Fluctuations in a NESS: is there a universal behavior ?

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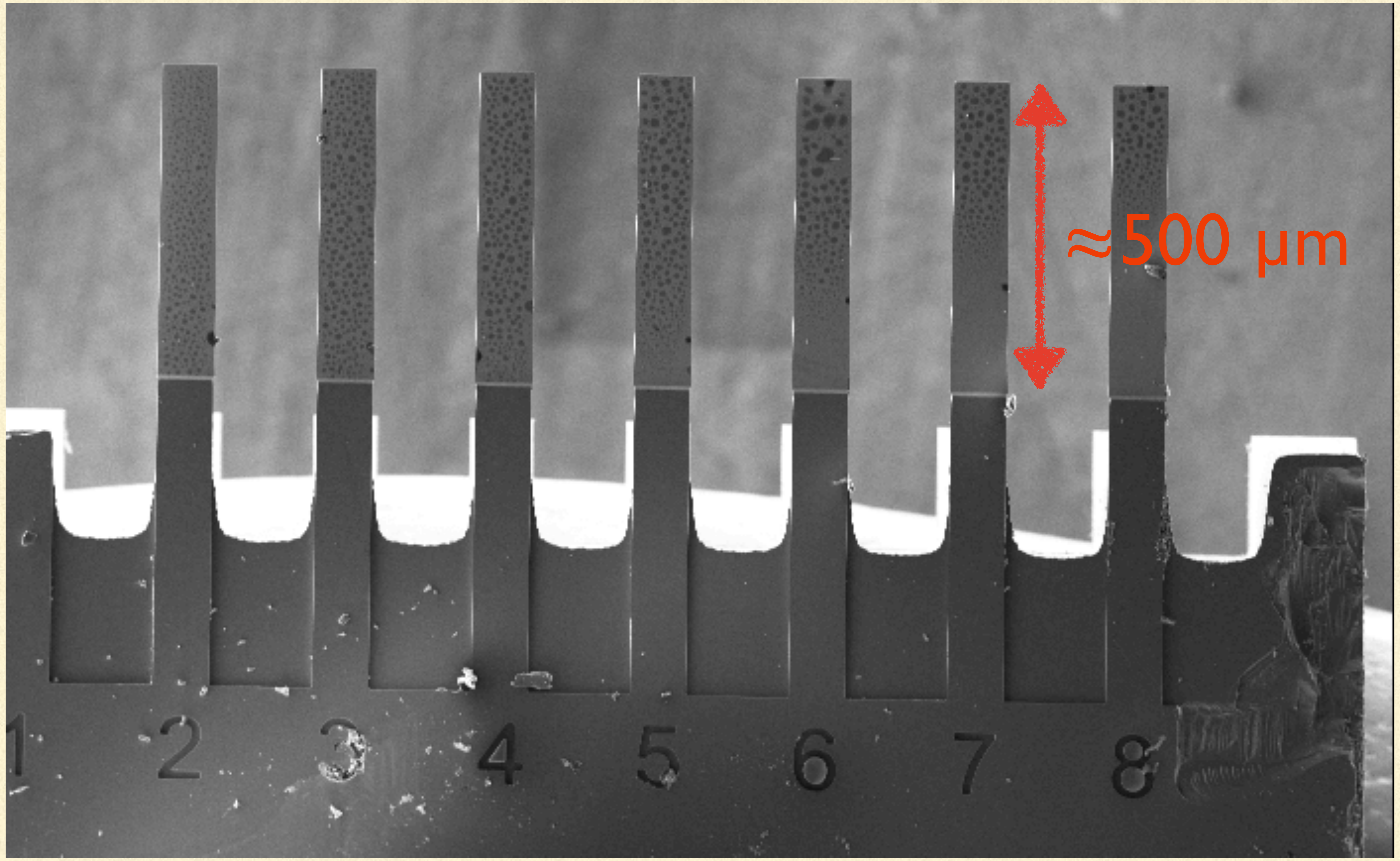
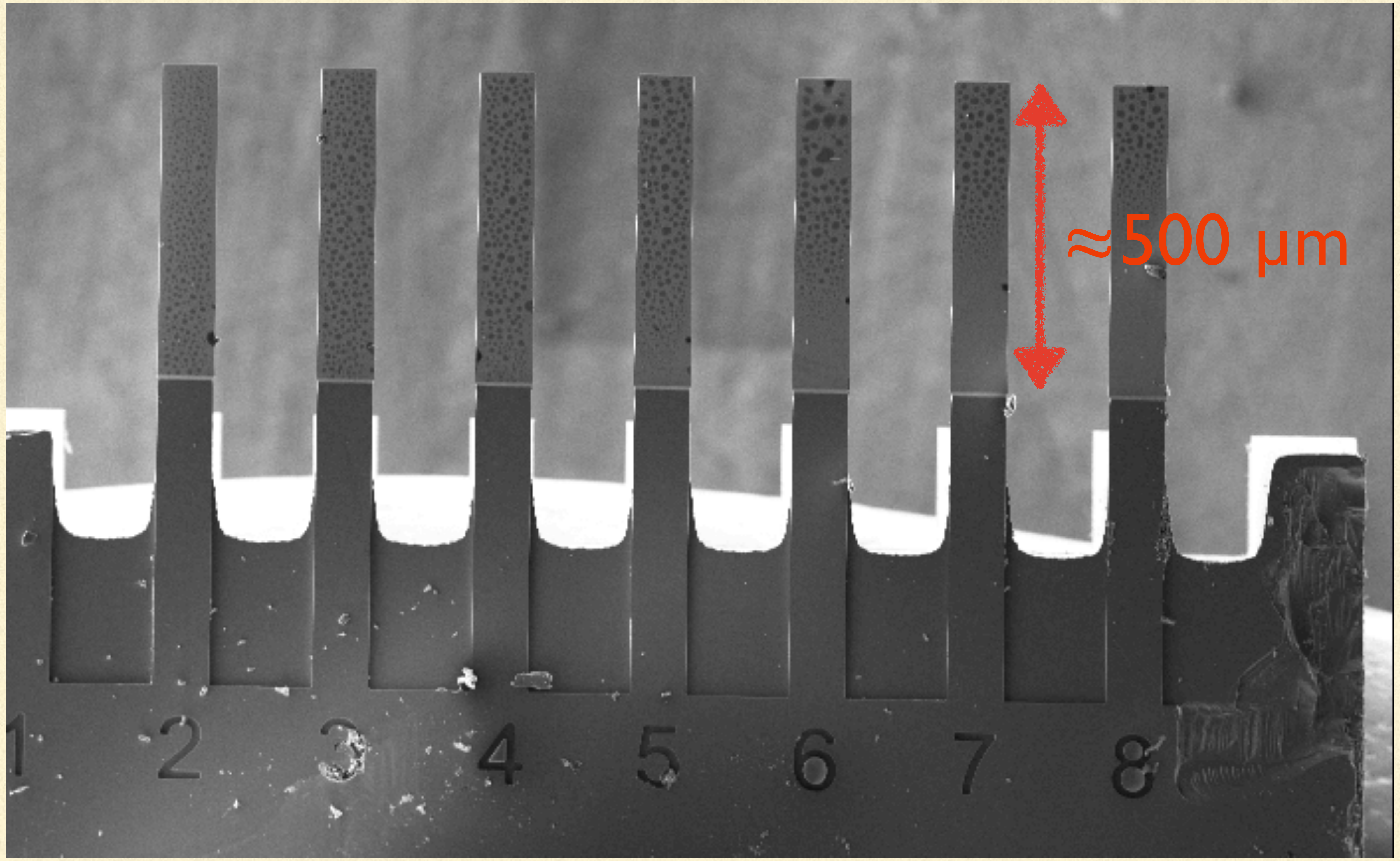
Univ Lyon, ENS de Lyon, Univ Claude Bernard, CNRS, Laboratoire de Physique

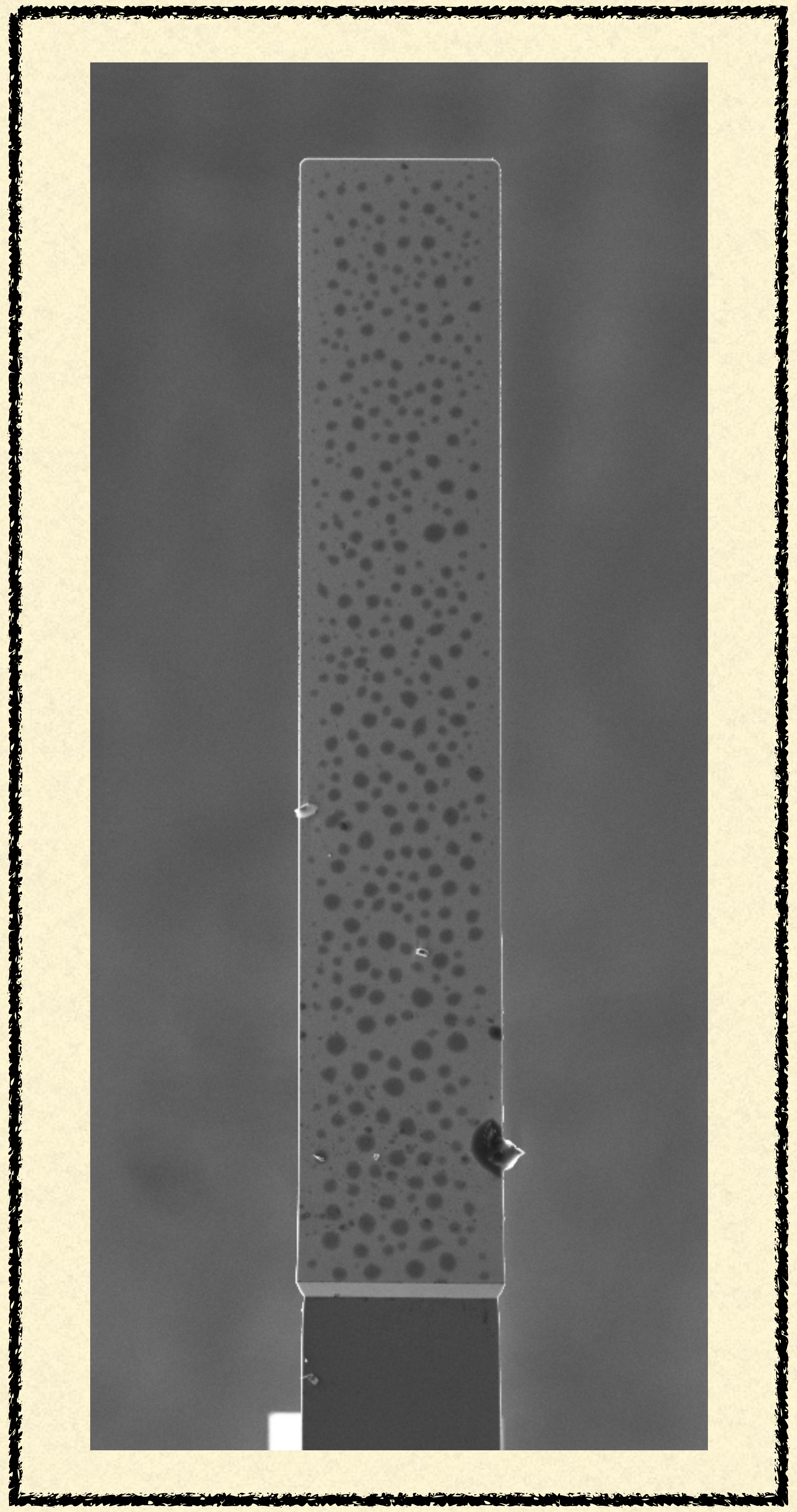
Silicon μ-cantilevers

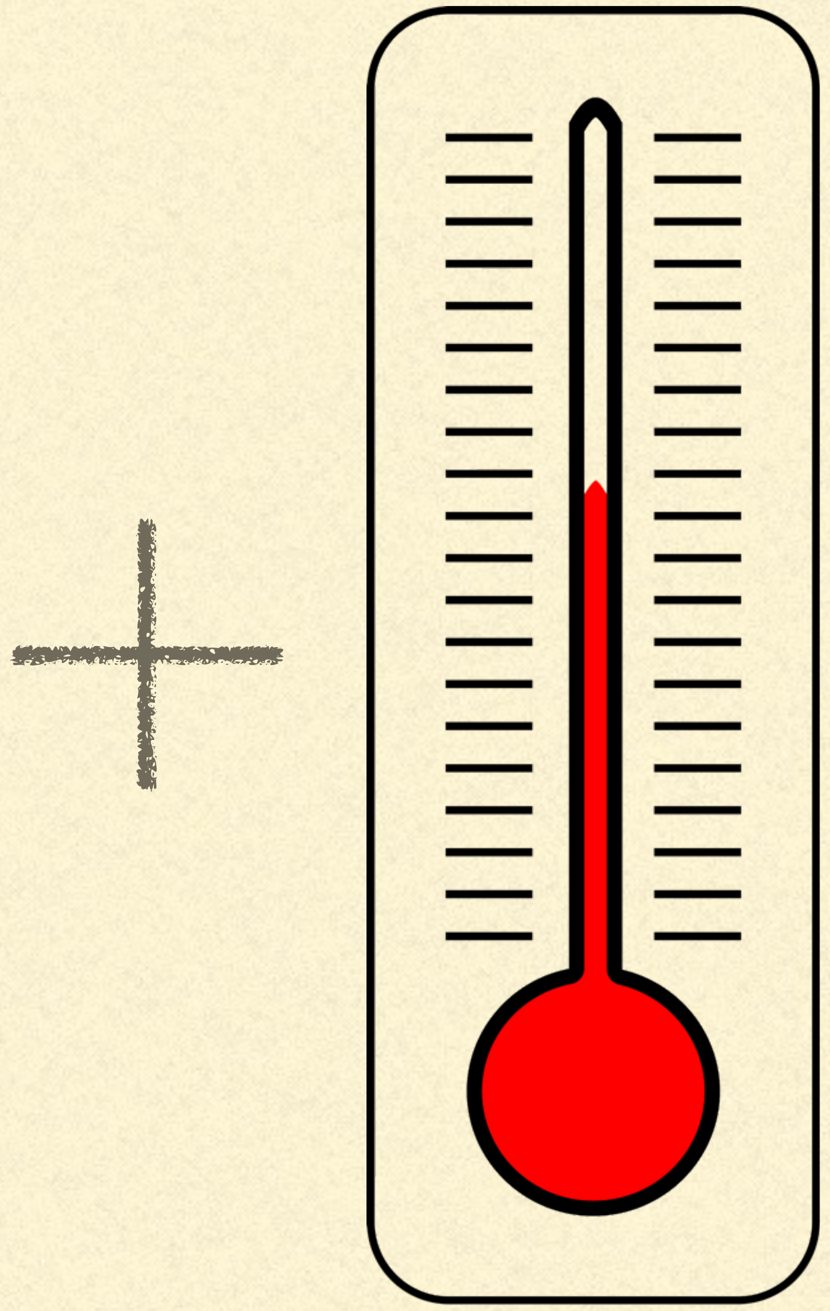


Thermal fluctuations

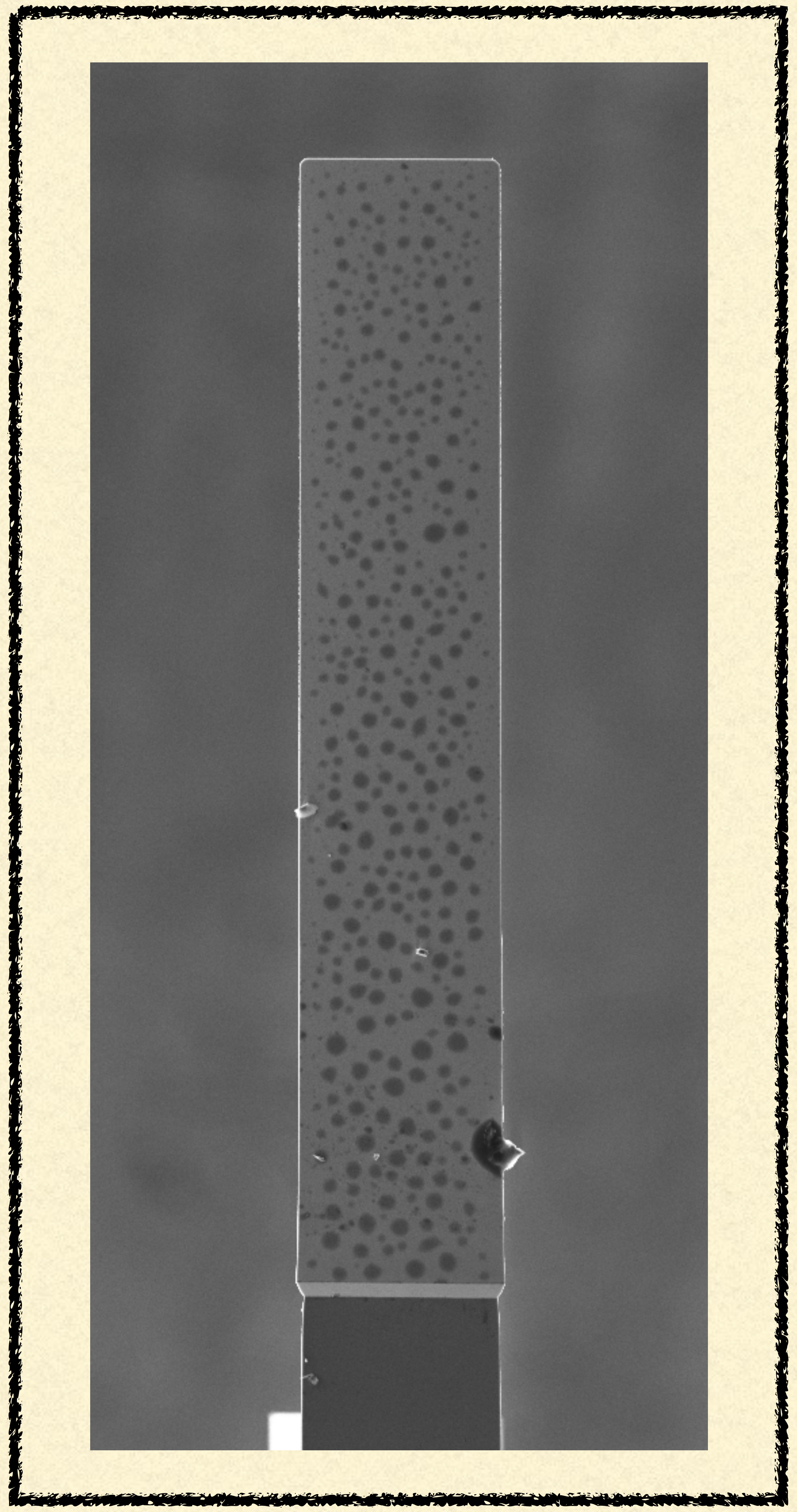


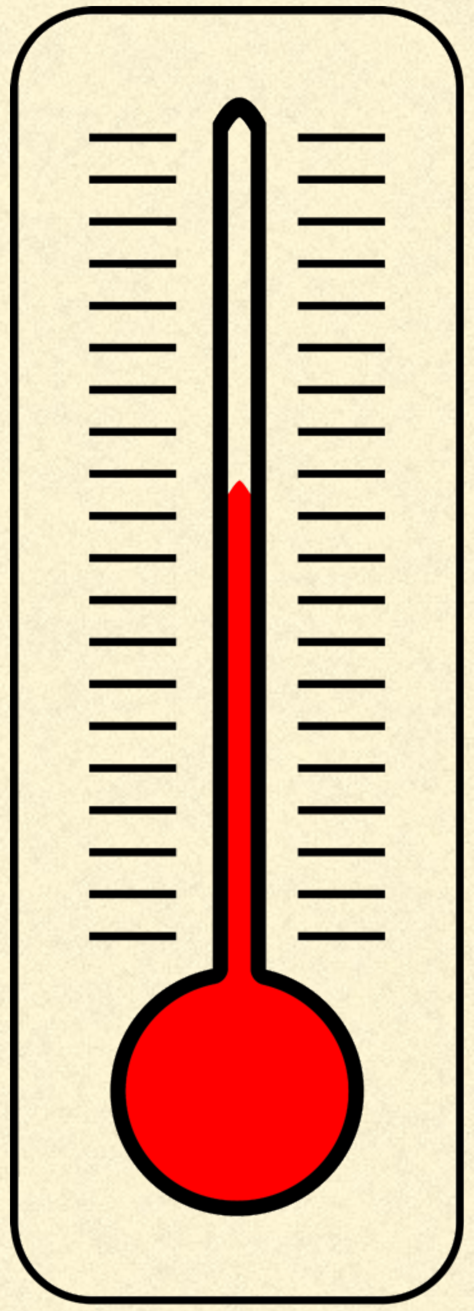
Thermal fluctuations

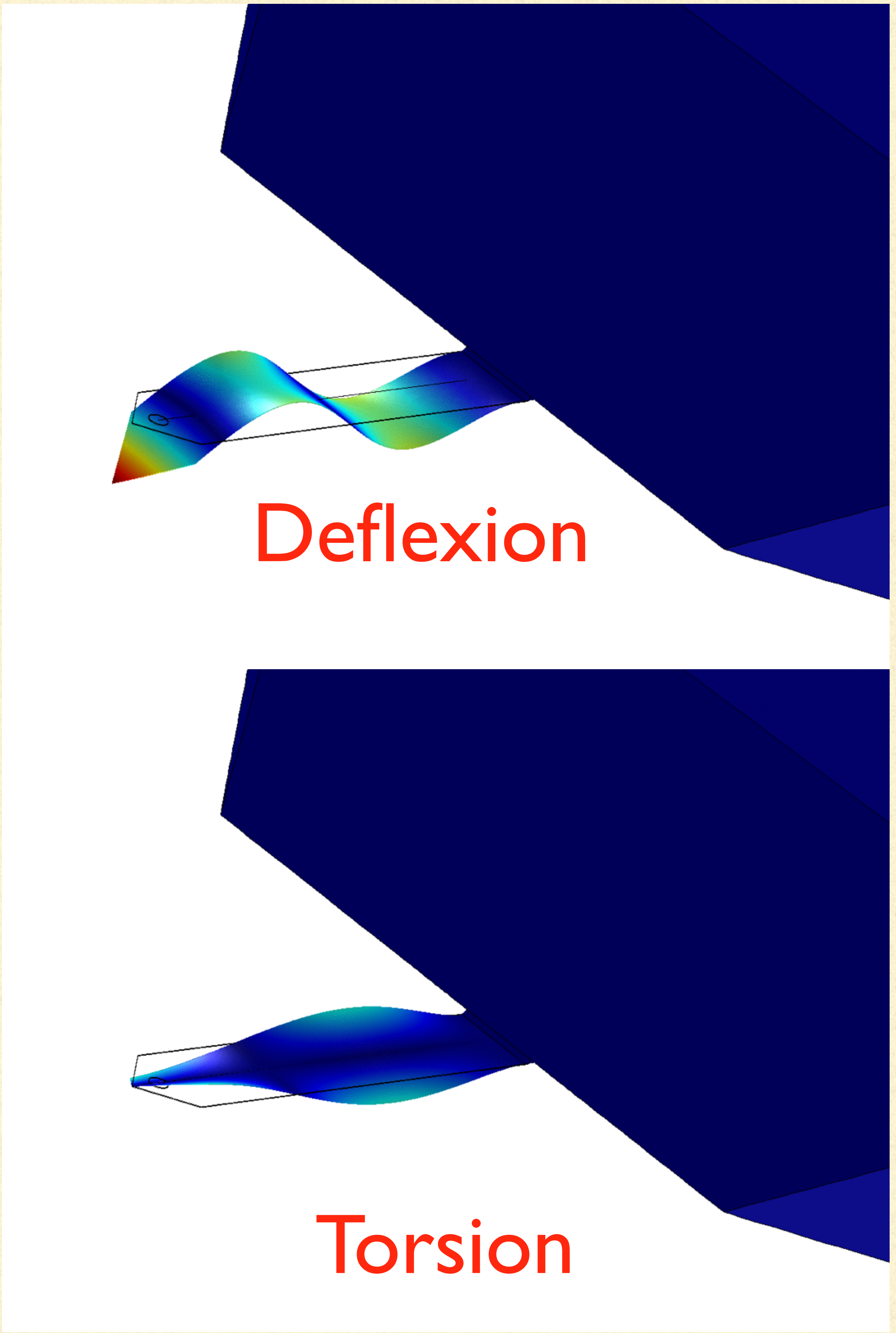




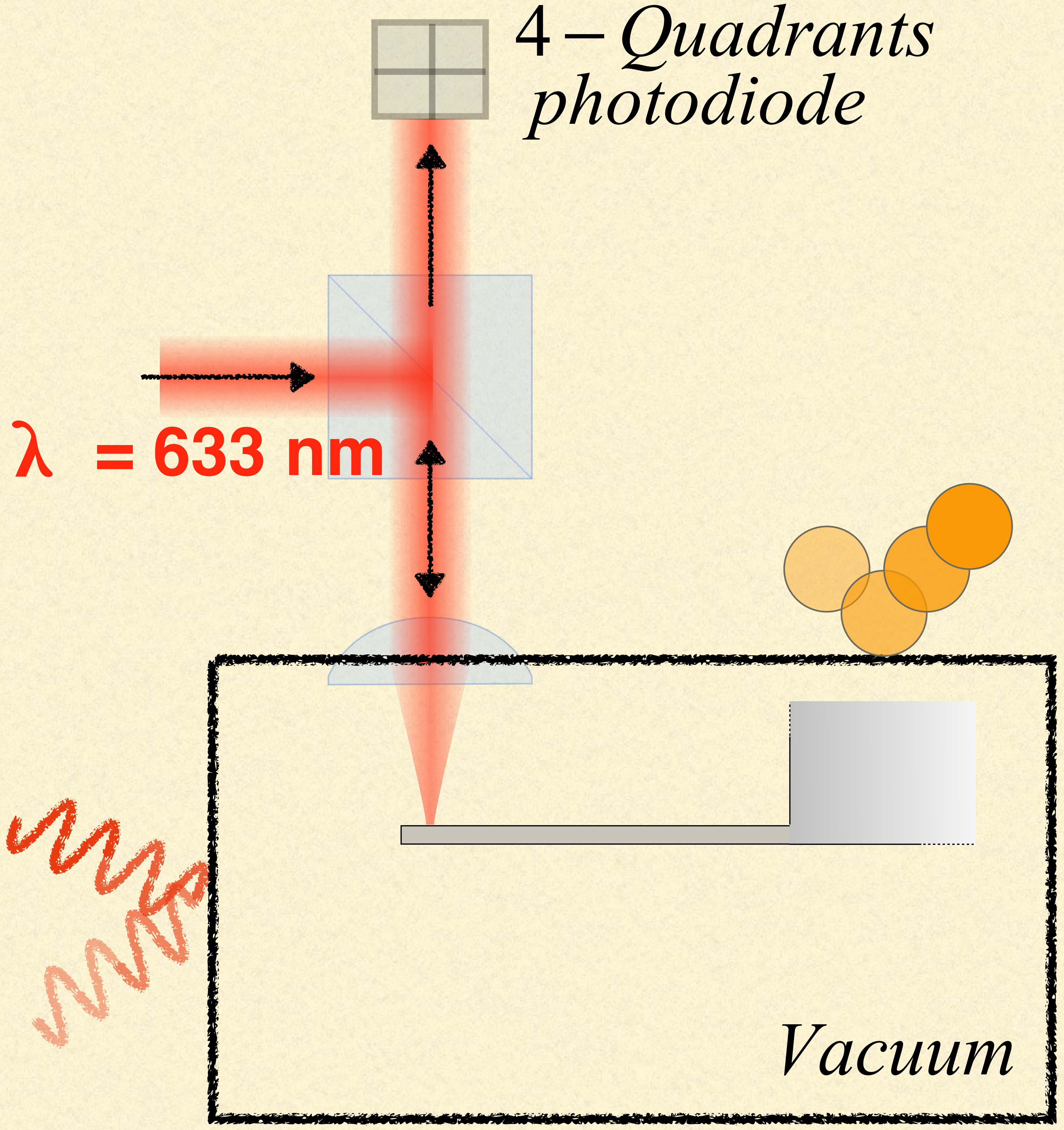
Thermal fluctuations

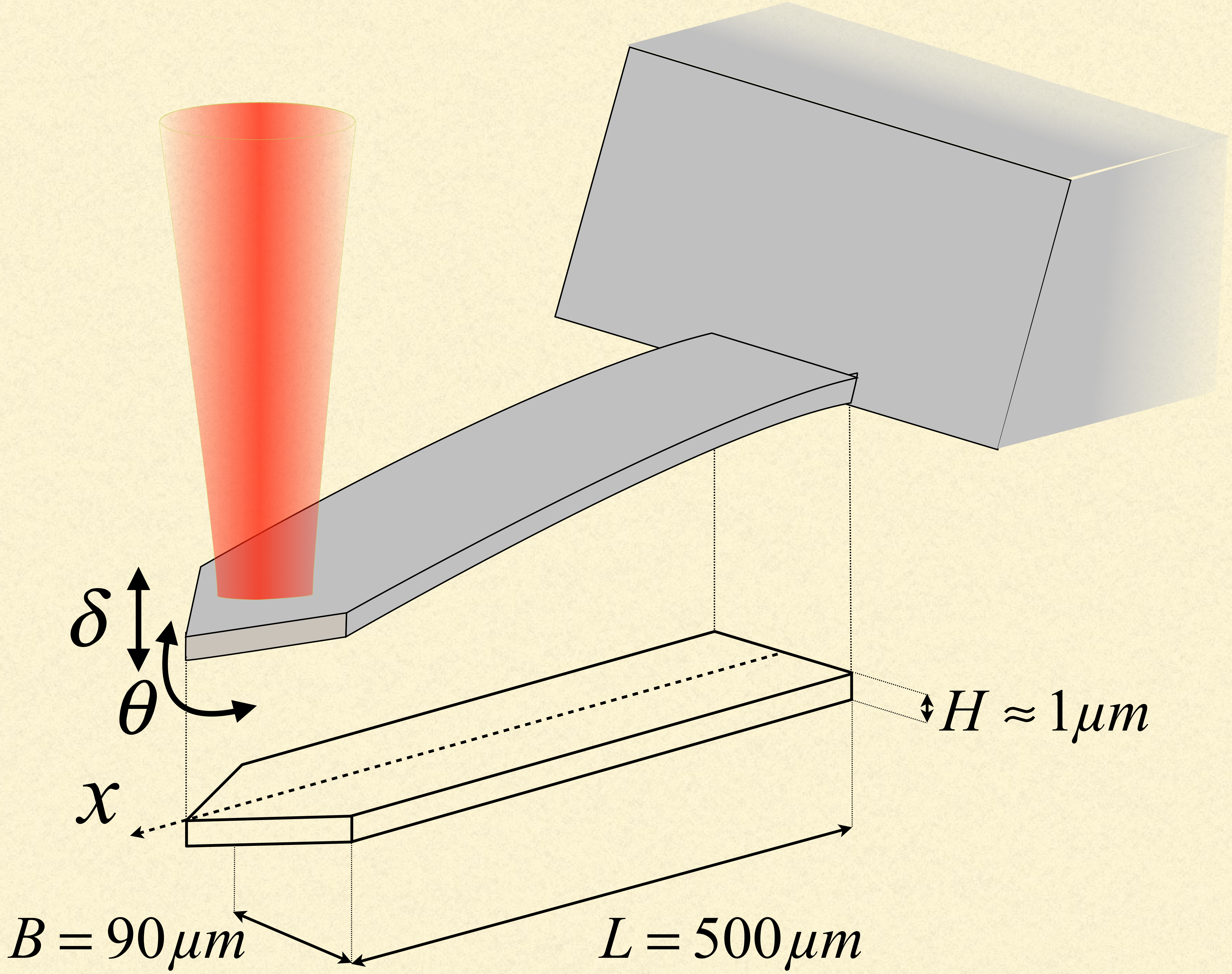




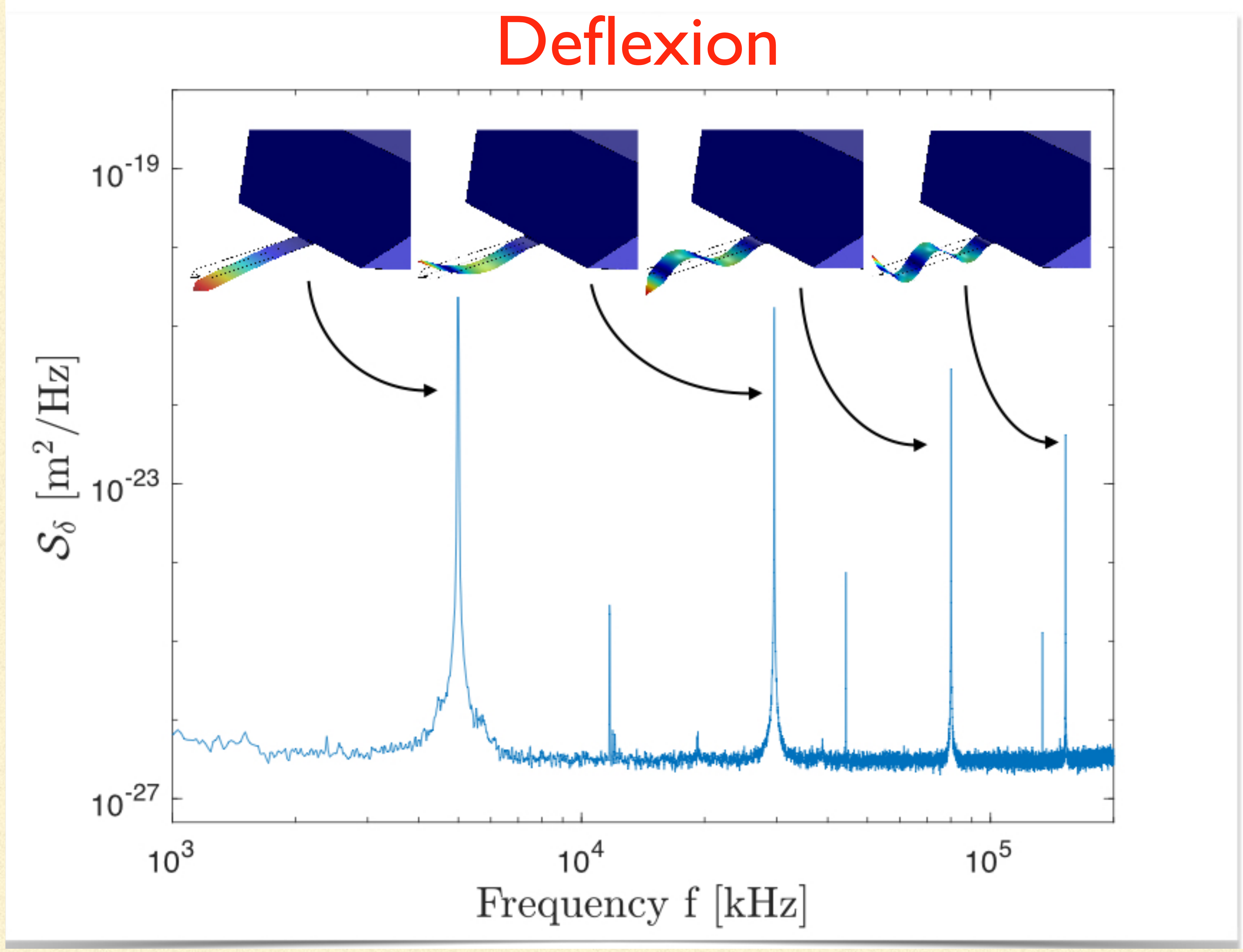


Our experiment

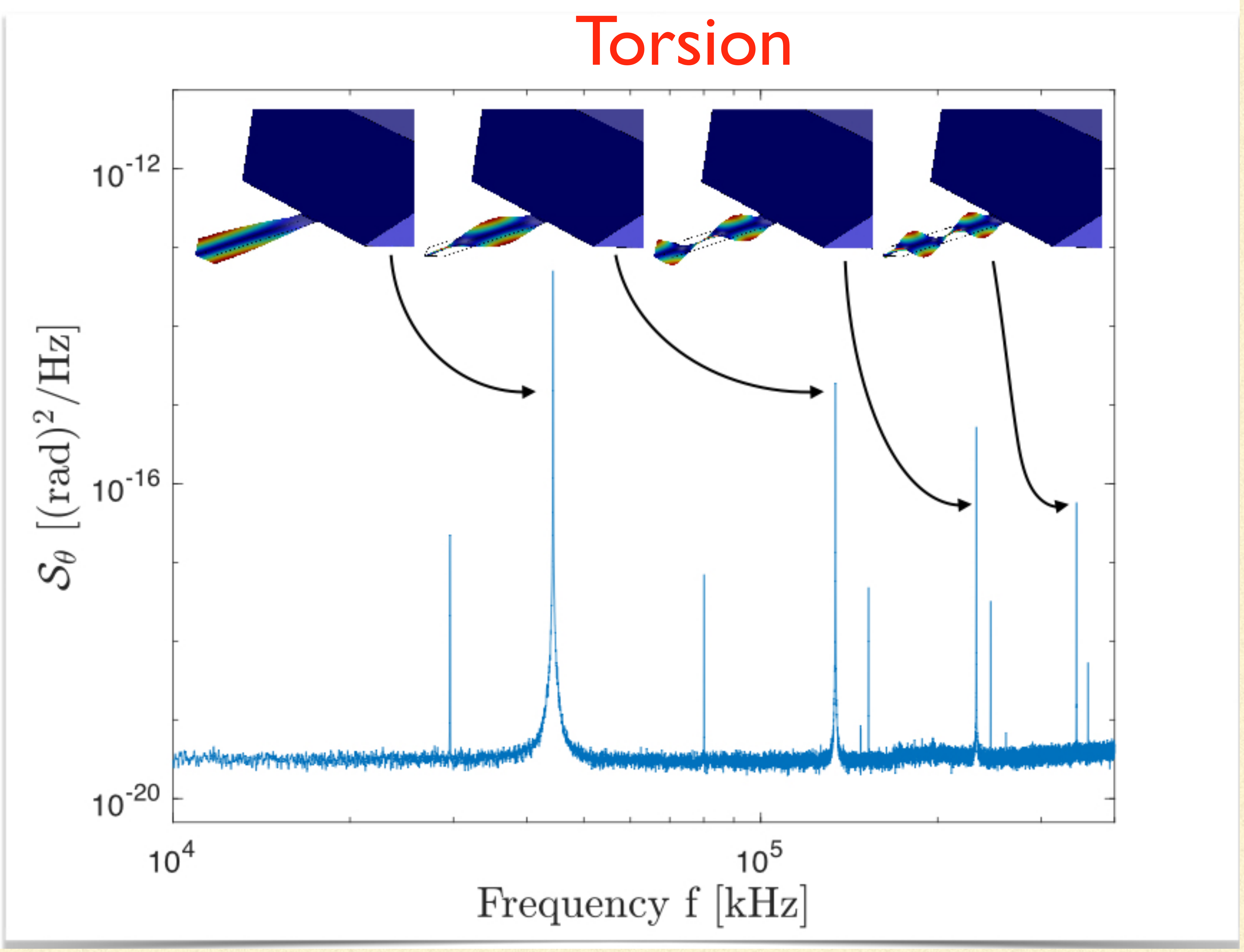




Spectra

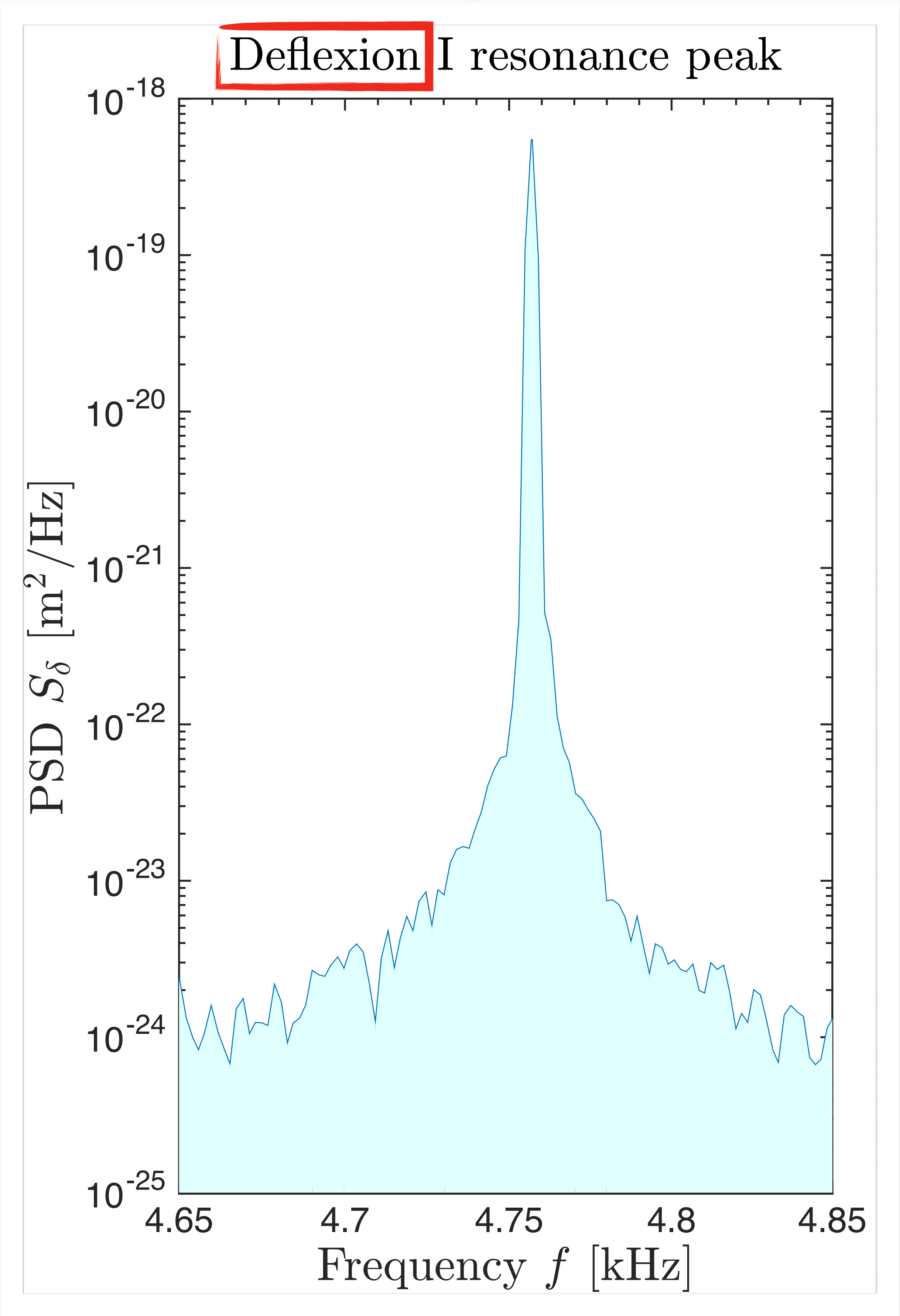


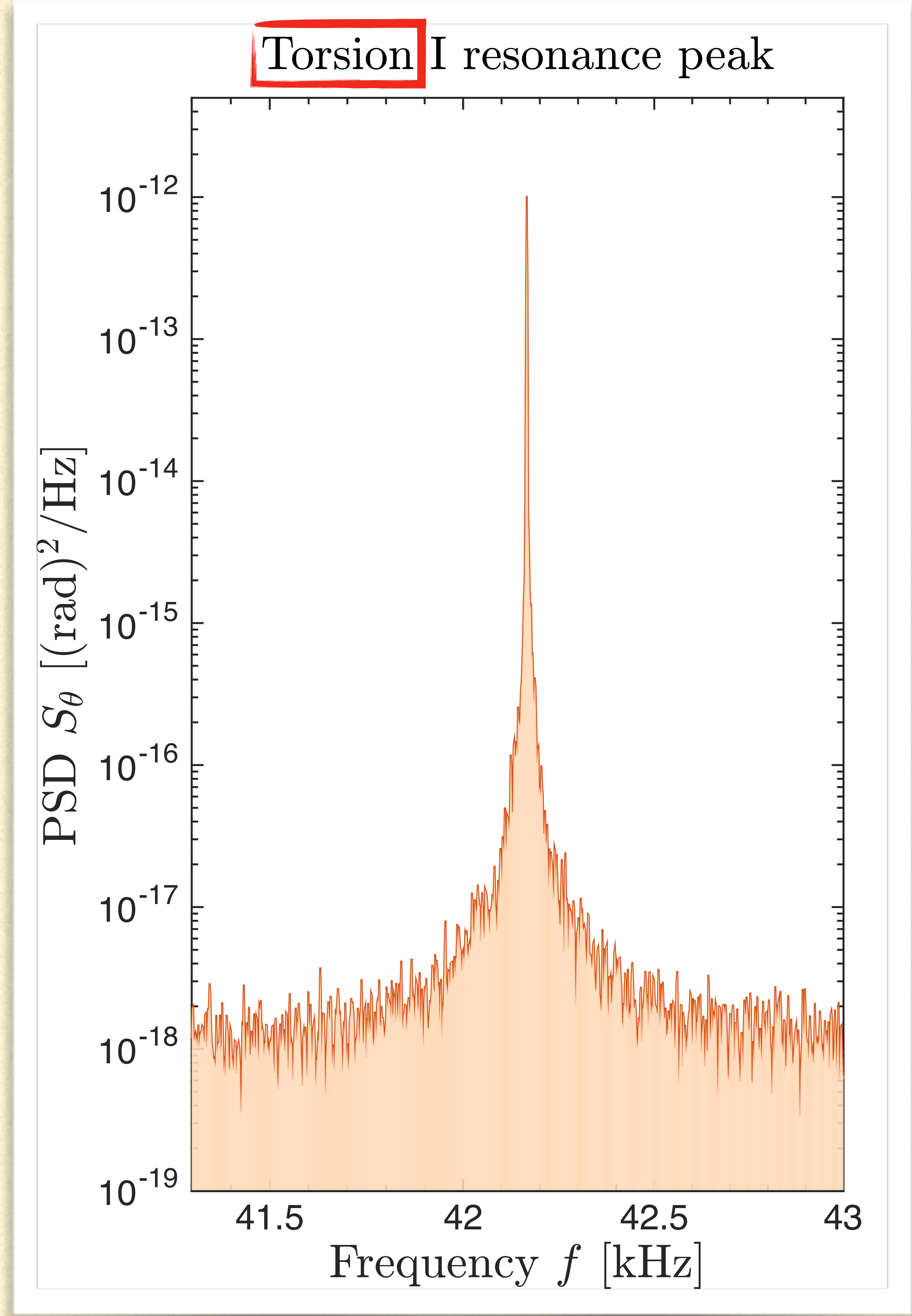
Deflexion
10^{-19}
10^{-23}
10^{-27}
S_δ [m^2/Hz]
10^3
10^4
10^5
Frequency f [kHz]



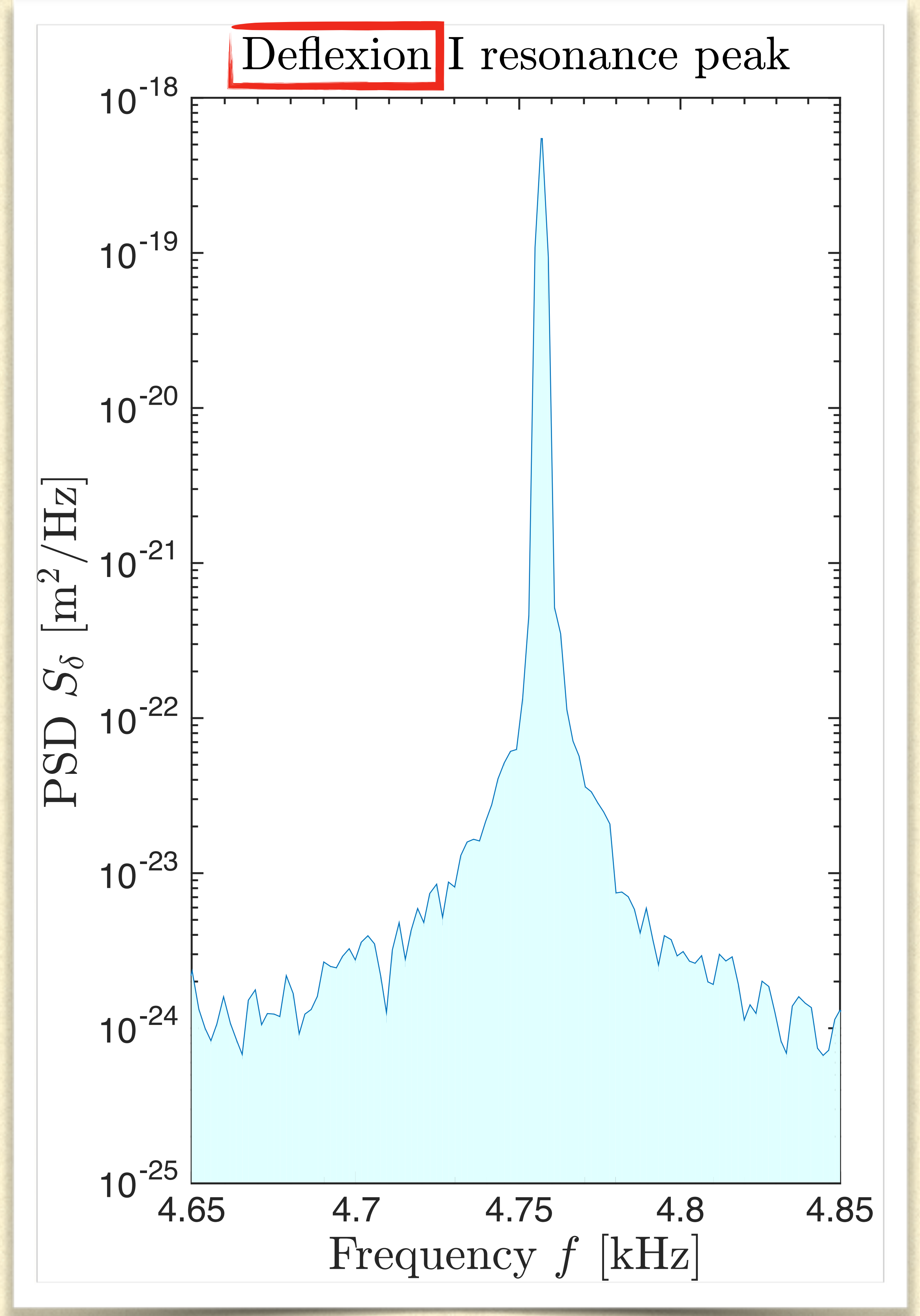
Torsion
10^{-12}
10^{-16}
10^{-20}
S_θ [(rad)^2/Hz]
10^4
10^5
Frequency f [kHz]

Resonance peaks

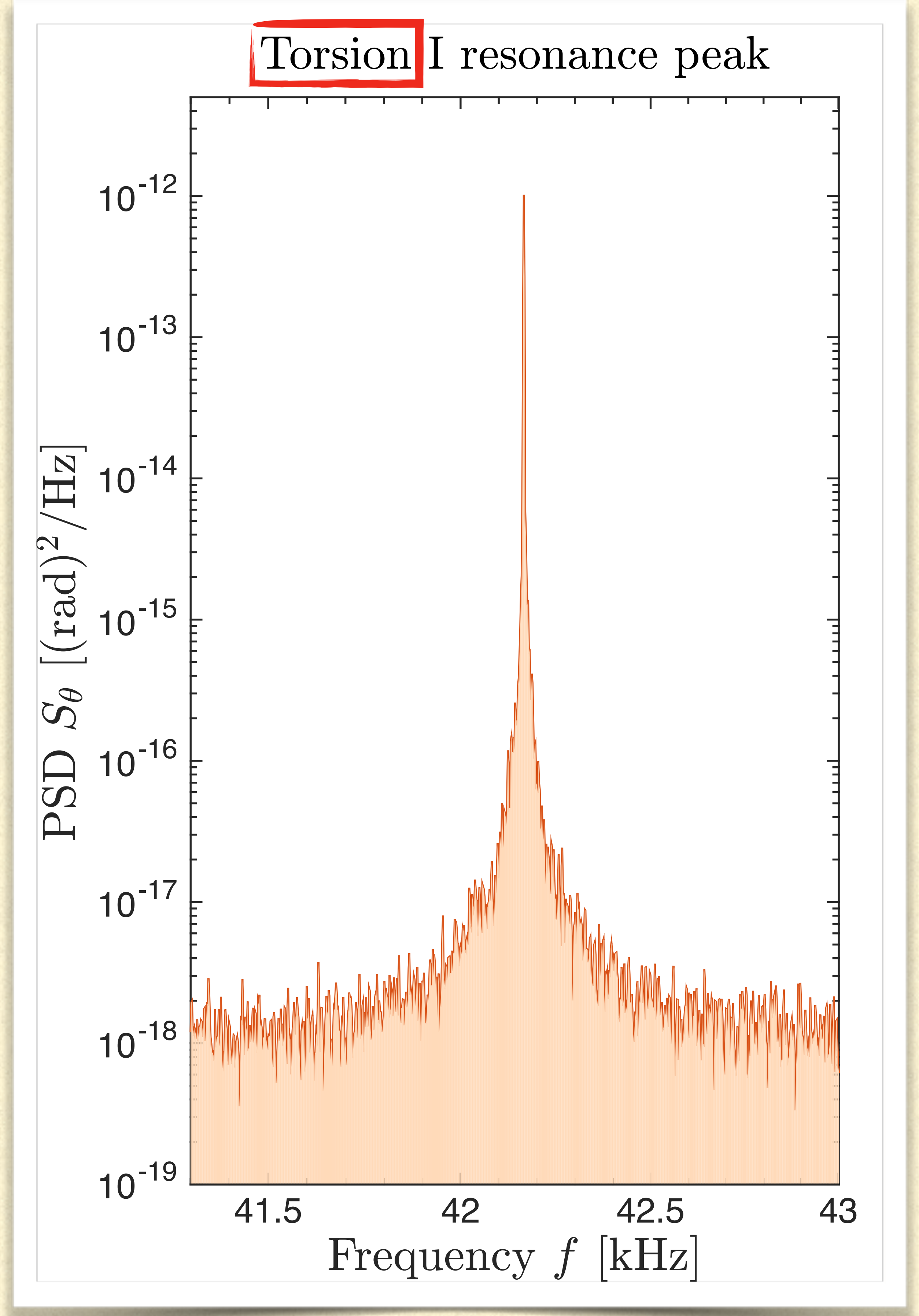




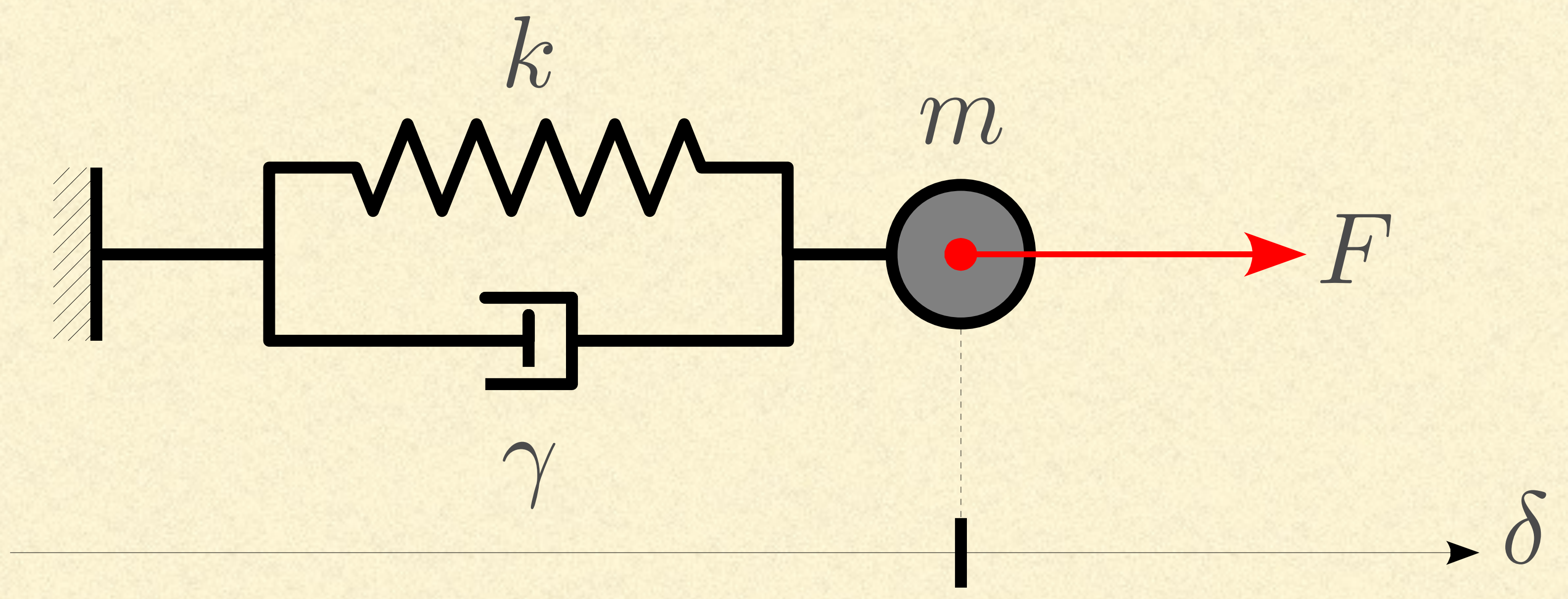
Equipartition principle



$$\langle \delta^2 \rangle = \int_{f \pm \Delta f} df \cdot S_\delta(f)$$



$$\langle \theta^2 \rangle = \int_{f \pm \Delta f} df \cdot S_\theta(f)$$

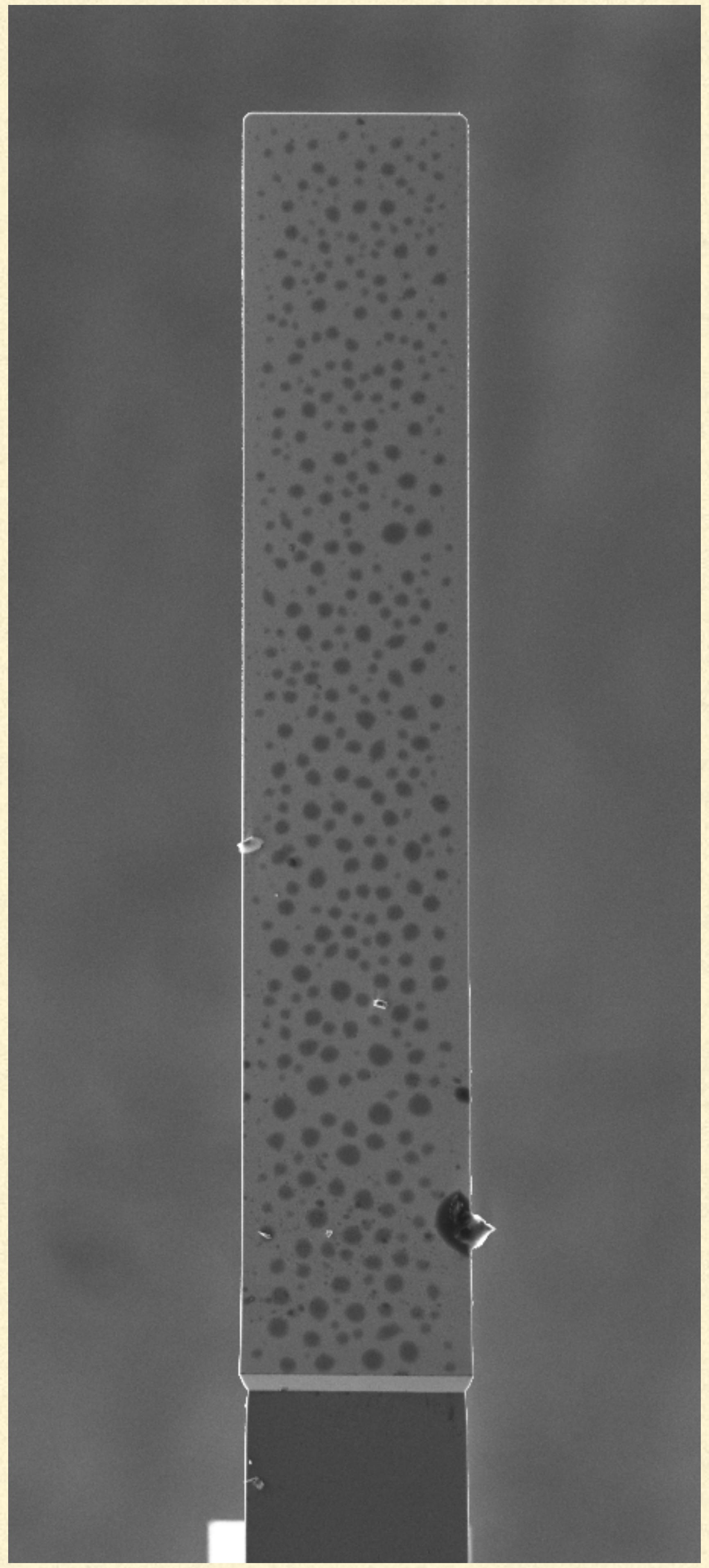


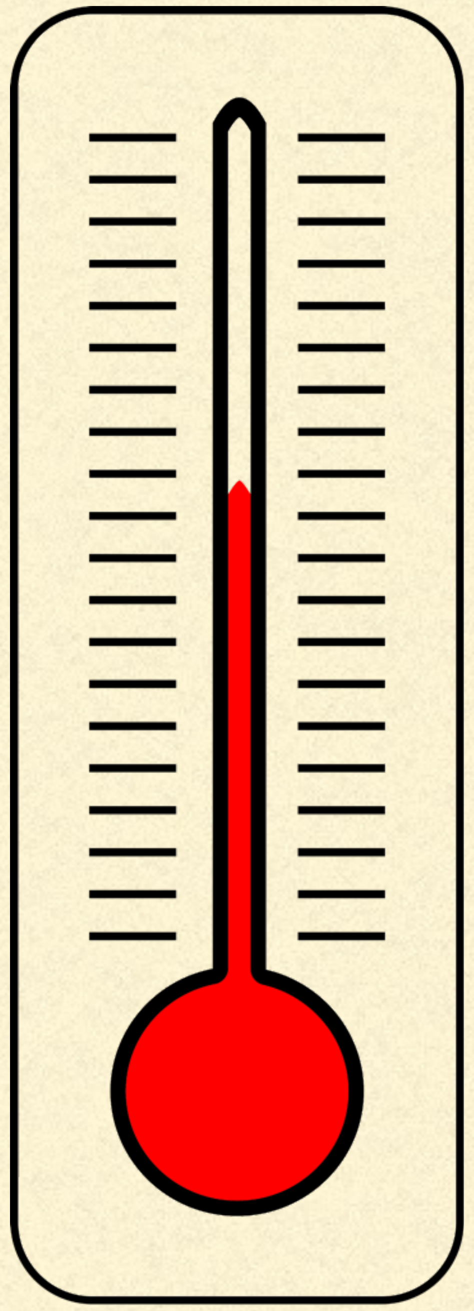
Equipartition Principle

$$\frac{1}{2} k^{defl} \langle \delta^2 \rangle = \frac{1}{2} k_B T$$

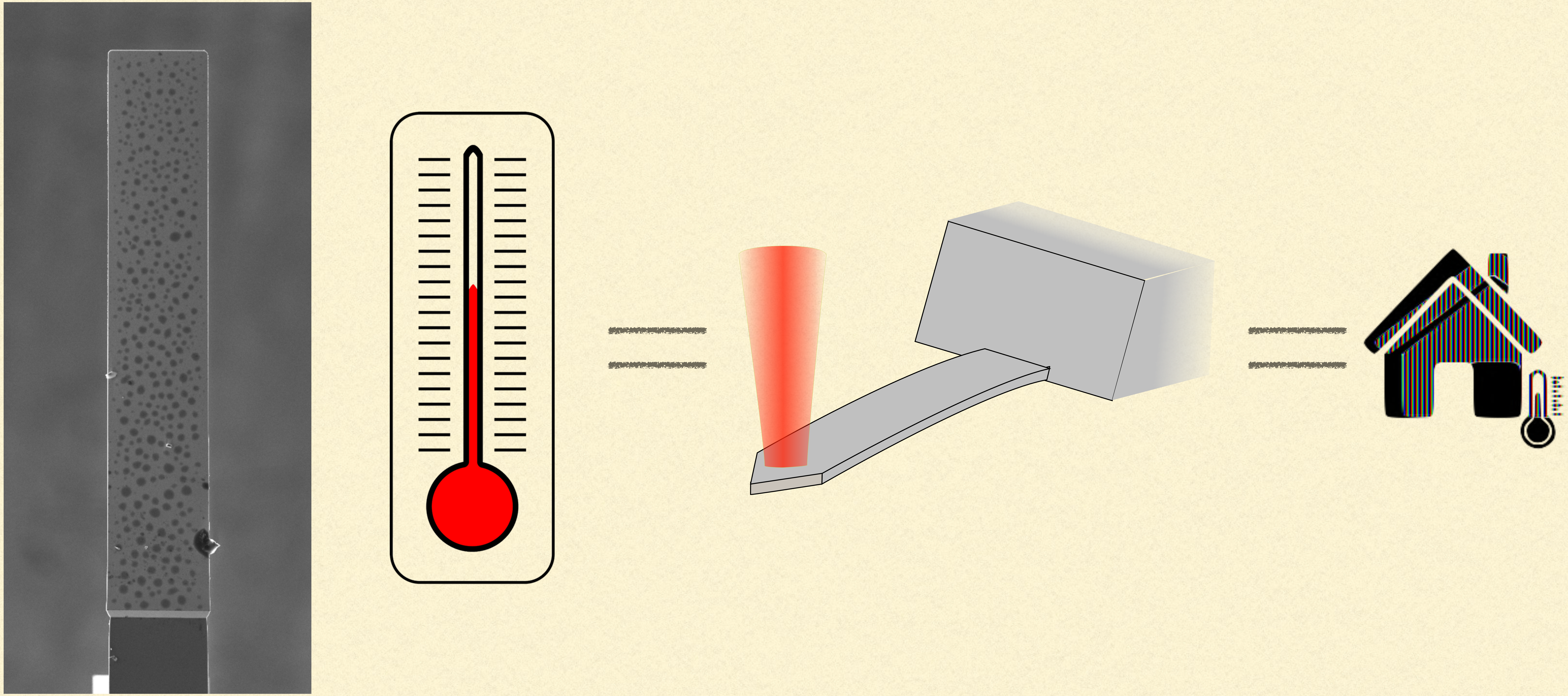
$$\frac{1}{2} k^{tors} \langle \theta^2 \rangle = \frac{1}{2} k_B T$$

Equilibrium

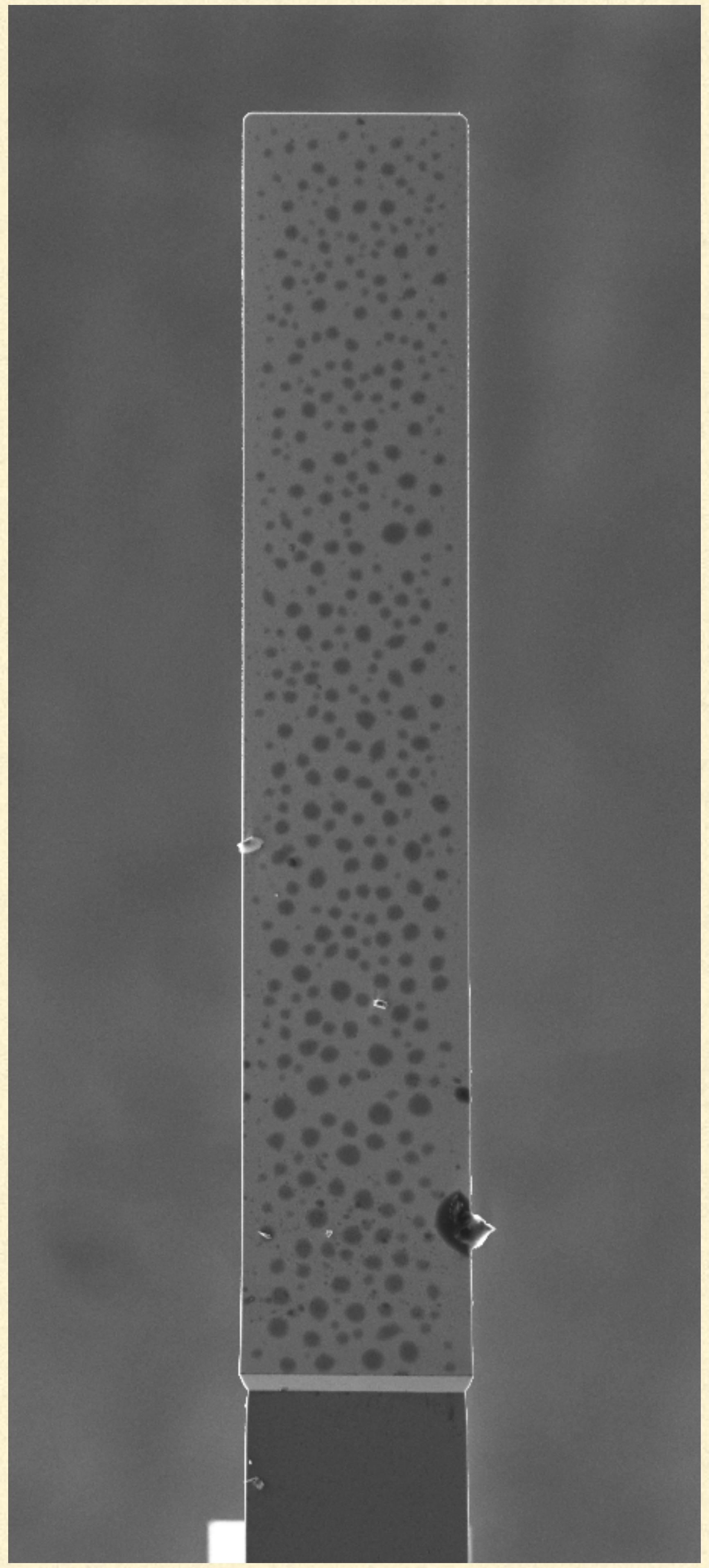


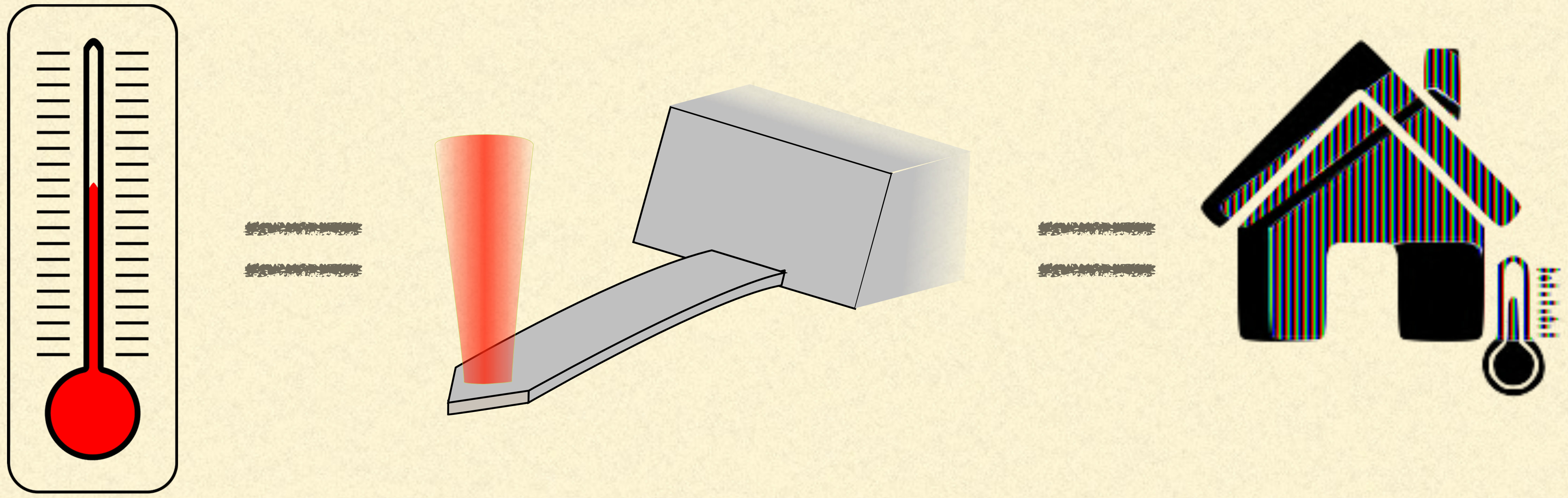


Equilibrium



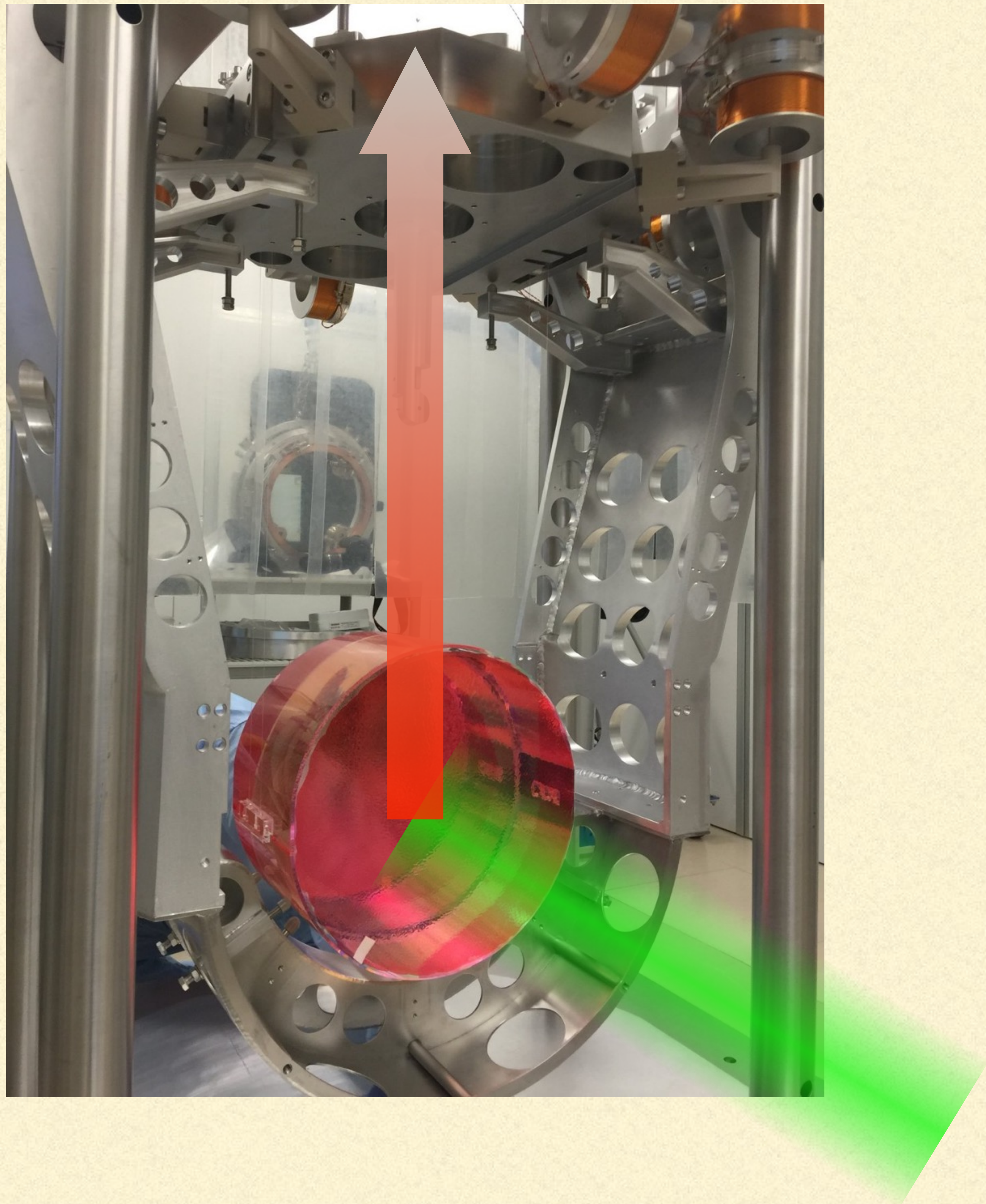
Equilibrium



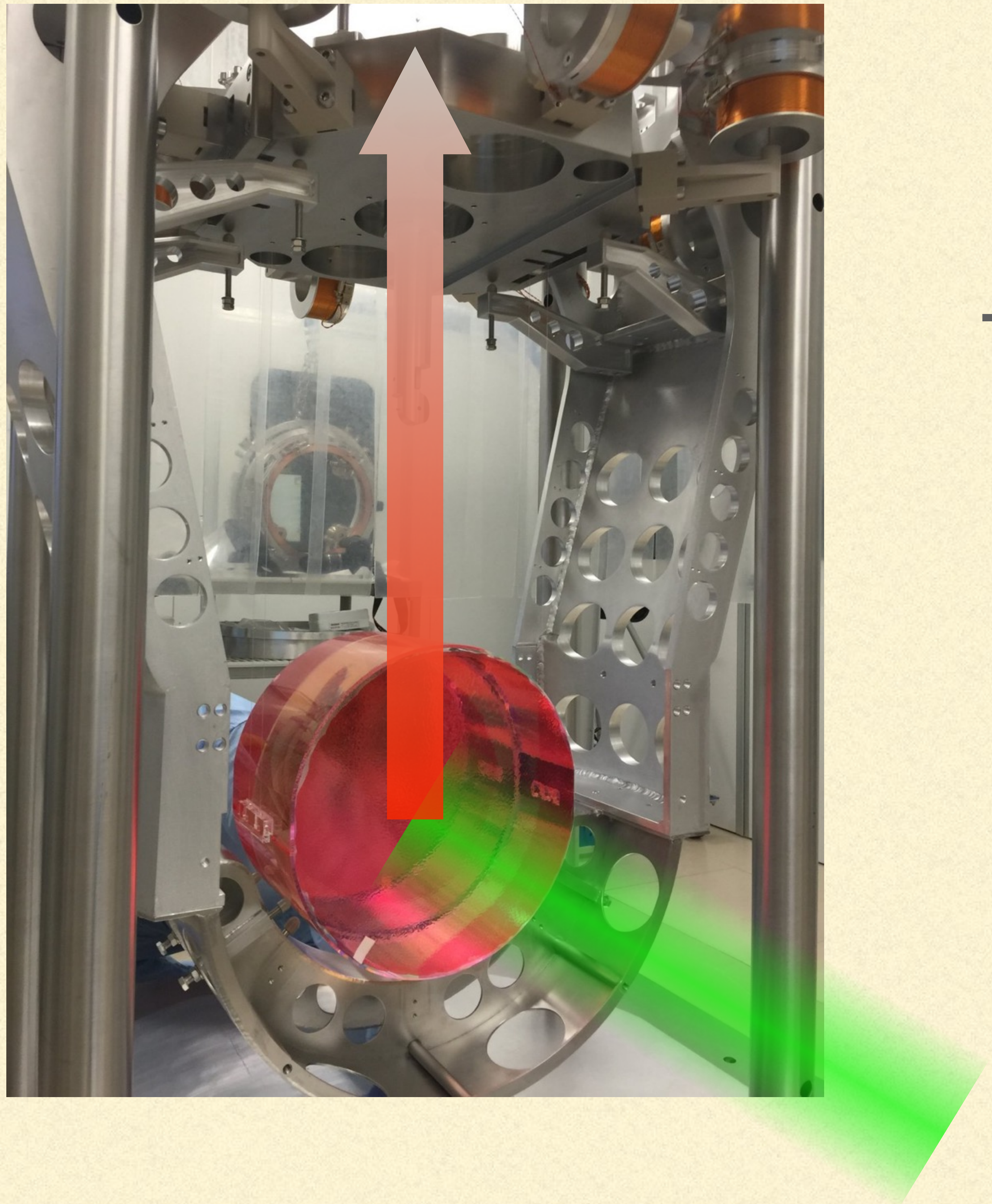


$$T = \frac{k^{defl} \left\langle \delta^2 \right\rangle}{k_B} \approx 300K$$

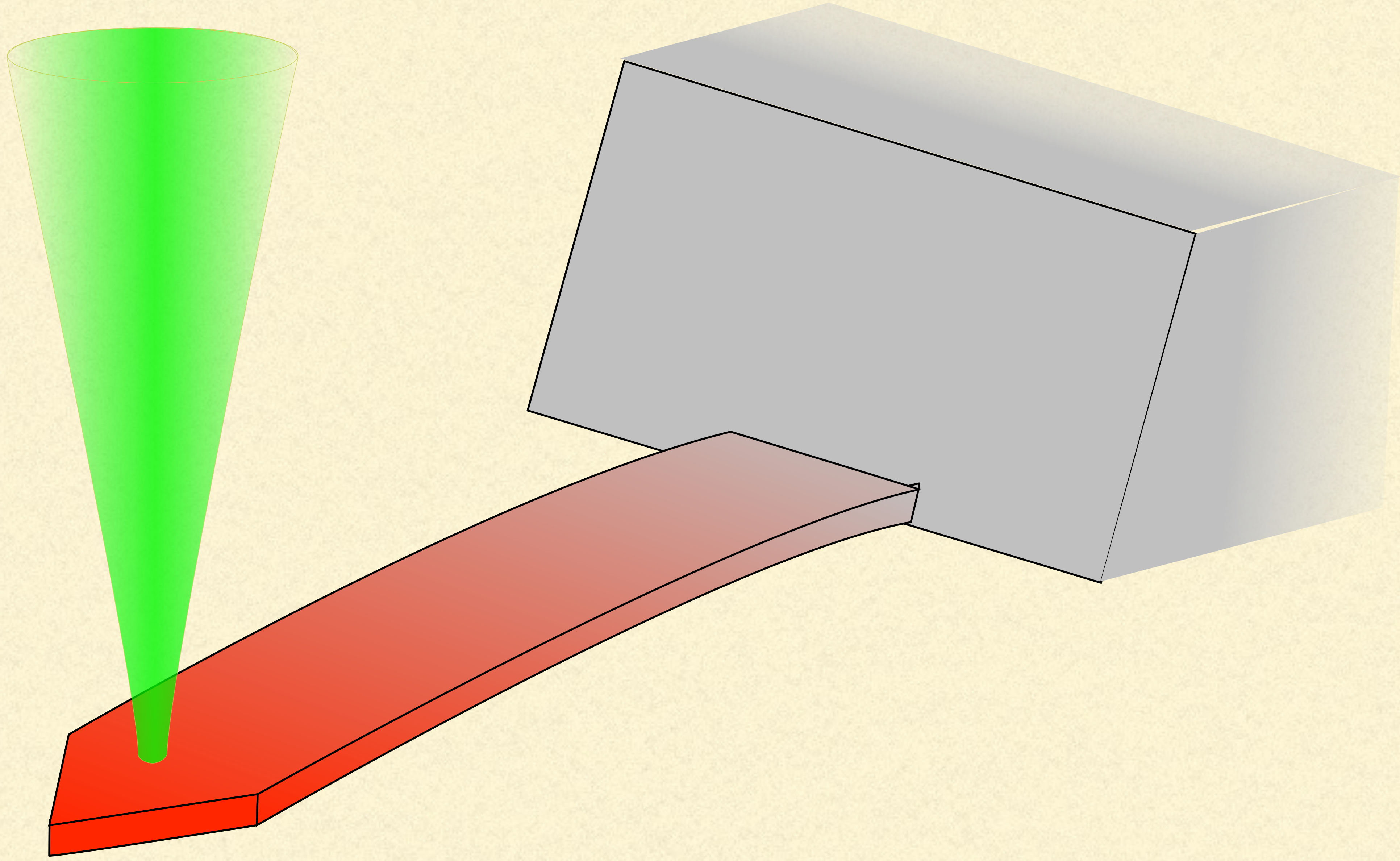
Out of equilibrium?



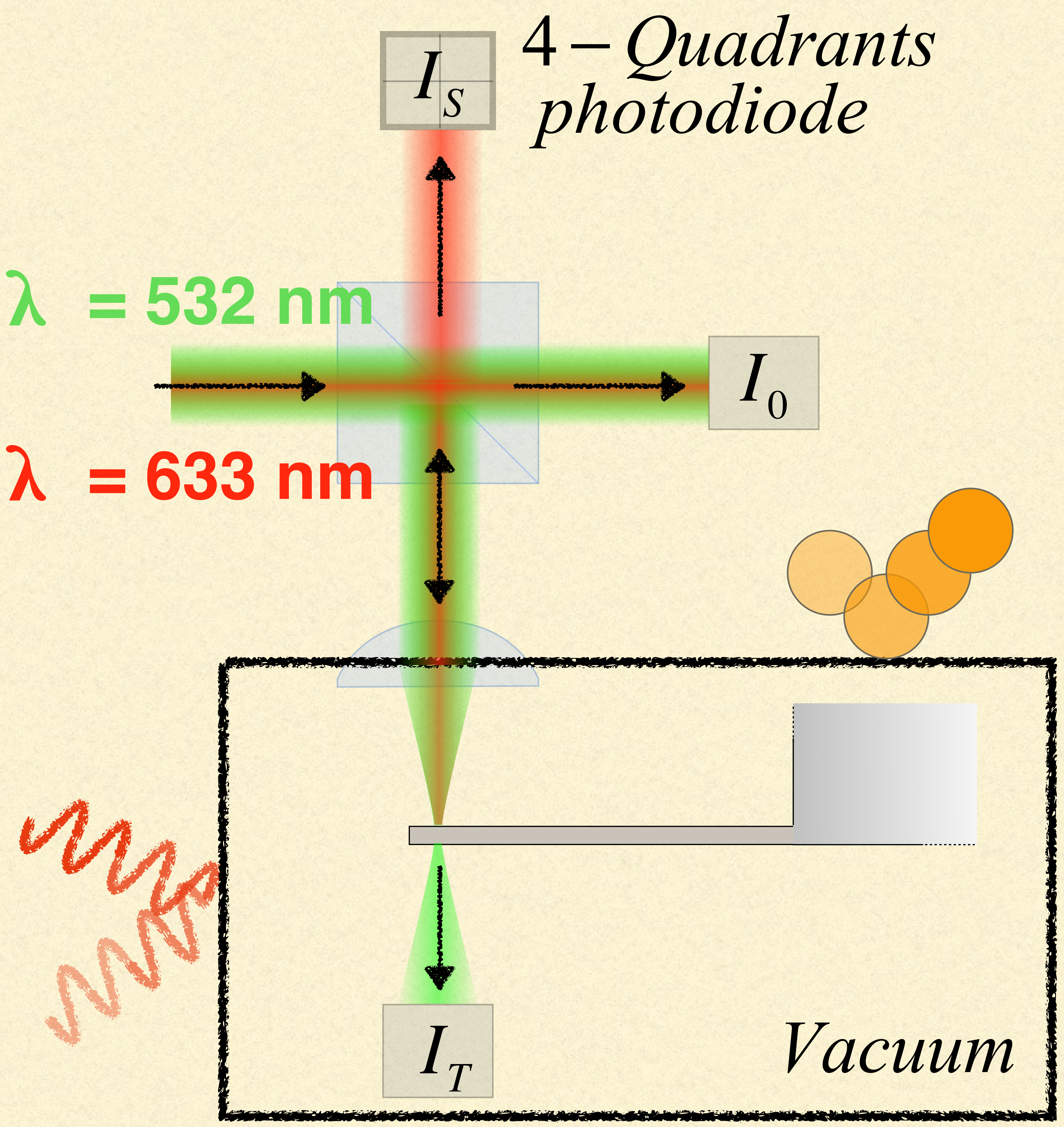
Out of equilibrium Lyon

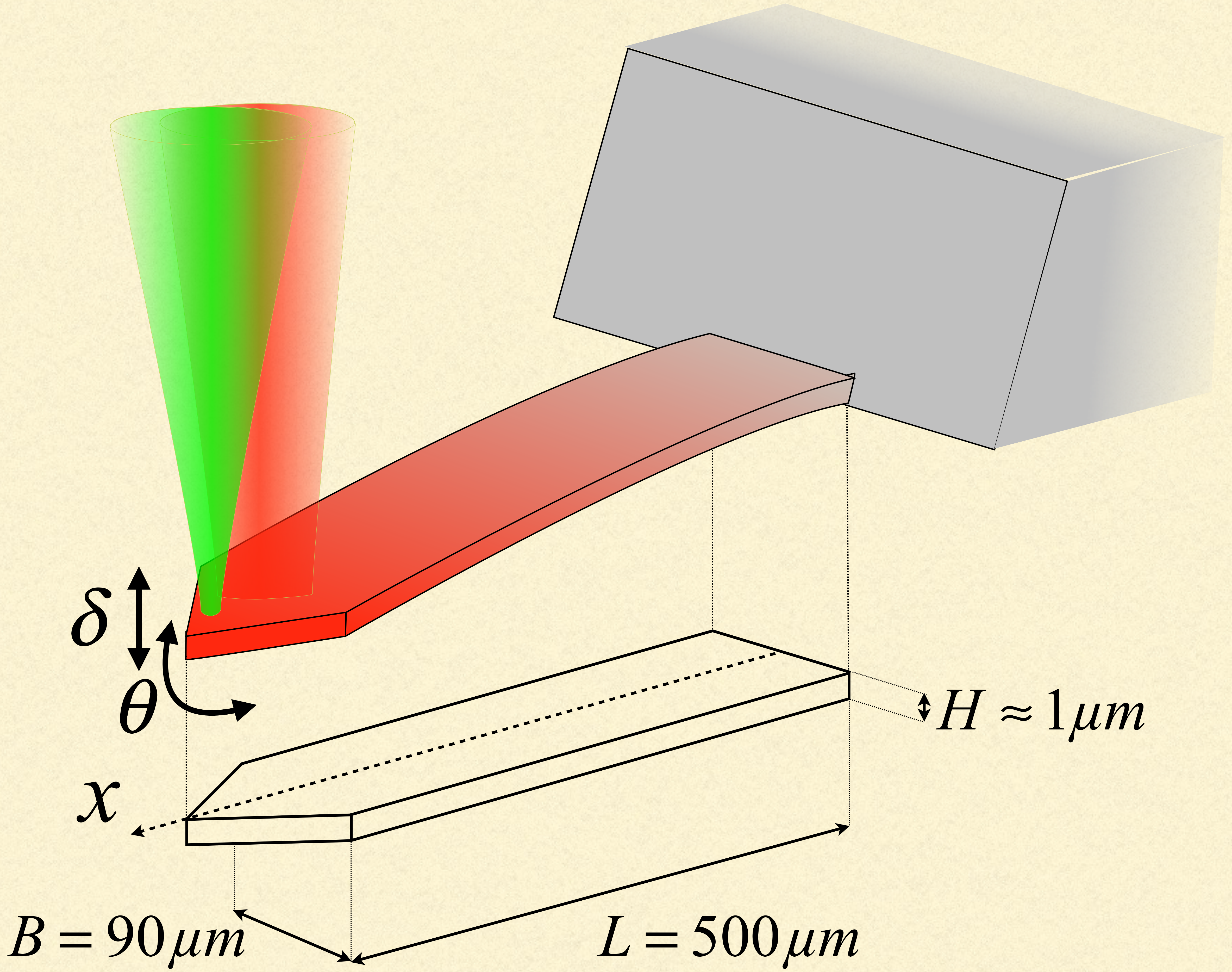


TEST BENCH

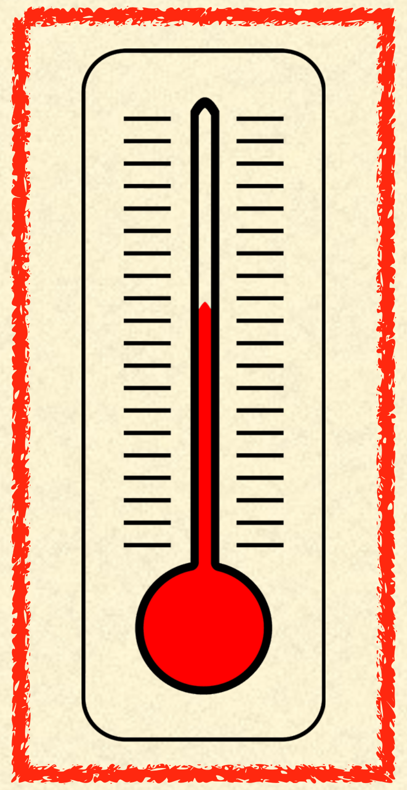


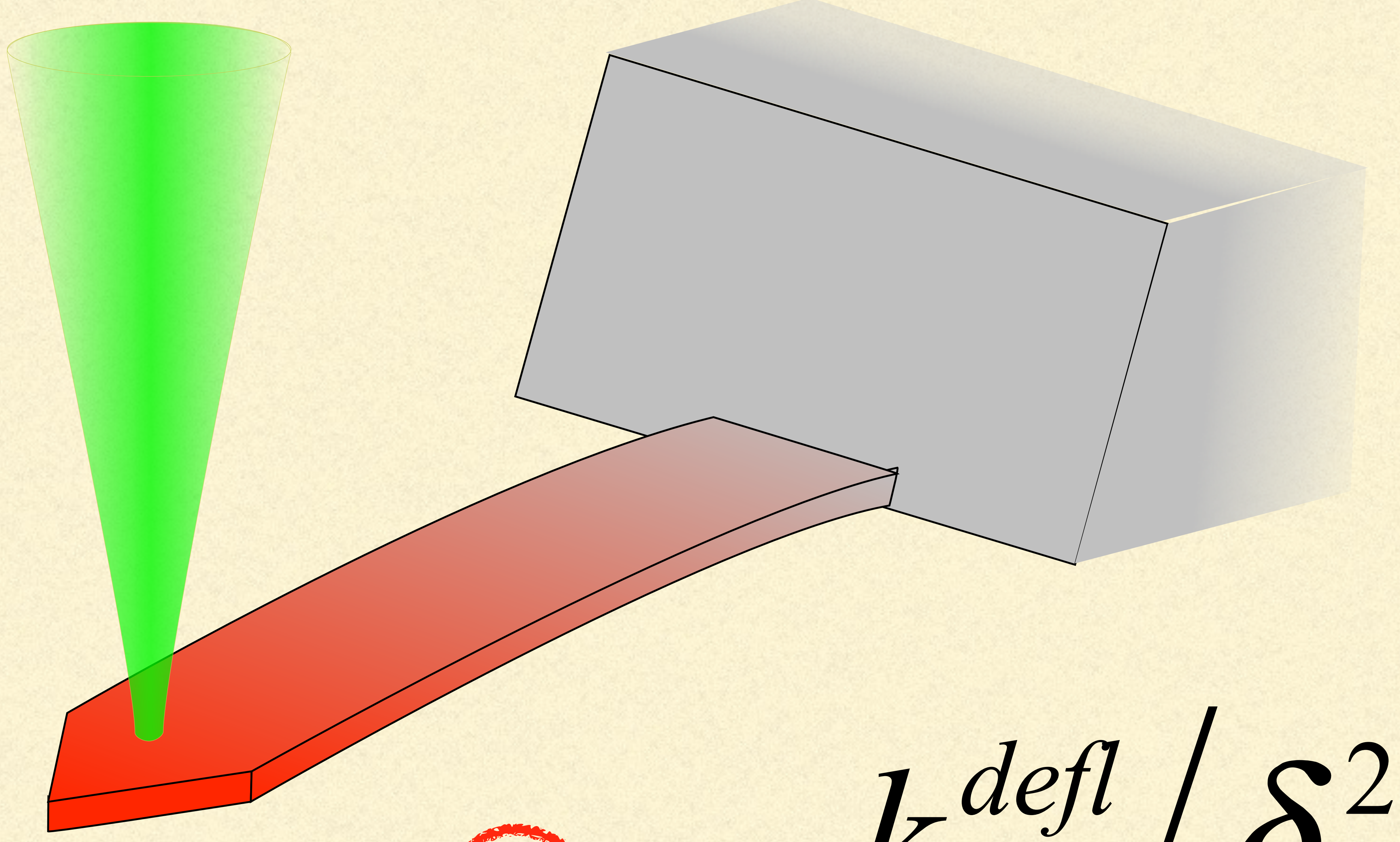
Our experiment

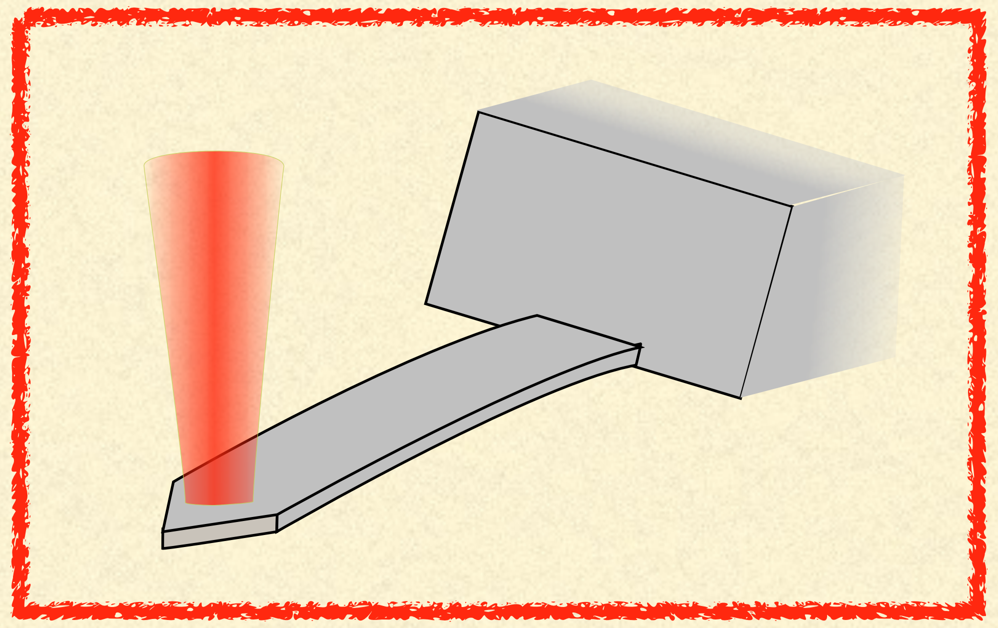




Two ingredients



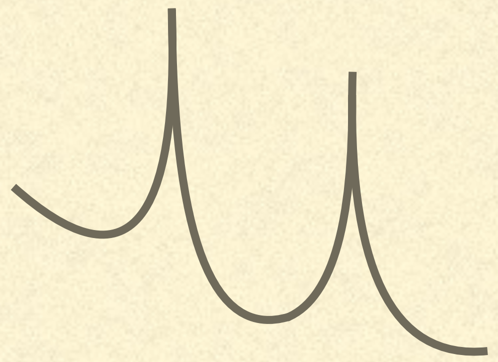


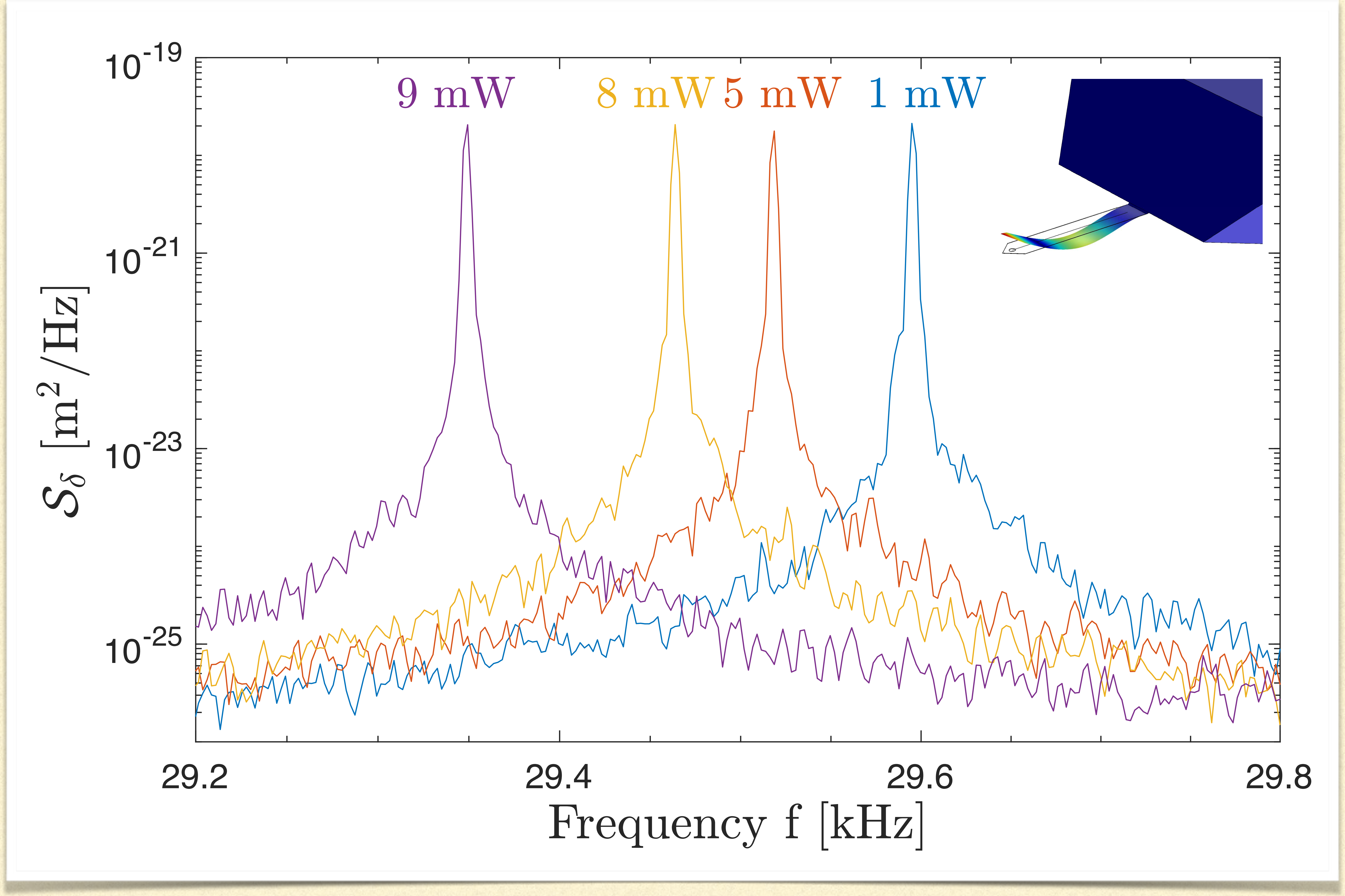


$$\Delta T$$

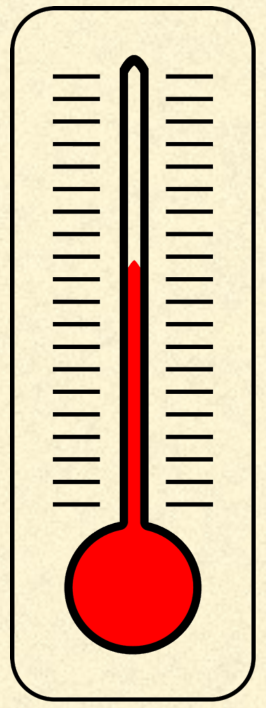
$$\frac{k^{defl}\left\langle \delta^2 \right\rangle}{k_B}$$

Temperature measurement

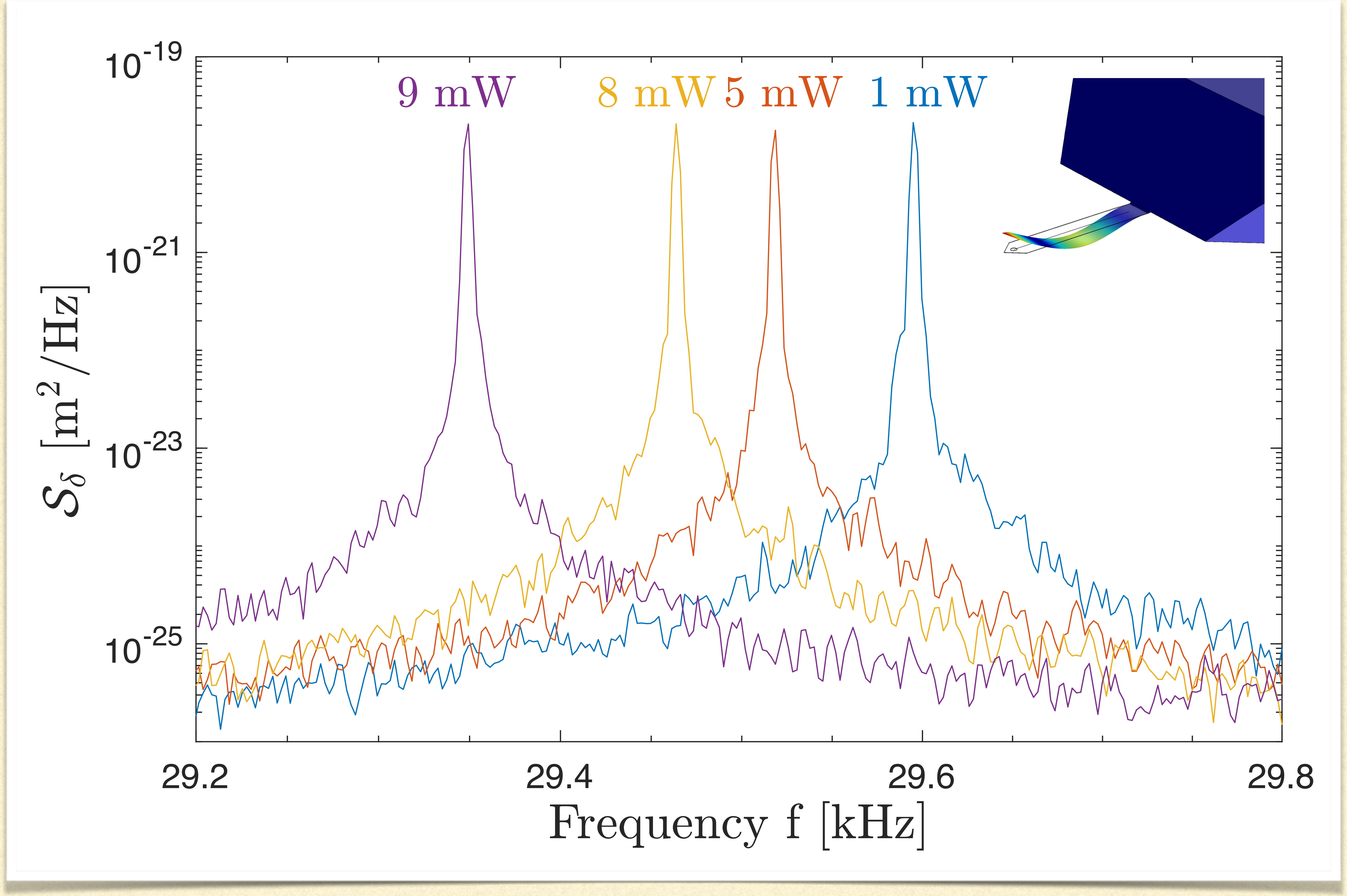




$$\omega_0 = \sqrt{\frac{k}{m}} \quad \& \quad k \propto T$$



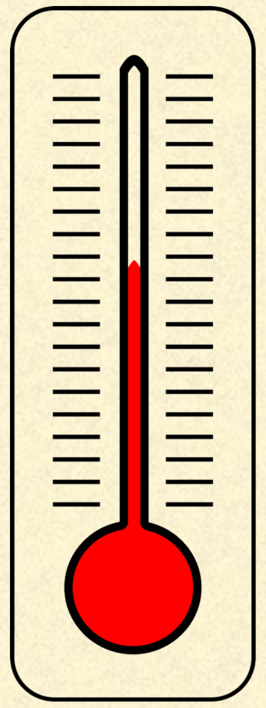
Temperature measurement



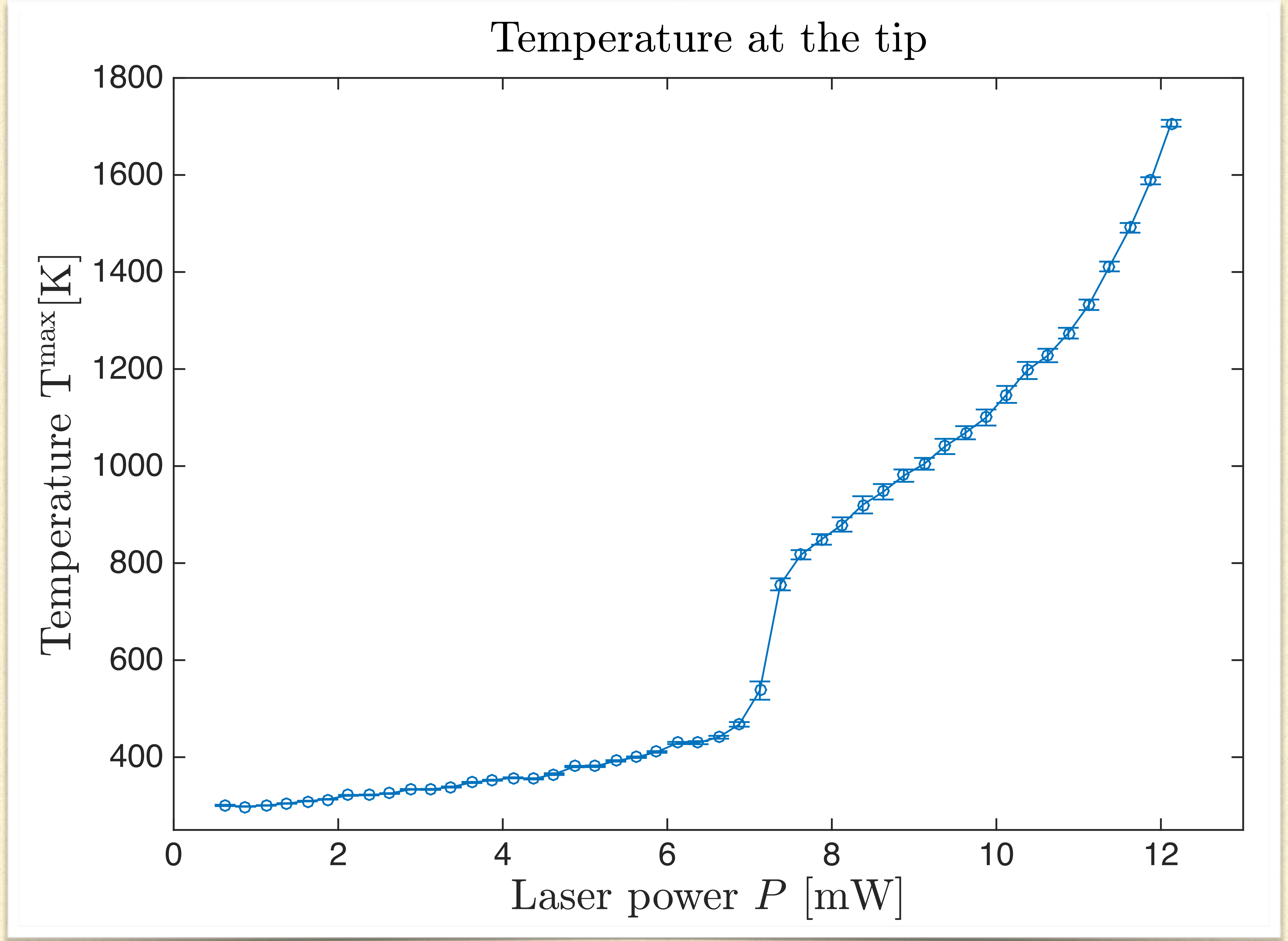
$$\omega_0 = \sqrt{\frac{k}{m}} \quad \& \quad k \propto T$$

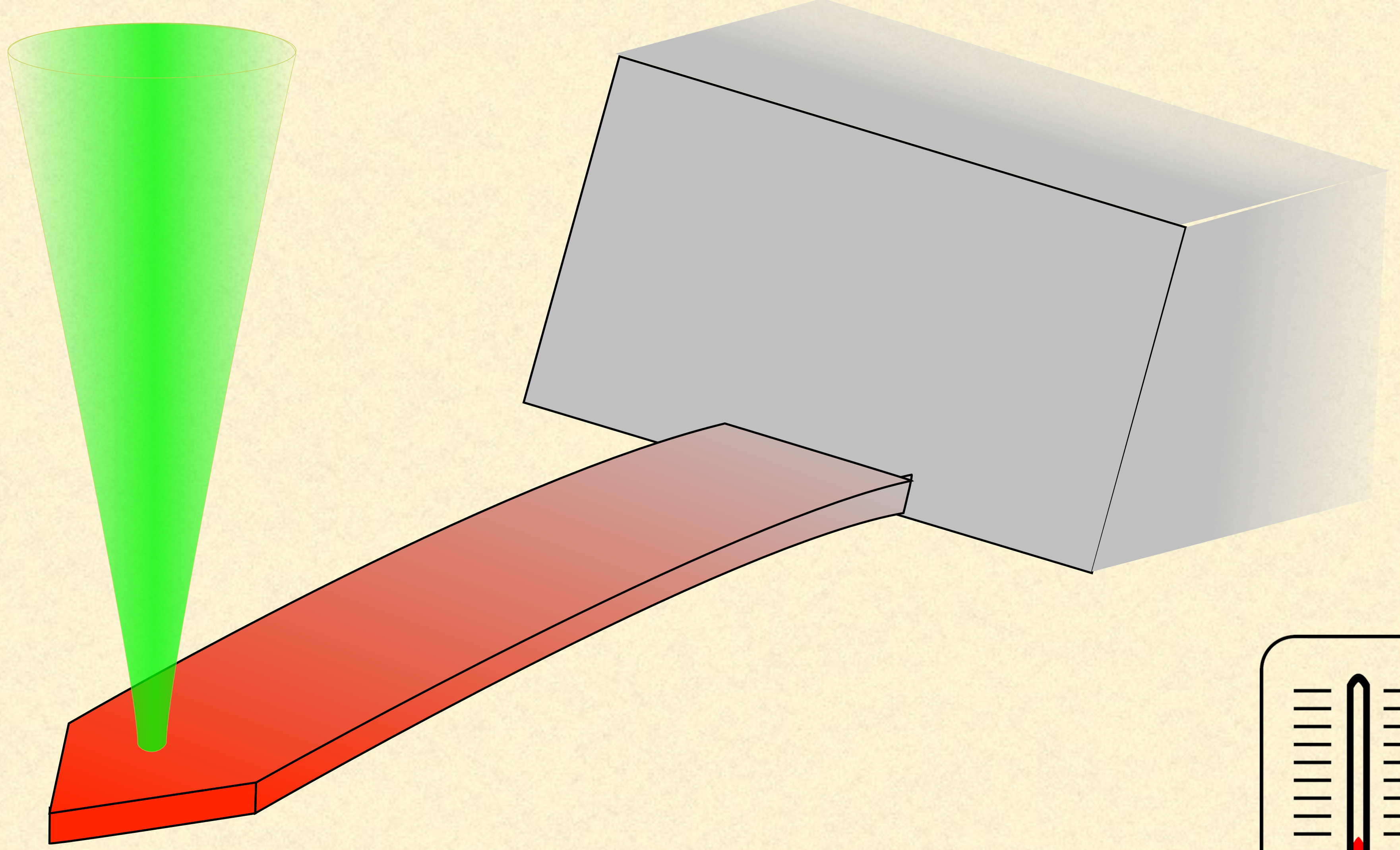
$$\frac{\Delta\omega_n}{\omega_0} \propto \Delta T_n$$

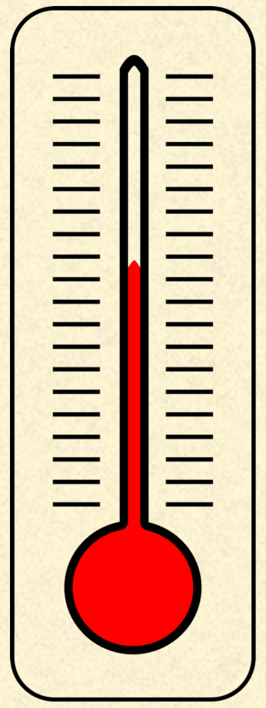
$$\Delta T_n \left(\frac{\Delta\omega_n}{\omega_0} \right)$$



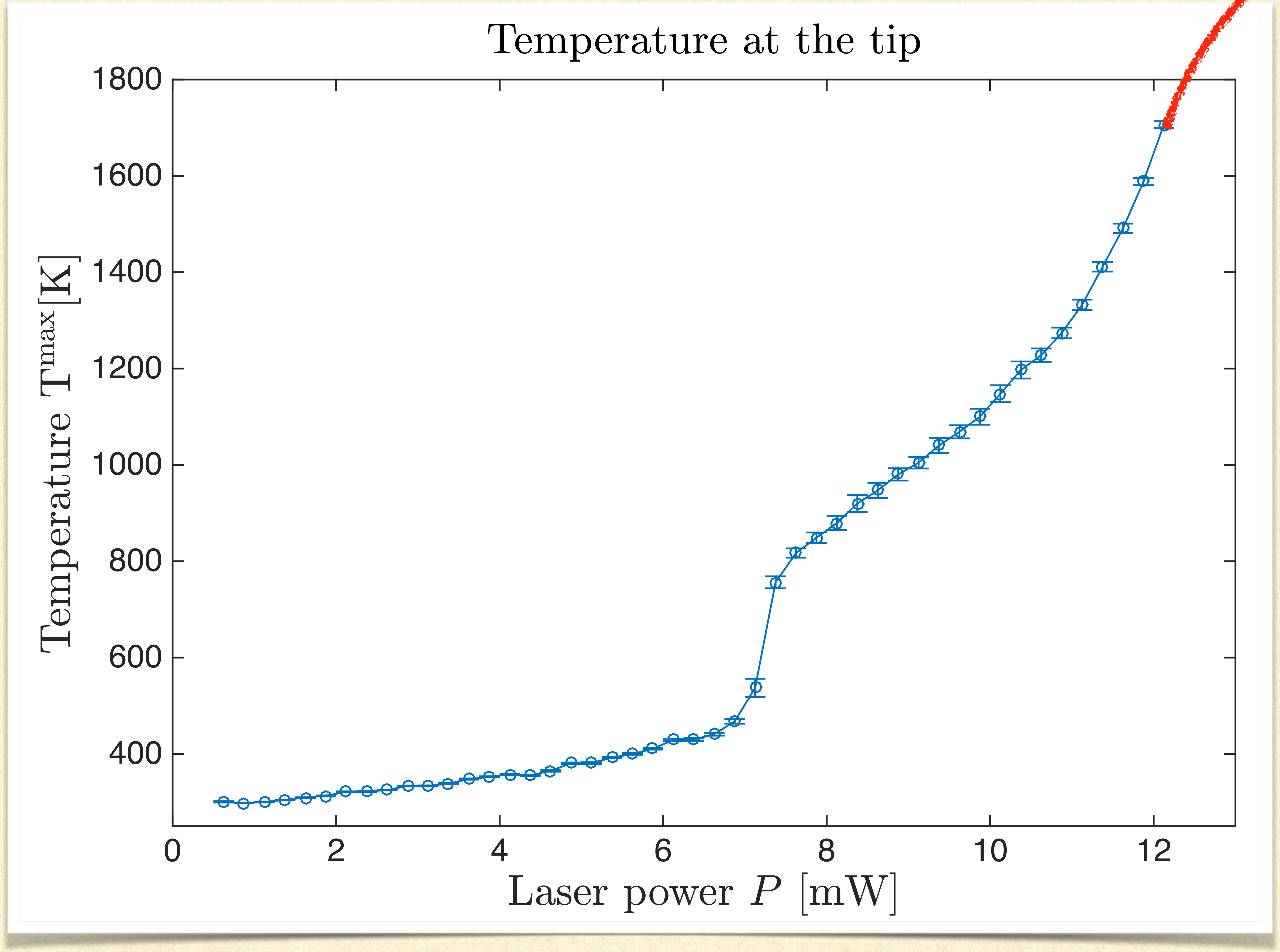
Results: T^{max}

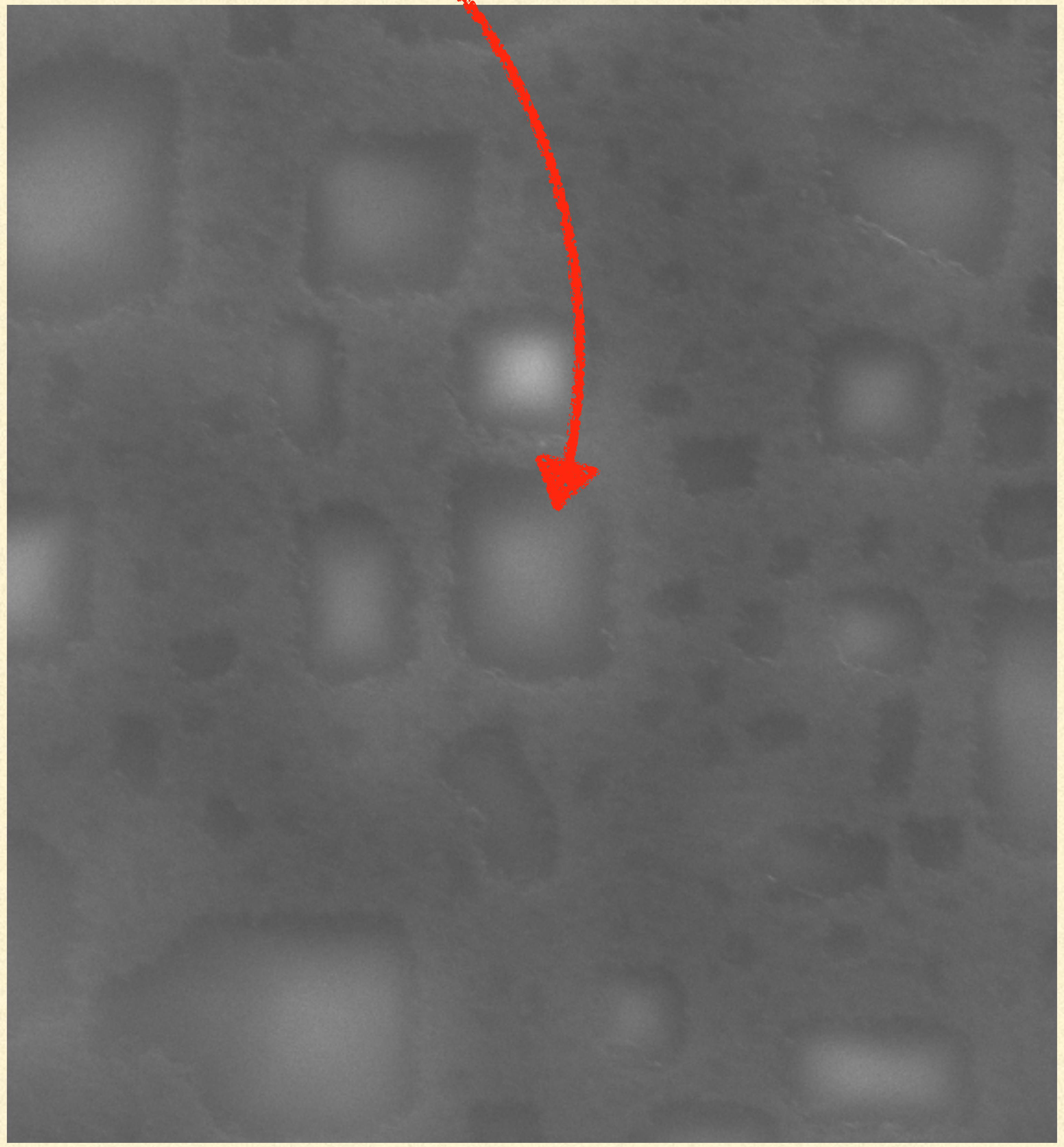


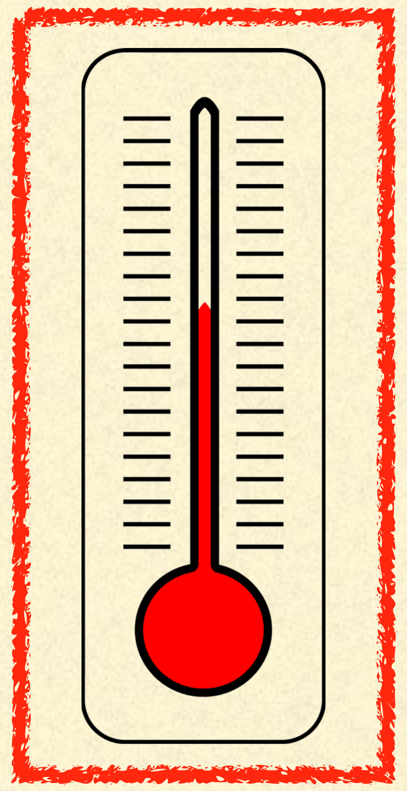




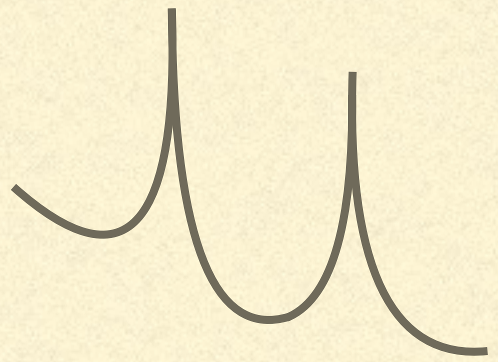
Results: fusion

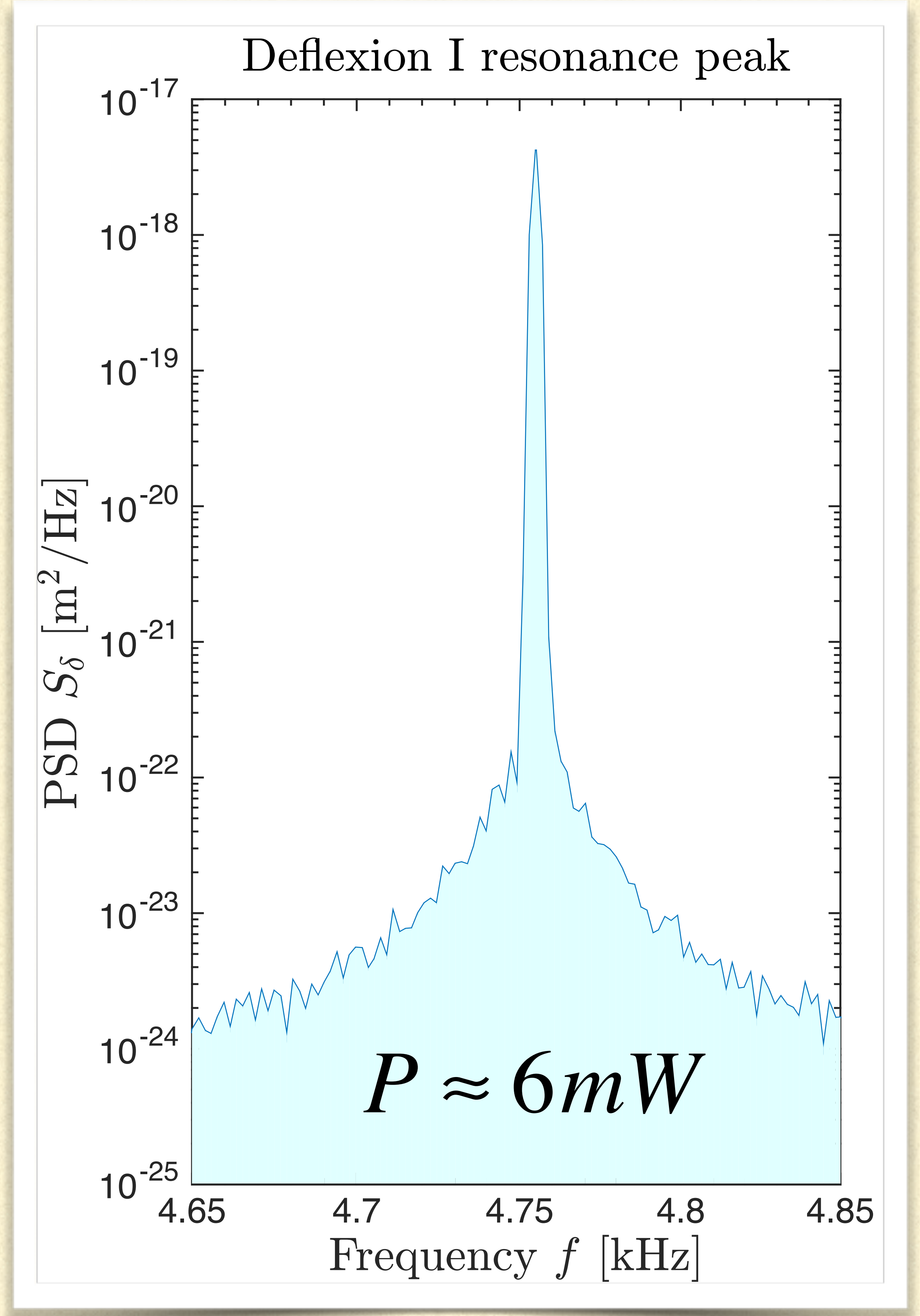


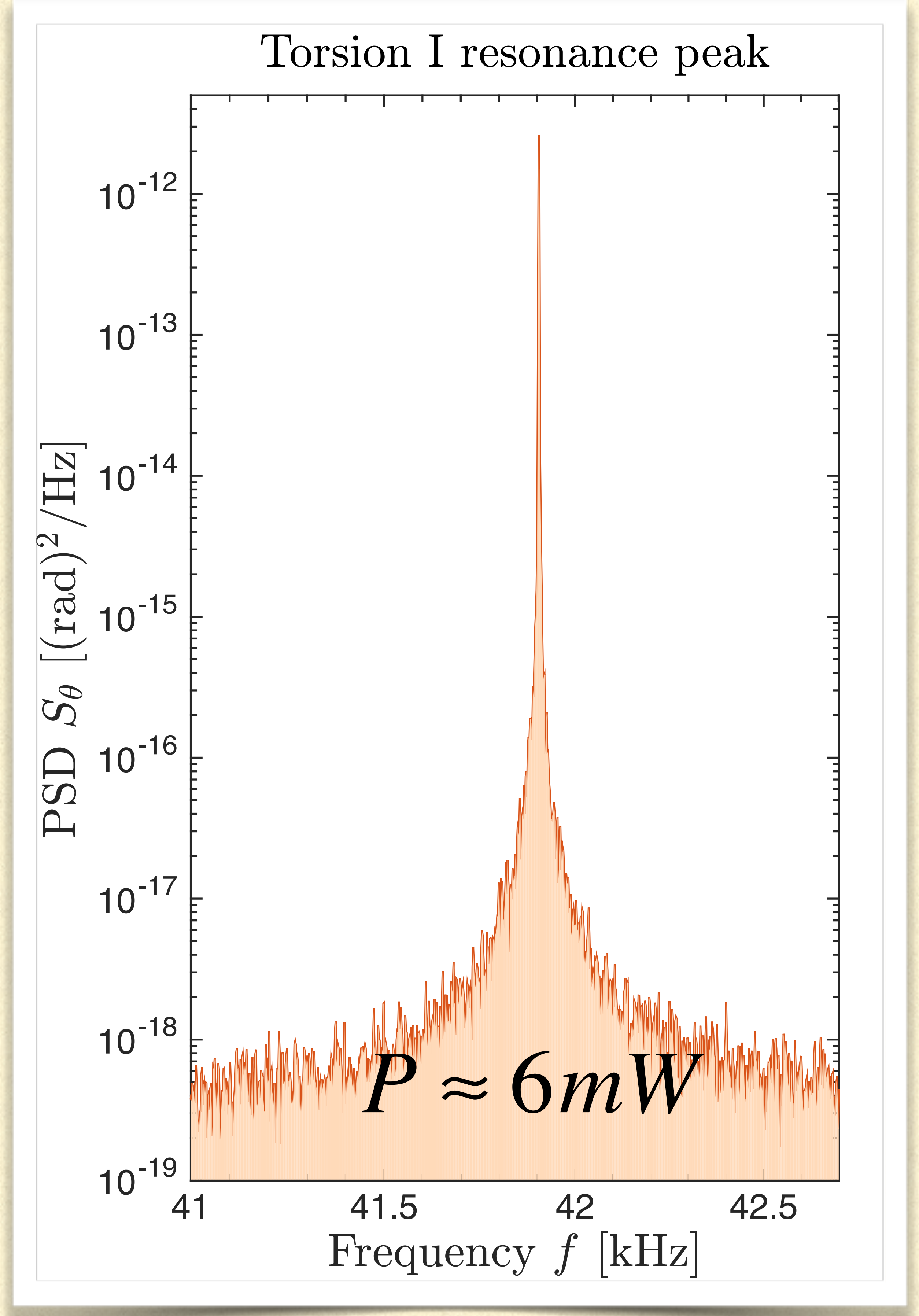


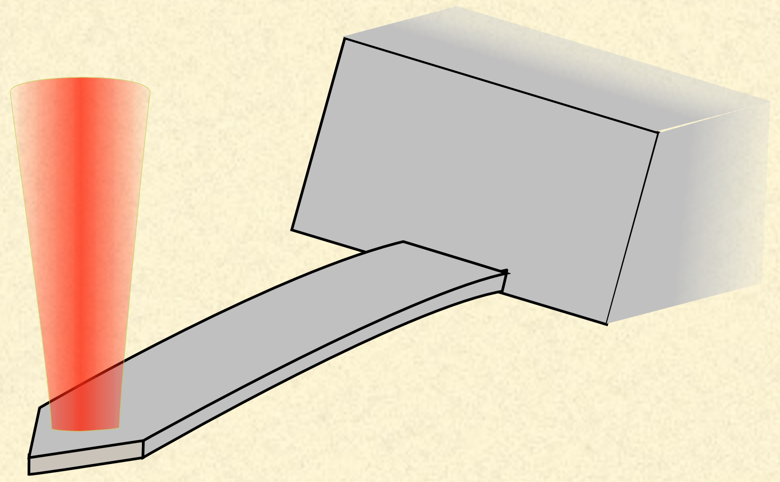


Fluctuation temperature

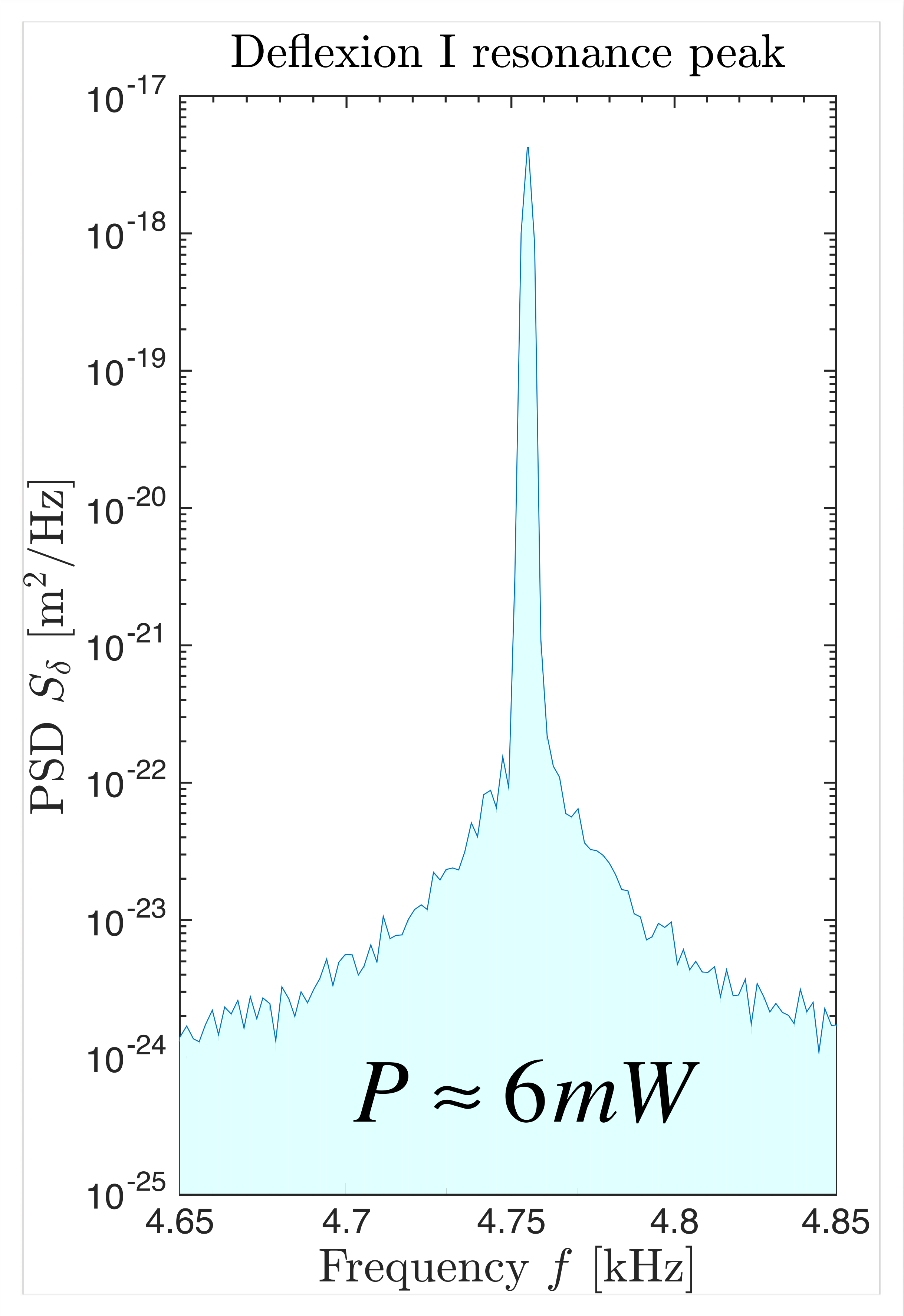




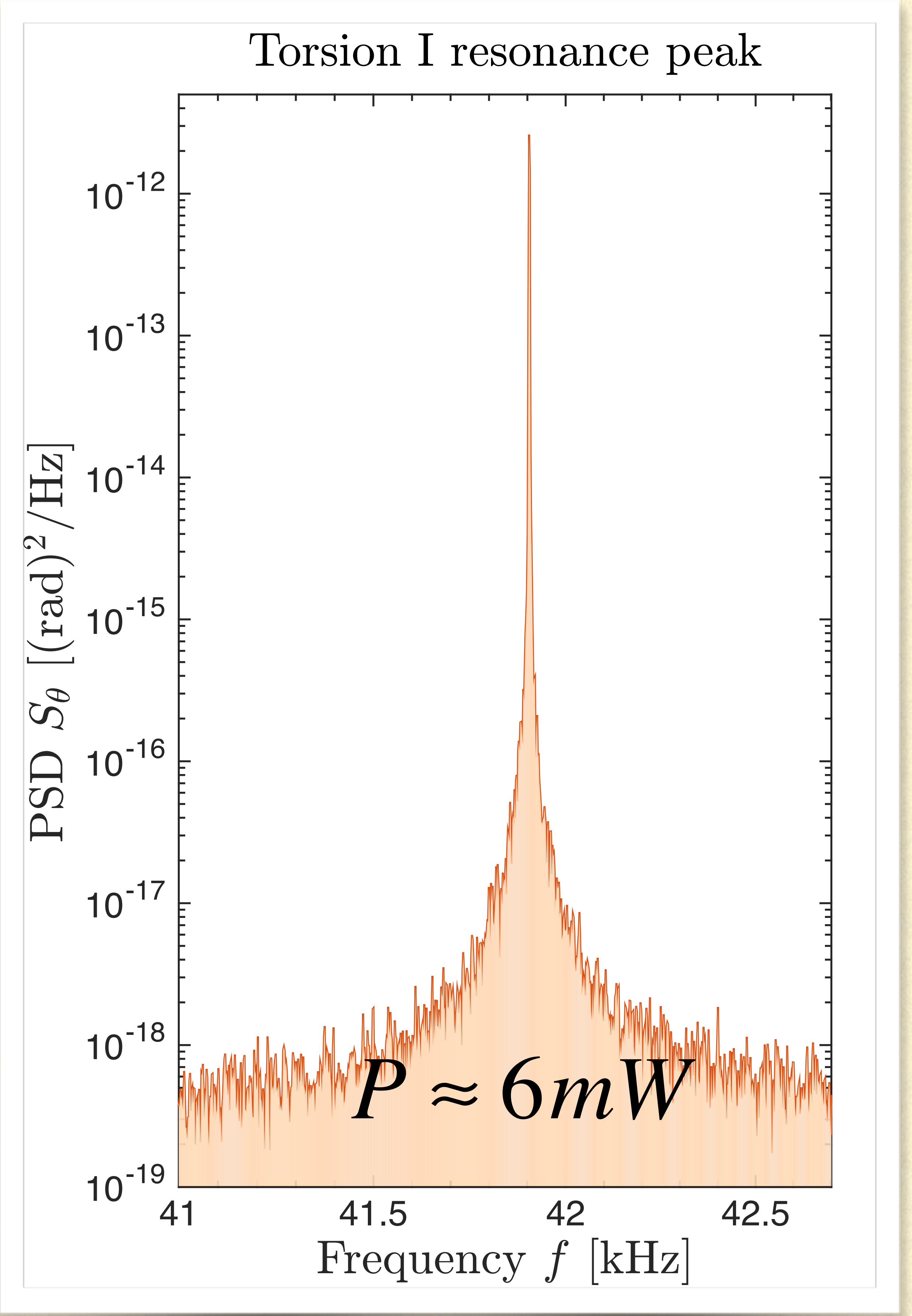




Fluctuation temperature: T^{eff}



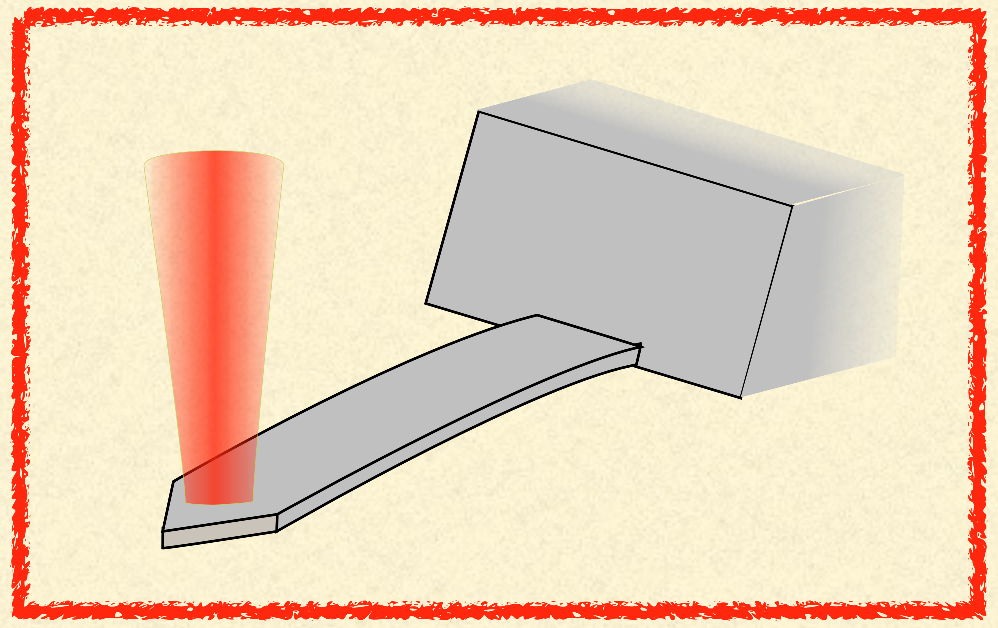
$$\langle \delta_n^2 \rangle = \int_{f_n \pm \Delta f} df \cdot S_\delta(f)$$



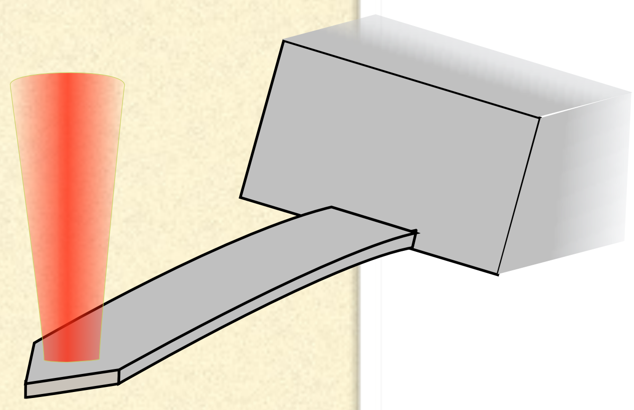
$$\langle \theta_n^2 \rangle = \int_{f_n \pm \Delta f} df \cdot S_\theta(f)$$

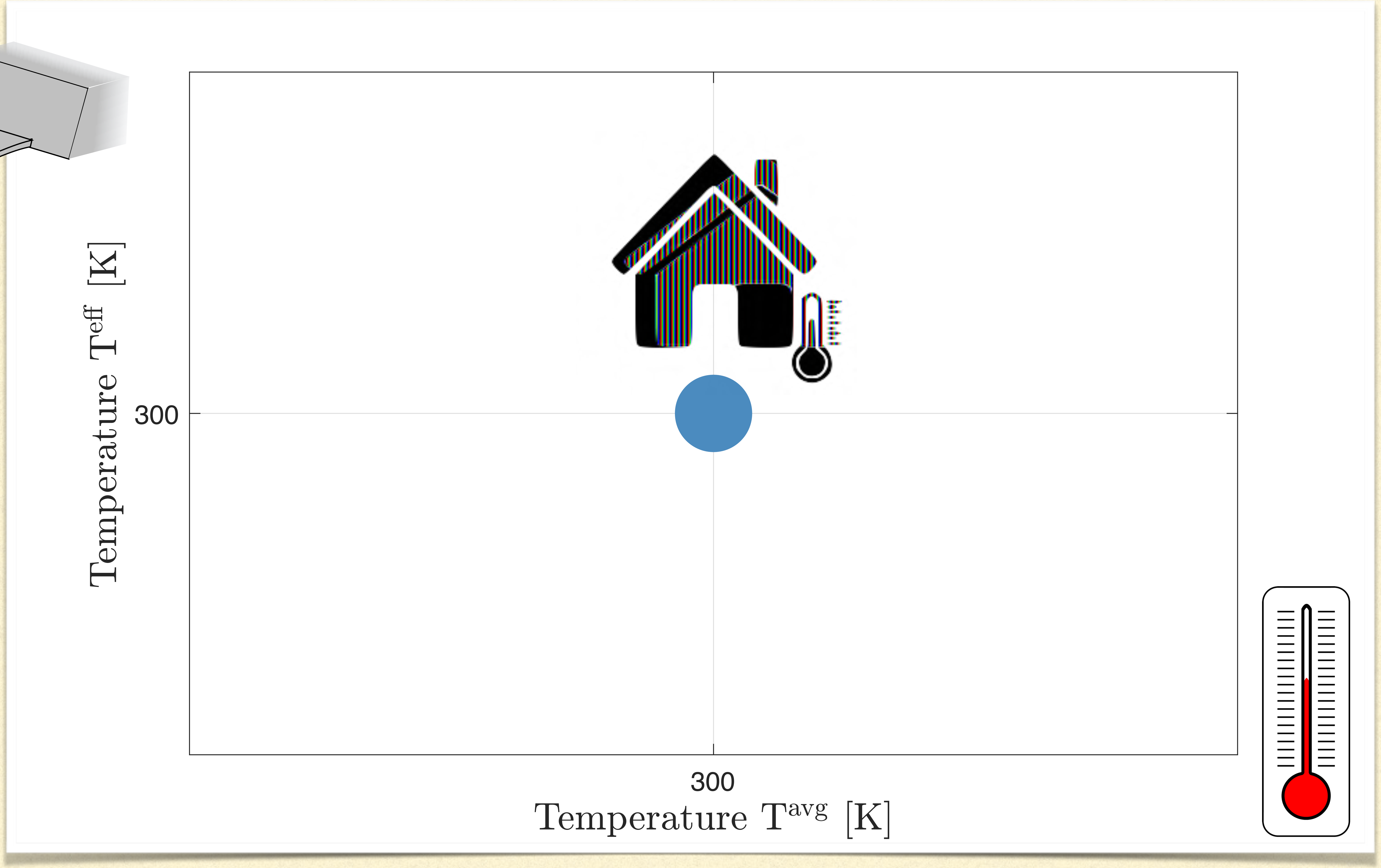
$$T_n^{eff} = \frac{k_n^{defl} \langle \delta_n^2 \rangle}{k_B}$$

$$T_n^{eff} = \frac{k_n^{tors} \langle \theta_n^2 \rangle}{k_B}$$



Digression to equilibrium





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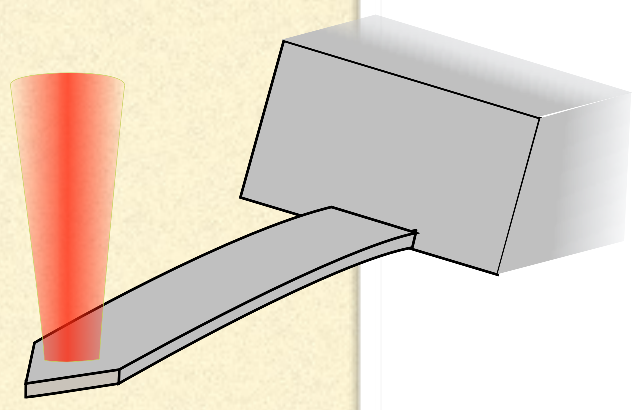
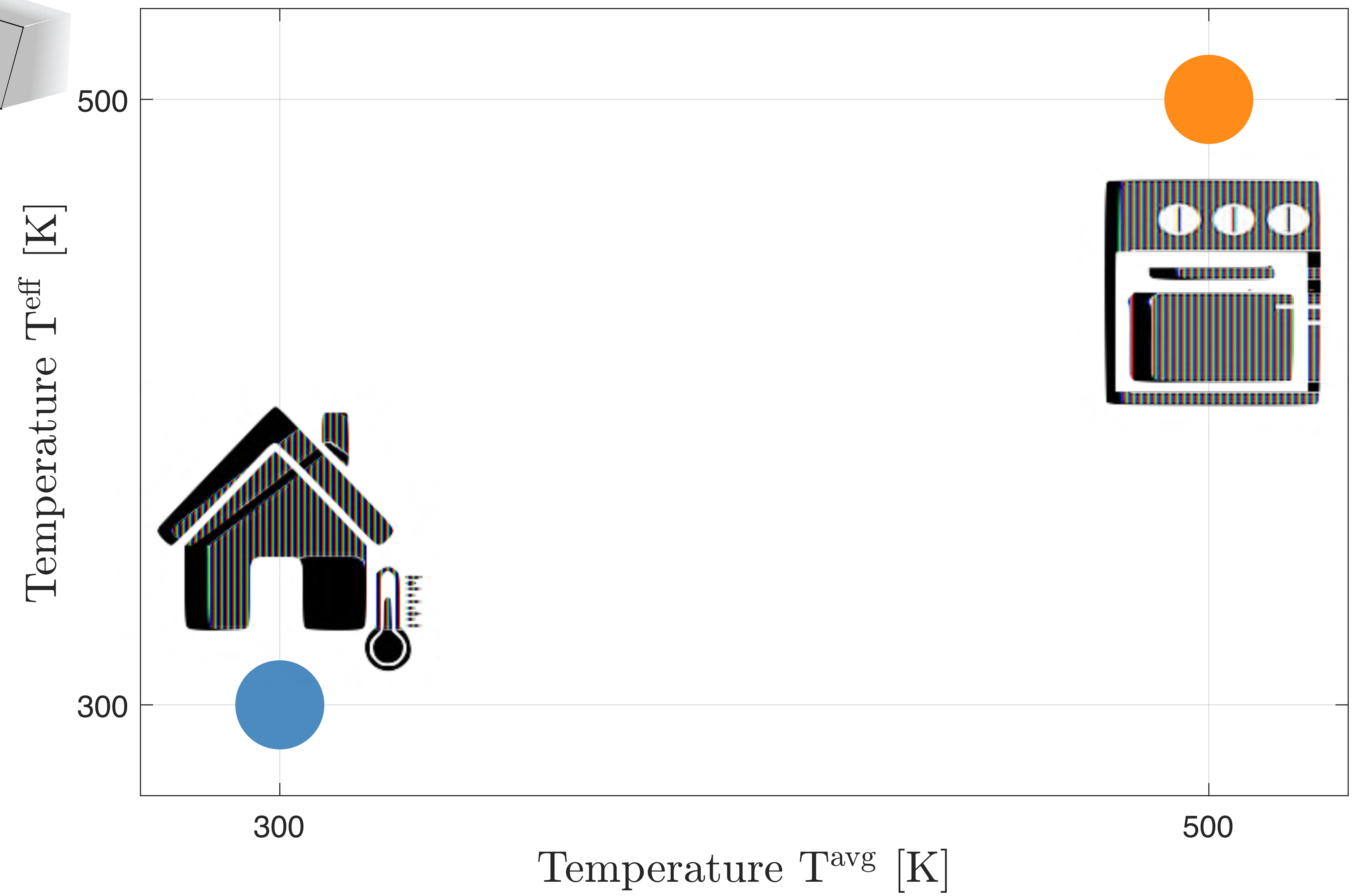
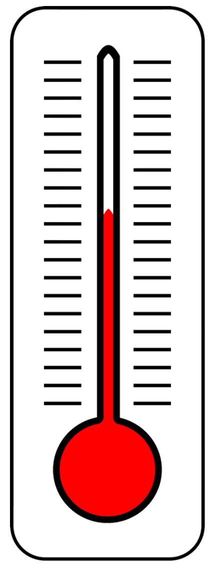
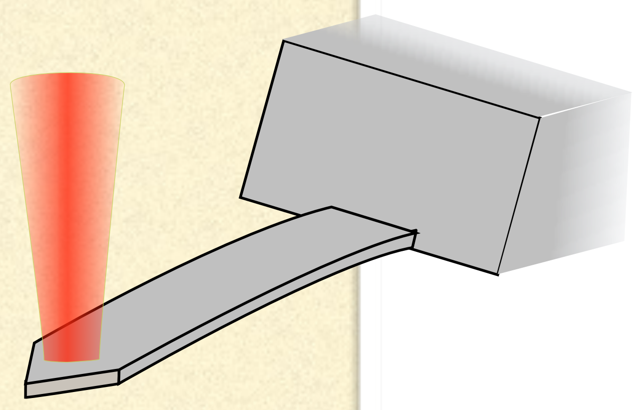
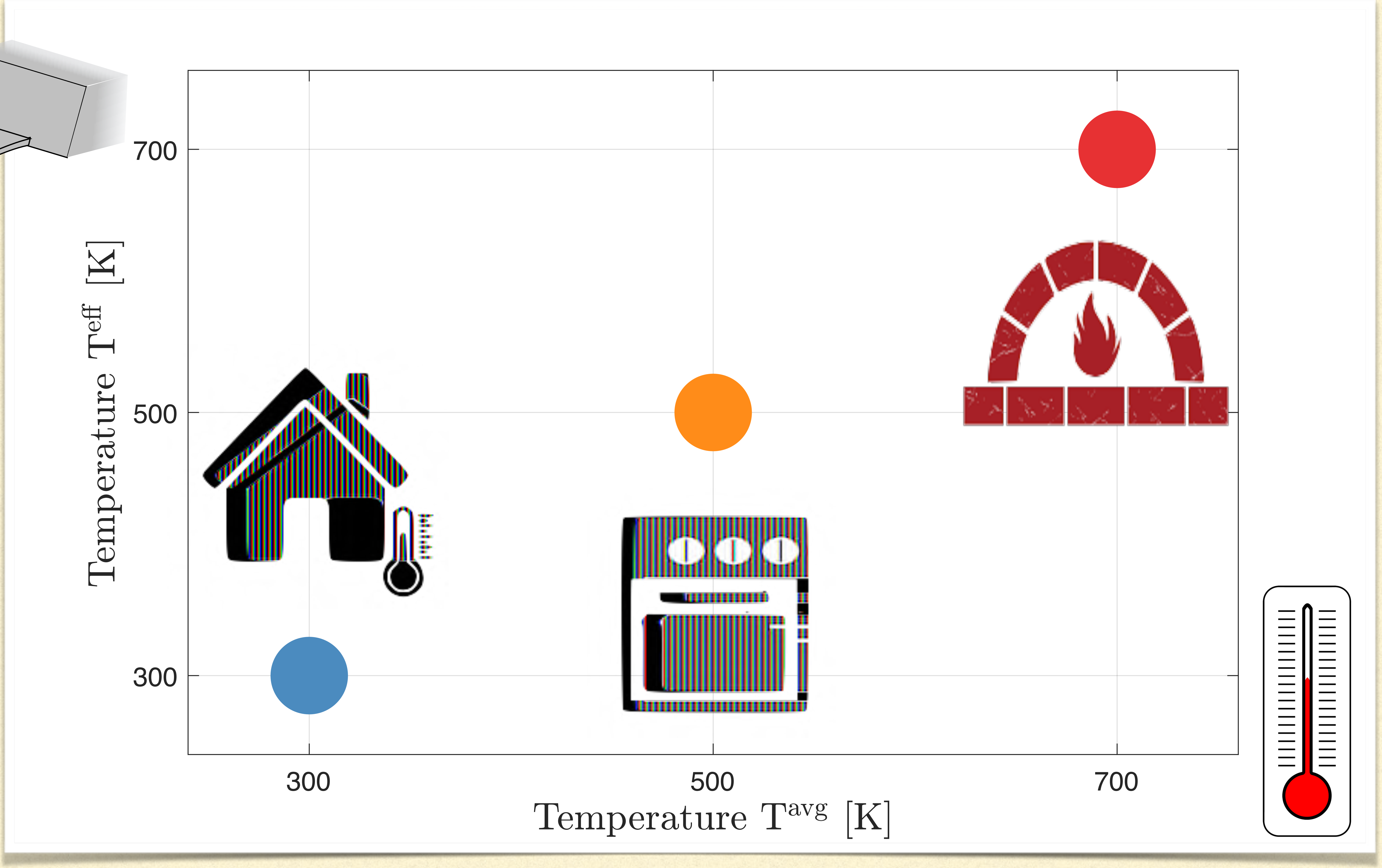




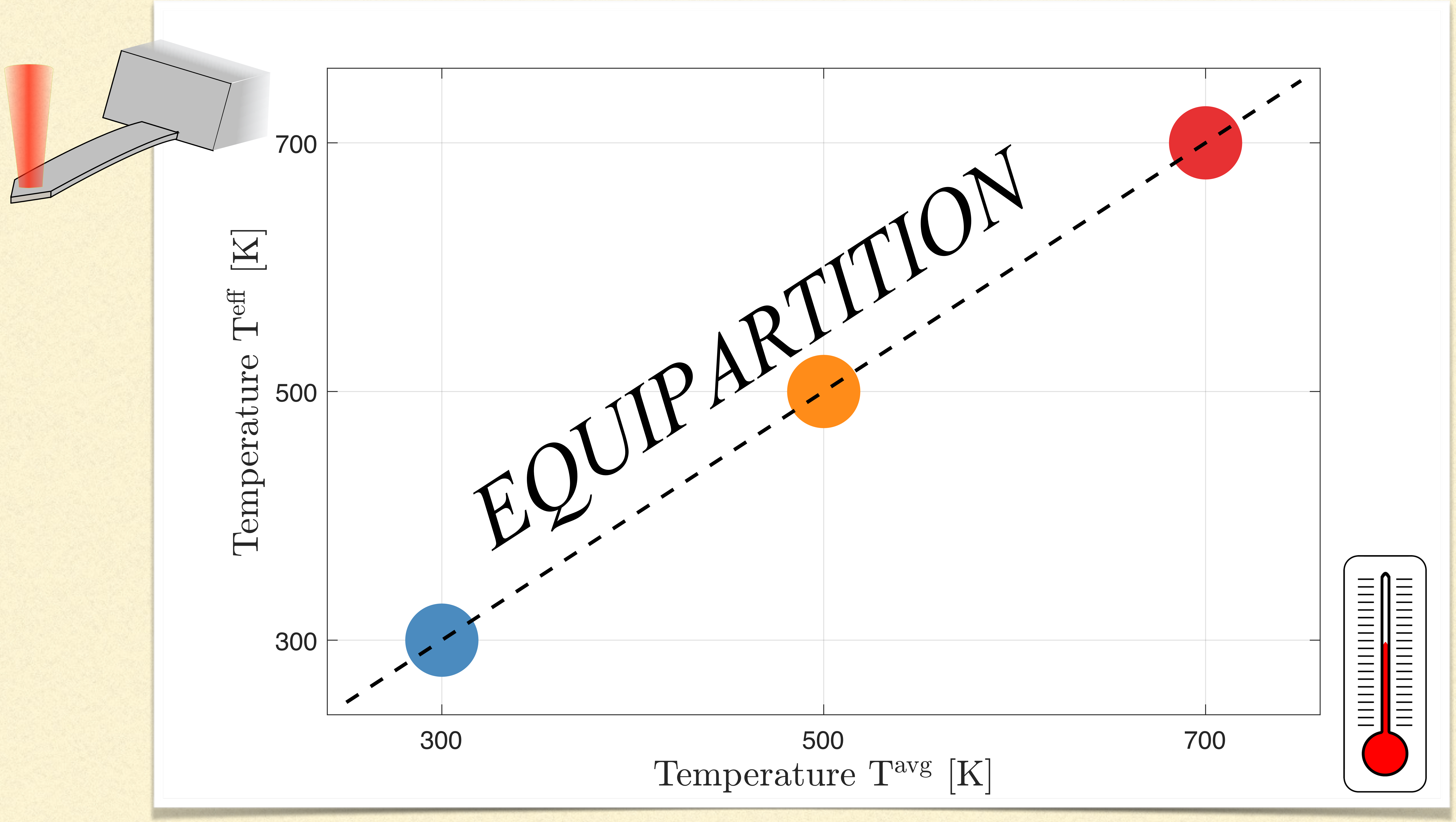


Digression to equilibrium



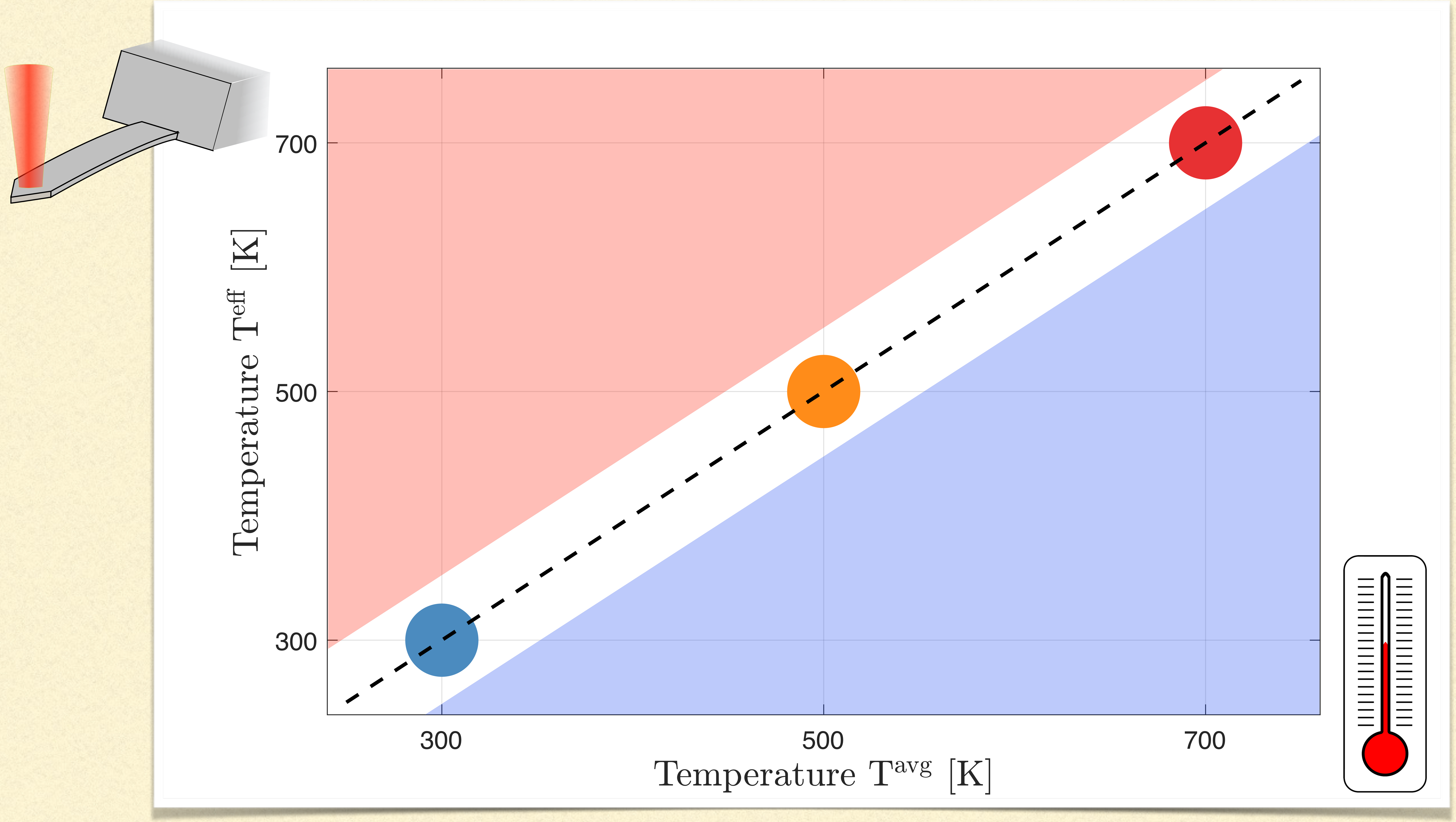


Digression to equilibrium



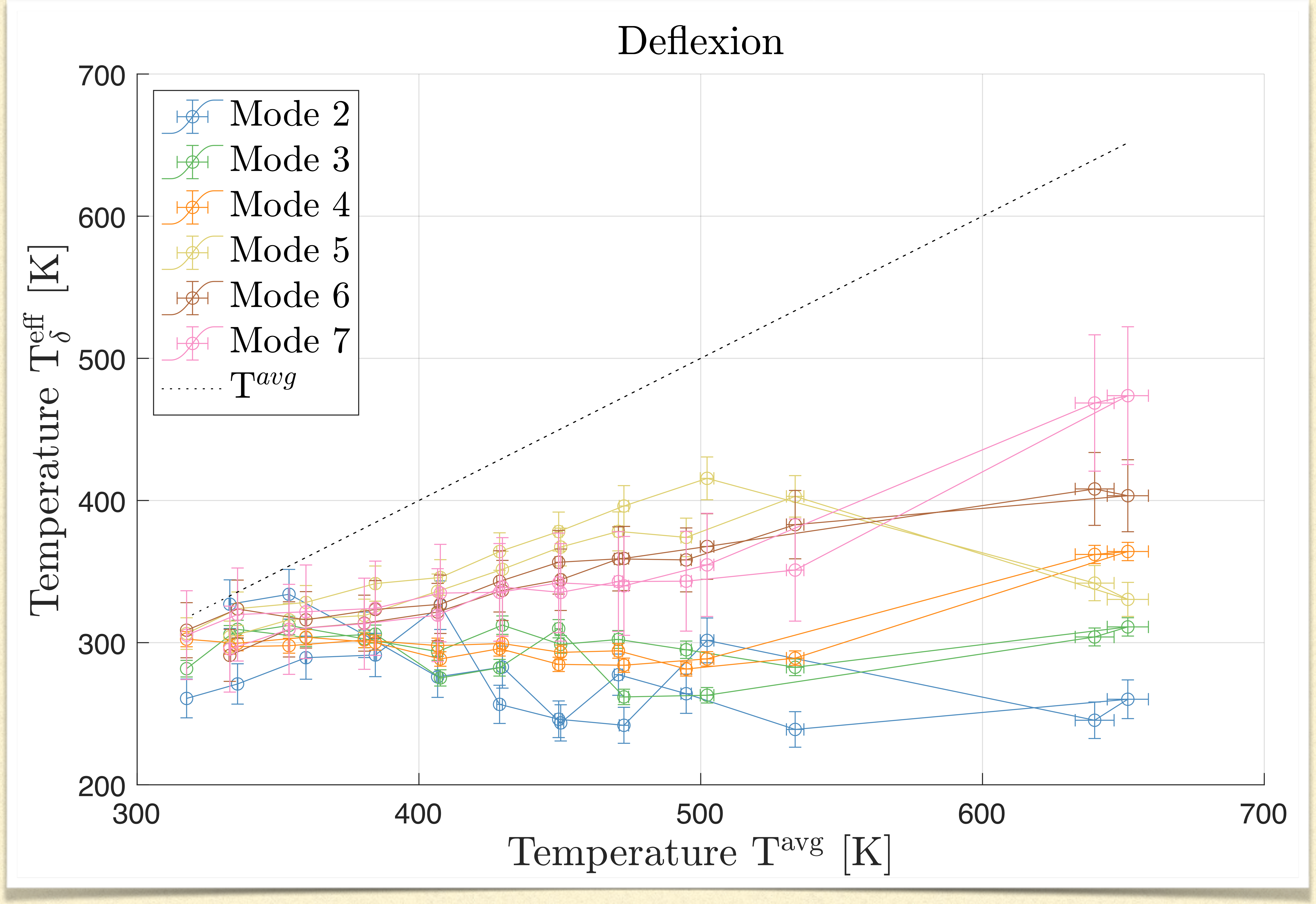
EQ

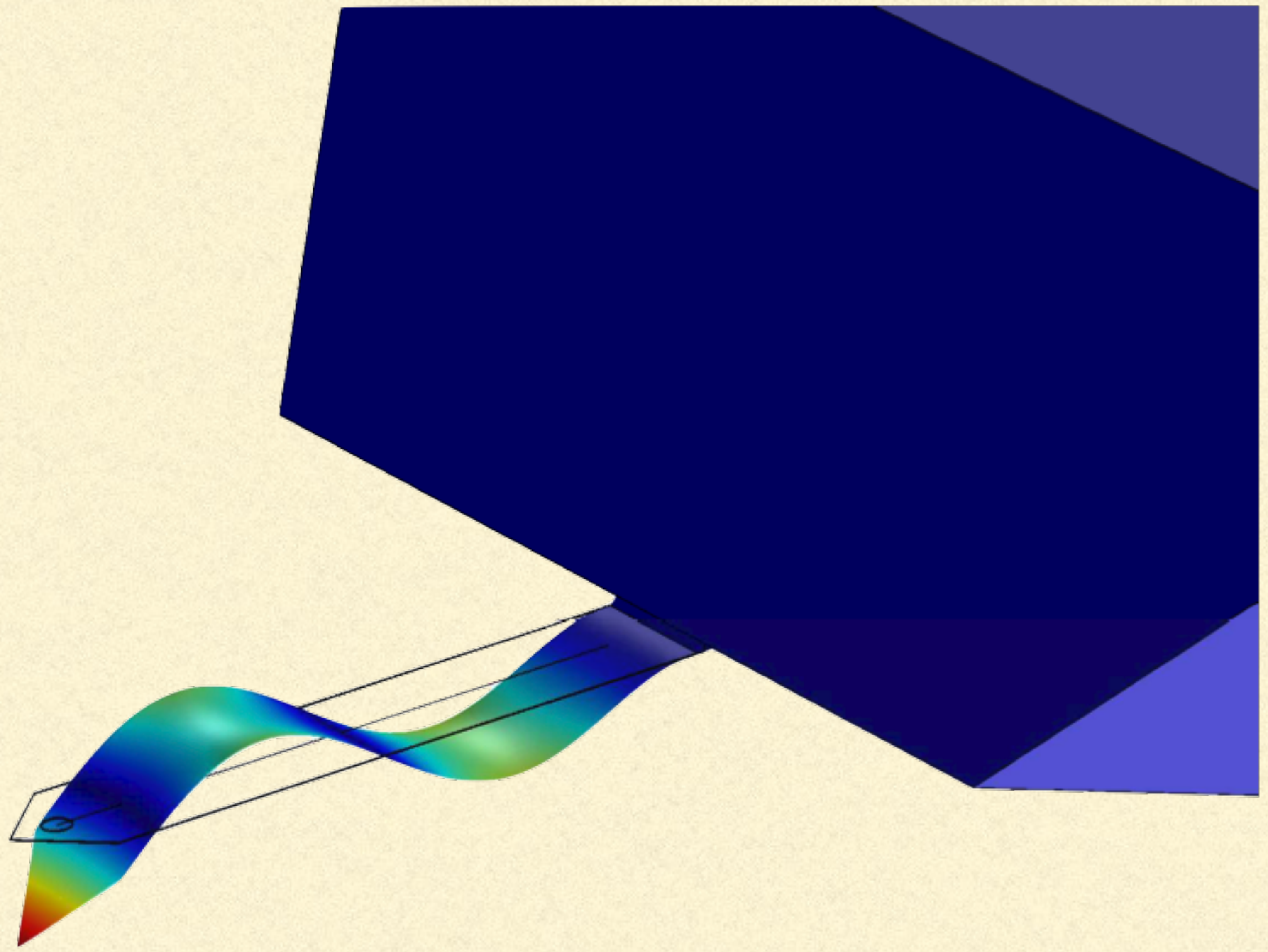
Digression to equilibrium



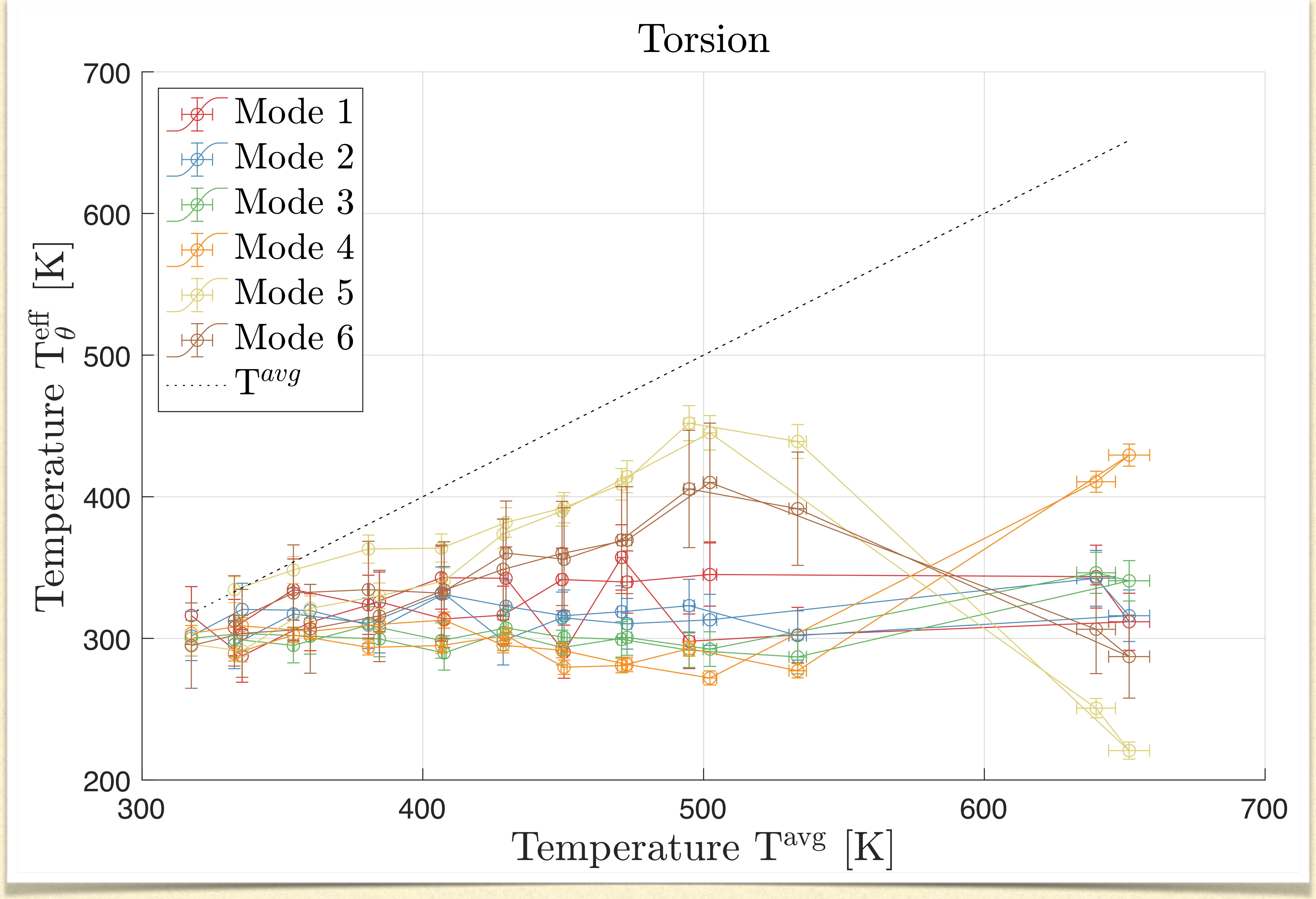
NESS?

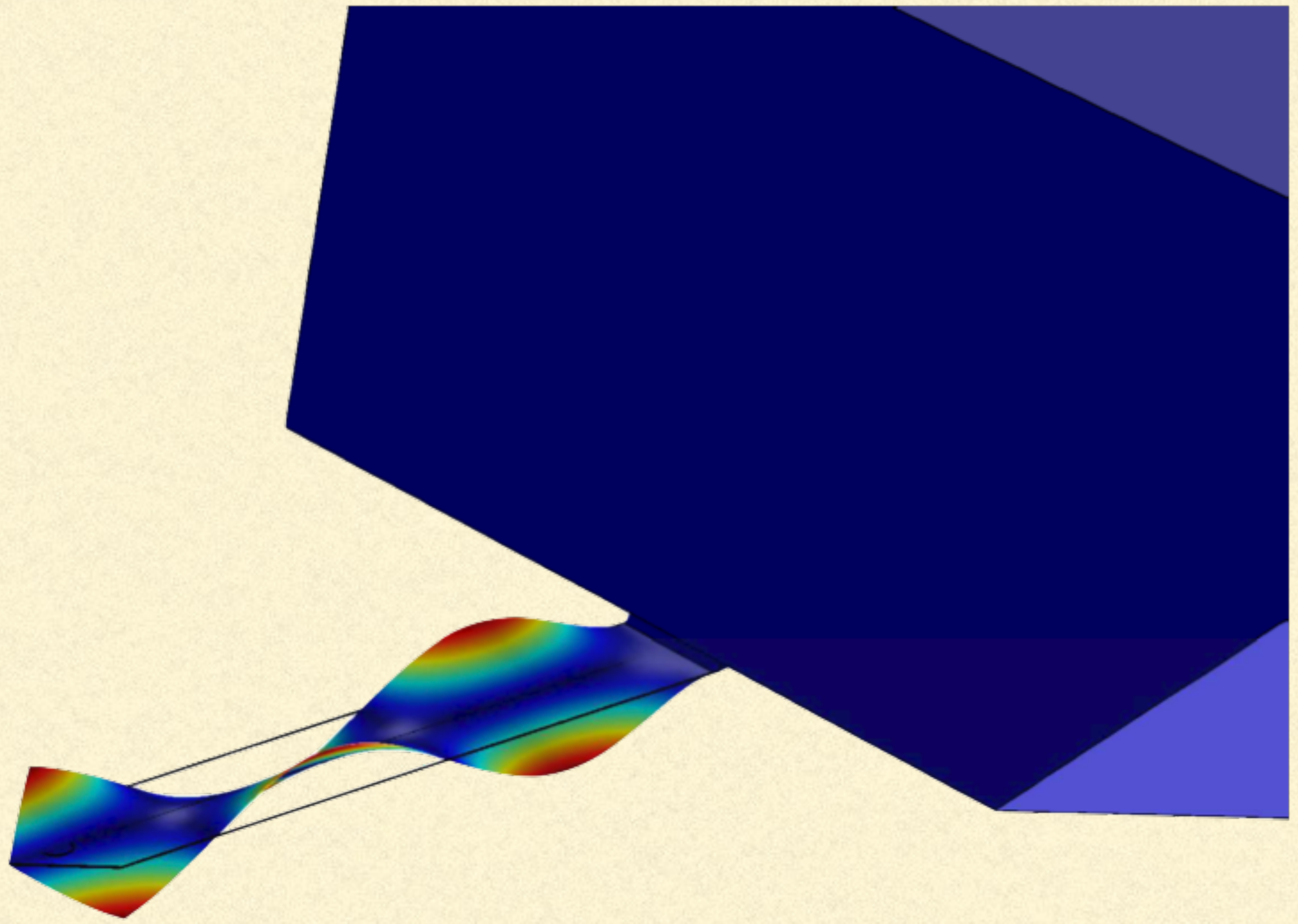
Measurements



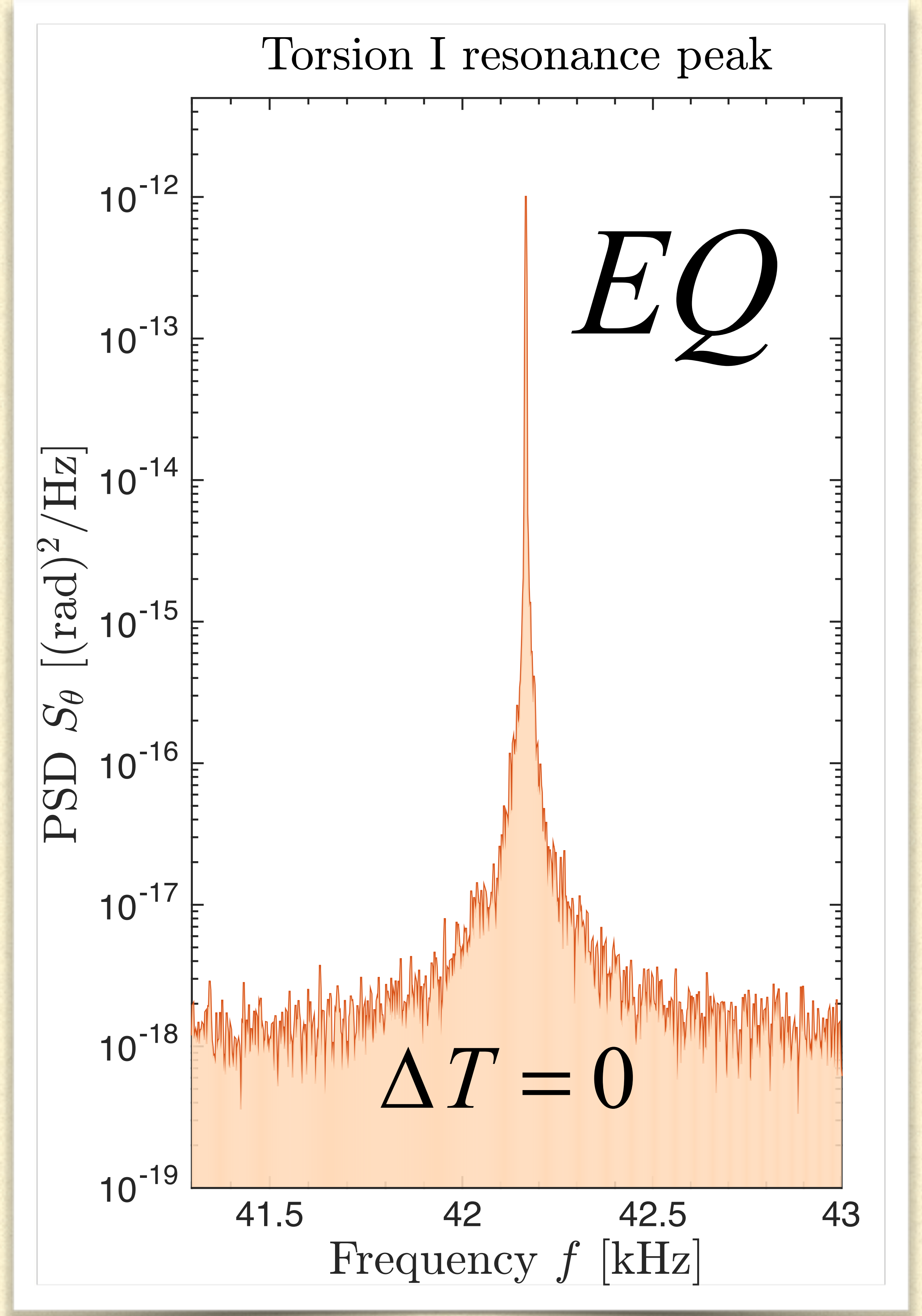


Measurements

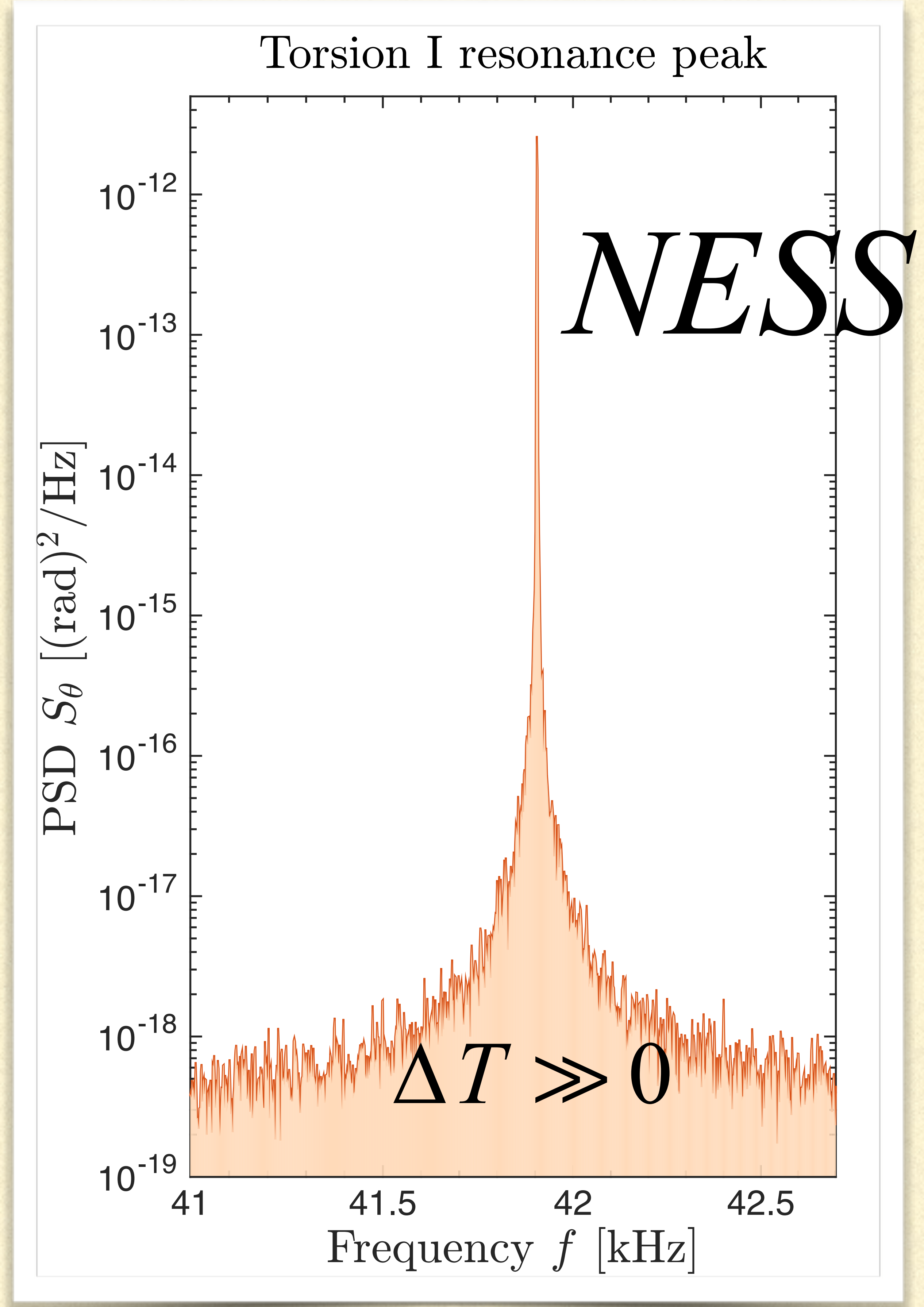




Effective temperature: ?

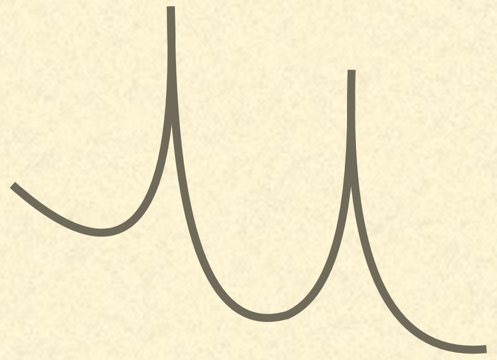


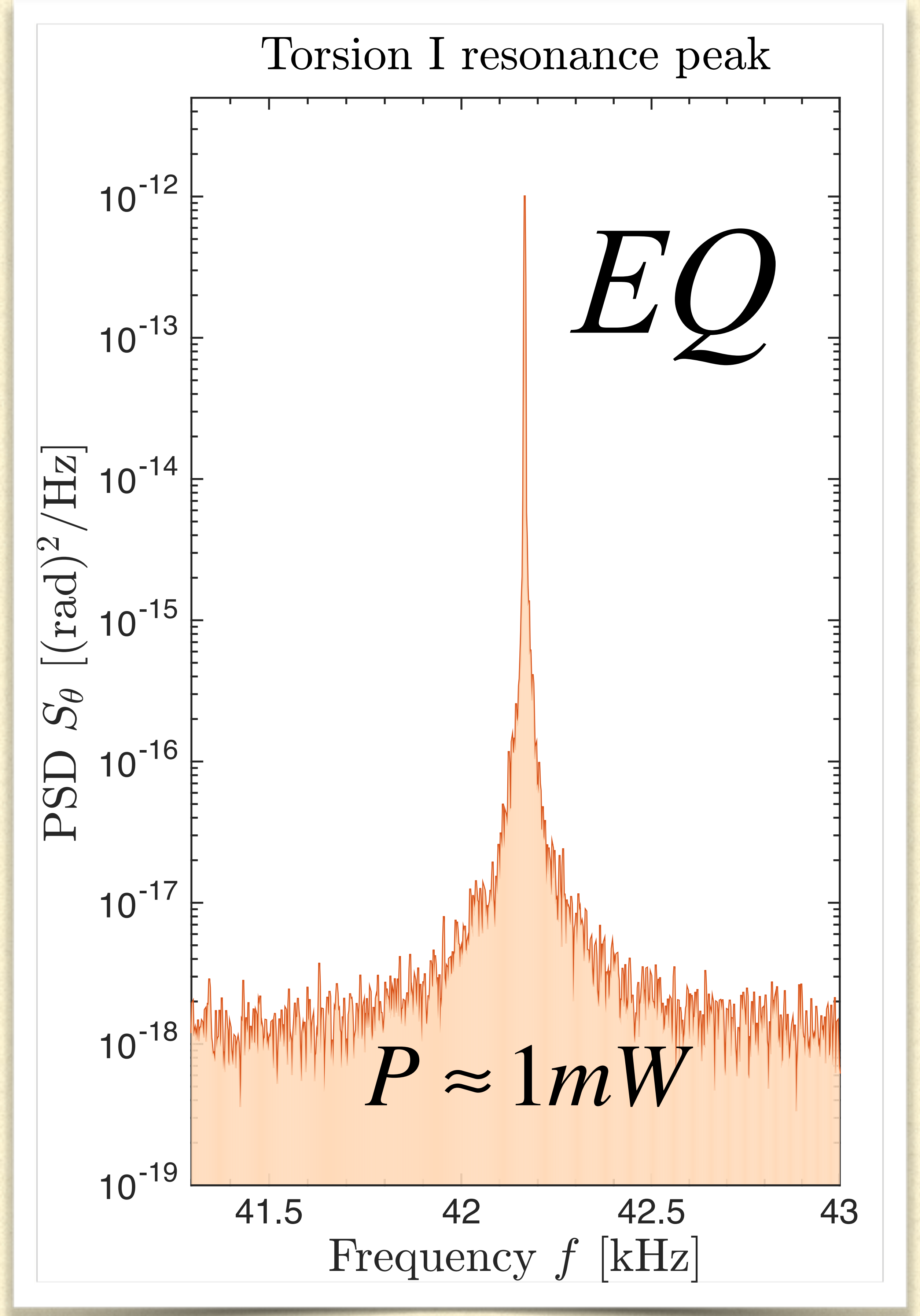
≈



?

Effective temperature: FDT





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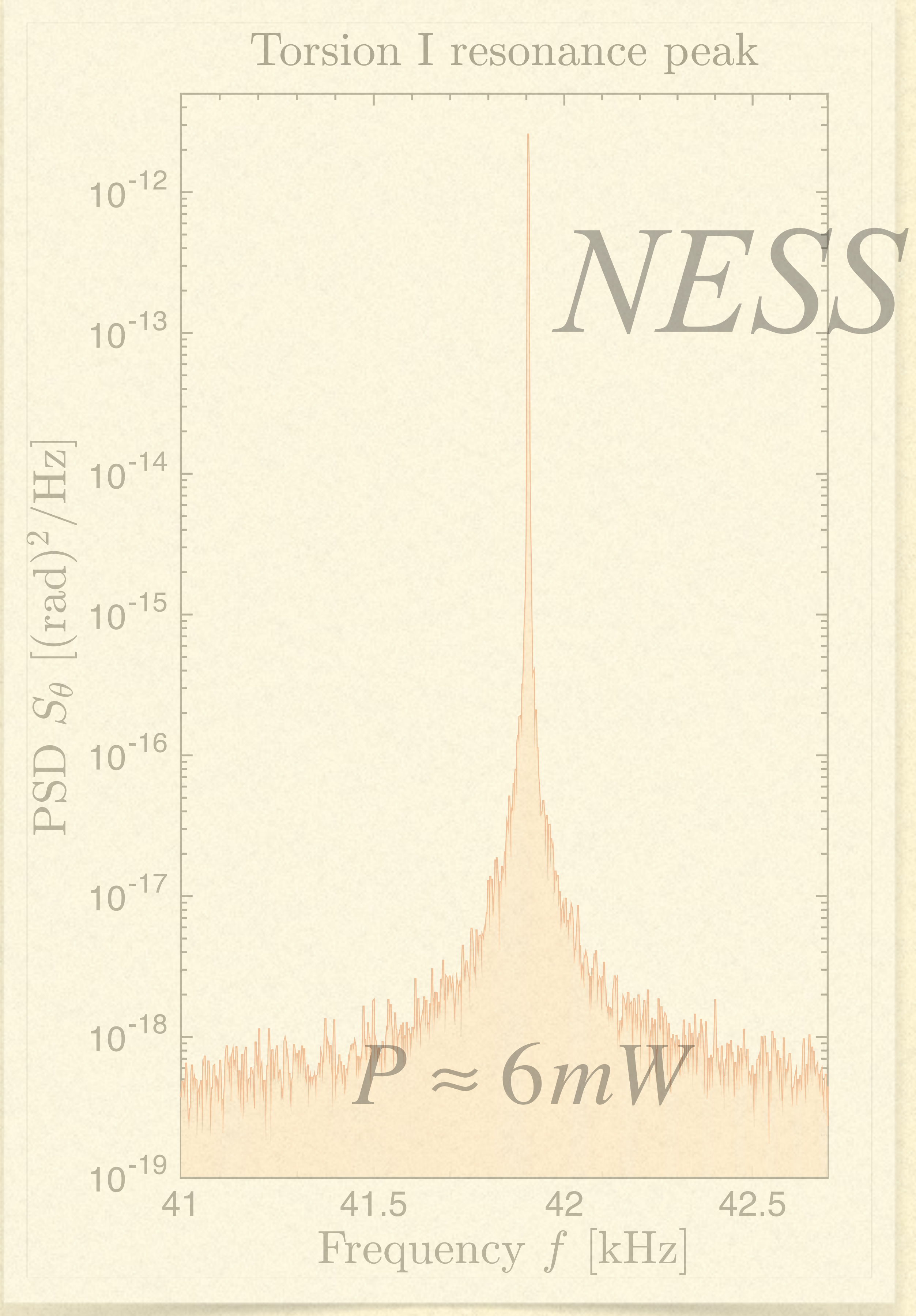
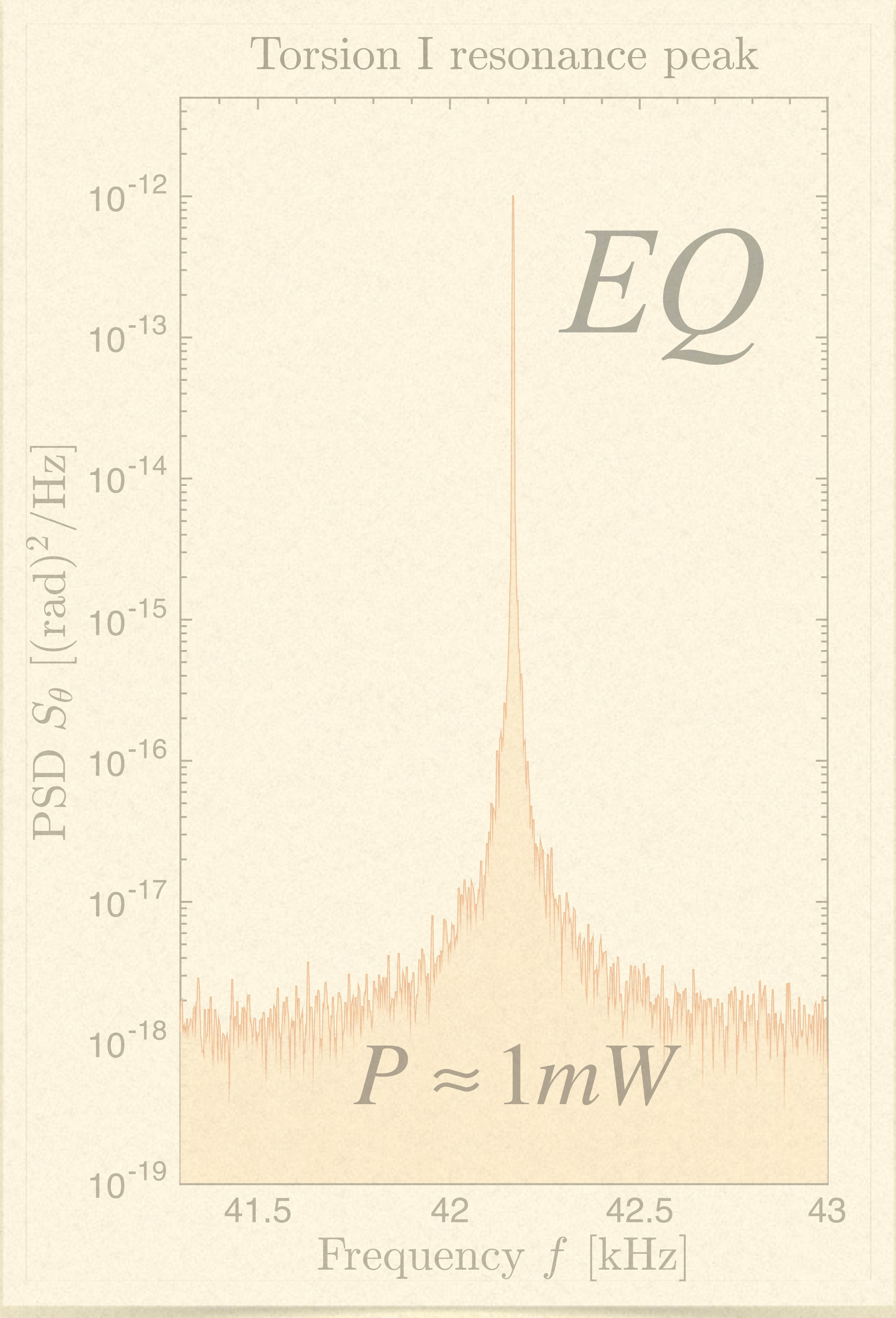


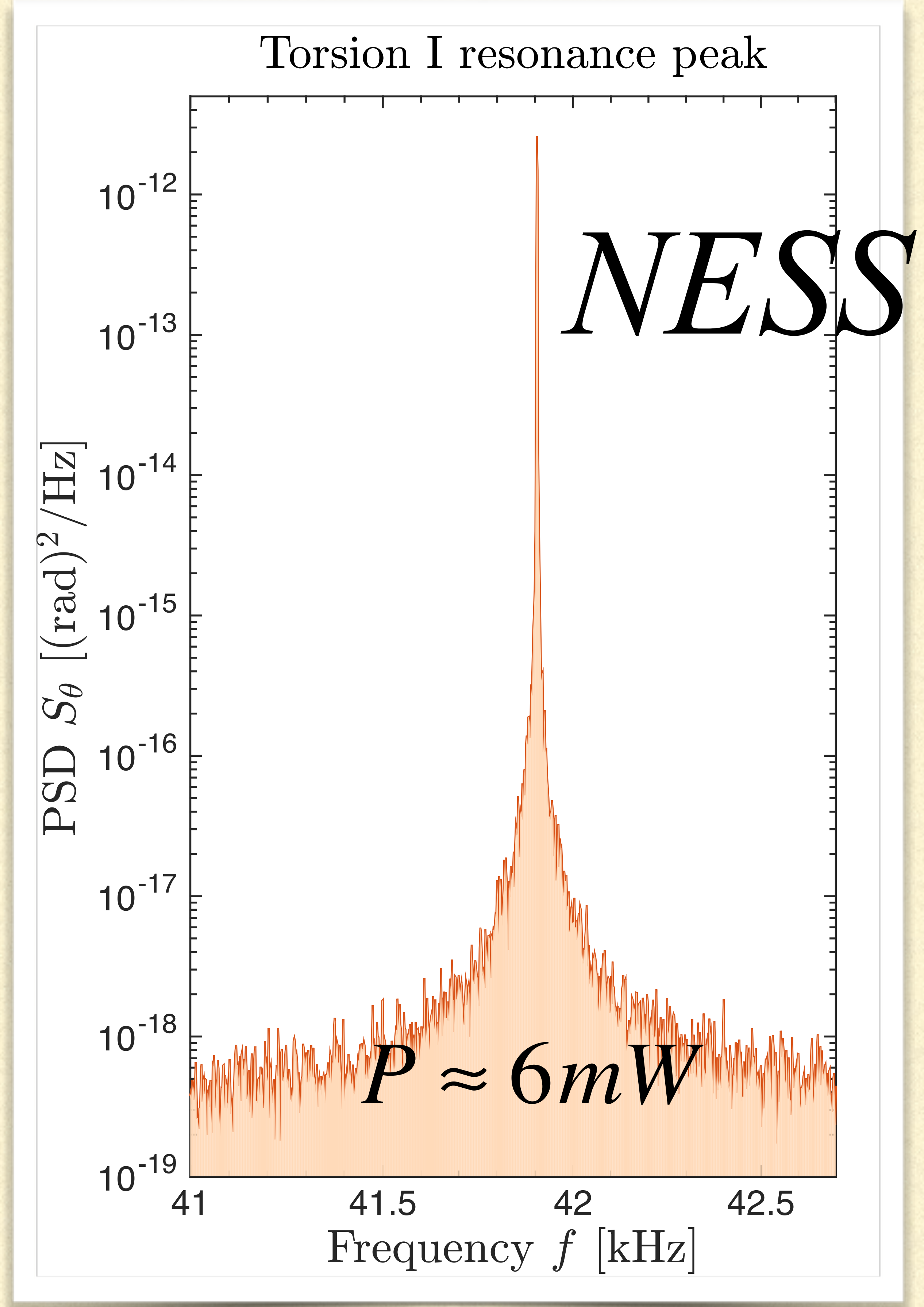
EQ

$$PSD = \frac{8k_B T}{(2\pi f)^2}\int dx\, \frac{E^{diss}(x)}{F^2}$$

Effective temperature: NESS FDT



$\approx$

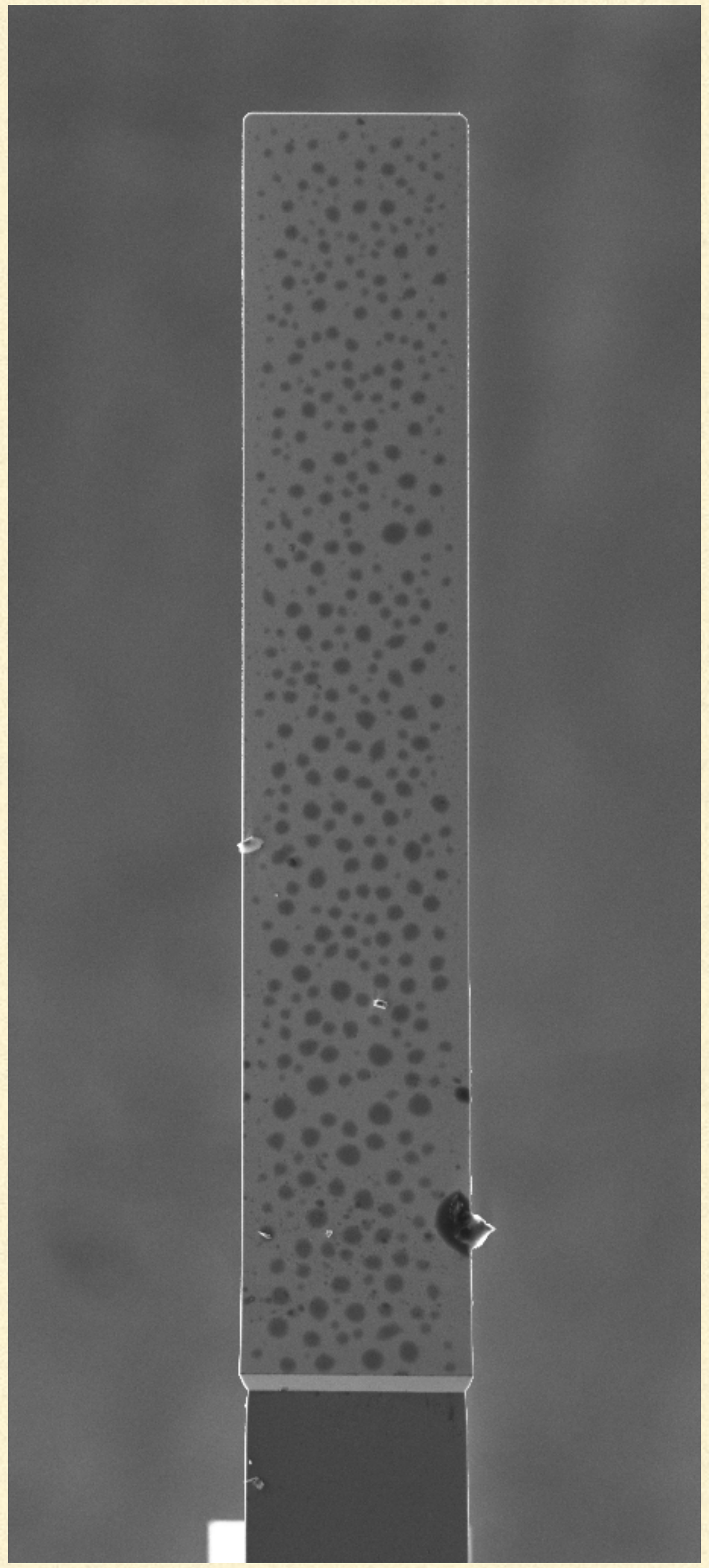


NESS

$$PSD^{(1)} = \frac{8k_B}{(2\pi f)^2} \int dx \frac{T(x) E^{diss}(x)}{F^2}$$

(1) K. Komori, et al. Physical Review **D 97**, 102001 (2018) .

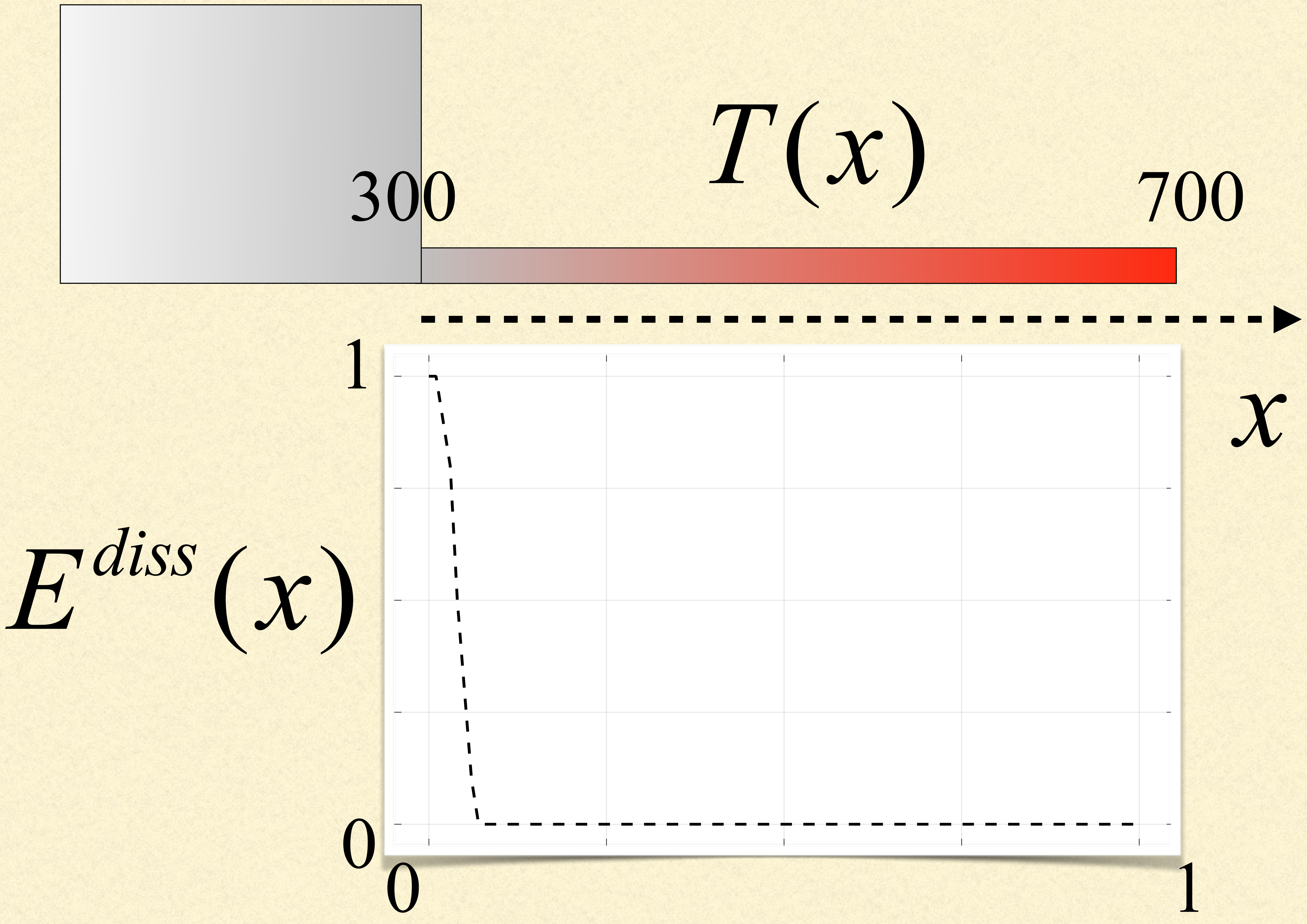
Effective temperature: E^{diss}



$$T_n^{eff} = \int dx \cdot T(x) E_n^{diss}(x)^{(2)}$$

(2) M. Geitner, et al. Physical Review **E 95**, 032138 (2017)

Effective temperature: E^{diss}

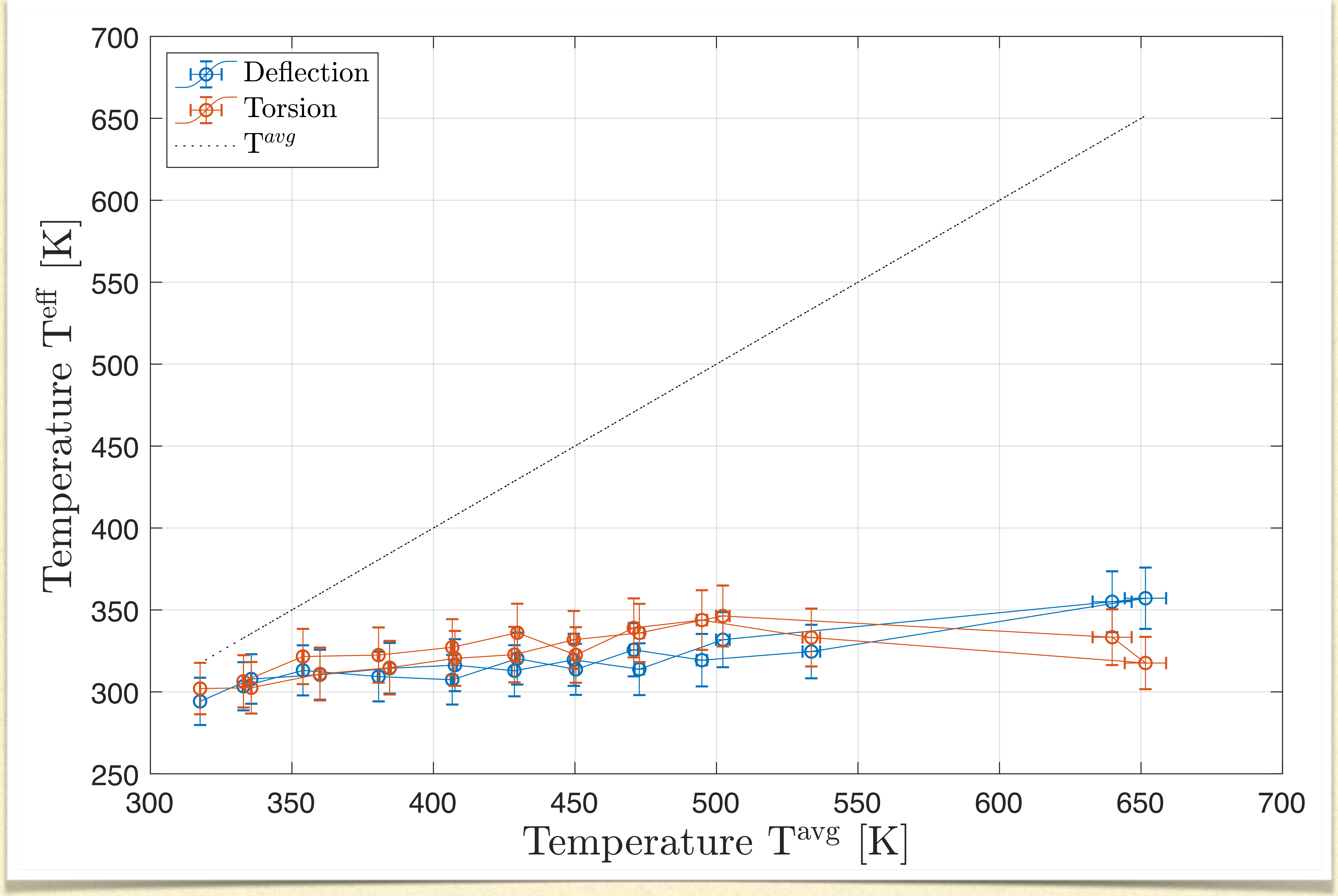


$$T_n^{eff} = \int dx \cdot T(x) E_n^{diss}(x)^{(2)}$$

$$E_n^{diss}(x) \approx Dirac(0)$$

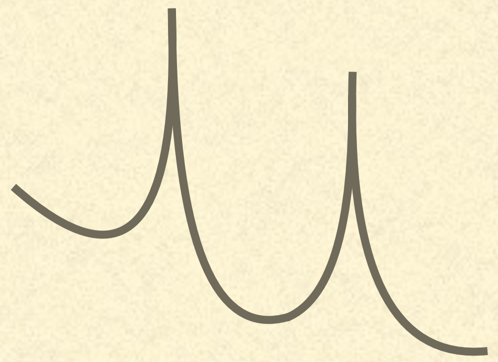
(2) M. Geitner, et al. Physical Review **E 95**, 032138 (2017

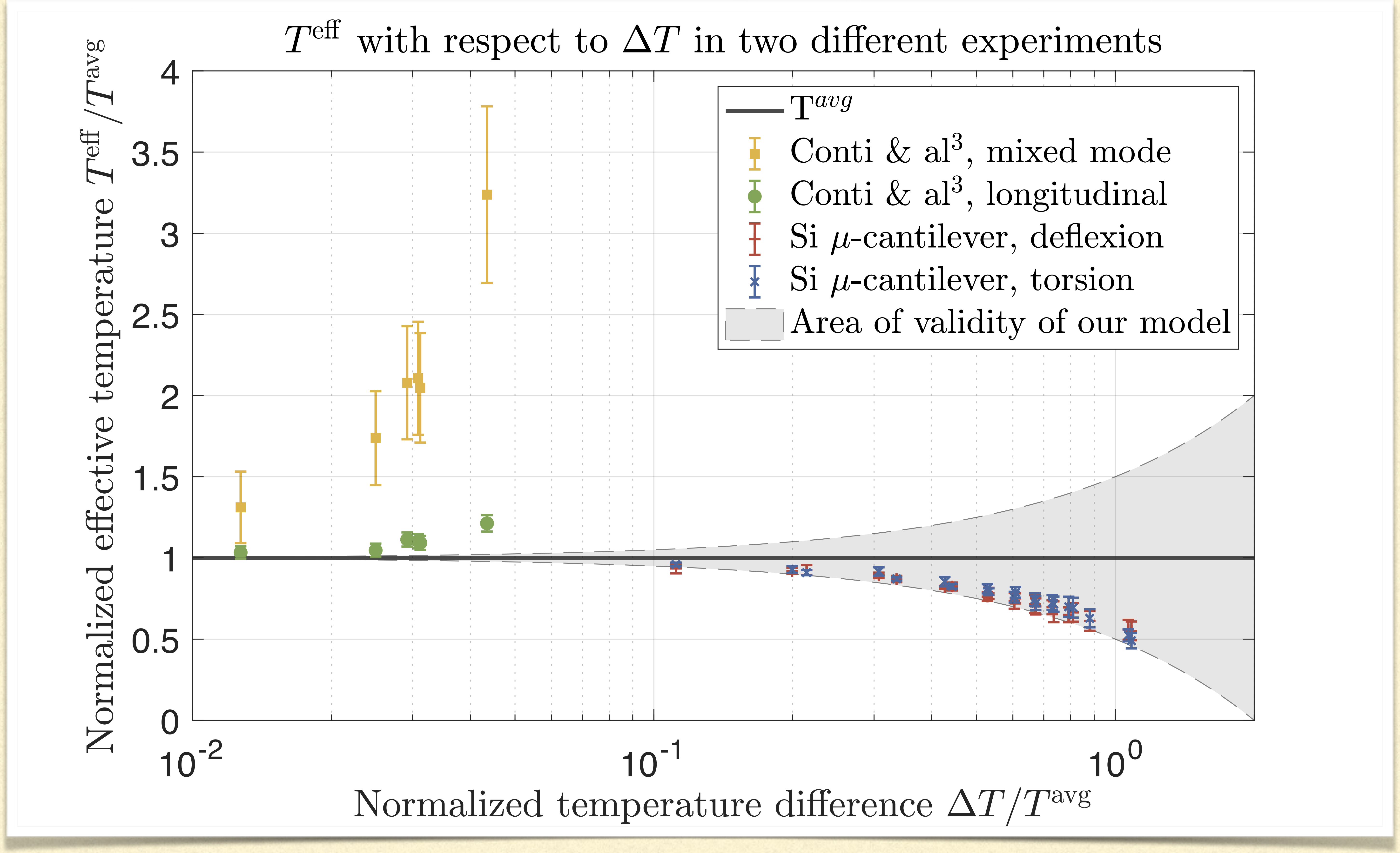
Effective temperature: answer

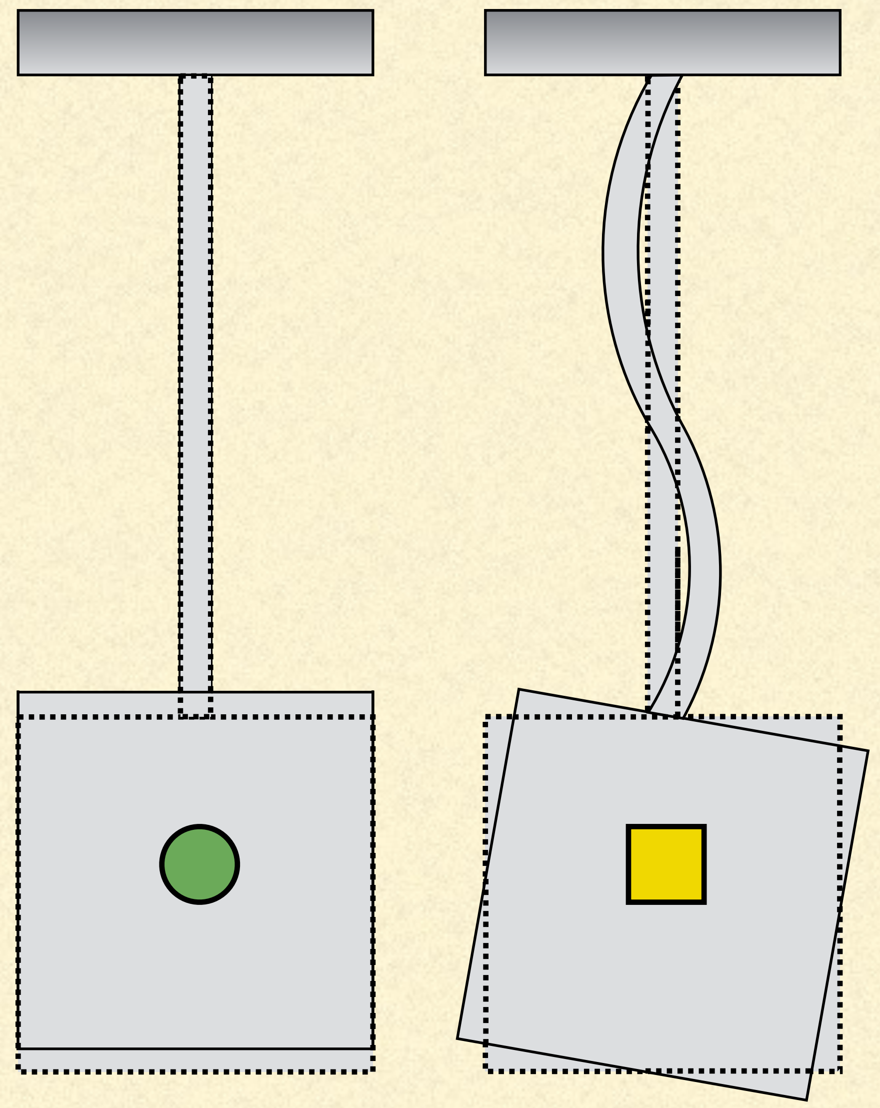


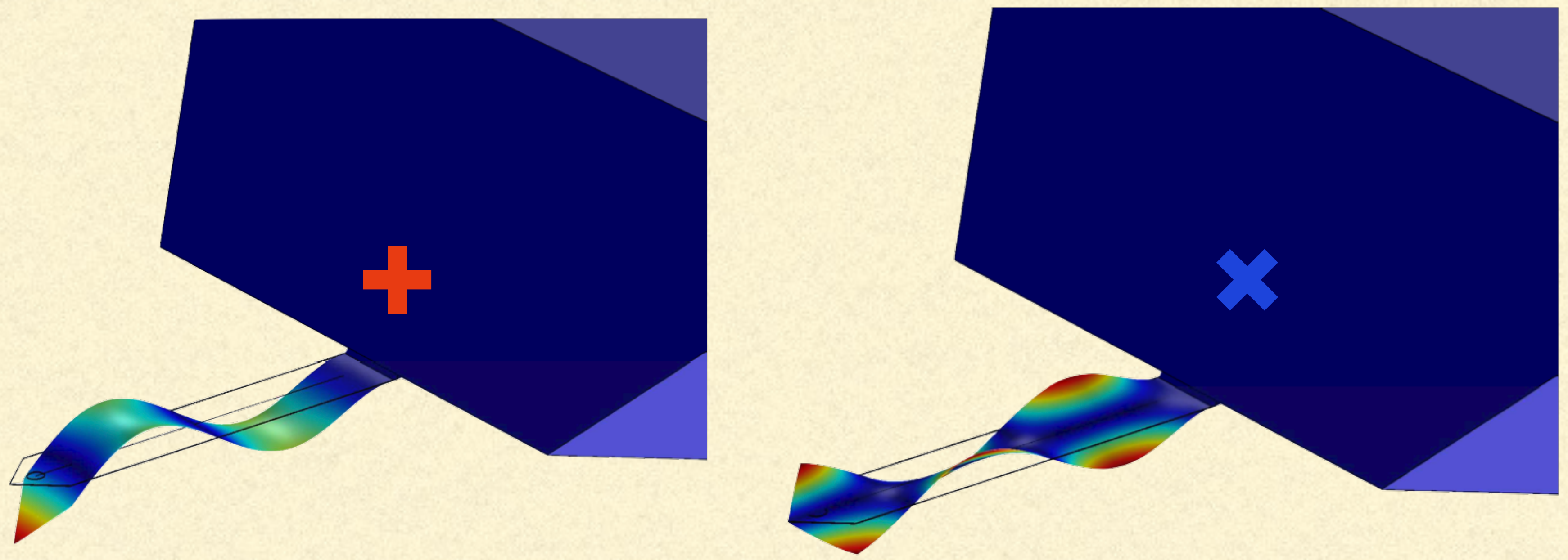
$$T_n^{eff} \approx T^{amb}$$

Comparison with Conti & al.[(3)]





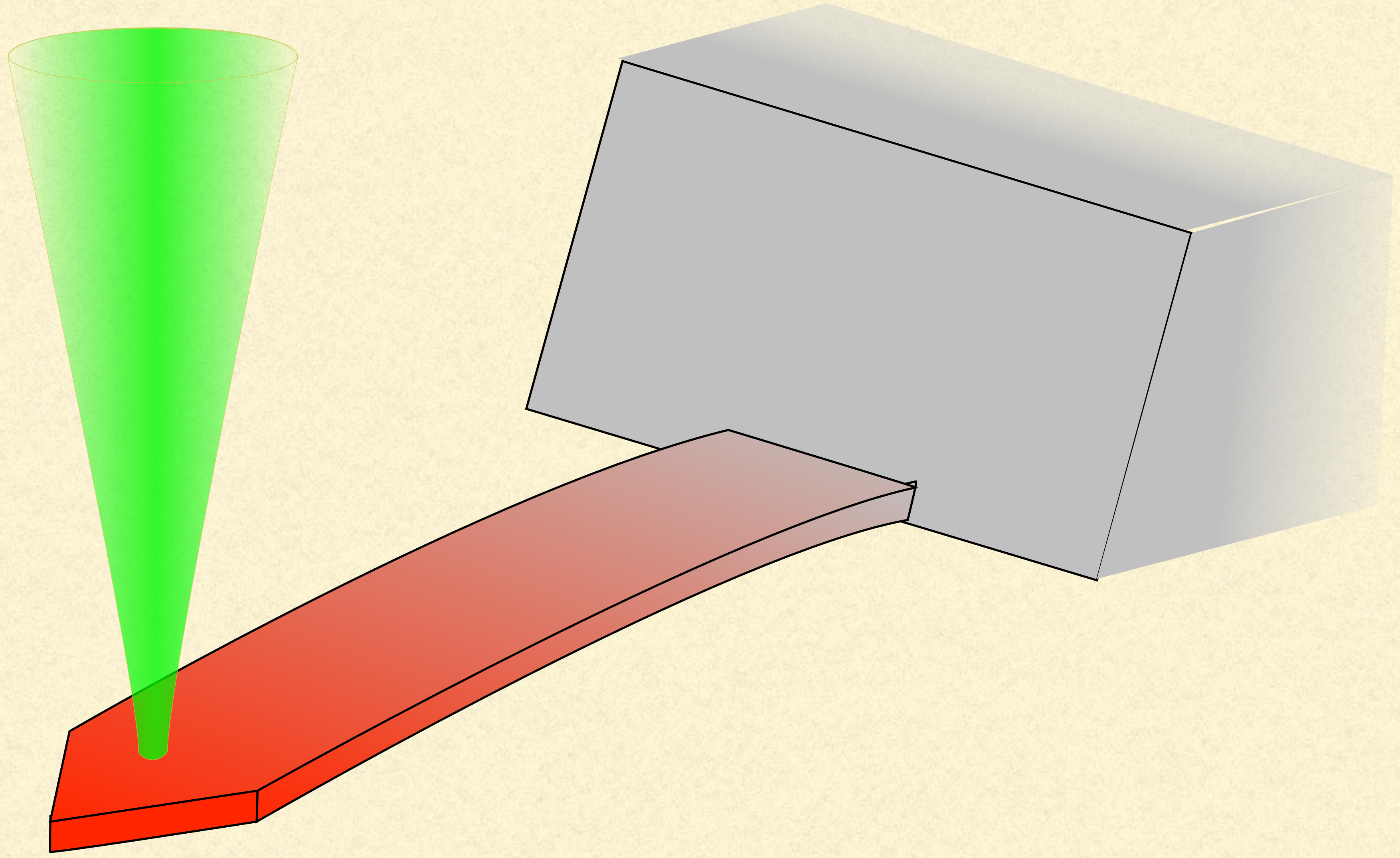




(3) L. Conti et al., J. Stat. Mech. , **P12003** (2013).

Conclusions

- We create a NESS
- We can observe a *lack* of fluctuations
- In Padua they measure an *excess*
- We have a large phenomenology to explore!



Thank you for your attention !