The quantum coin toss—observation of quantum superposition in a mesoscopic coin

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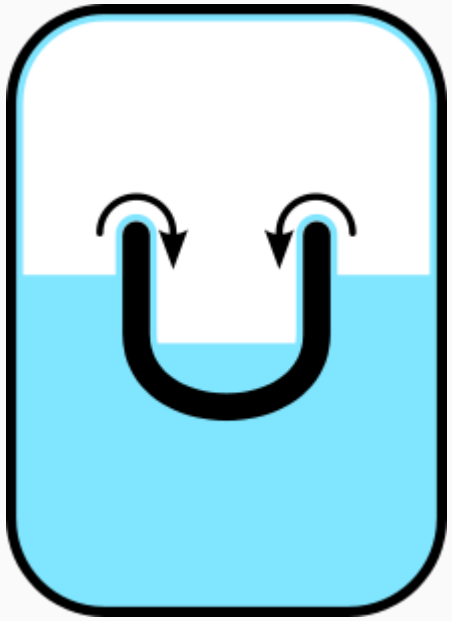
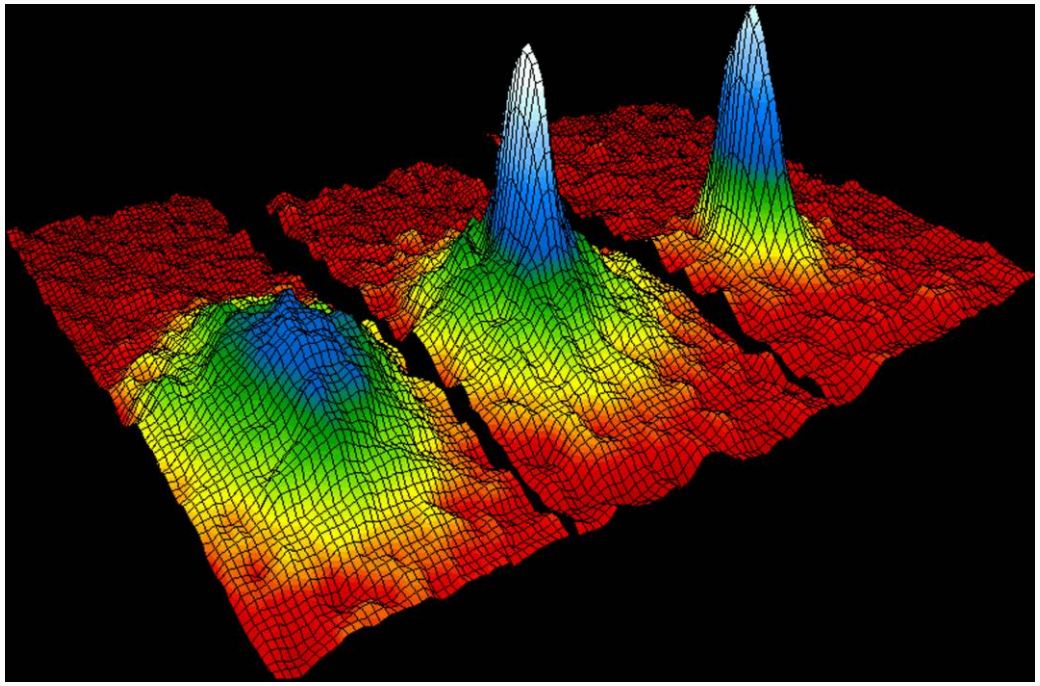
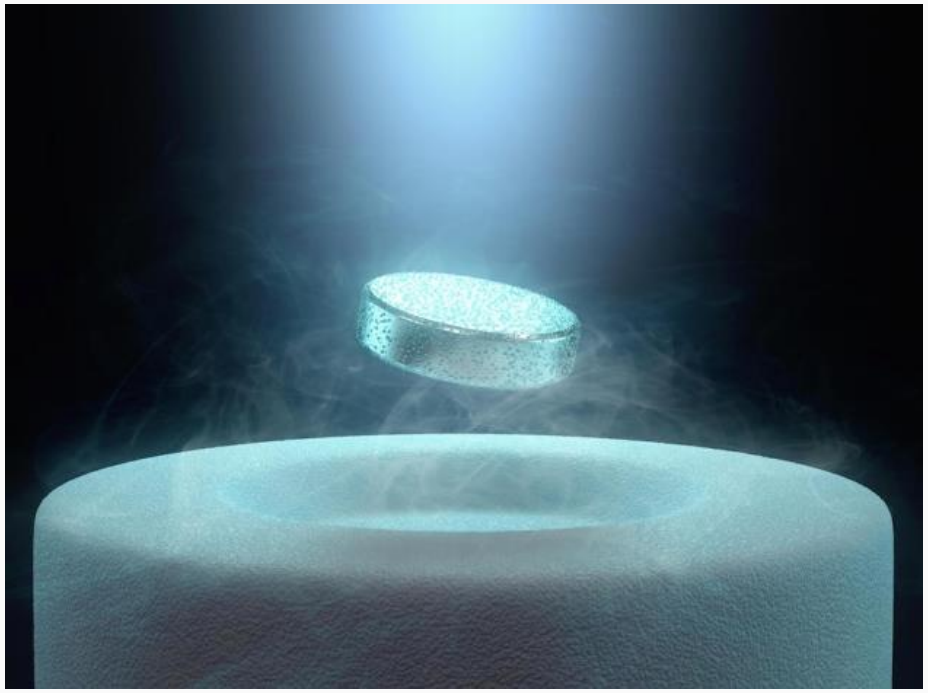
Macroscopic quantum phenomena

- E.g. superconductivity, Bose-Einstein condensation, superfluidity, quantum Hall effect.

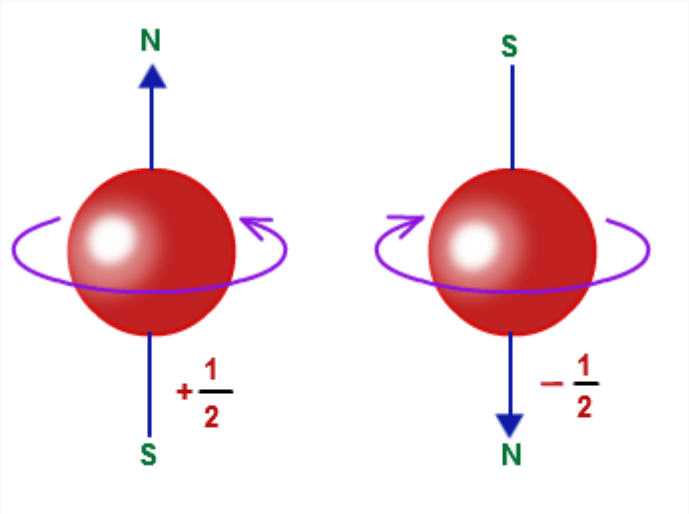


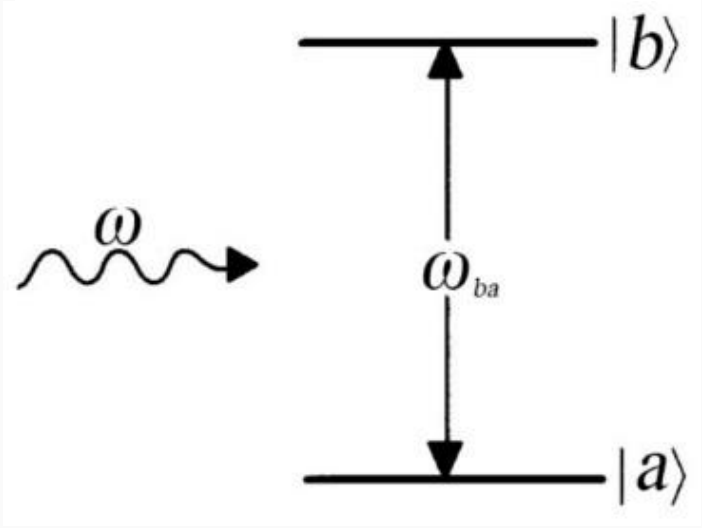


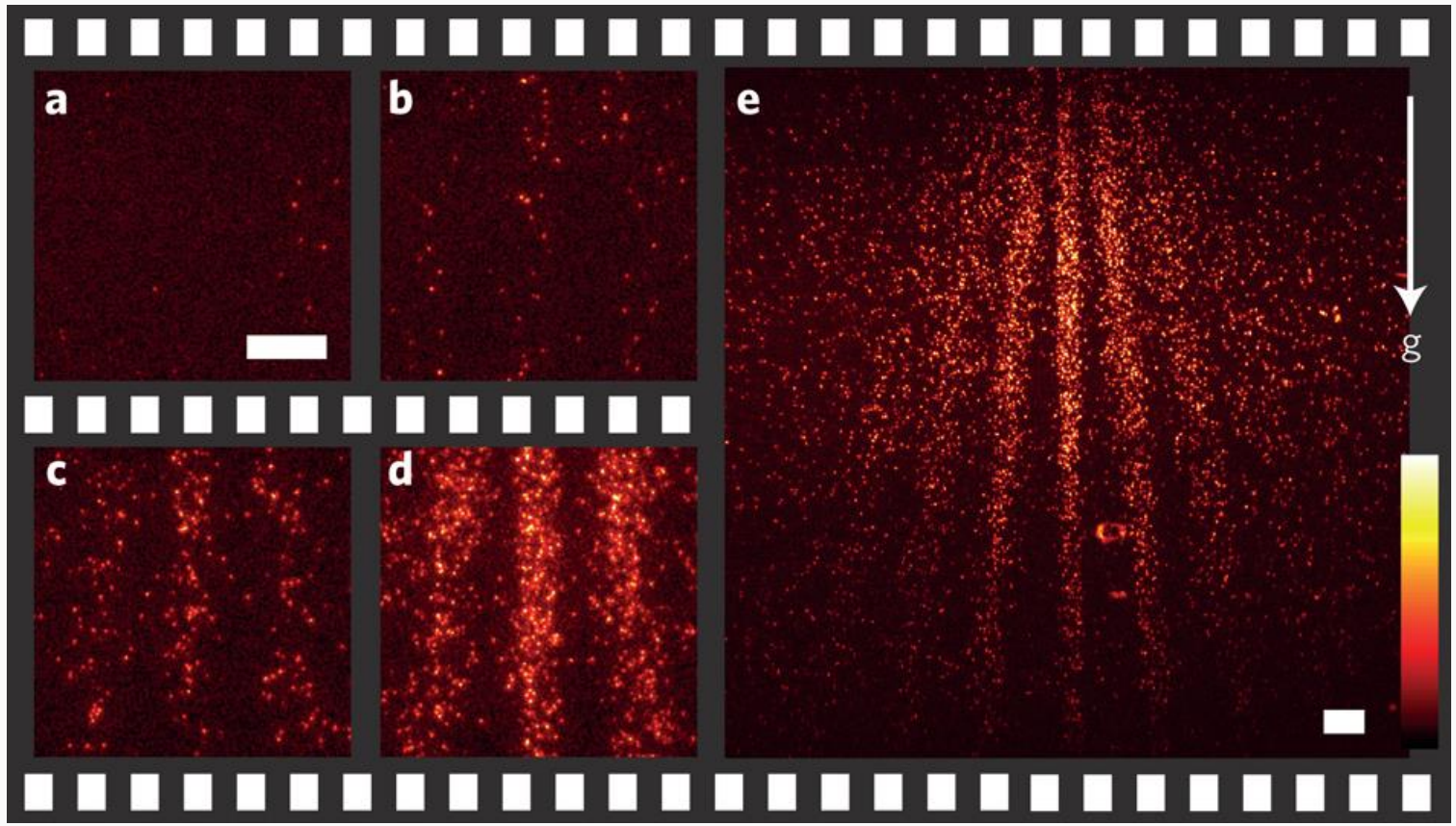


Quantum superpositions

- Usually just for electrons, photons, atoms, etc.



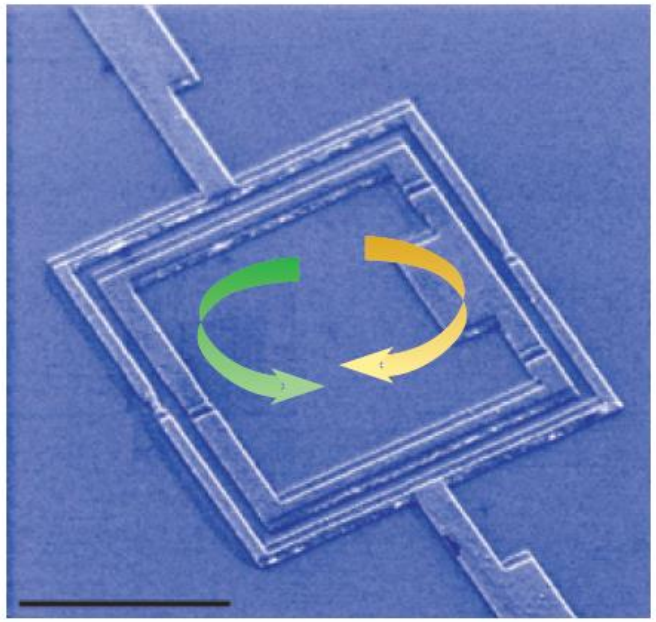




Juffmann et al, *Nature Nanotechnology* ***7***, 297–300 (2012).

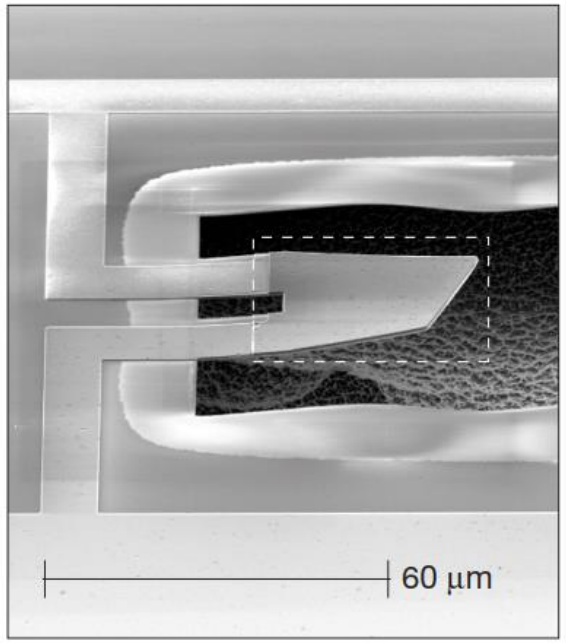
Quantum phenomena in macroscopic optomechanical systems

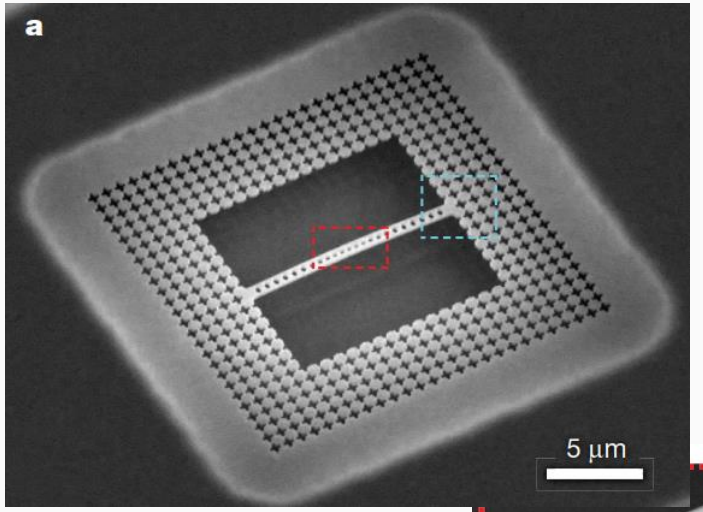
- Have been cooled to their ground state and superposition states have been prepared.



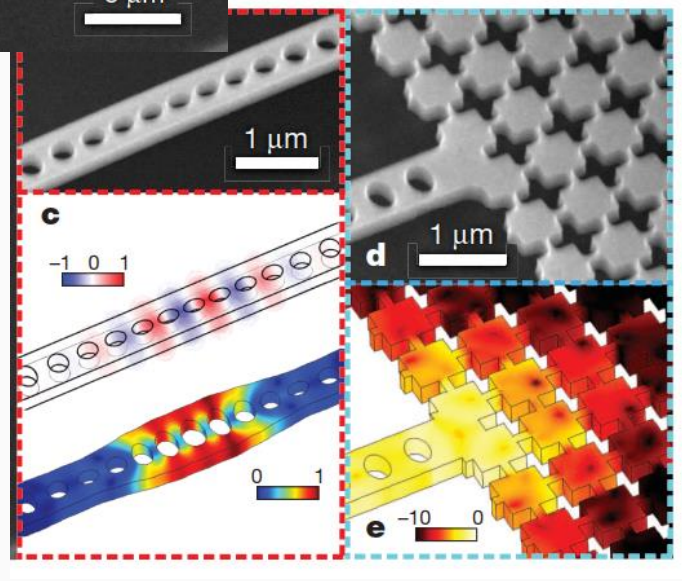
Friedman et al, *Nature* **406**, 43-46 (2000).

O'Connell et al, *Nature* **464**, 697-703 (2010).



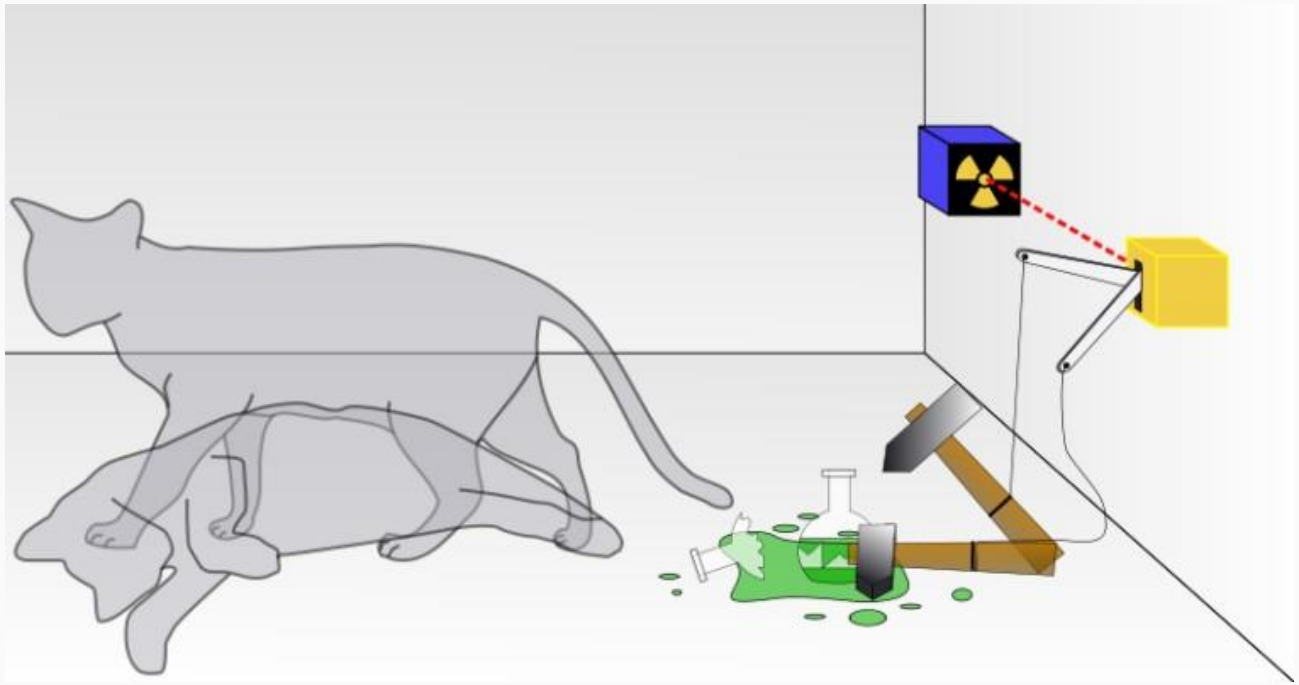


Chan et al, *Nature* **478**, 89-92 (2011).



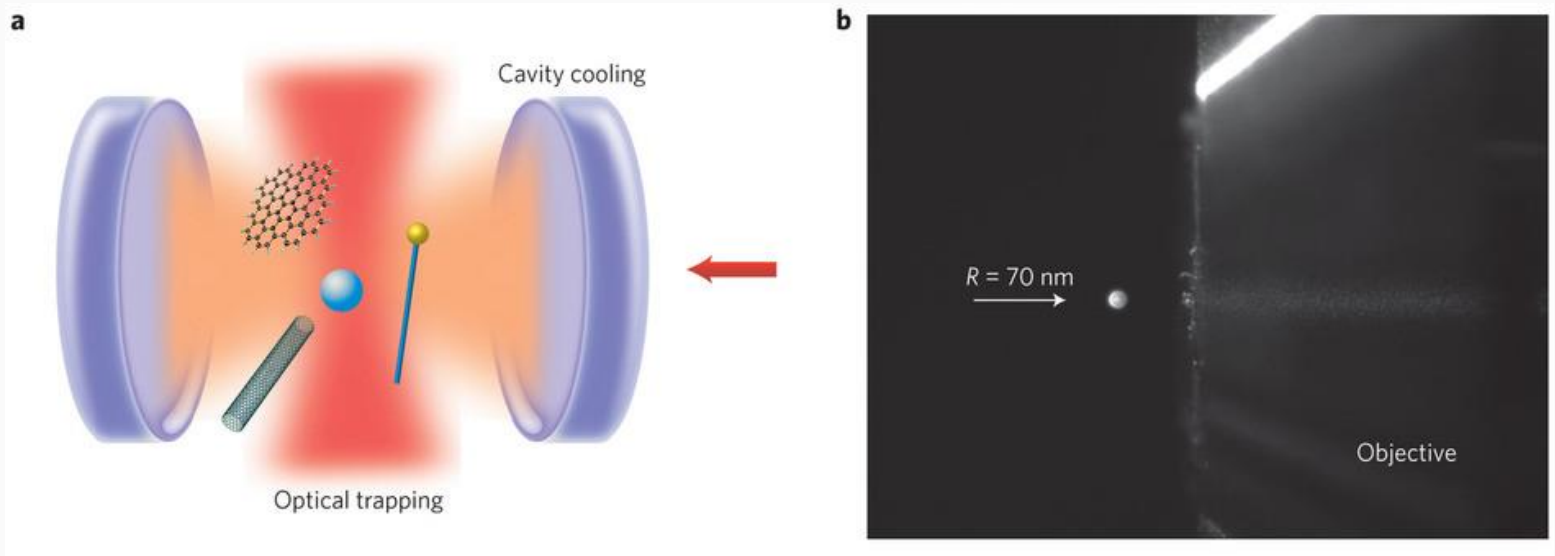
The quantum coin toss

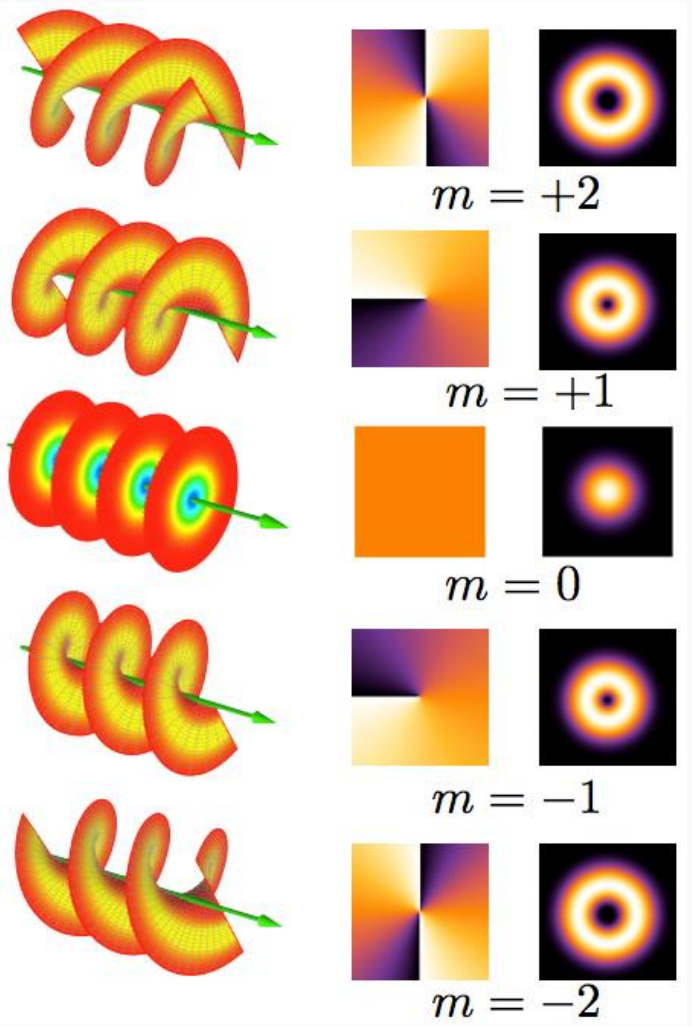
- What about something like a coin?



Trapping and cooling a coin

- Use counter-propagating Lageurre-Gauss beams to trap and cool both translational and rotational motion.

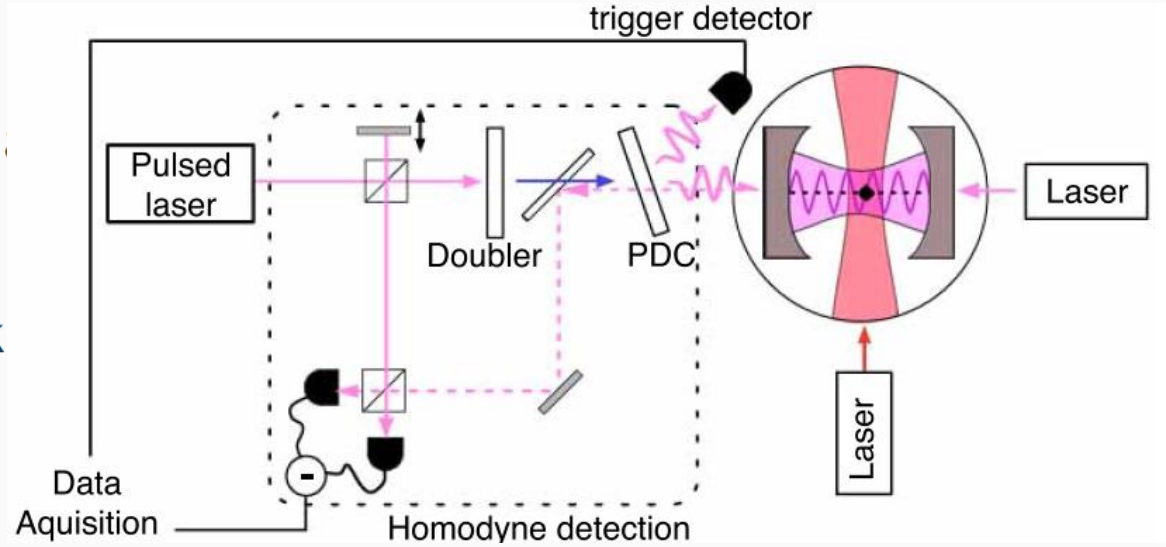




Maragò et al, *Nature Nanotechnology* **8**, 807–819 (2013).

Flipping the coin: preparation of the quantum superposition state

1. Shine single-photon Fock state from parametric down conversion onto cavity. Only let half of it in!
2. Drive cavity with a red-detuned laser to swap the state of the light inside the cavity with the mechanical motional state.
3. You now have $\frac{1}{\sqrt{2}}\left(\left|\tilde{0}\right\rangle|H\rangle + \left|\tilde{1}\right\rangle|T\rangle\right)$.
4. Perform balanced homodyne measurement switch off driving field.
5. You now have $|\psi\rangle = c_H|H\rangle + c_T|T\rangle$. Pick experimental conditions such that $c_H = c_T$ if you want.



Romero-Isart et al, *New Journal of Physics* **12**, 33015 (2011).

Heads or tails? Measurement of the quantum superposition state

- $\langle \hat{z} \rangle$ oscillations indicate a successful preparation of a quantum superposition state.
- This lets you check for a successful preparation but doesn't actually tell you whether you got heads or tails.
    - Note that $|T\rangle$ will be doubly degenerate.

Conclusion: Why does this proposal fail?

- Relied on too many other proposals. Everything was just about doable with current technology.
- Authors refers to multiple publications in preparation that did not pan out.
- Experimental realizations are more difficult than proposals make them sound.
- Verdict: maybe quantum superpositions of macroscopic systems is possible but you probably won't see one with your own eyes.
    - If you could see it with the naked eye, you would be perturbing the system...