Quantum sensing: from single molecules to quantized vortices

Catxere Andrade Casacio, Christopher Baker, Larnii Booth, Stefan Forstner, Glen Harris, Xin He, Lars Madsen, Nicolas Mauranyapin, Yauhen Sachkou, Andreas Sadawsky, Yasmine Sfendla, Michael Taylor, Muhammad Waleed and Warwick Bowen

Australian Centre of Excellence for Engineered Quantum Systems, School of Mathematics and Physics, University of Queensland, Australia.

It has been known for over a century that, in quantum physics, even the act of looking can have dramatic consequences. For instance, it kills the cat in Schrödinger’s famous thought experiment. However, it has proved extremely difficult to observe such effects in practice, except for the smallest atom-scale objects, let alone to use them as a tool to enhance technologies.

Over the past decade, however, advances in nanotechnology have allowed us to engineer devices which exhibit this distinctive quantum behavior [1]. These “quantum optomechanical devices” consist of a nanoscale mechanical object – for example, a nanoparticle, molecule or cantilever – coupled to light via radiation pressure, often concentrated in a tiny optical cavity. In essence, they are miniature versions of the kilometer-scale interferometers that have enabled the extraordinary detection of gravitational waves from distant black hole collisions (see Figure). Quite remarkably, they can allow measurements of mechanical motion at the sub-attometre level – more than a thousand times below the width of an atomic nucleus. At the fundamental level, this allows us to ask new questions of quantum physics for macroscopic systems consisting of trillions of atoms. For applications, it provides a pathway to future quantum technologies and precision optical sensors that far outperform the current state-of-the-art.

In this talk, I will provide an overview of quantum optomechanical sensing. I will focus on recent experiments in my laboratory which apply techniques from the field to probe biophysics [2], most recently the dynamics of single unlabeled biomolecules; and to observe and control elementary excitations in superfluid helium [3], a naturally occurring quantum fluid akin to a superconductor that was the subject of the 2016 Nobel Prize in Physics.

Figure: Left, Laser Interferometric gravitational wave interferometer (LIGO). Right, miniaturised silicon chip based optomechanical sensor.

References