# MEMS 共振器内部モード間結合による熱感度の巨大な増大効果
# Giant enhancement in thermal responsivity of MEMS resonators by internal mode coupling

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Microelectromechanical system (MEMS)-based resonators are very attractive for sensing applications owing to their high sensitivities. Recently, we proposed an uncooled, all electrical driving and detecting, sensitive bolometer by using a doubly clamped MEMS beam resonator, which is very promising for realizing high sensitivity and fast terahertz (THz) detection at room temperature[1]. It has been considered that the thermal responsivity of the MEMS resonator is determined by the material and geometrical parameters of the beam and cannot be changed.

In this work, we show that the internal mode coupling can greatly improve the thermal responsivity of the MEMS resonators. When we drive a resonance mode ($f_L$ in Fig. 1(a)) of the beam resonator strongly in the nonlinear regime, and its frequency is exactly equal to one third of a higher resonance mode ($f_H$ in Fig. 1(a)), a strong internal mode resonance between $f_L$ and $f_H$ is realized through the nonlinearity of the mechanical resonator. We have found that the thermal responsivity of the MEMS resonator is suppressed when a static heat is applied to the resonator at the mode resonance. However, when we apply a dynamic heat at a particular modulation frequency to the resonator at the mode resonance, we have observed a giant enhancement in the thermal responsivity, ~20 times higher than that of the resonator without mode coupling, as shown by the black and red curves in Fig. 1(b). Furthermore, the enhancement factor of the thermal responsivity by the mode coupling can be modulated by the coupling strength between $f_L$ and $f_H$, and the largest enhancement factor we have observed is over 2000. We explain this enhancement by the coherent energy transfer between the two strongly coupled modes. The observed effect can be widely applied to high-sensitivity sensing applications by MEMS resonators.

**Ref.** [1] Y. Zhang, Y. Watanabe, S. Hosono, Nagai, and K. Hirakawa, Appl. Phys. Lett. **108**, 163503 (2016).

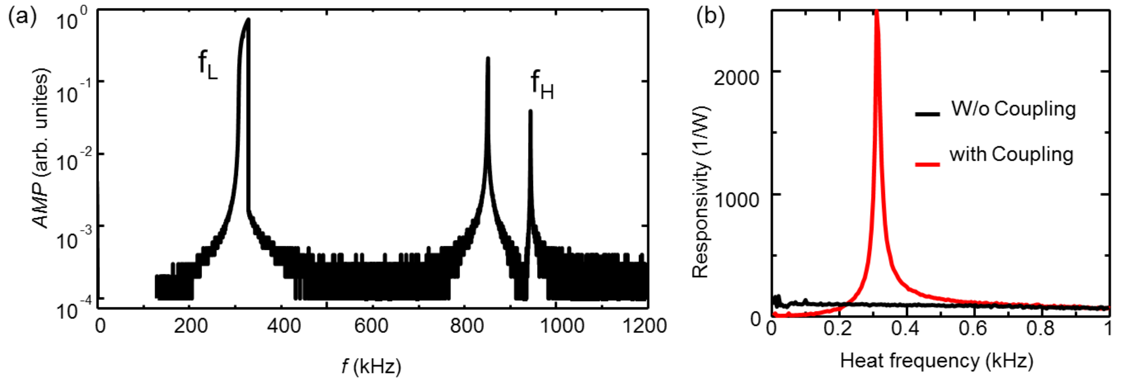


Fig.1 (a) The first three mechanical resonant modes of a MEMS beam resonator with a geometry of 128×30×1.2 μm$^3$. $f_L$ and $f_H$ denote the first bending mode and the first torsional mode, respectively. The reosance frequencies fulfill the relation that $f_H = 3\times f_L$. (b) The measured thermal responsivity of the beam resonator with and w/o internal mode coupling between $f_L$ and $f_H$.