National Aeronautics and Space Administration

An Optical Dipole Trap for NASA's Cold Atom Lab

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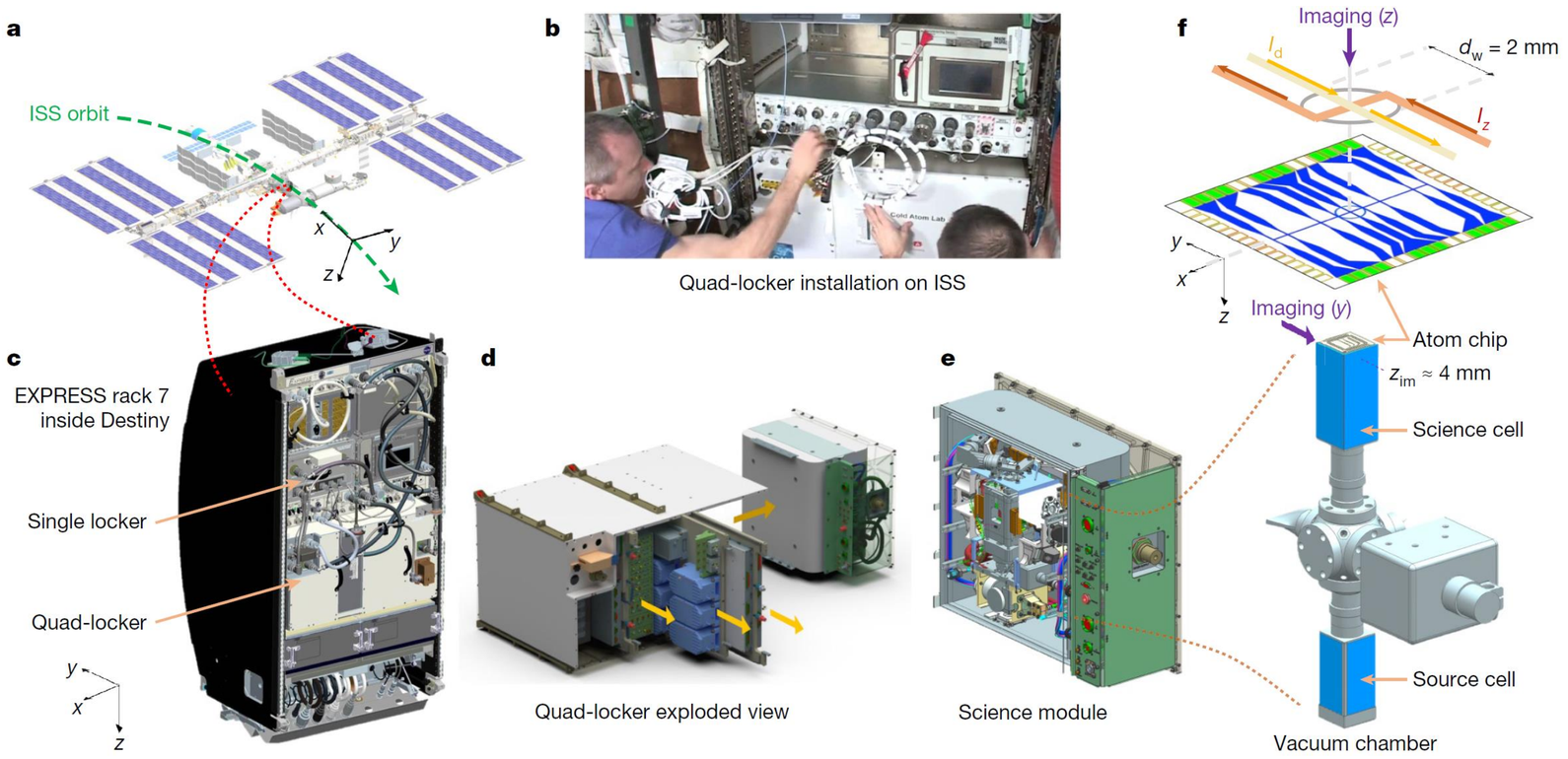
NASA's Cold Atom Lab (CAL) Operating Onboard the ISS



[Aveline, Williams, Elliott, *et al., Nature* **582,** 193–197 (2020)]

- **Multi-user facility for performing quantum experiments with ultra-cold quantum gases onboard the ISS.**
- **Microgravity environment that circumvents the gravitational limits of terrestrial quantum experiments.**

CAL Enabled Science in Space

- **Delta-kick cooling to sub-nanoKelvin temperatures.**
- **First Bose-Einstein Condensate (BEC) in orbit.**
- **Exceeded 1s of free-fall in orbit.**
- **Dual-species mixtures capability ($^{87}Rb^{39}K$ or $^{87}Rb^{41}K$).**
- **First realization of a "bubble" BEC.**
- **Demonstrated single and dual species matter-wave atom interferometry in orbit.**
- **Few-body physics and tunable interactions.**

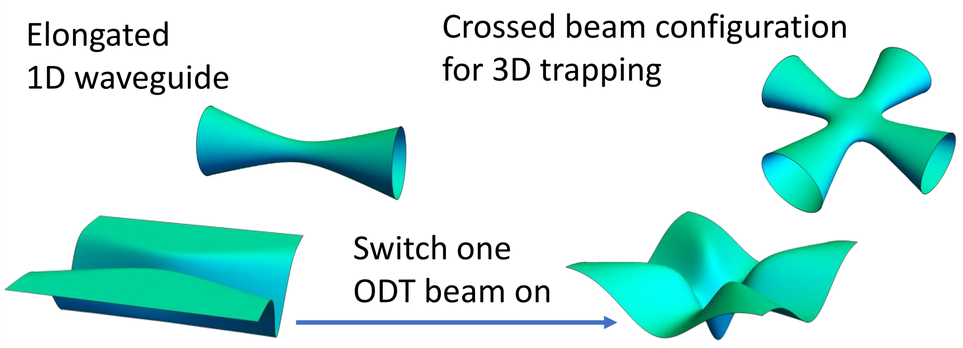
[Aveline, Williams, Elliott, *et al., Nature* **582,** 193–197 (2020)]

Optical Dipole Trap (ODT) Addition

<u>Objective:</u> demonstration of an Optical Dipole Trap (ODT) with the CAL-1B Physics Package (PP). Such an ODT addition could be delivered as a technology demonstration in a future resupply of the Science Module (SM).

<u>Motivation:</u> The ODT addition would be a new tool and enable new experiments, as atoms could be confined purely optically, such as:

- **Trapping independent of internal (magnetic) states.**
- **Free use of magnetic fields for e.g. tuning atomic interactions.**
- **New science (e.g. quantum droplets, few-body physics,…).**
- **Localized potentials for stirring up vortices and painting traps.**



Summary & Outlook

➡ **No laser-induced damage done to the PP AR coating surface & to the bulk of the CAL-1B science cell**

Next step: demonstrate a 1D ODT with the CAL-1B PP setup

Compatibility Tests of ODT Laser Beams on CAL-1B Science Cell

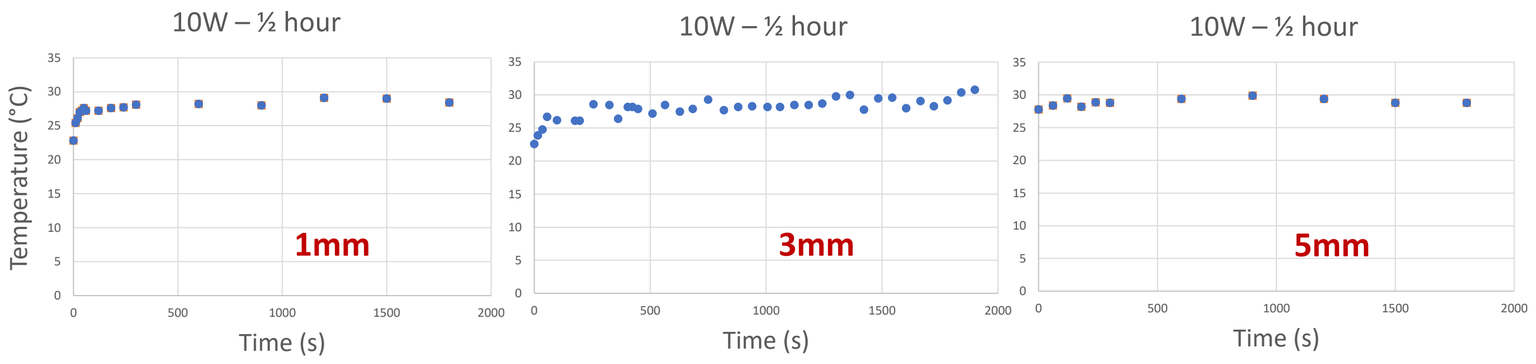
- **No harm tests to assess the risk of laser-induced damage done to the PP Anti-Reflective (AR) coating surface & to the bulk of the science cell**

1. Transmitted (T) & Reflected (R) power measured from the top surface of the science cell

Distance from atom chip	T (%)	R (%)
1mm	96.94	0.77
3mm	97.45	0.83
5mm	97.94	0.52

➡ **<1% measured reflectivity of the science cell AR coating measured after four surfaces**

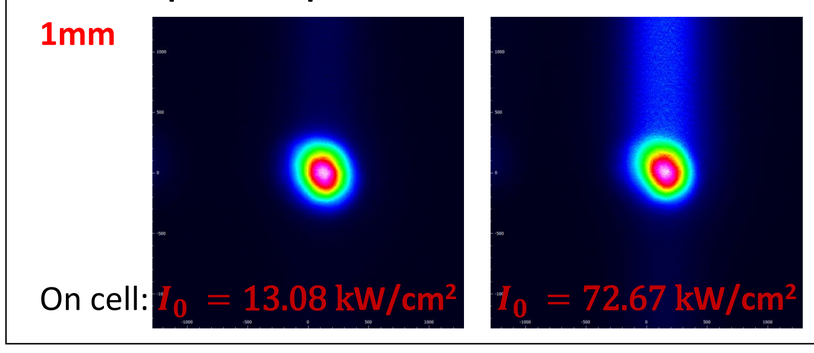
2. Temperature measured over time at the entrance surface of the science cell



Peak intensity that could be applied on the science cell: $I_0 = 9.40\ \mathrm{kW/cm^2}$
Intensity applied to the science cell for **½ hour**: $I_0 = 72.67\ \mathrm{kW/cm^2}$
Intensity applied to the science cell for **2 hours**: $I_0 = 13.08\ \mathrm{kW/cm^2}$

➡ **applied x8 more intensity for ½ hour & x1.5 more intensity for 2 hours than the peak intensity that could be applied on the science cell – no heating of the science cell observed**

3. Beam profile & polarization after the science cell



Science cell (3mm)	Polarization Extinction Ratio [dB]
w/o	**25.3**
13 deg	**25.3**

- **No interference fringes observed & no birefringence induced**

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Publications:

E. Elliott, […], S. Botsi, *et al., Quantum Gas Mixtures and Dual-Species Atom Interferometry in Space,* arXiv:2306.15223, (2023) (**accepted in Nature**)

J. Williams, […], S. Botsi, *et al., Interferometry of Atomic Matter-Waves in a Cold Atom Lab onboard the International Space Station,* (2023) (**in preparation**)

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