Measurements beyond the Heisenberg uncertainty bound

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This tutorial will revisit quantum limits for measurement and sensing. It is well known that a measurement of a position of an object imposes a random quantum back action perturbation on its momentum. This randomness translates with time into position uncertainty, thus leading to the uncertainty of the measurement of motion. The Heisenberg microscope is a textbook example illustrating this fundamental effect. As a consequence, the precision of sensing of position, velocity and force becomes limited in quantum mechanics. Remarkably, those limits can be surpassed by performing measurements in a special reference frame with an effective negative mass [1]. A spin polarized atomic ensemble can play the role of such reference oscillator. Evasion of quantum back action of the measurement and generation of an entangled state of a sensor and of the reference frame has been demonstrated in [2,3]. Sensing of fields and motion beyond standard quantum limits has become possible using this principle. Examples of applications include sensing of tiny magnetic fields [4] and detection of gravitational waves [5].

REFERENCES

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