QSS27 - Oriol Romero-Isart - Questions & Answers

Oriol Romero-Isart

Iñigo Arrazola: Is there any "spin-echo" type (or dynamical decoupling type) of protocol to protect bosonic states against frequency noise?

ORIOL: I'm not aware of any study in this direction.

Julen Simon Pedernales: Is gravitational acceleration noise a limiting factor in these setups?

ORIOL: It is not a limiting factor in current experiments. Gravitational acceleration noise is a low frequency weak noise that might be of relevance only in precision measurements.

Miskeen Khan: Can back ground gas scattering is always obselte and plays no role in the decoherence at all ?

ORIOL: It plays no role if each experimental run is much shorter than the timescale required for a single scattering event to be relevant. The latter timescale is given by Eq (27) in PRA 84, 052121 (2011) and is within a millisecond for 10^{-9} mbar.

The bang-bang protocol is done at time intervals that correspond to harmonics of the harmonic oscillator frequency. It seems that this makes it extremely sensitive to noise on the drive, because that leads to parametric heating. Can this be circumvented somehow?

ORIOL: I do not know how this can be circumvented. Perhaps one could try to find optimal solutions of the potential modulation that are more robust to frequency noise. However, I have the feeling that one will always need to pay a price for achieving large delocalization in a fast way.

Can you use squeezed light for the optical trapping beams -in order to reduce "displacement noise" compared to classical light?

ORIOL: Yes, squeezed light can reduce displacement noise. However, the power required for optically trapping a nanoparticle is not compatible with the squeezing that you need to make this reduction significant.

What are typical heating rates in trapped nanoparticles (in quanta/s) compared to trapped ions or atoms? Is vacuum quality the dominant effect?

ORIOL: In optical trapping, the phonon heating rate due to laser scattering is around 1KHz . At pressures below 10^{-6} mbar, vacuum quality is not the dominant effect. See for instance PRL 116, 243601 (2016).

What sets the upper and lower limits on the masses that can currently be used in experiments?

ORIOL: The answer depends very much on the physical implementation. Generally speaking, the bigger the mass, the larger the decoherence (e.g. recoil heating in optical manipulation for sub-wavelength particles scales with the volume of the particle). The smaller the mass the more difficult it is to measure its position (e.g. optical imaging, as the polarizability scales with the volume of the particle).

In measuring gravity at short distances, what is the advantage of using a macroscopic reference mass compared, for example, to atoms (as in atom interferometers)?

ORIOL: It is the higher mass density which allows us to place more mass near the source. See PRL 105, 101101 (2010).

How hot is the actual temperature of the particle? There must be a lot of scattering and heating going on. How does this limit the experiments that can be envisioned?

ORIOL: In optical manipulation, the bulk temperature is estimated to be even above 1000K in current experiments (see PRA 97, 043803 (2018)). However, the center-of-mass of a trapped nanoparticle is decoupled to internal acoustic phonons due to the huge mismatch in frequencies. The coupling is off resonant. In terms of experiments in which the center-of-mass is delocalized over large distances, the decoherence due to emission of black-body radiation is very dominant (PRA 84, 052121 (2011)). Managing decoherence due to black-body radiation is indeed one of the main challenges to be circumvented.

What are the main challenges of making the particles bigger? Picking up on the introduction, where you mentioned Frogs, are additional opportunities with diamagnetically levitated particles?

ORIOL: Yes, there are already experiments in which magnetic particles are diamagnetically levitated. Here a couple of examples: PRL 124, 163604 (2020) and PRApplied 13, 064027 (2020). However, these experiments are far from bringing the center-of-mass motion to the quantum regime. Alternatively, one can consider to magnetically levitate dimagnetic particles (we proposed it in PRL 109, 147205 (2012)), see also the experiment in NJP 20, 063028 (2018).

To what extent does using the impressive force and acceleration sensitivity you have, it seems that there are a lot of practical applications. To what extent could these be used for probing fundamental physics (e.g., establishing better values for the gravitational constant, big G?)

ORIOL: This question is addressed in the recent review arXiv:2008.13197.