Matter-Wave Interferometry of a Levitated Nanodiamond Induced and Probed by a Spin

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Quantum mechanics has always puzzled scientists because its features do not seem to be valid in everyday life, as exemplified by the well known paradox of Schroedinger's cat, where a cat can be in a superposition of *dead* and *alive* states. Since quantum mechanics works extremely well when we describe the microscopic world, there must be a boundary which establishes to what extent the theory gives the correct predictions and when the *microscopic* world becomes *macroscopic*.

Optomechanics is a new field of quantum optics whose aim is to test the validity of quantum mechanics with objects (such as vibrating mirrors interacting with the quantized electromagnetic field) which we would like to take bigger and bigger.

In our contribution, we propose a novel optomechanical system, where an oscillating nanodiamond interacts with the spin of a defect embedded in it. The spin-motion coupling is realized by means of a suitable magnetic field gradient, which induces a spin-dependent conditional displacement on the center of mass of the bead. We show that the evolution of the spin evidences phases which come from the interaction of the diamond with the gravitational field. The possibility of revealing quantum superpositions of the motional states of the nanodiamond by measuring the spin only may considerably simplify future tests of the validity of quantum mechanics and shed new light on our understanding of the microscopic/macroscopic transition. To this aim, we consider also extensions of our scheme which would allow us to test models of quantum collapse with our device.

Finally we discuss practical metrological applications aimed at building miniaturized gravimeters.

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