ICFO in Nature

An experiment in the group of Morgan Mitchell exceeds the "Heisenberg limit," thought to be the ultimate limit for ultra-sensitive measurements.

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In an experiment with ultra-cold atoms, physicists at ICFO have for the first time exceeded the "Heisenberg limit," often described as the ultimate limit for gravitational wave detection, magnetic imaging, and other ultra-sensitive measurements. The result is of fundamental importance for interferometry and the quantum limits of measurement, and may find application in fields from medical diagnosis to satellite-based navigation.

Interferometry uses the quantum *superposition principle*, which allows quantum particles to take multiple paths at the same time, in order to detect tiny path differences. It uses quantum entanglement to organize groups of particles, to reduce their inherent quantum randomness. The new work shows how to use *interactions* among the particles to make an interferometer even more sensitive. In the experiment, controlled interactions inside the interferometer pushed the sensitivity beyond the Heisenberg limit, the best possible with only superposition and entanglement.

The team used a "polarization interferometer" designed to detect magnetic fields rather than gravitational waves. To make the photons interact, they filled the interferometer with ultra-cold rubidium atoms. Although photons do not interact directly, these atoms mediate the interaction, allowing the photons to exchange energy. This interaction-based measurement showed scaling better than the Heisenberg limit and beat a traditional interferometer by a factor of ten. The picture illustrates the atom-mediated photon interaction that results in the ultra-sensitive measurement.

The article **Interaction-based quantum metrology showing scaling beyond the Heisenberg limit** has been published in the 24 March issue of the journal *Nature* by PhD students Mario Napolitano, Marco Koschorreck, Brice Dubost, Naeimeh Behbood, postdoctoral researcher Robert Sewell, and Professor Morgan Mitchell, leader at ICFO of the group of quantum information with cold atoms and non-classical light.