National Aeronautics and Space Administration

Ultra-high flux atom source (UFAS) for precision atom interferometric sensing

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Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Quantum Sensing for Science Missions - Strategic Initiative Leader: Edward T Chow

Objectives:

- Generate high-flux ultracold atoms for quantum sensing applications, such as quantum gravity gradiometer (QGG) for Earth mass change missions (Fig. 1)
- Target: 10^8 Cs atoms at 1nK
- SWaP optimized for space missions

Background:

- Quantum sensing is part of the National Quantum Initiative, and NASA's quantum initiative.
- Spaceborne QGG is identified as the most promising instrument development to yield impactful result.
- QGG performance is limited by number of ultracold atoms. Required atom number: 10^8, state-of-the-art (CAL): 10^5
- Conventional method doesn't scale, need new approaches

Approaches and Results:

- Direct laser cooling vs evaporative cooling (Fig. 2):
  - Atom efficiency > 25% (in literature)
- Blue-detuned box potential vs (red-detuned) optical dipole trap (Fig. 3):
  - Larger trap volume, less density-dependent atom loss
  - Lower optical power requirement
- Blue box overlapped with cold atoms (Fig. 4)
- Simulation showing direct laser cooling (Fig. 5)

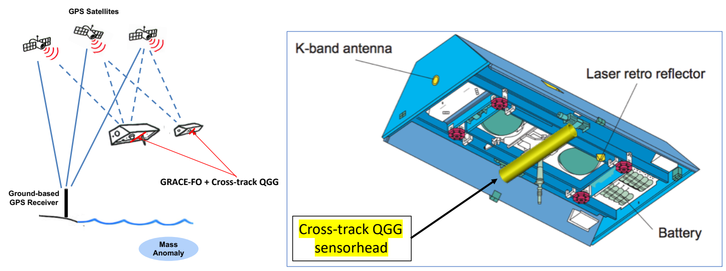

Figure 1. QGG for Earth gravity measurements

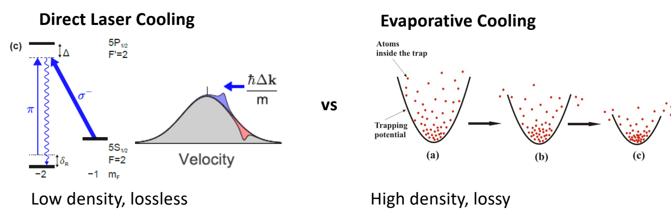

Figure 2. Left: Direct laser cooling. Right: Conventional BEC generation.

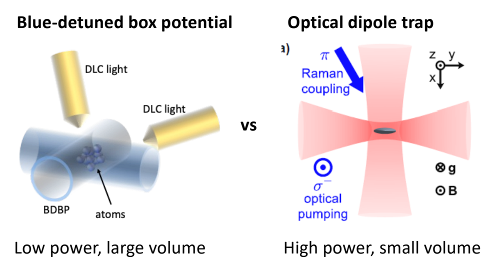

Figure 3. Direct laser cooling of trapped atoms in a blue box potential (left) and in an optical dipole trap (right).

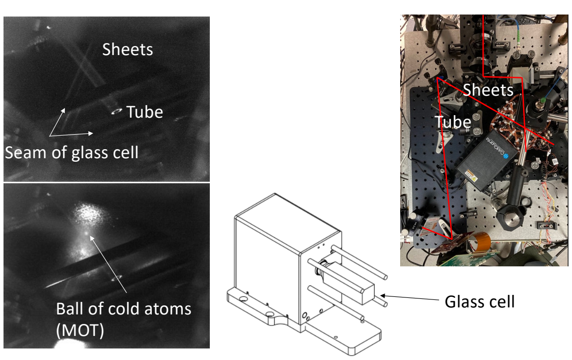

Figure 4. Cold atoms in a blue box.

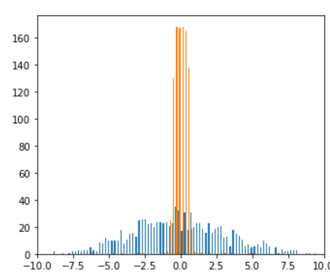

Figure 5. Raman cooling simulation. Velocity distribution before (blue) and after (red) cooling.

Significance/Benefits to JPL and NASA:

- JPL has been leading in space quantum sensor technology and applications.
- This SRTD will position JPL in a competitive and competent position to capture the next mission opportunity deploying the first high-performance quantum sensor measurement system in space, such as QGG for mass change.

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Clearance Number: CL#22-5116
Poster Number: RPC#R22035