CRC 1227
Designed Quantum States of Matter

GUEST LECTURE

Dr. Stuart Szigeti

The Australian National University, Canberra
Department of Quantum Science
(Guest of Prof. Dr. Klemens Hammerer)

Leibniz Universität Hannover
DQ-mat Colloquium
23 July 2020, 1:00 pm
(via Zoom-Meeting)

"High Precision, Quantum-Enhanced Gravimetry with a Bose-Einstein Condensate"

Atom interferometry is a leading precision measurement technology that has demonstrated state-of-the-art measurements of accelerations and rotations, gravity, magnetic fields, and the fine structure constant. Transitioning this technology out of the laboratory and into the field is being actively pursued by many research groups (including ours at ANU). In particular, improving the sensitivity for stationary applications and improving the robustness to environmental noise arising from vehicle motion in mobile applications would unlock new capabilities in inertial navigation, mineral exploration, and hydrology. More ambitious improvements could enable tests of the weak equivalence principle capable of proving/disproving candidate theories of quantum gravity.

Quantum entanglement offers a promising route to improved cold-atom gravimetry, since it enables relative-phase measurements below the shot-noise limit (SNL). Spin-squeezed atomic states have provided the largest degree of spin squeezing (20 dB), in the largest particle-number ensembles (> one million atoms), directly resulting in the most precise relative phase measurement ever made. Despite this success, no quantum-enhanced (sub-shot-noise) atom interferometer has demonstrated any sensitivity to gravity, even in laboratory-based proof-of-principle apparatus. The key challenge is that most methods of generating entangled atomic states are incompatible with the stringent requirements of precision gravimetry. Cold-atom gravimeters require the creation and manipulation of well-defined and well-separated atomic matter-wave momentum modes. Although entanglement generation between internal atomic states is relatively mature, no experiment has shown that entanglement between internal states can be converted into entanglement between well-separated, controllable momentum modes suitable for gravimetry.

In this seminar, I will present a scheme for generating useful quantum correlations in a Bose-Einstein condensate (BEC) that is compatible with the stringent requirements of high-precision atom interferometry. Detailed numerical simulations demonstrate that our scheme produces spin-squeezed states with variances up to 14 dB below the SNL, and that absolute gravimetry measurement sensitivities between 2 and 5 times below the SNL are achievable. Equivalently, this allows a decrease in device size by a factor of 2 - 5 at fixed sensitivity, which would likely improve robustness to environmental noise experienced in mobile sensing applications. Our proposal is immediately achievable in current laboratories, since it needs only a small modification to existing state-of-the-art experiments and does not require additional guiding potentials or optical cavities.

All DQ-mat members and all interested
are cordially invited to attend.