Heads or tails? Observation of quantum superposition in a macroscopic coin*

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Abstract

It is well known that atoms and molecules obey the laws of quantum mechanics which often seem counterintuitive to everyday observations. A simple extension would be to argue that all systems are composed of atoms and molecules and so should subsequently obey the same laws—quantum mechanics in principle applies to arbitrarily large systems. Of course, due to strong interactions with their environment leading to decoherence, larger systems do not exhibit any quantum behavior on macroscopic scales. But could a macroscopic object behave in a quantum manner under the right conditions?

While macroscopic mechanical oscillators have been laser cooled into their quantum ground state [1], only proposals exist so far for probing macroscopic quantum superposition [2]. We extend proposals of preparing quantum superpositions of viruses [3] and recent thought experiments placing temporal limits on tests of quantum superposition [4] to prepare a macroscopic dielectric coin in a superposition state and conduct the world's most sophisticated coin toss.

To carry out the coin toss, we fabricated a miniature-sized[1] dielectric Canadian toonie which we then trap in a high-finesse optical cavity using optical tweezers, cooling its mechanical motion to the ground state. The driving field that generates the cooling radiation pressure can also be used to measure the average phonon number per mechanical mode. We also cool the coin's rotational motion. The coin is then prepared in a quantum superposition state $|\psi\rangle = (|H\rangle + |T\rangle)/\sqrt{2}$ by sending in half of a one-photon pulse and then making a homodyne measurement of the cavity's output modes. Another homodyne measurement, this time of the cavity light field, collapses the coin into one of the heads $|H\rangle$ or tails $|T\rangle$ state.

References

[1] Chan, J. et al, "Laser cooling of a nanomechanical oscillator into its quantum ground state", *Nature* **478**, 8992 (2011).

[2] Arndt, M. and Hornberger, K., "Testing the limits of quantum mechanical superpositions", *Nature Physics* **10**, 271277 (2014).

[3] Romero-Isart, O. et al, "Toward quantum superposition of living organisms", *New Journal of Physics* **12**, 033015 (2010).

[4] Mari, A., Palma, G., and Giovannetti, V., "Experiments testing macroscopic quantum superpositions must be slow", *Scientific Reports* **6**, 22777 (2016).

*This is a "proposal" for a fake experiment.

[1] Right now the coin's size must have sub-wavelength dimensions. I'm hoping to find a convincing method of cooling a more macroscopic coin.