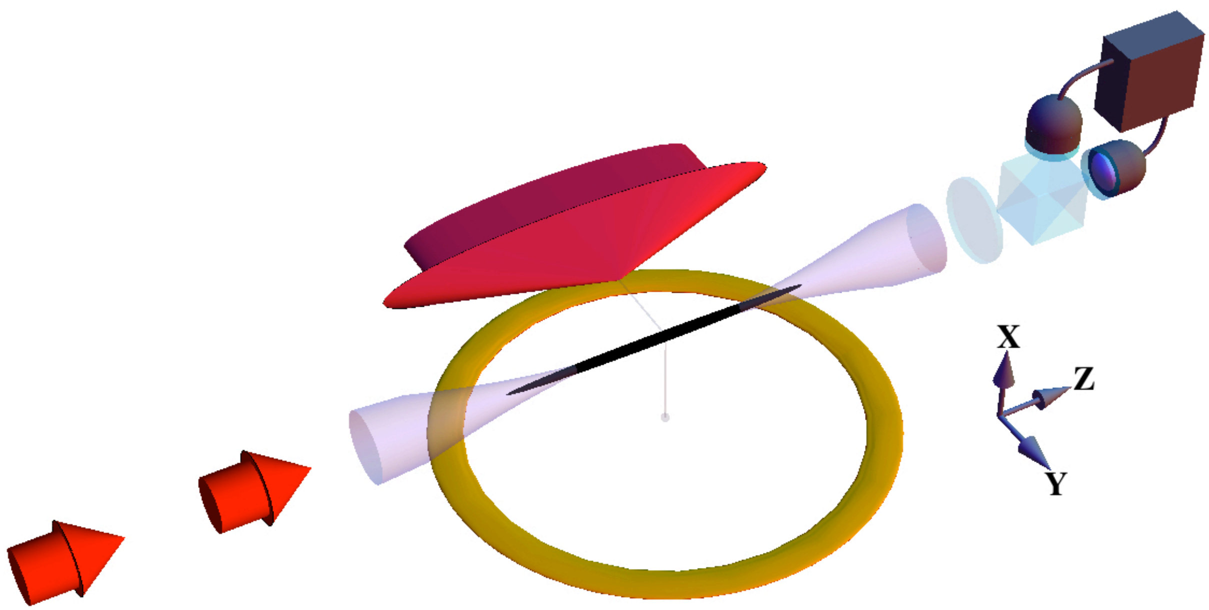
Detecting radio waves with entangled atoms

August 2 2017



Schematic illustration of the experimental setup. Credit: ICFO

In a study published in *Physics Review Letters* and highlighted by *APS Physics*, ICFO researchers demonstrate a new technique for the coherent detection of radio frequency magnetic fields using an atomic magnetometer. They used highly sensitive, nondestructive measurements to entangle the atoms while maintaining their collective coherence, and a new technique to allow the coherent buildup of signal from arbitrarily shaped waveforms.

In this study, ICFO researchers Ferran Martin Ciurana, Dr. Giorgio

Colangelo, Dr. Rob Sewell, led by Prof. Morgan Mitchell, trapped an ensemble of more than a million rubidium atoms that were laser-cooled to 16°K, near absolute zero. They applied a static magnetic field to the trapped atoms to make the atomic spins precess (rotate) synchronously (coherently) at a precise frequency of 42.2 kHz, which is within the low frequency band used for AM radio broadcasting. They then applied a weak resonant radio frequency field in an orthogonal direction, which perturbed the atomic spin precession—this was the signal they wanted to detect.

In a standard RF magnetometer, the atomic spins are allowed to evolve freely for some time under the influence of this perturbation to allow the coherent buildup of signal before the change in the atomic state is detected. Typically, this technique is only sensitive to an RF field applied at a fixed resonant frequency.

In this study, the authors used two techniques to improve their measurement. First, they used stroboscopic quantum non-demolition measurements to prepare an entangled atomic spin state at the start of the detection sequence. This allowed them to reduce the quantum noise coming from the atoms, and improve the sensitivity of the magnetometer beyond the standard quantum limit.

Second, they used a new technique developed in the group to allow the coherent detection of an RF field with a changing frequency—as is used, for example, in an FM radio broadcast. During the free evolution time, they used the applied static magnetic field to continuously shift the resonance frequency of the atoms to match the changing frequency of the RF field. This allowed the atoms to coherently build up signal from a single arbitrary RF waveform, while blocking unwanted signals from orthogonal waveforms.

They then detected the perturbed atoms using a second stroboscopic quantum non-demolition measurement in order to measure the signal due to the RF field, and verify the entanglement generated among the atomic spins.

The researchers demonstrated their technique by detecting a linearly chirped RF field with a sensitivity beyond the standard quantum limit. They were able to measure the weak RF magnetic field signal with a 25 percent reduction in experimental noise due to the quantum entanglement of the atoms, and a sensitivity comparable to the best RF magnetometers used to date.

The technique may have applications including the detection of bio-magnetic fields, characterization of micro-electronics, and searches for extraterrestrial civilizations.

More information: F. Martin Ciurana et al. Entanglement-Enhanced Radio-Frequency Field Detection and Waveform Sensing, *Physical Review Letters* (2017). DOI: 10.1103/PhysRevLett.119.043603

Provided by ICFO