NEMS Actuator Enhanced by Gradient Optical Force with A Large Range

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This research demonstrates an optical force enabled NEMS actuator, whose travel range can be extended by as much as 20%. By taking advantage of the high quality factor of the cavity, the cavity optomechanics can not only change the travel range of the electrostatic capacitive actuator, but also provide an ultra-sensitive approach to detect the mechanical motion. This method gives a new approach to extend the actuation range of NEMS actuator and an ultra-sensitive way to detect the small actuator motion. There are several problems for traditional electrostatic mechanical actuators, for example, the breakdown of the electrostatic force [1], in which the actuator can only move small ratio of the designed gap. Even through several proposals are used to solve this problems, such as adding another capacitor or feedback control [2]. The unwanted capacitance becomes a much bigger problem, because the capacitance is much larger than the natural capacitance. In this way, this method is quite ineffective. The optical gradient force which arises from the optical energy, [3], on the other hand, plays an important role in the actuator at the nano scale. Therefore, the optical force can play an important role in the NEMS systems and have more good ways to manipulate. In this paper, we worked out a NEMS actuator enhanced by gradient optical force. More importantly, this system can provide a good method to detect small mechanical motion.

The NEMS actuator is with a silicon beam with two side metal pads. The optical force points to the actuation ring when the control light is input and is balanced with the electrostatic force when electric voltage is applied on metal pad. An extended travel range can therefore be realized at the sensing ring. The deformation Δx of the moveable capacitor under the optical and the electrical force are in opposite directions. Traditional NEMS actuator model is adjusted by the optical force with a travel range amplification factor β. The effective air gap of the actuator is also amplified with the same factor. The original pull-in curve is modified by the optical force, making the pull-in point closer to the substrate. The protuberance at the top of the curve is due to the cavity enhanced optical force. The small mechanical motion induced by the combination of the electrical and the optical force can be sensed by the resonant wavelength shift. Due to the high optical quality factor of the ring resonator, the maximum resolution can reach 1 nanometre. The small mechanical motion can be detected by the sensing ring. The measured amplification factor is shown in Fig. 8, which is mainly determined by the optical wavelength.

In conclusions, the optical force enabled NEMS actuator with extend travel range is demonstrated. The novel monolithic integration of the electrostatic actuation and optical force actuation makes the NEMS actuator work with extended travel range. The ultrasensitive detection method makes it extreme useful to detect small mechanical motion, which is often overwhelmed by the spurious coupling and background noise.

[1] Rezazadeh, *Microsystem technologies* 12.12 (2006): 1163-1170.

[2] Hung, Elmer S., *Microelectromechanical Systems, and Journal of* 8.4 (1999): 497-505.

[3] Van Thourhout, *Nature Photonics* 4.4 (2010): 211-217.