (b) Band schematic which shows the energy swapping and mode splitting of the oscillators. (c) Device configuration with the mechanical mode of one of the oscillators. The oscillator is a typical mass-spring system: folded nanobeams work as spring and nanobeam PhC cavities with the supporting structures are the mass. **Fig. 2.** (a) Optical spectrum of the double-nanobeam PhC cavity. (b,c) Optical spring effect [5] of the two oscillators (constant Pump power). **Fig. 3.** (a) Schematic of the experimental setup. (b,c) Avoided crossings of the oscillators' RF spectra, which correspond to the mode splitting in Fig. 1(b) and verify the light mediated strong coupling (coupling rate: 4 kHz) between the two disparate mechanical oscillators.