Estimation of the thermal noise by direct measurement of the mechanical conductance at an anti-resonant frequency

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Estimation of the thermal noise of the mirror

- **Normal mode expansion**

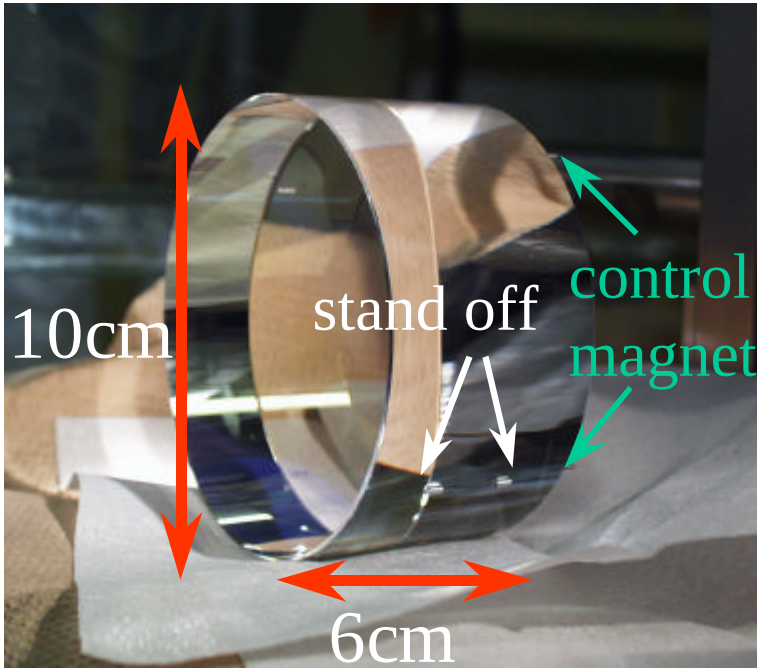
$$x^2(w) \sim \frac{4k_BT}{w} \sum_i \frac{1}{m_i w_i^2 Q_i}$$

$$Q_i = f_i^{-1}(w_i)$$

- **Assumption**

  (1) f(w)=constant

  (2) f(*x*): homogeneous



Direct measurement of Im[H(w)]

- **Fluctuation-Dissipation Theorem**

$$x^2(\mathrm{w}) = -\frac{4k_B T}{\mathrm{w}}\,\mathrm{Im}[H(\mathrm{w})] \quad : H(\mathrm{w}) = \frac{x(\mathrm{w})}{f(\mathrm{w})}$$

- **Anti-resonance**

  Re[H(w)] vanishes while Im[H(w)] remains

- **Merit of this method**

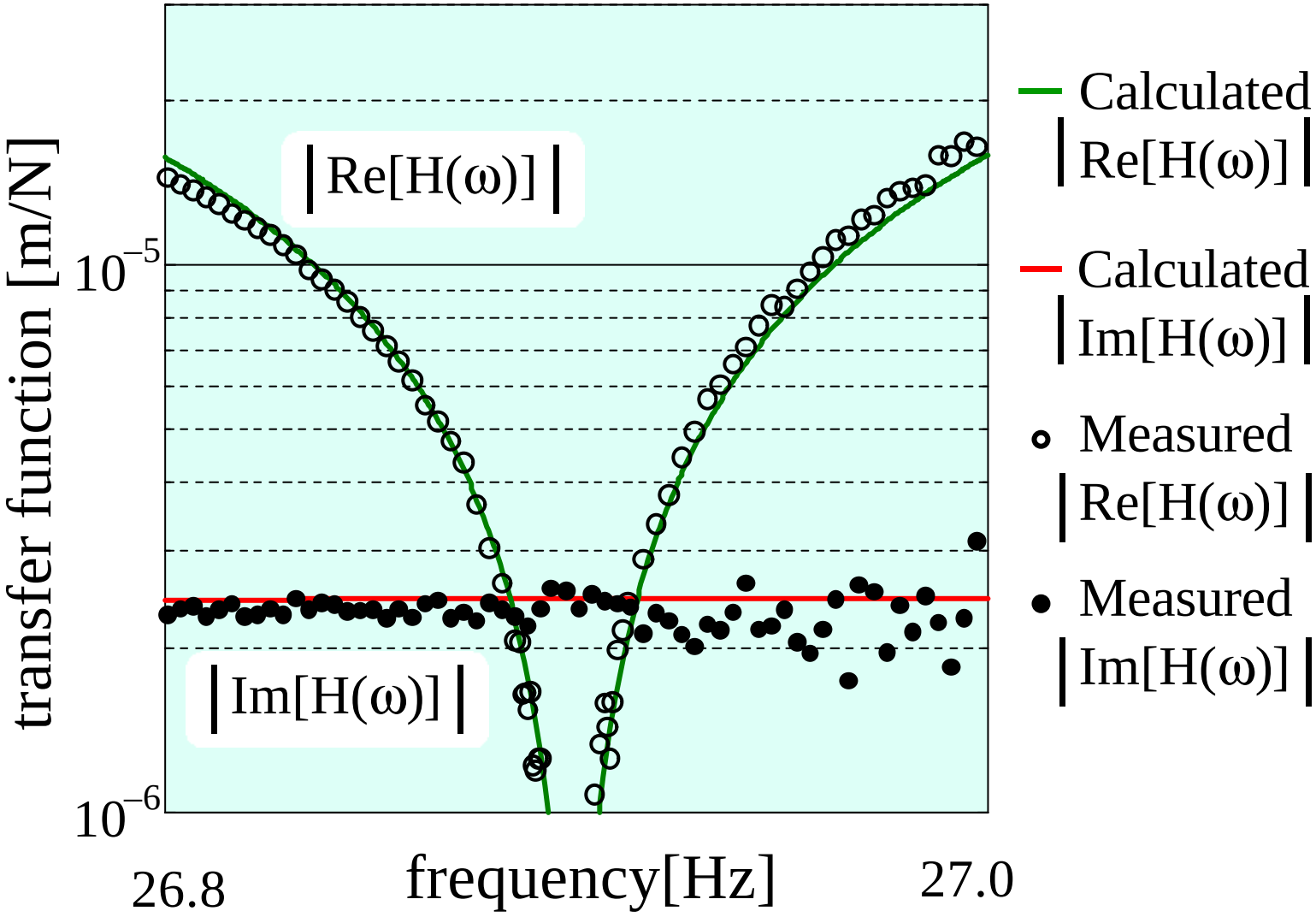
  (1) no assumption is needed on f(w)

  (2) valid if the f(x) is inhomogeneous

  (3) effects of all modes are considered

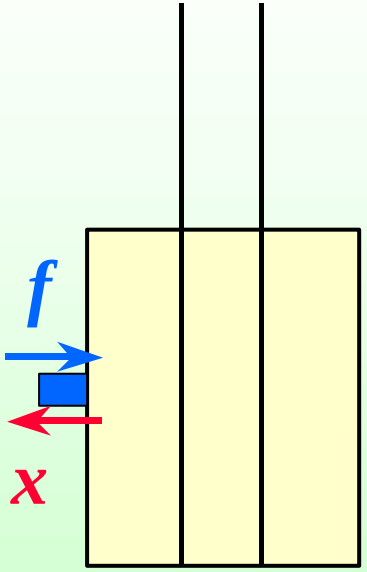
Anti-resonance

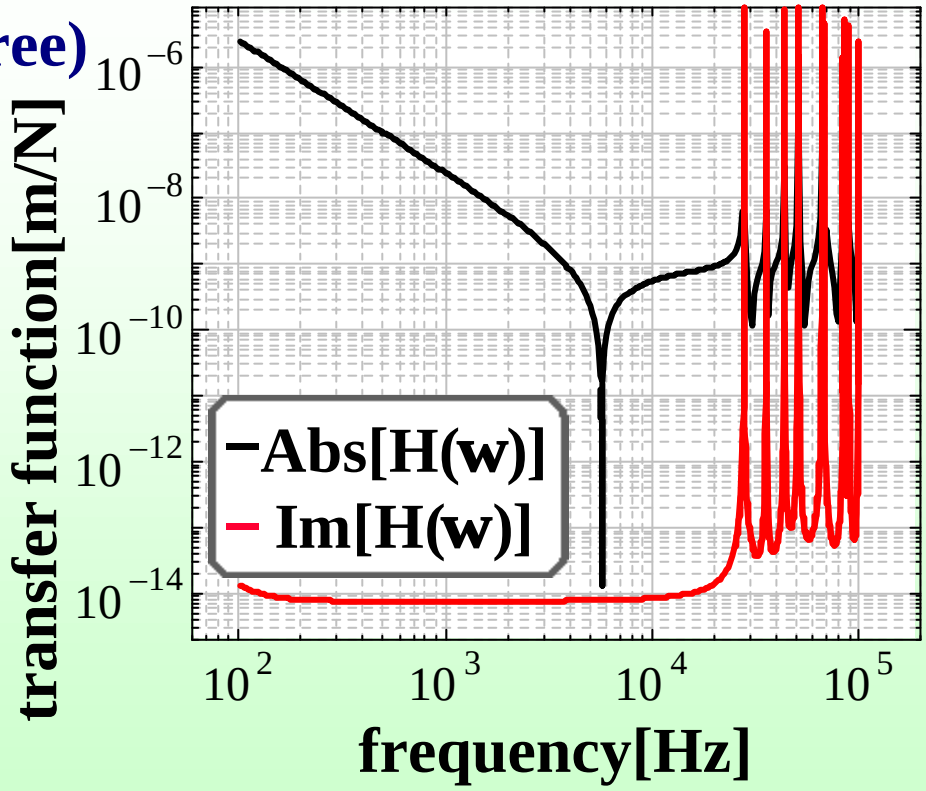
Measured transfer function 2.



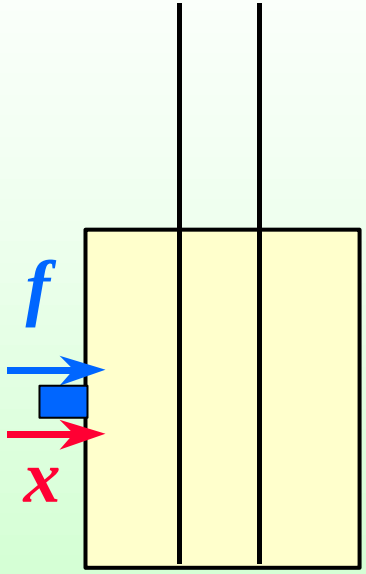
Application to the Mirror

• **Pendulum(Free)**



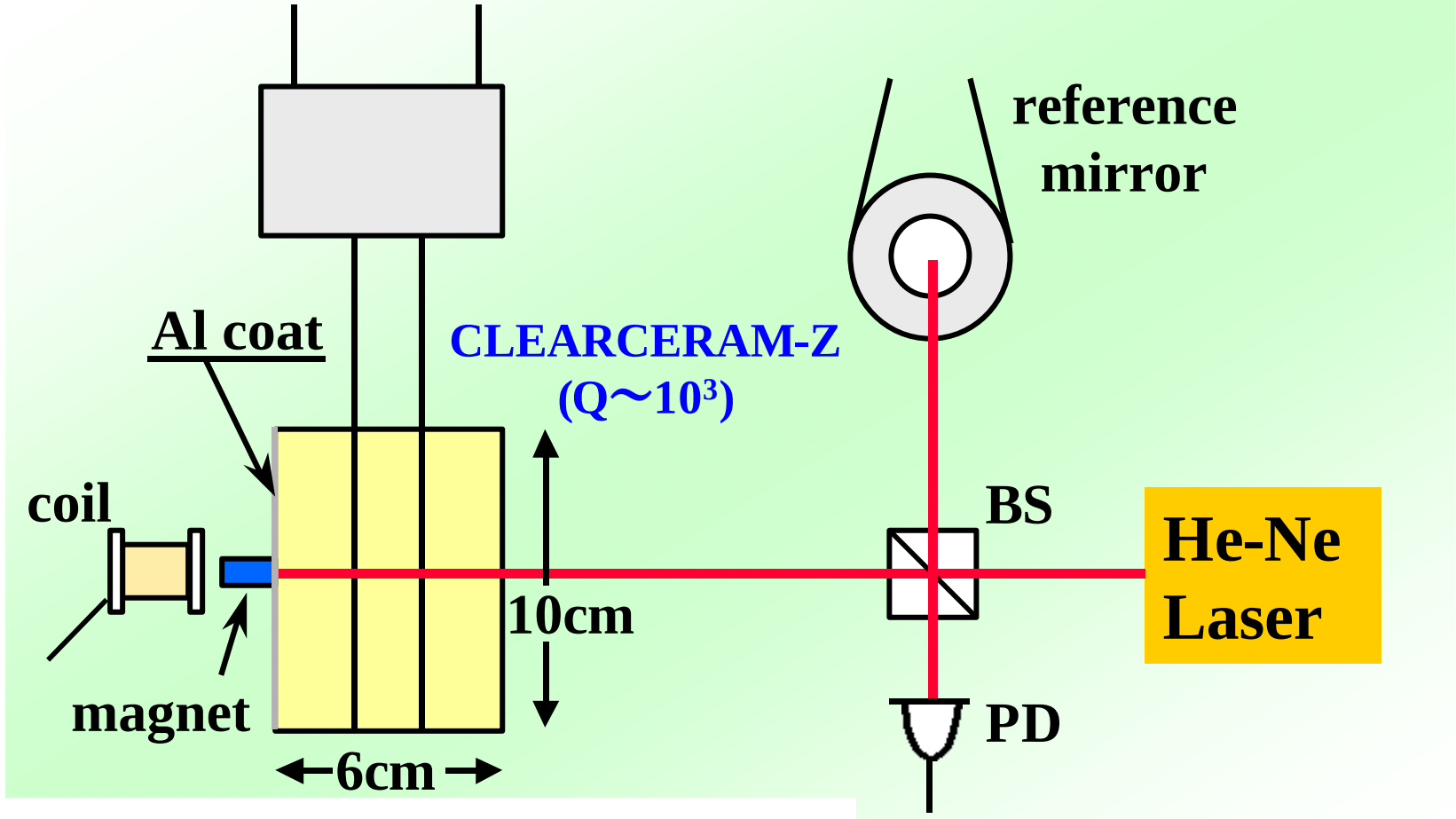


• **Elastic body**



The anti-resonant frequency depends on the reduced mass.

Measurement system



f is applied by a coil-magnet actuator

and *x* is measured by an interferometer

Summary

- **We proposed a new estimation method by direct measurement of the Im[H(w)].**

- **Im[H(w)] of a 2-mode oscillator was measured at an anti-resonant frequency. It agreed with the estimated one by normal mode.**

- **Application to the mirror is in progress.**
  $f_{\mathrm{anti}} \sim 2\mathrm{kHz}$