

Measuring very small things

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Toward quantum superposition of living organisms

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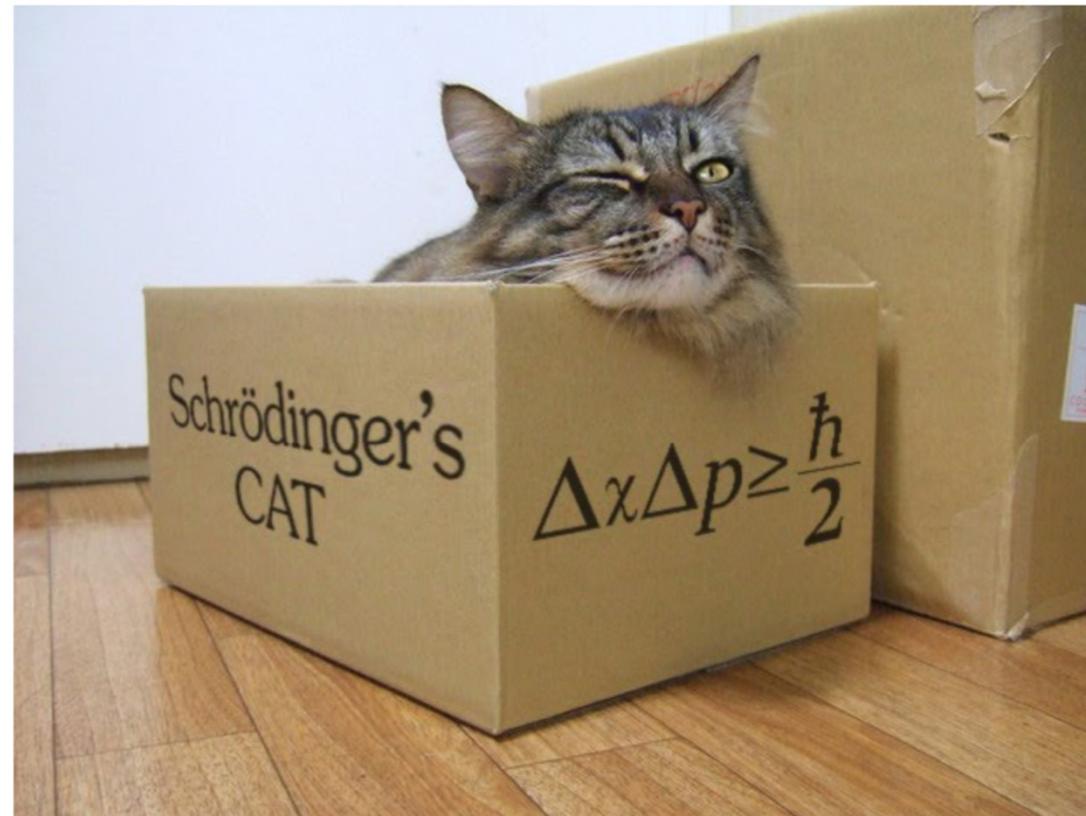
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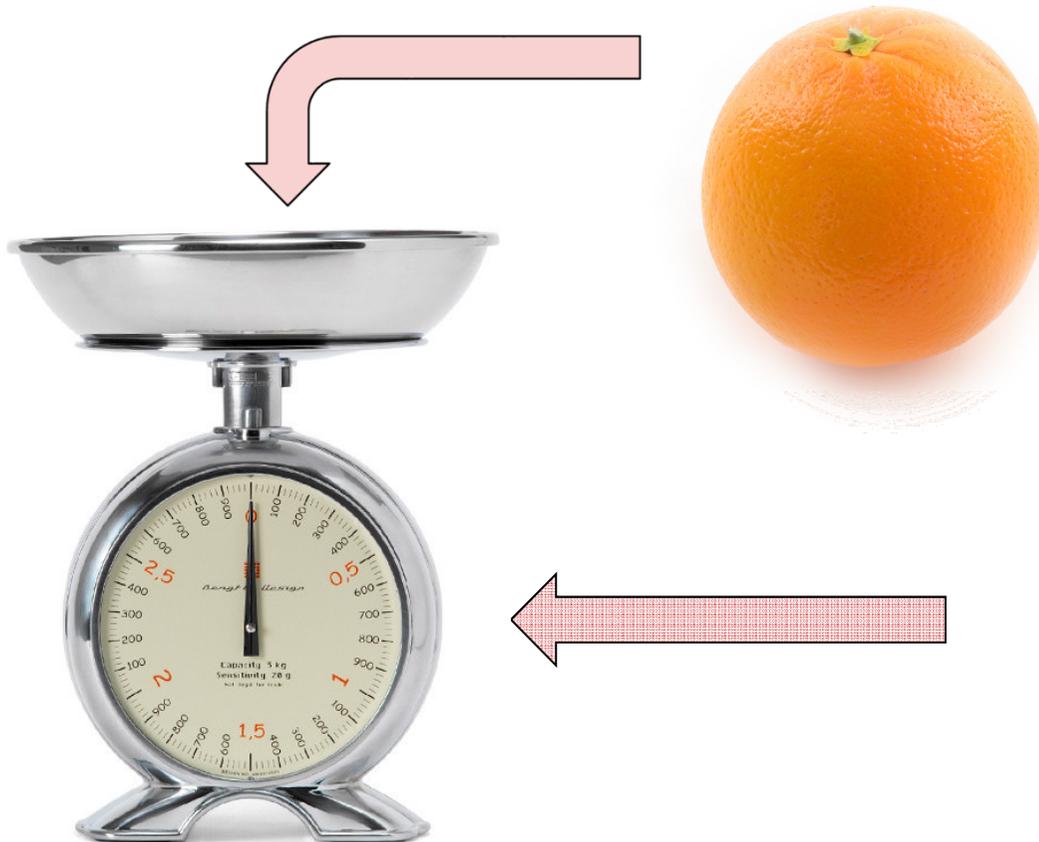
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What is a measurement?

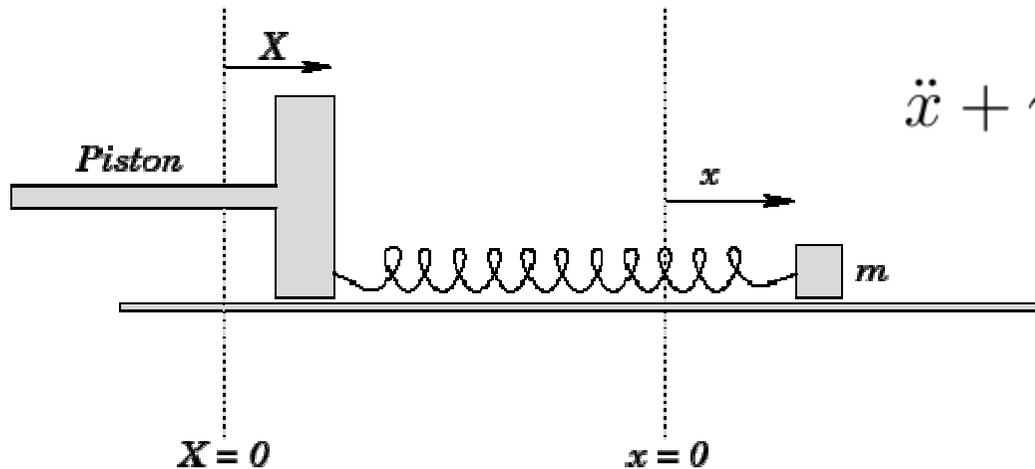


Perturbation of the measurement system

Ideally: controlled, predictable, verifiable

Reality: depends of the details of the system (sensitivity, noise)

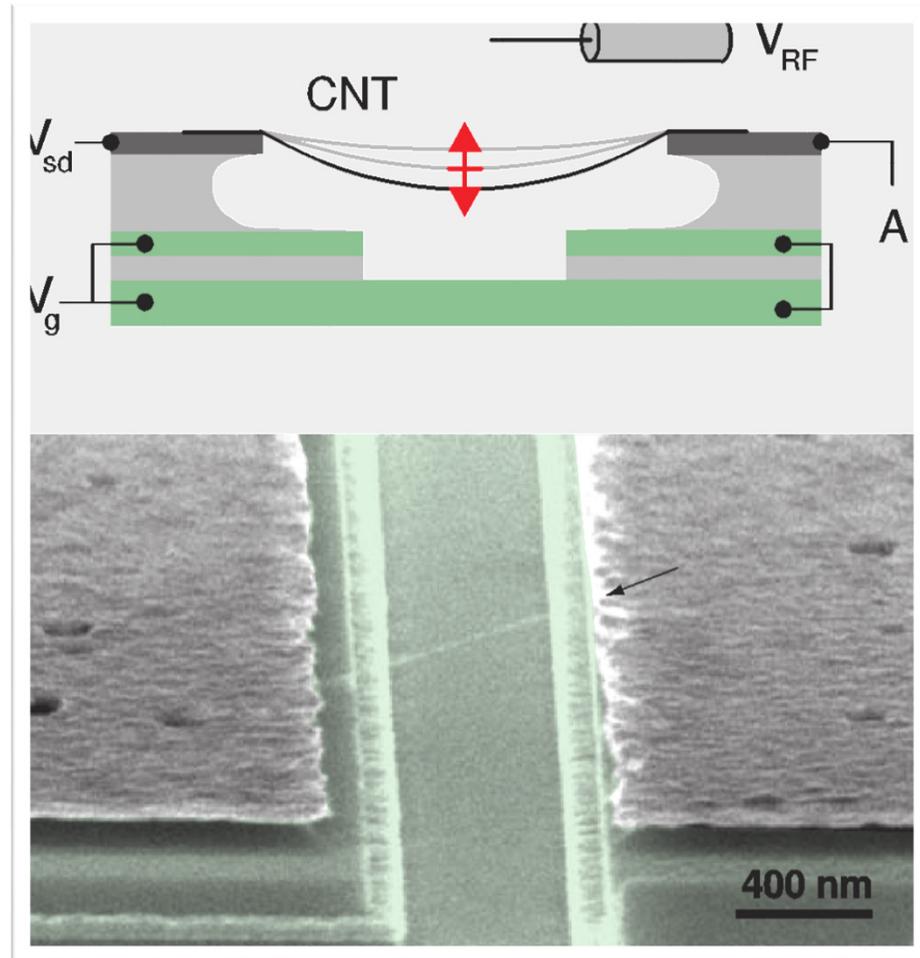
Driven harmonic oscillator

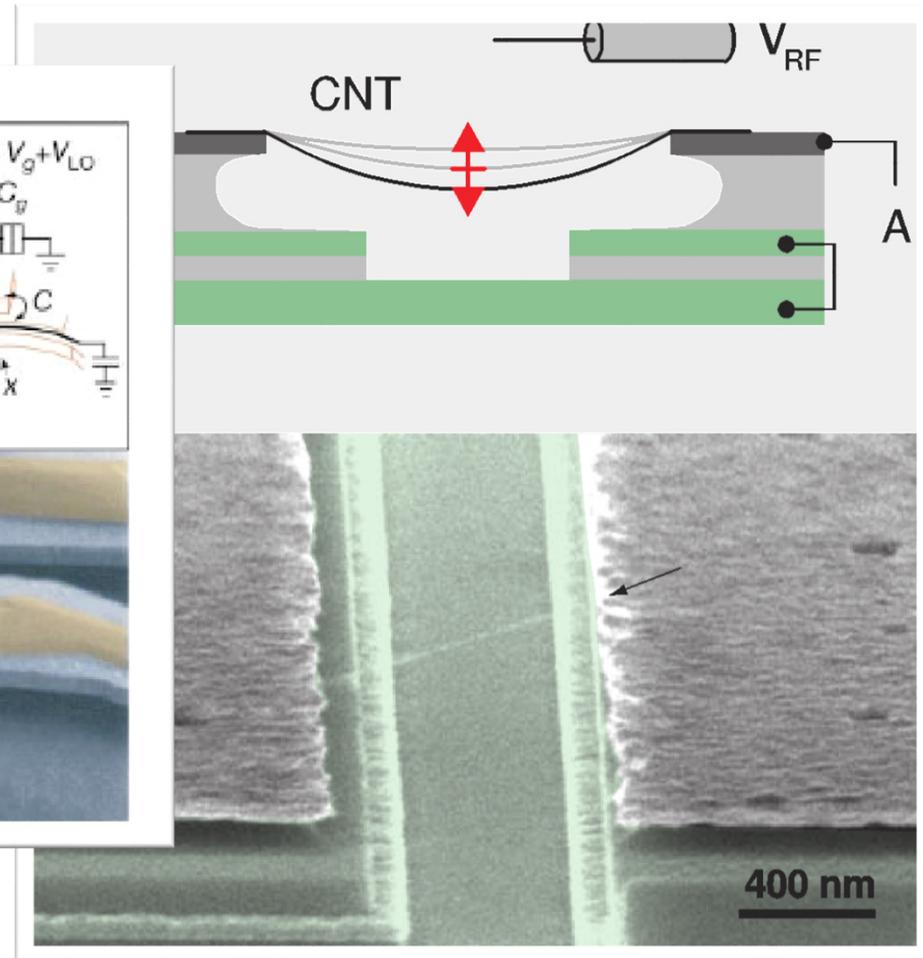
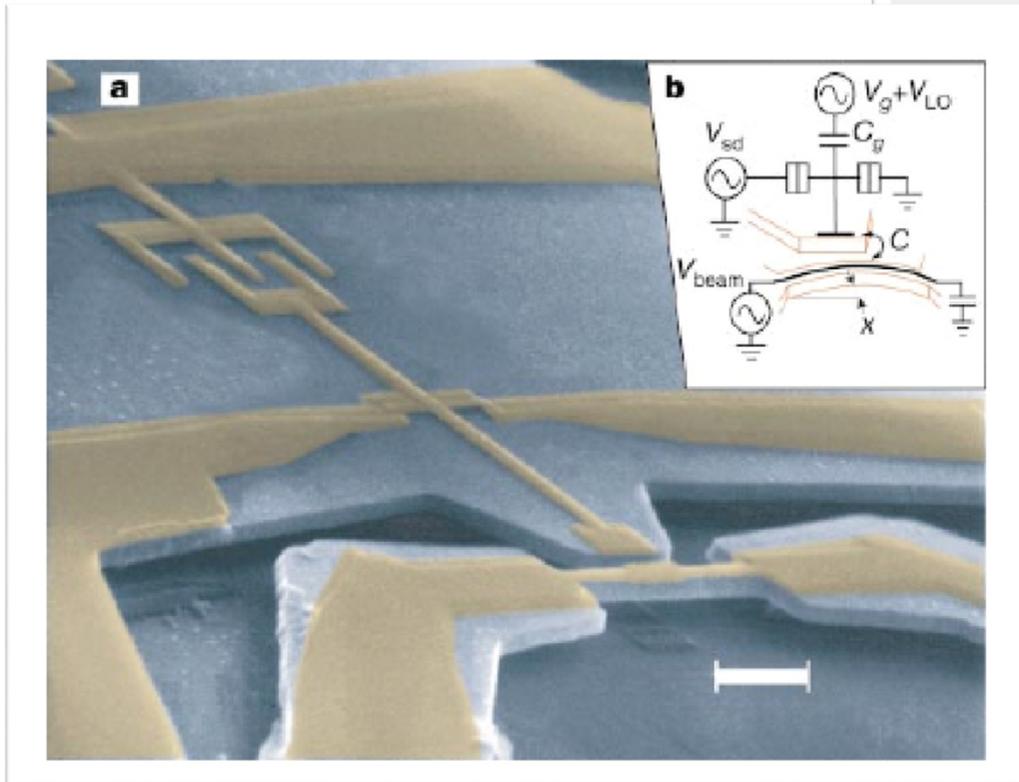


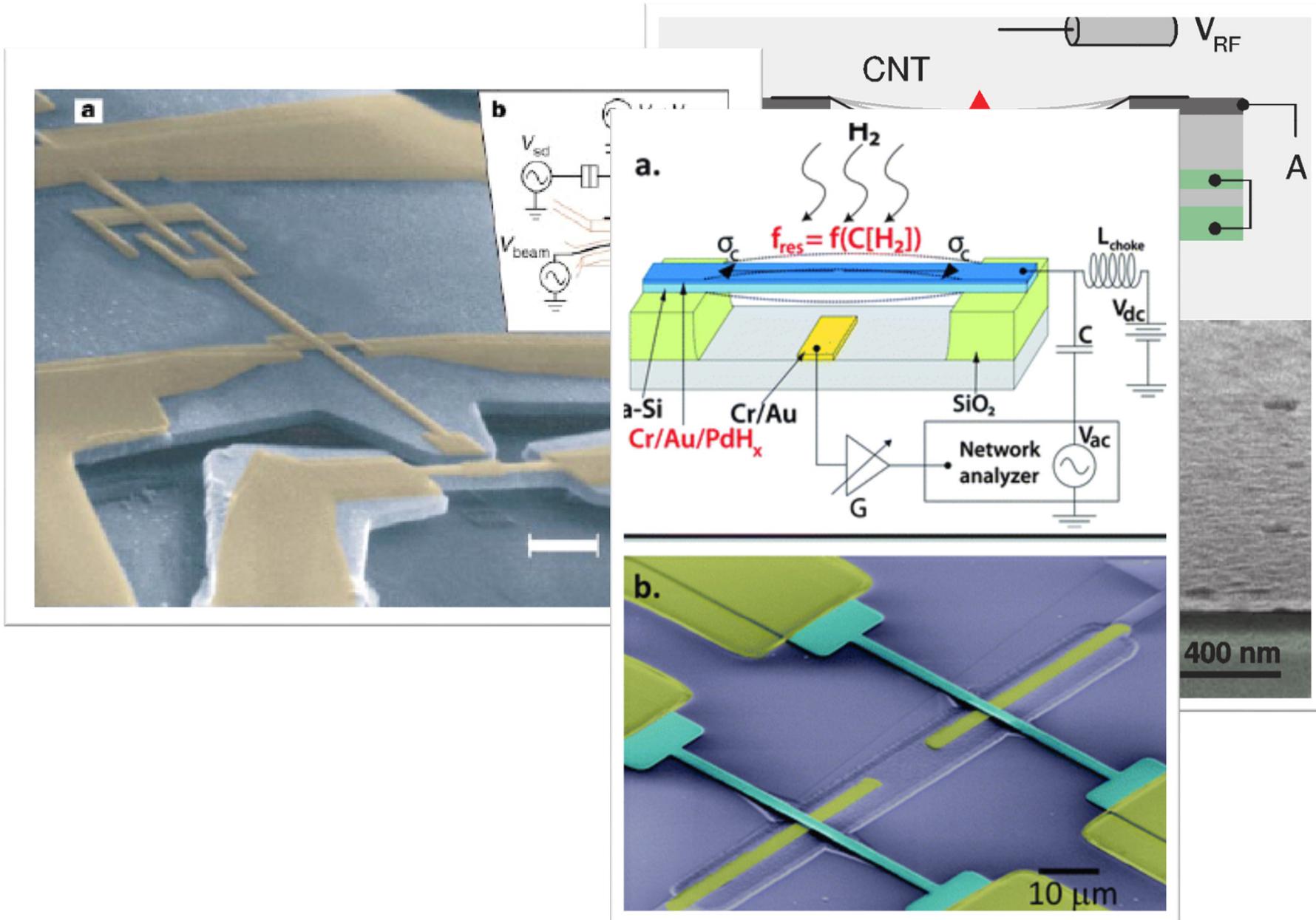
$$\ddot{x} + \gamma\dot{x} + \omega_0^2 x = \omega_0^2 X_0 \cos \omega t$$

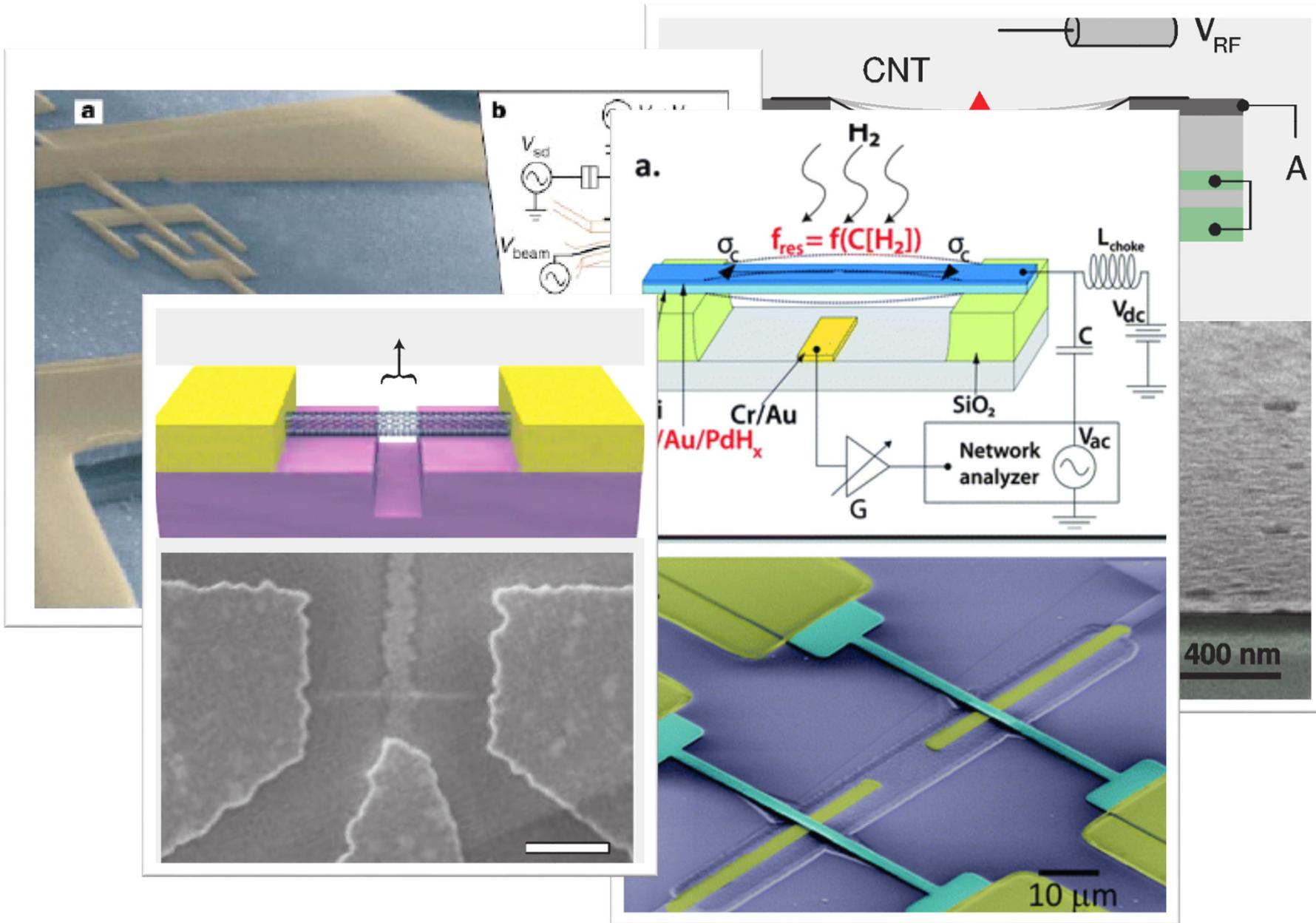
$$x(t) = \frac{\omega_0^2 X_0 \cos(\omega t - \phi)}{\sqrt{(\omega_0^2 - \omega^2)^2 - \gamma^2 \omega^2}},$$

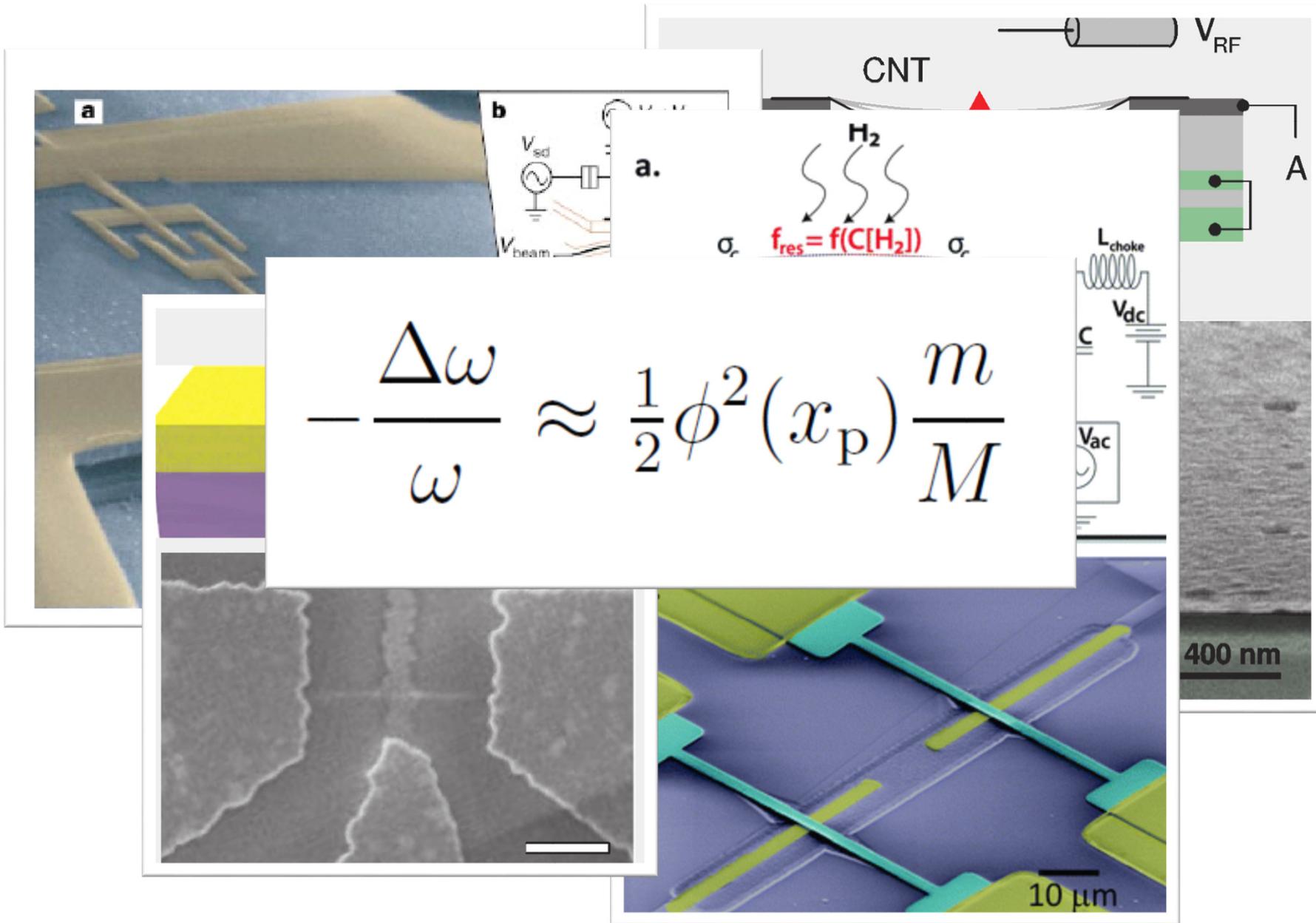
$$\tan \phi = \frac{\gamma \omega}{\omega_0^2 - \omega^2}$$



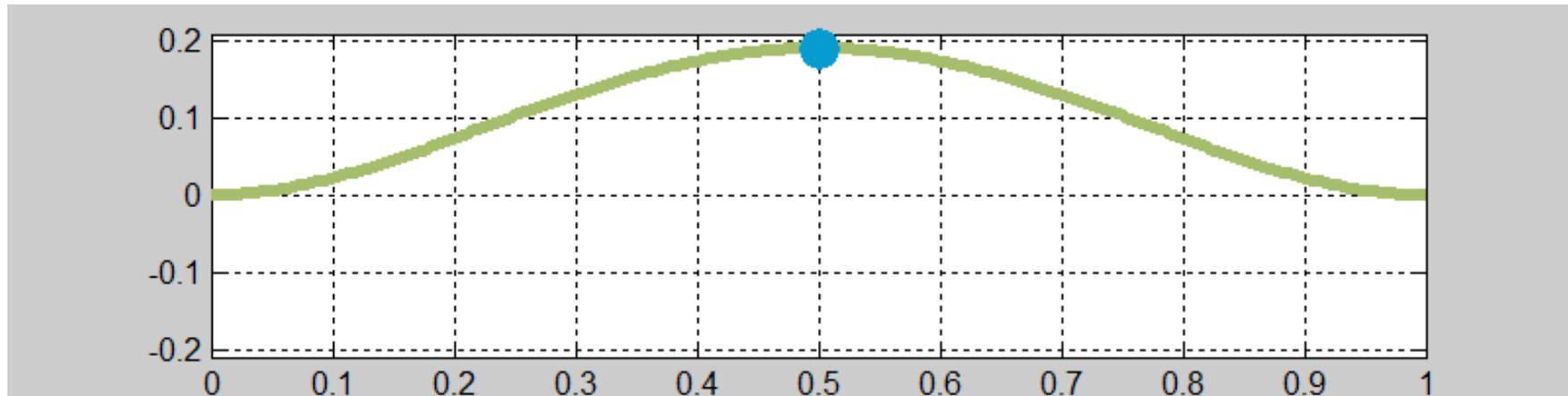




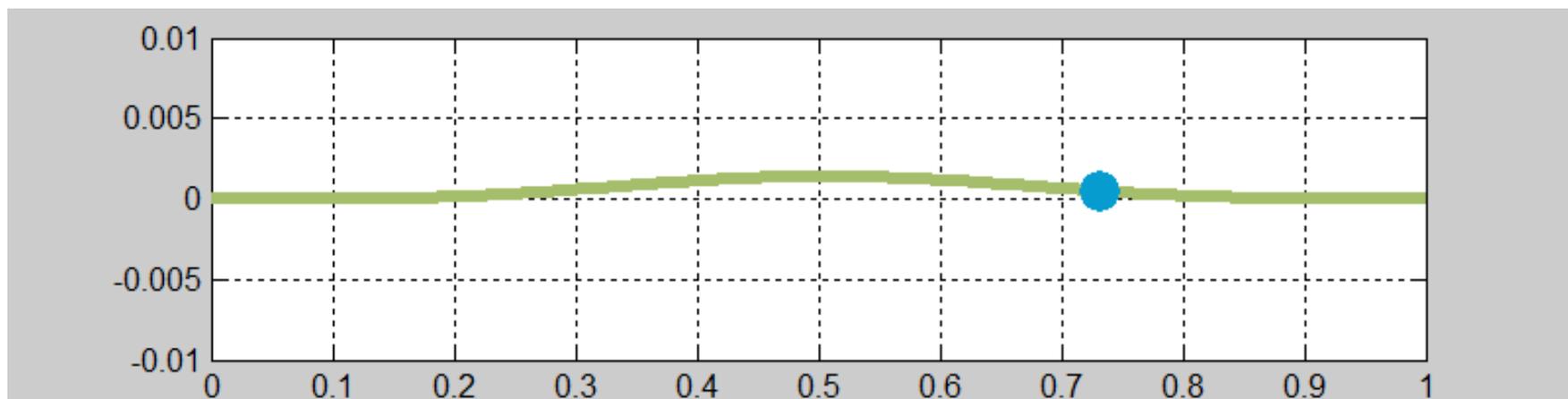


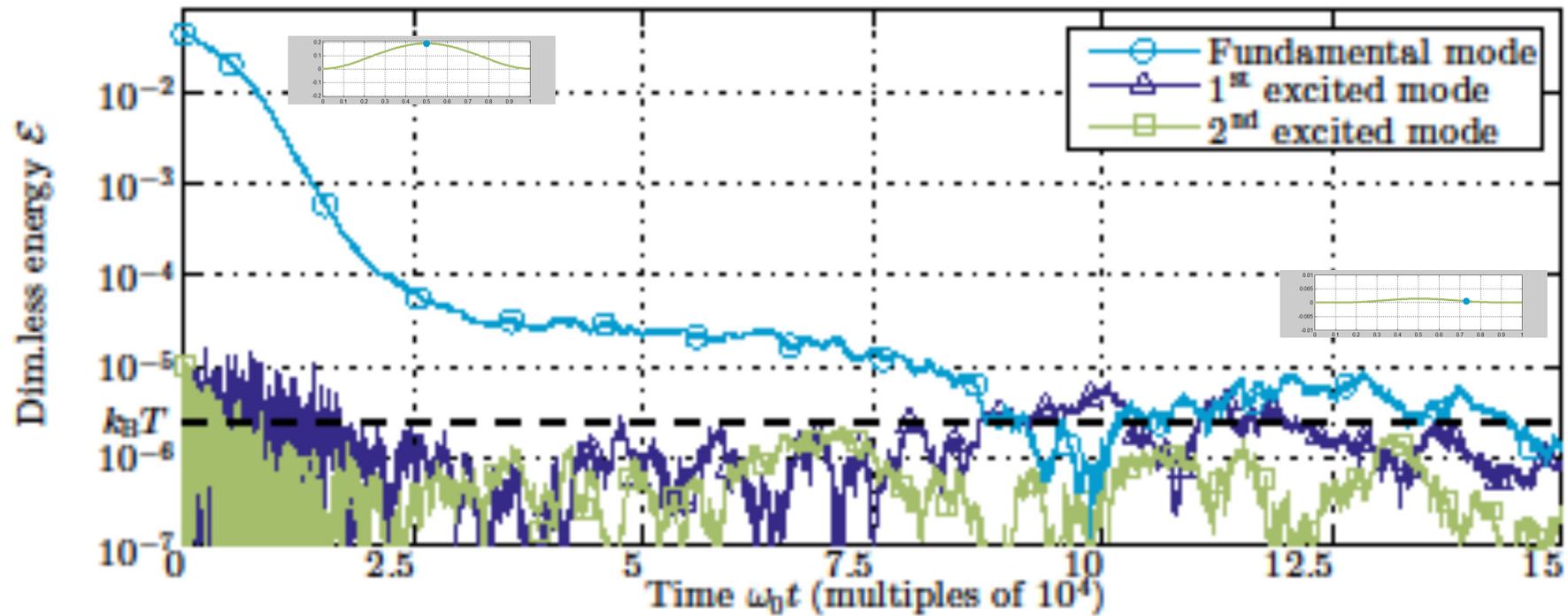


Initial ringdown



Thermalized state



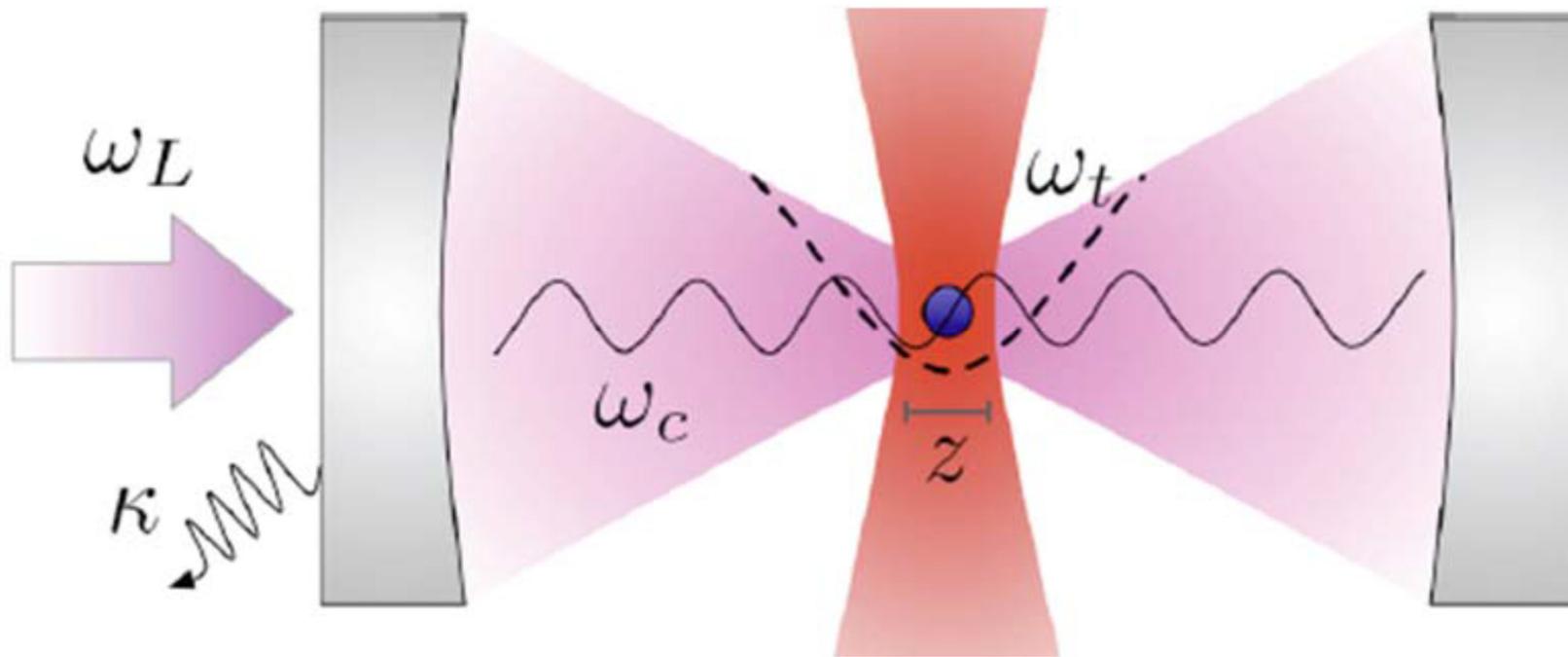


$$\ddot{q}_n + \omega_n^2 q_n - \epsilon \varphi_n^\dagger(\mathbf{x}_p) \sum_k \omega_k^2 q_k \varphi_k(\mathbf{x}_p) = 0,$$

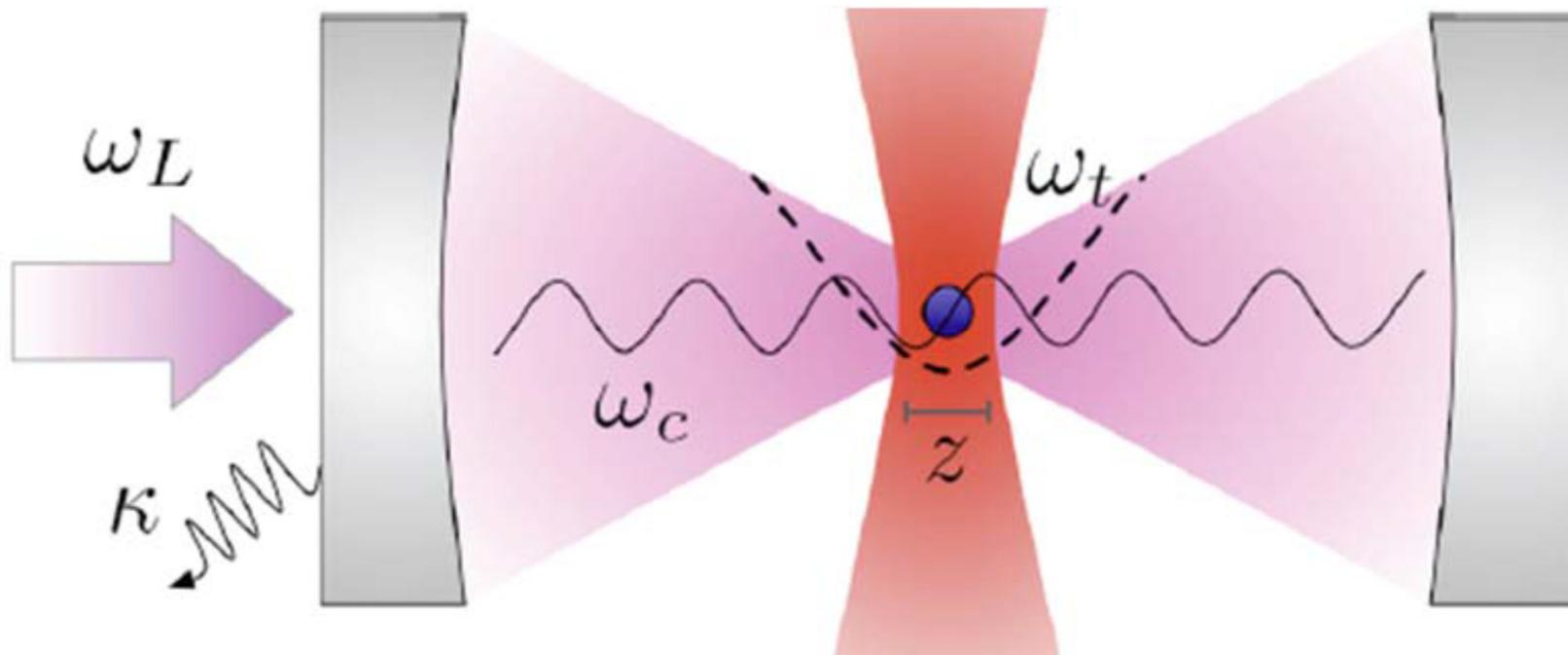
$$\dot{\mathbf{x}}_p - \frac{1}{\gamma} \sum_{k,l} \omega_k^2 q_k q_l \varphi_k(\mathbf{x}_p) \varphi_l'(\mathbf{x}_p) = \sqrt{2D} \xi(t),$$

If only there was an analogous system that was naturally isolated from the environment and could be controlled with a very high precision...

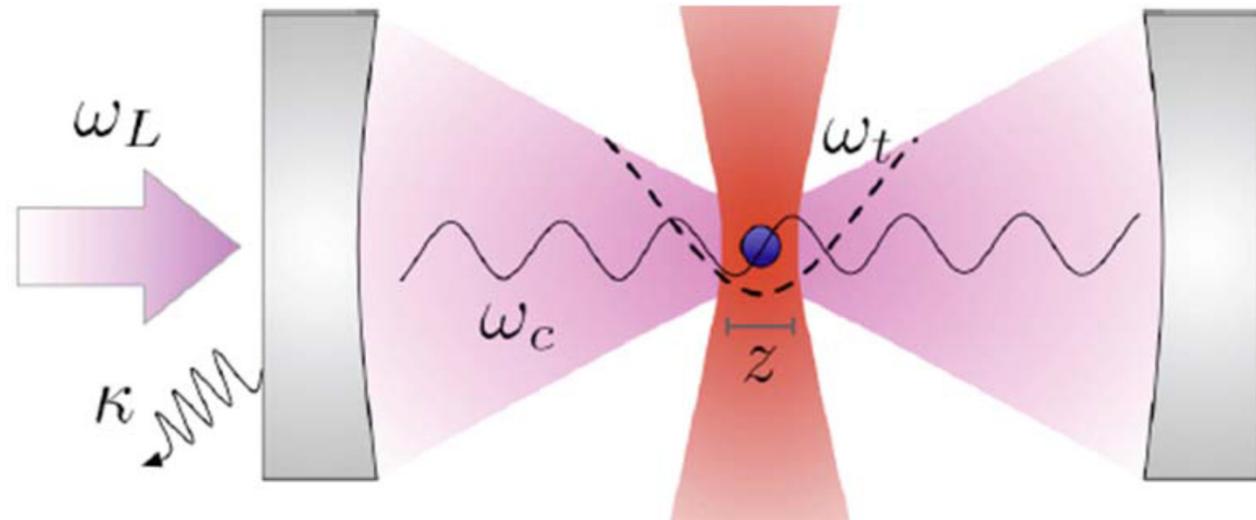
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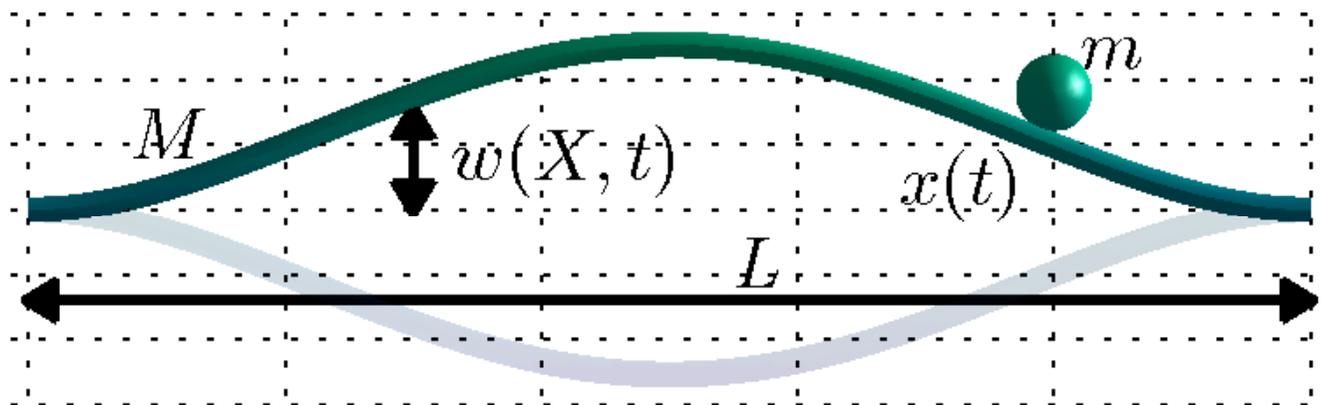
$$H = \hbar\omega_c a^\dagger a + \hbar\omega_t b^\dagger b - \hbar g(a + a^\dagger)(b + b^\dagger)$$

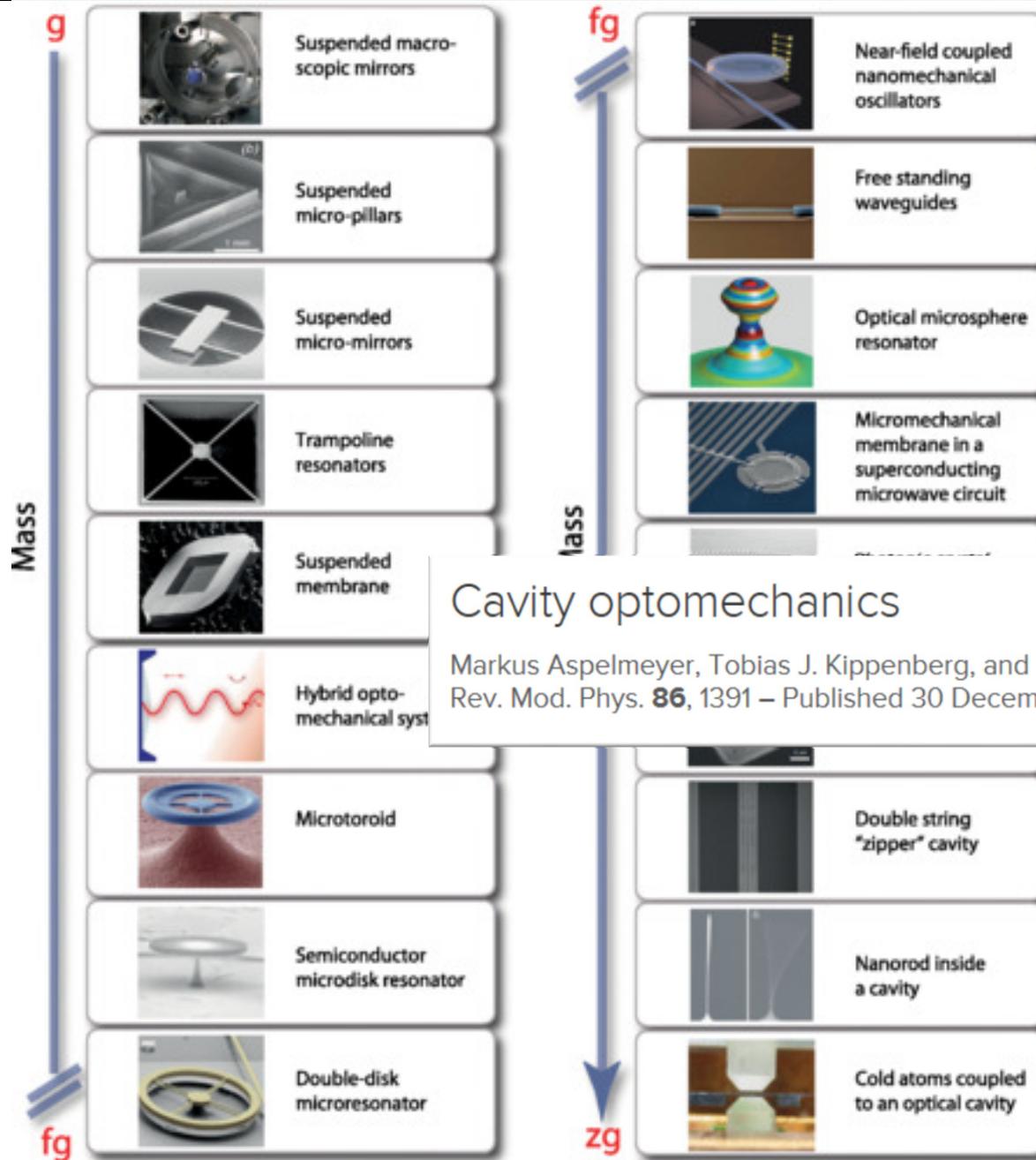


$$H = \hbar\omega_c a^\dagger a + \hbar\omega_t b^\dagger b - \hbar g(a + a^\dagger)(b + b^\dagger)$$



Equivalent to nanomechanical system?





Cavity optomechanics
 Markus Aspelmeyer, Tobias J. Kippenberg, and Florian Marquardt
 Rev. Mod. Phys. **86**, 1391 – Published 30 December 2014

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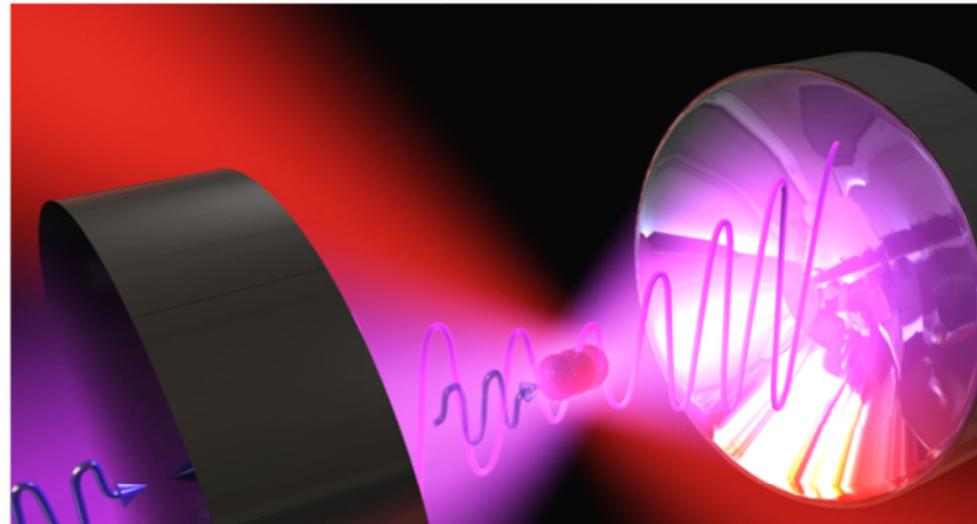
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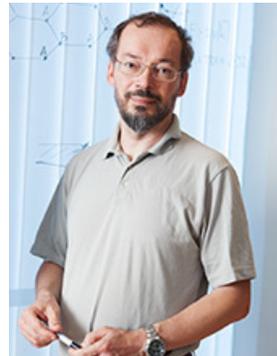
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creating quantum superposition states in very much the same spirit as the original Schrödinger's cat 'gedanken' paradigm (Schrödinger 1935 *Naturwissenschaften* **23** 807–12, 823–8, 844–9). We anticipate that our paper will be a starting point for experimentally addressing fundamental questions, such as the role of life and consciousness in quantum mechanics.

Acknowledgments



Andreas Isacsson



Jari Kinaret



SWEDISH FOUNDATION *for*
STRATEGIC RESEARCH

