An optomechanical approach for dynamical modification of spontaneous emission

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Introduction: The Purcell effect changes spontaneous emission (SE) process when emitters are coupled with a cavity enviroment [1]. Recently, dynamic modification of the Purcell effect are demonstrated [2,3]. Here, we first realize an optomechanical (OM) approach to dynamically modify the SE via OM-modulated Purcell effect.

Device and results: We adopt double-coupled nanobeam photonic crystal cavities (DC-NB-PhCCs) as an OM device whose OM coupling coefficient ($g_{OM}/2\pi$) is 59 GHz/nm (Fig. 1a). The device is fabricated by silicon and the copper atoms are doped into it to form the emitters of copper isoelectronic centres (Cu-IECs) [4]. When zero-phonon line (ZPL) of the Cu-IECs coincides with the cavity even mode, the SE intensity is enhanced by around 14-fold, where the Purcell effect works (Fig. 1b,c). Pulsed UV laser excites not only the SE but also the mechanical resonance of the nanobeam at 4.01 MHz by choosing its repetition frequency, where the optical gradient force is generated by the focused UV beam waist (Fig. 1d,e). The cavity even mode is OM-modulated and periodically passes through the ZPL (Fig. 2), and thus the SE process is dynamically modified by the OM-modulated Purcell effect. With the various detuned frequencies of the mechanical resonance, the real-time modifications of the SE decay curves are observed (Fig. 3).

Conclusion: The mechanical resonance successfully modified the SE process in real time. This approach opens ways to couple the phonons to the cavity QED system and to control the integrated light sources with nano-opto/electromechanical systems.

Reference and acknowledgement: [1] E. M. Purcell, Phys. Rev. **69**, 681 (1946). [2] C.-Y. Jin et. al., Nat. Nanotech. **9**, 886-890 (2014). [3] F. Pagliano et. al., Nat. Commun. **5**, 5786 (2014). [4] H. Sumikura et. al., Sci. Rep. **4**, 5040 (2014). This work was supported by JSPS KAKENHI Grant Number 15H05735.

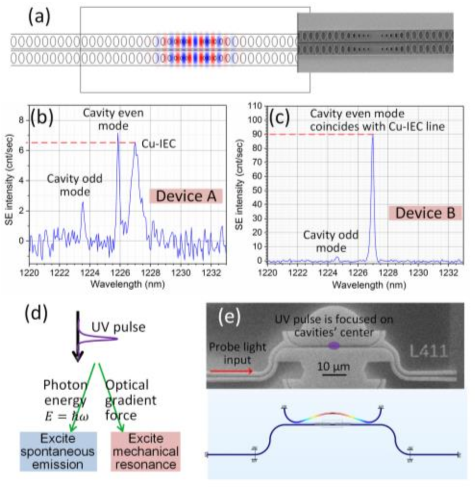

Fig. (1)

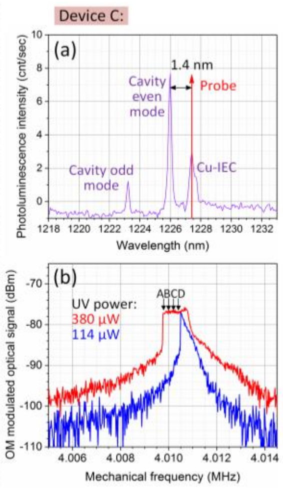

Fig. (2)

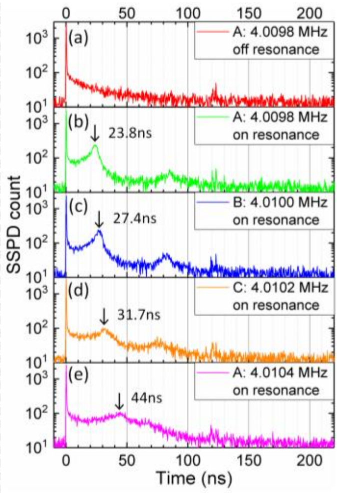

Fig. (3)

Fig. 1(a) FEM-simulated optical even mode of the DC-NB-PhCCs, inset: cavities' SEM image; (b,c) PL spectra of devices A and B, where the Cu-IECs' ZPL are off- and on-resonances of the cavity even modes, respectively; (d) Schematic of pulsed UV laser to excite both the SE and the mechanical resonance. (e) SEM image of whole device configuration, lower inset: FEM-simulated mechanical mode. Fig. 2(a) PL spectrum of device B for the OM-modulation of the SE process; (b) RF spectrum of the device B's mechanical resonance. Fig. 3 time domain decay curve of device C on mechanical resonance, (a) Cu-IECs' ZPL is off-cavity-resonance, (b-e) Cu-IECs' ZPL is on-cavity-resonance but nanobeam is driven by various on-mechanical-resonance frequencies.