BEC3 Lab

NaLi molecule experiment

Collisional Dynamics of Ground-State $^{23}Na^{6}Li$ Molecules

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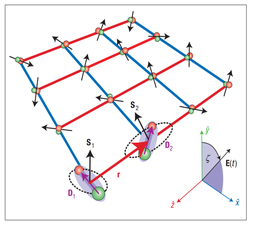
Dipolar Molecules with Spin

Why NaLi Triplet Molecules?

- Both electric & magnetic dipole moments (0.2 Debye, $2\mu_B$)
- Magnetic trapping, molecular and atom-molecule Feshbach resonances, spin-lattice Hamiltonian simulation
- Chemically reactive (2NaLi → Na_2 + Li_2); possibility for quantum chemistry
- However, still long-lived since NaLi is fermionic and light; ~5 seconds lifetime at density $5x10^{10}$ cm^{-3}

Lattice Spin Models



[A Micheli *et al.* Nat. Phys. (2006)]

[Rvachov et al. PRL, *119*.14 (2017) 143001]

[Rvachov et al. PCCP, *20*.7 (2018) 4739-4745.]

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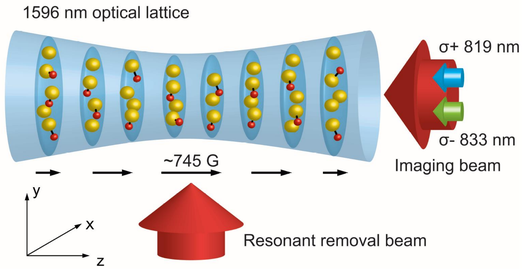
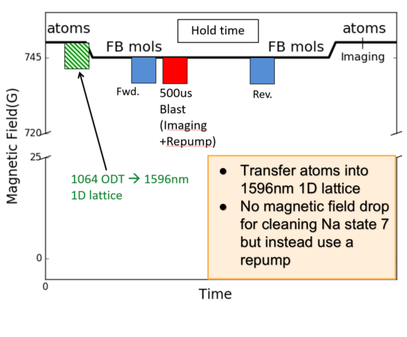
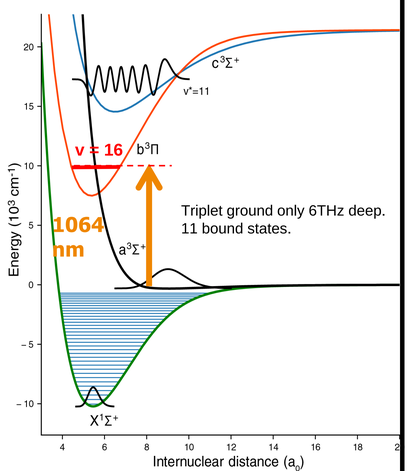
Forming Ground-State Molecules



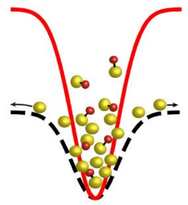
- 10^6 ^{23}Na and 10^6 ^6Li atoms in their lowest hyperfine states near quantum degeneracy (2uK) in 1D lattice (used to be 1319nm ODT)
- Magnetically associate Na & Li atoms to Feshbach molecules
- Transfer Feshbach molecules to the ground state using Stimulated Raman Adiabatic Passage (STIRAP)

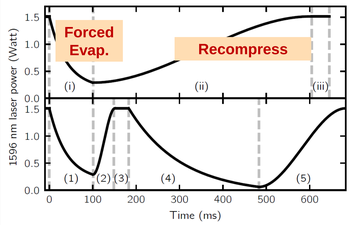


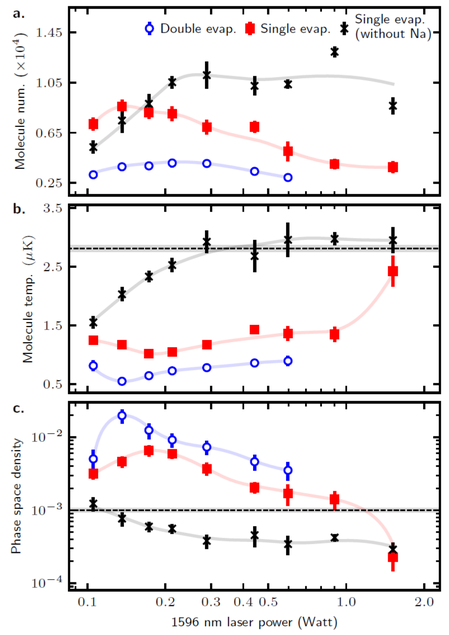


Sympathetic Cooling of Molecules

- Ground state molecules live long even in the presence of Na state 8 atoms
- The trapping potential of molecules is deeper than that of Na atoms
- Na atoms can be evaporated with negligible loss of molecules
- Increase in PSD by a factor of 20 and temperature as low as 220nK can be reached by two stages of evaporation

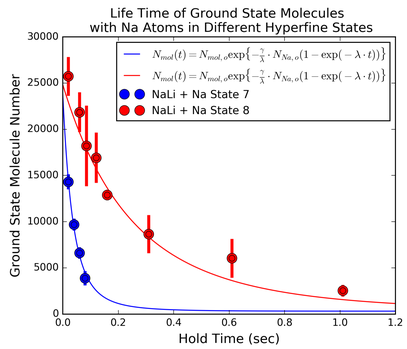


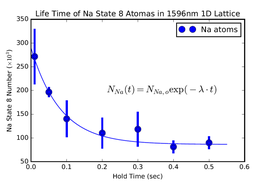




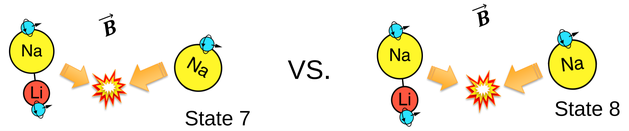
[Son, Hyungmok, et al. Nature 580.7802 (2020): 197-200.]

State Dependent Collision





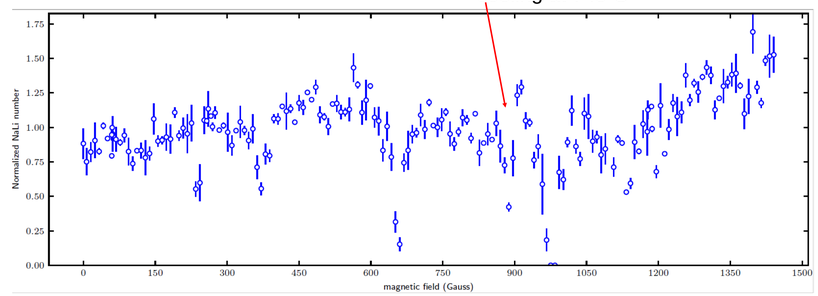
- $\frac{d}{dt} n_{mol}(t) = -\gamma \cdot n_{mol} n_{Na}$
- $n_{Na}(t) = n_{Na,o} \exp(-\lambda \cdot t)$

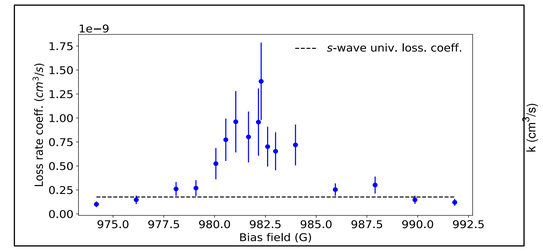


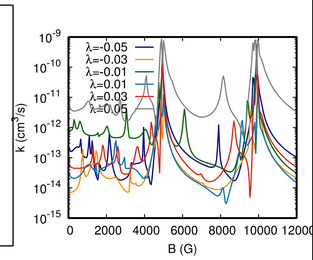
Molecule-Atom Scattering Resonance

Observed about 10 resonances in 1450 Gauss
molecules, Na atoms ~ 2uK

Previous sympathetic cooling at 745 G







Calculation by Dr. Tijs Karman

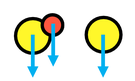
~ 5 times more lossy than universal limit

Resonances at 5000, 10000 G are insensitive to the potential!
→Inelastic spin-flip with excitation to N = 2 state of NaLi

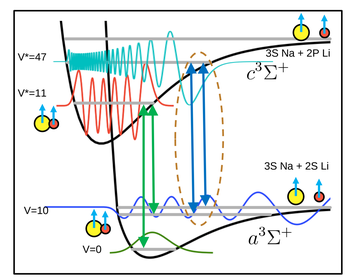
resonances at lower fields are associated with lower-energy excitations
: relative rotation of atom-molecule (i.e. higher moment of inertia)

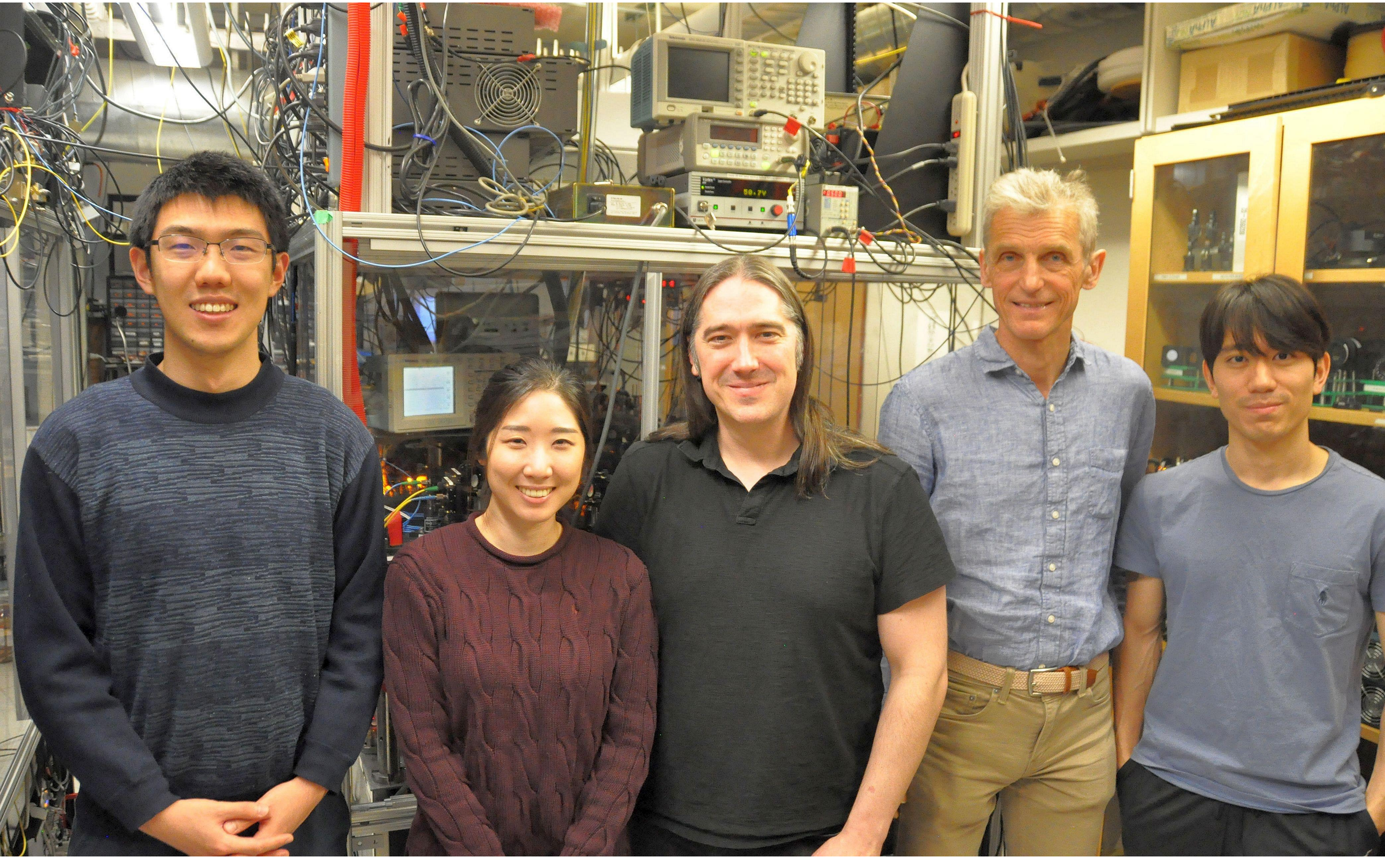
Prospects

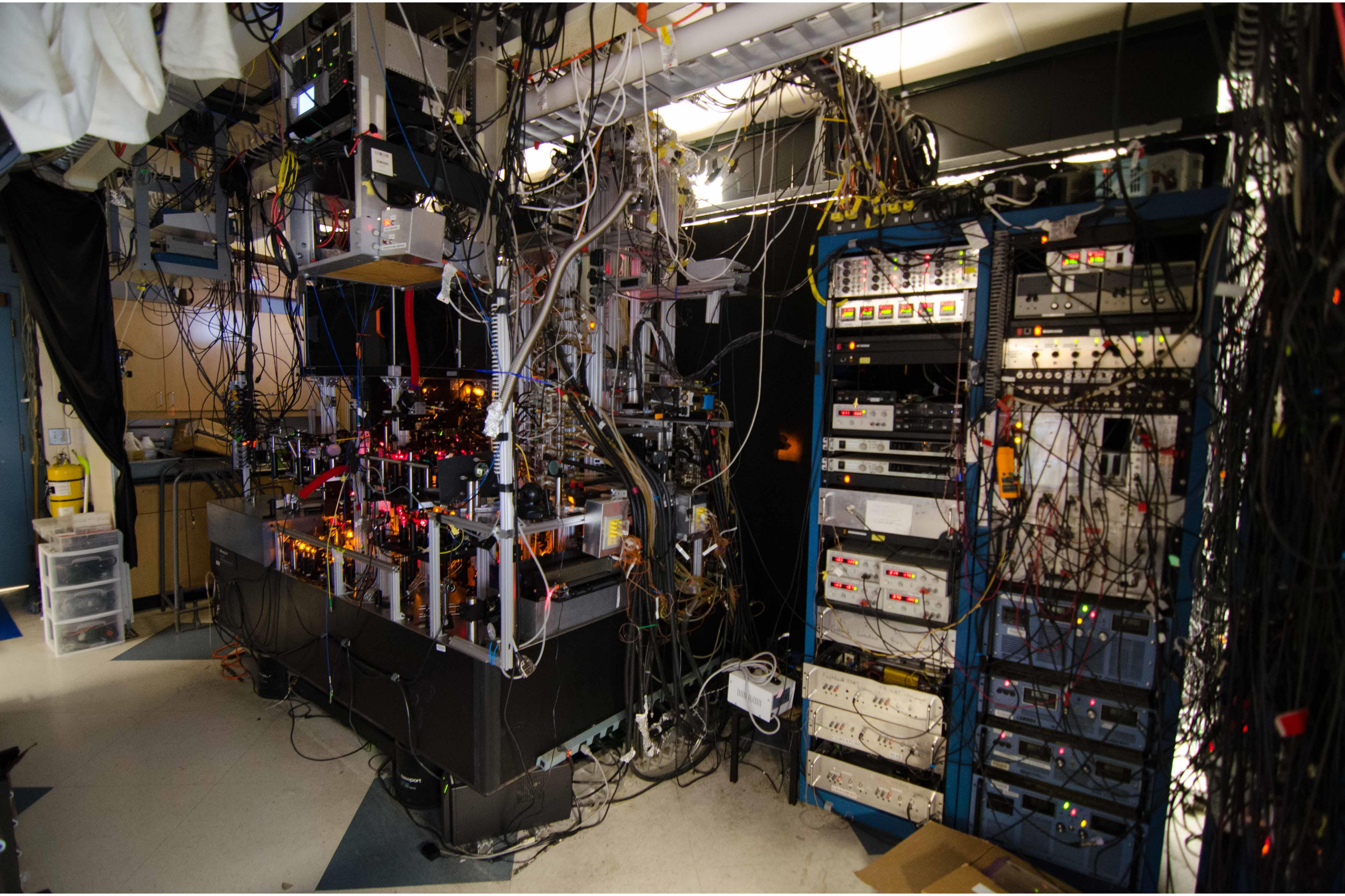
- Pure magnetic trapping of the NaLi molecules
- Quantum degenerate molecules through evaporative cooling in a magnetic trap or a deeper 1550nm cross ODT
- Study Collisional properties between molecules and atoms in different hyperfine states. (i.e. lower" spin-stretched (which is in a quartet potential), with zero doublet character)

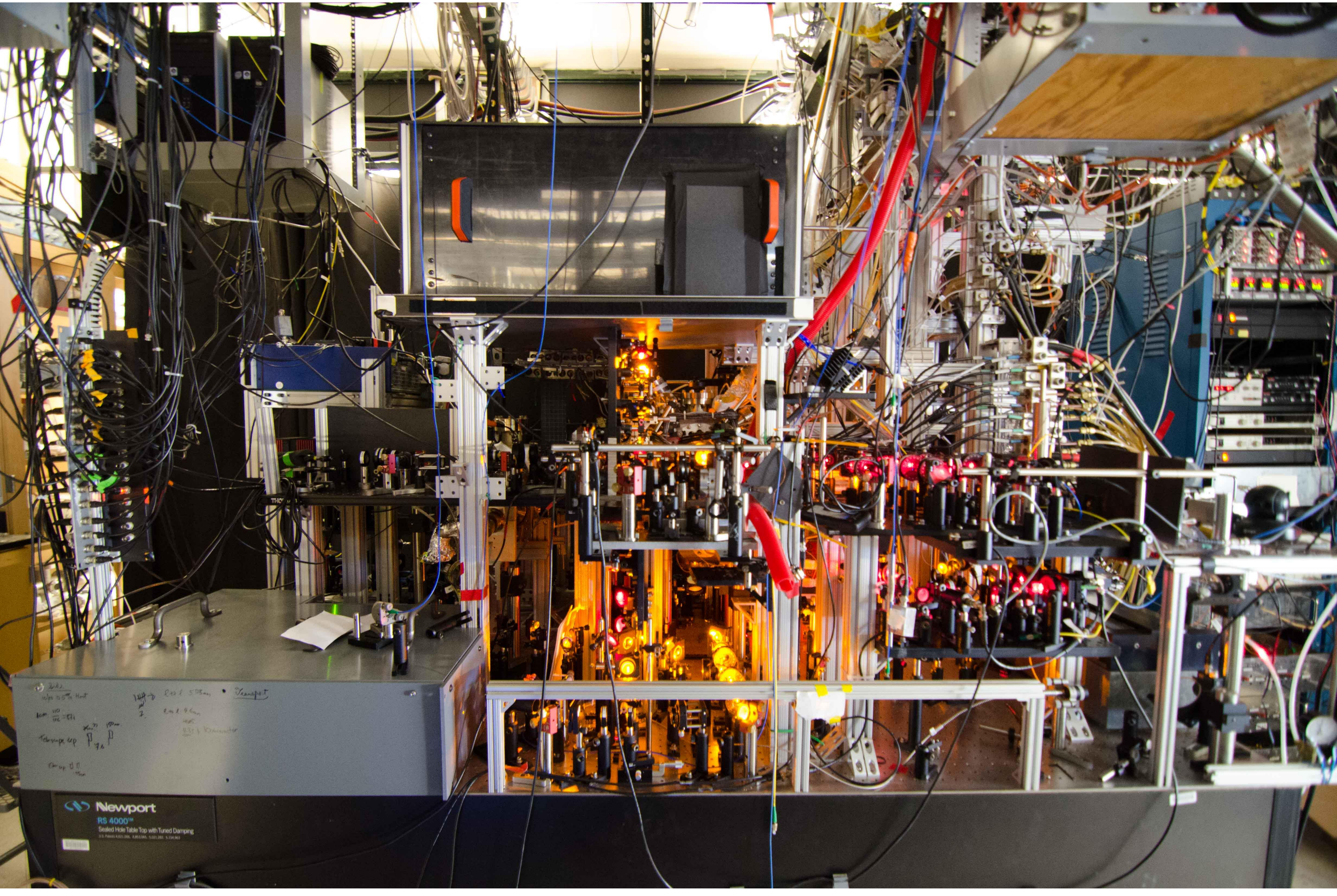


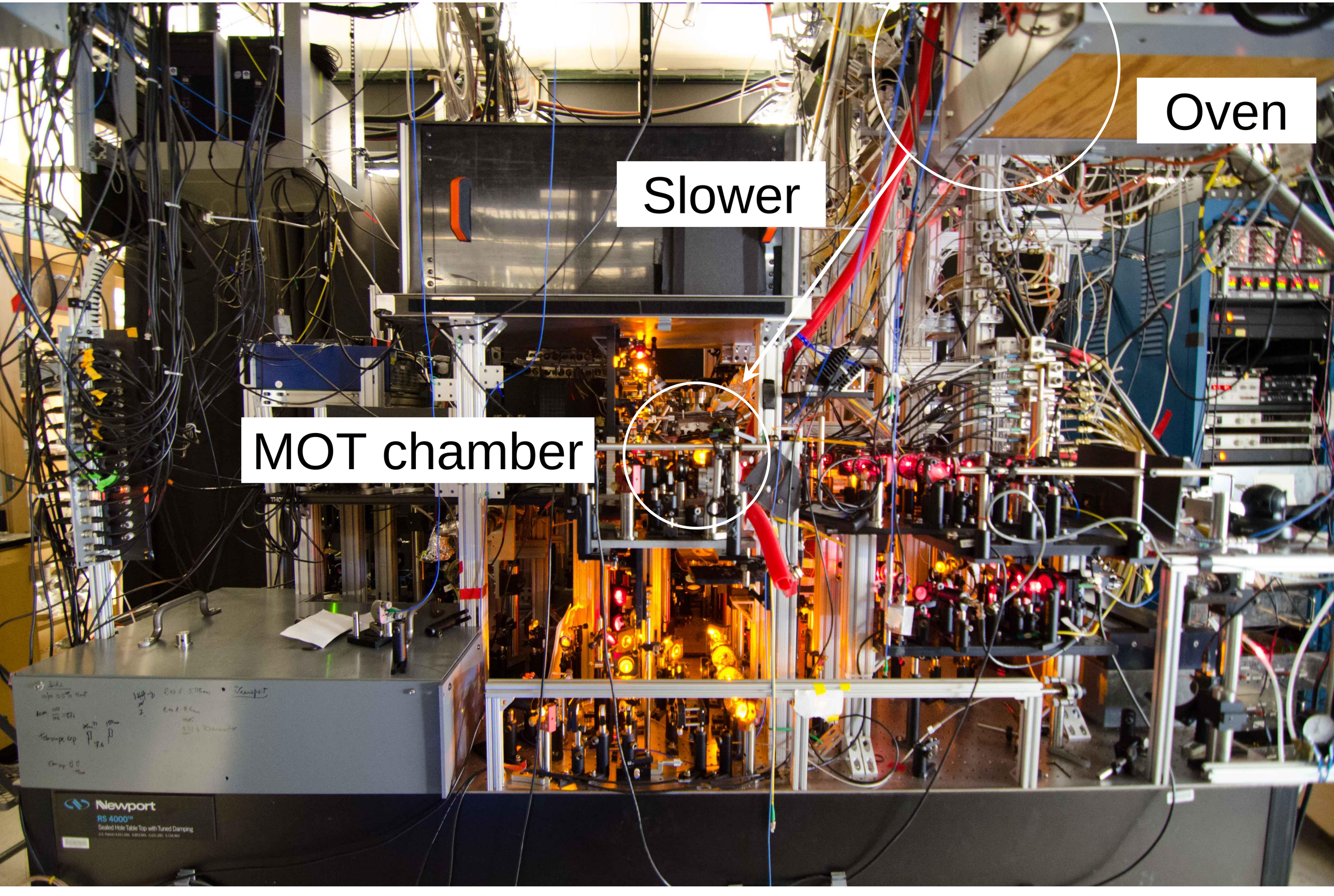
- All optical association of molecules

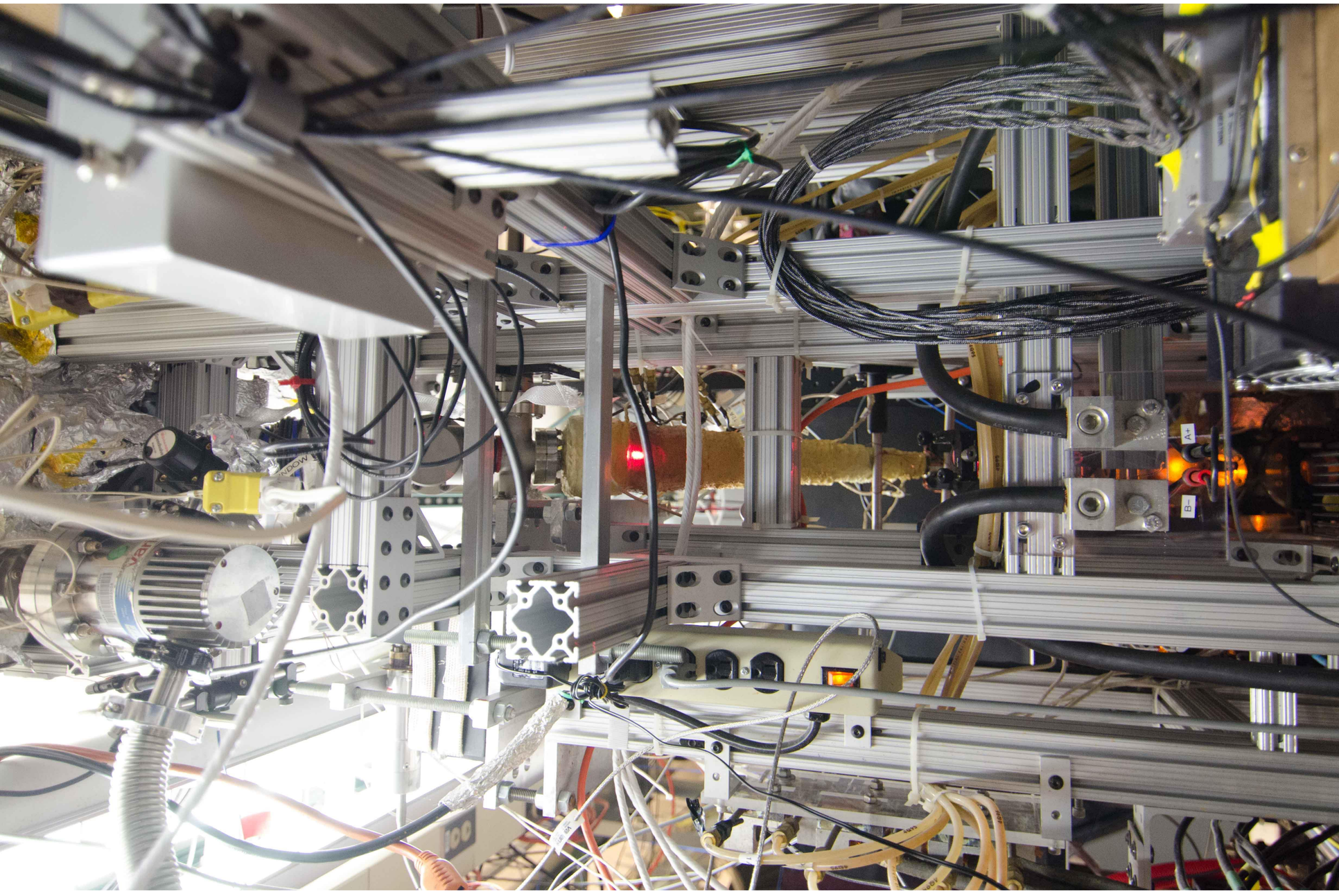


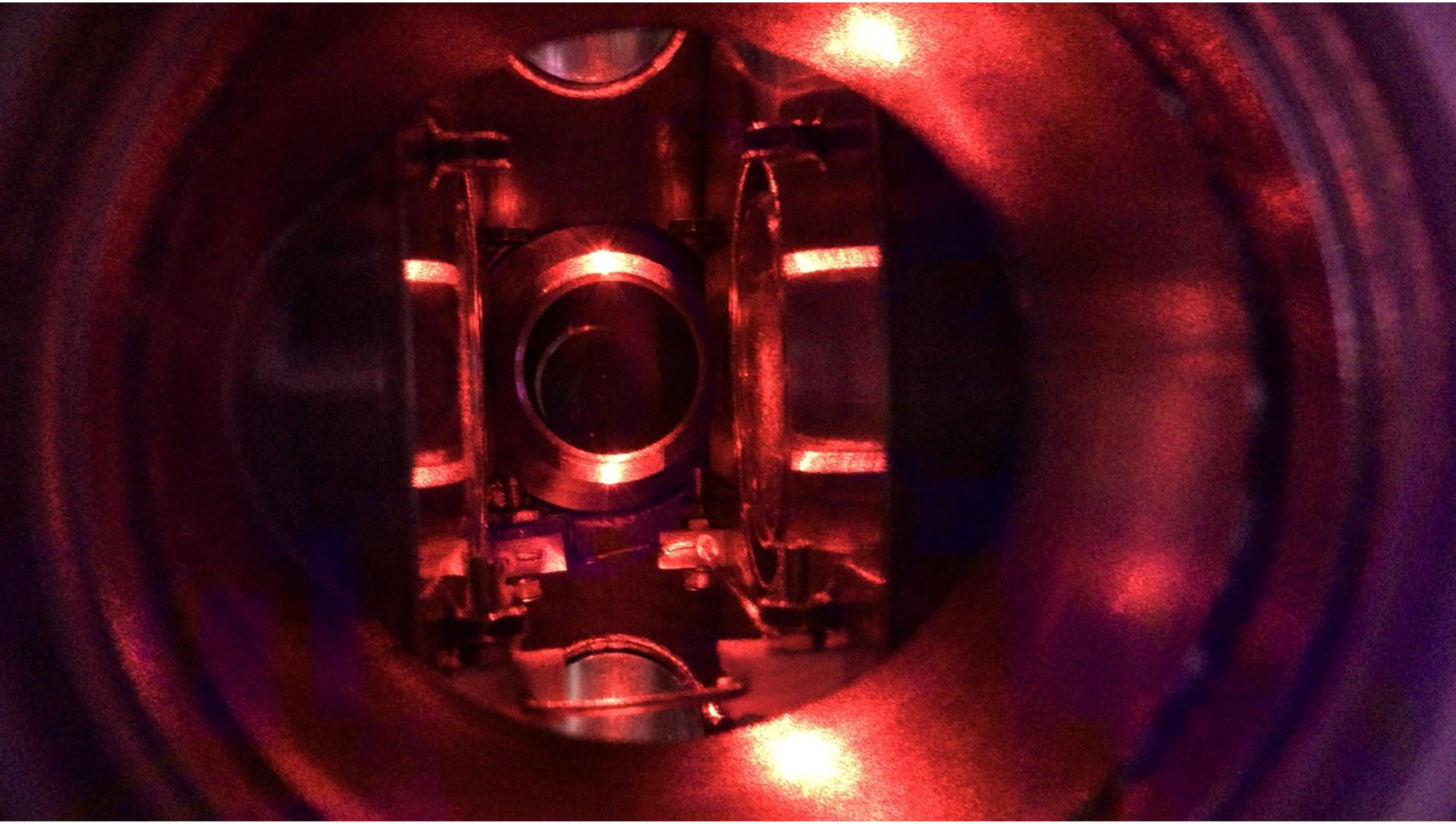


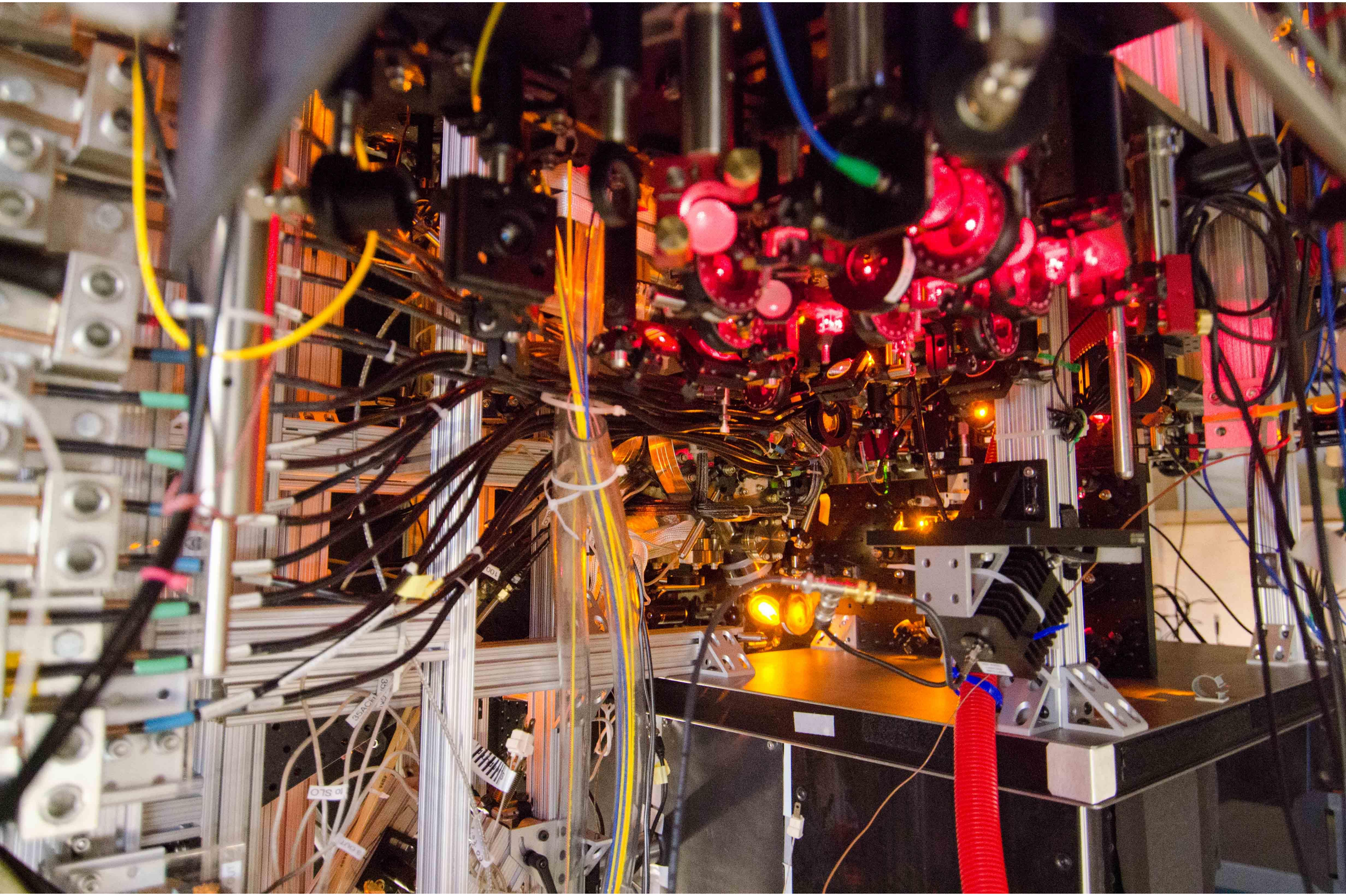


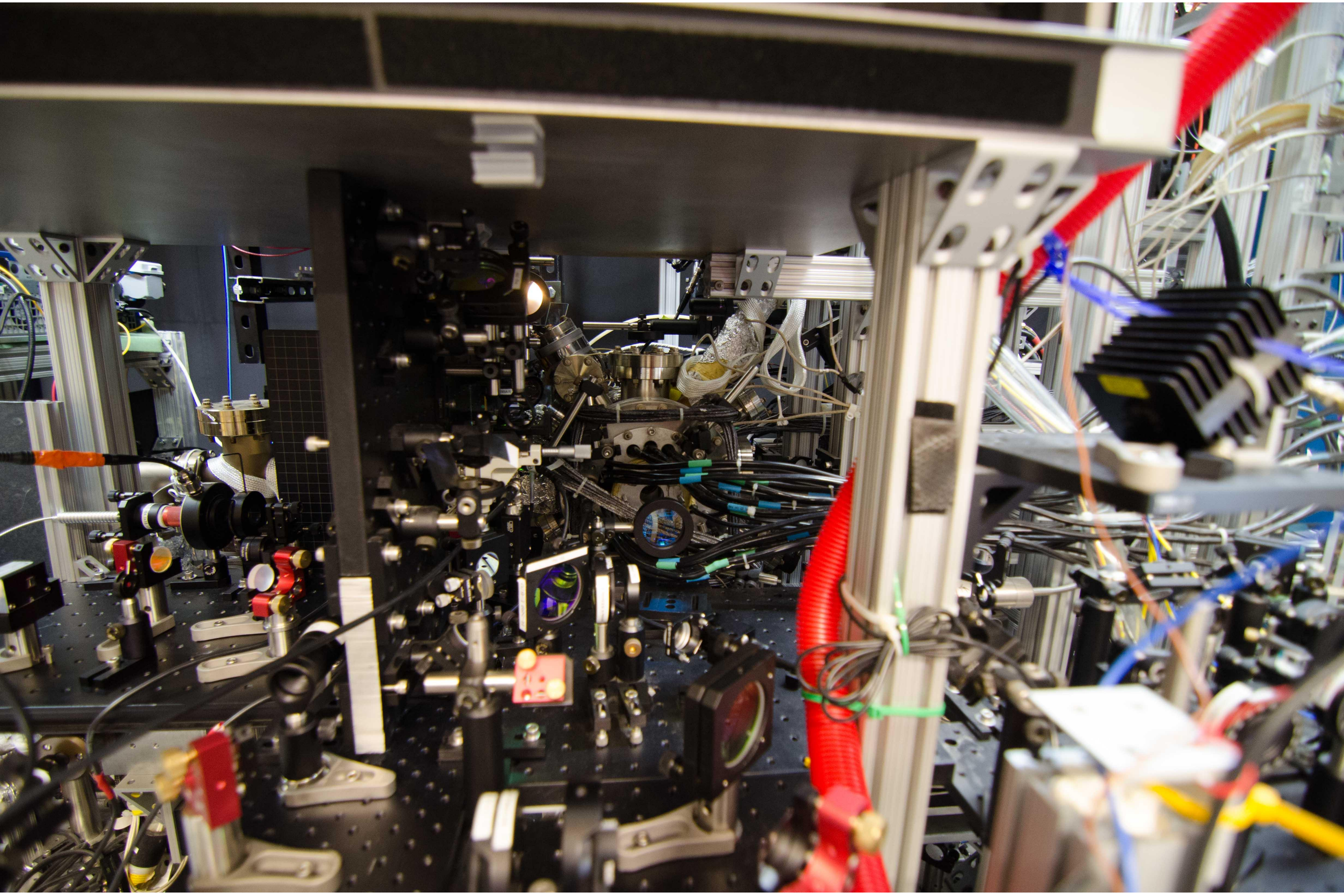

Newport
RS 4000™
Sealed Hole Table Top with Tuned Damping

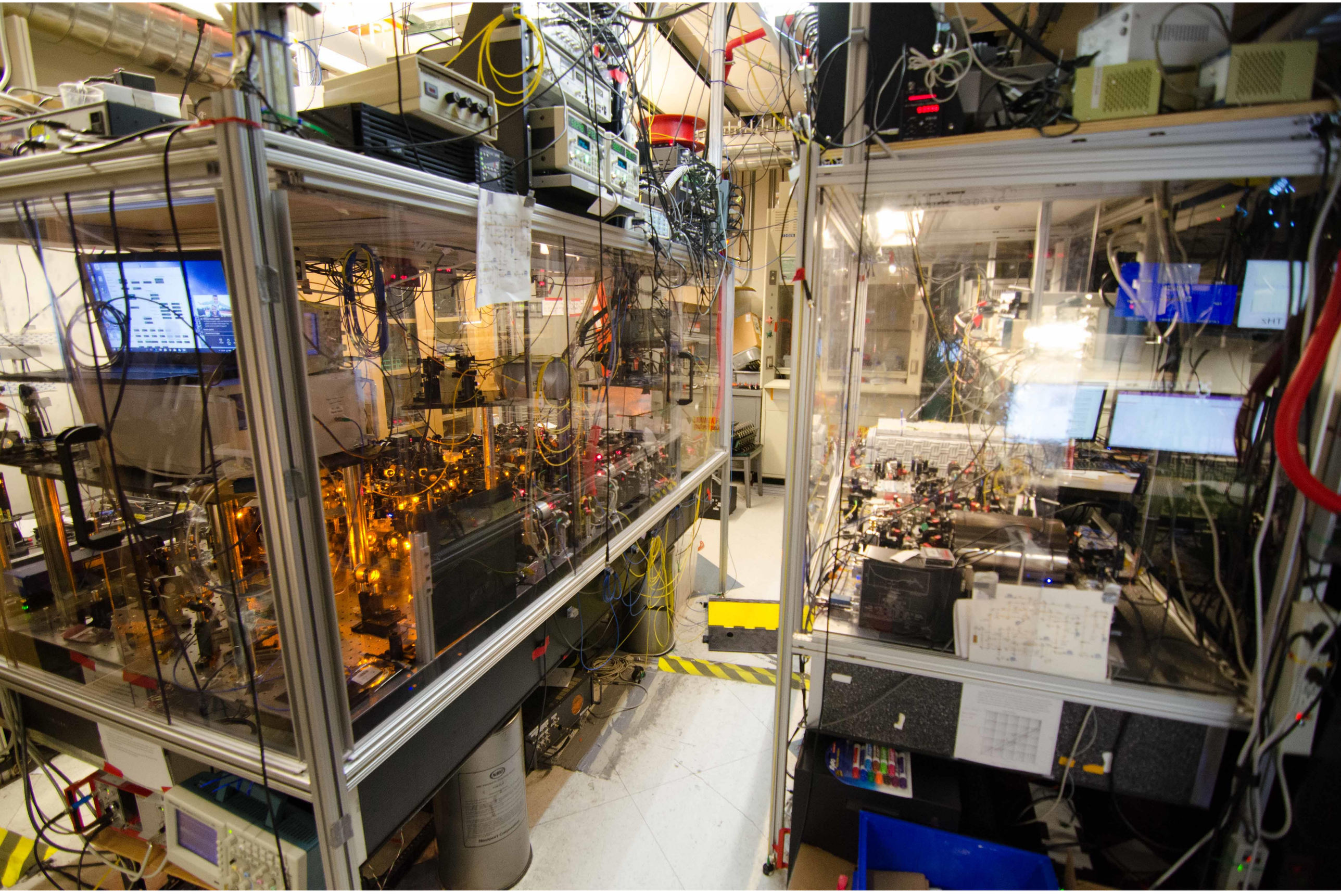

Oven
Slower
MOT chamber
Newport
RS 4000™
Sealed Hole Table Top with Tuned Damping

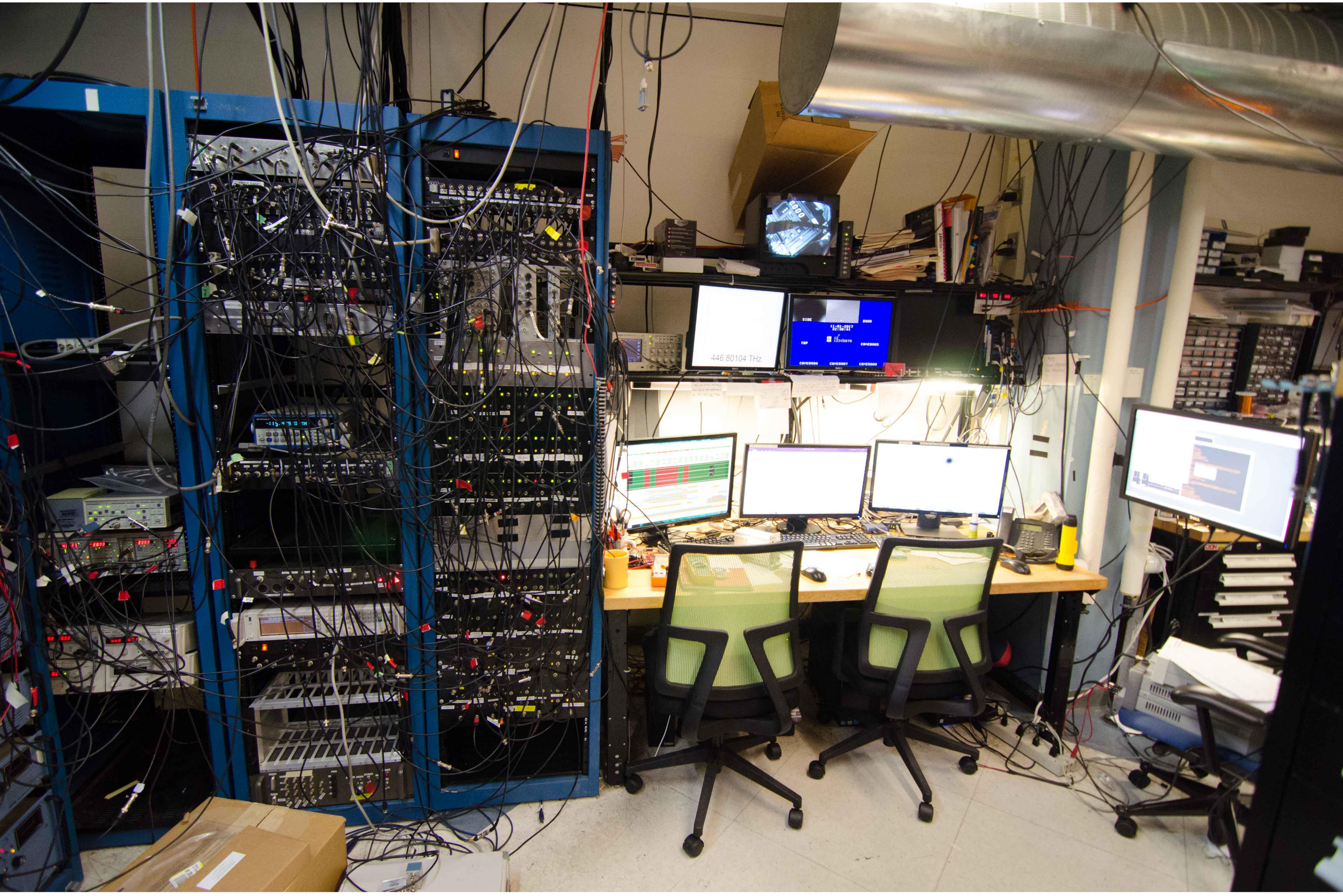








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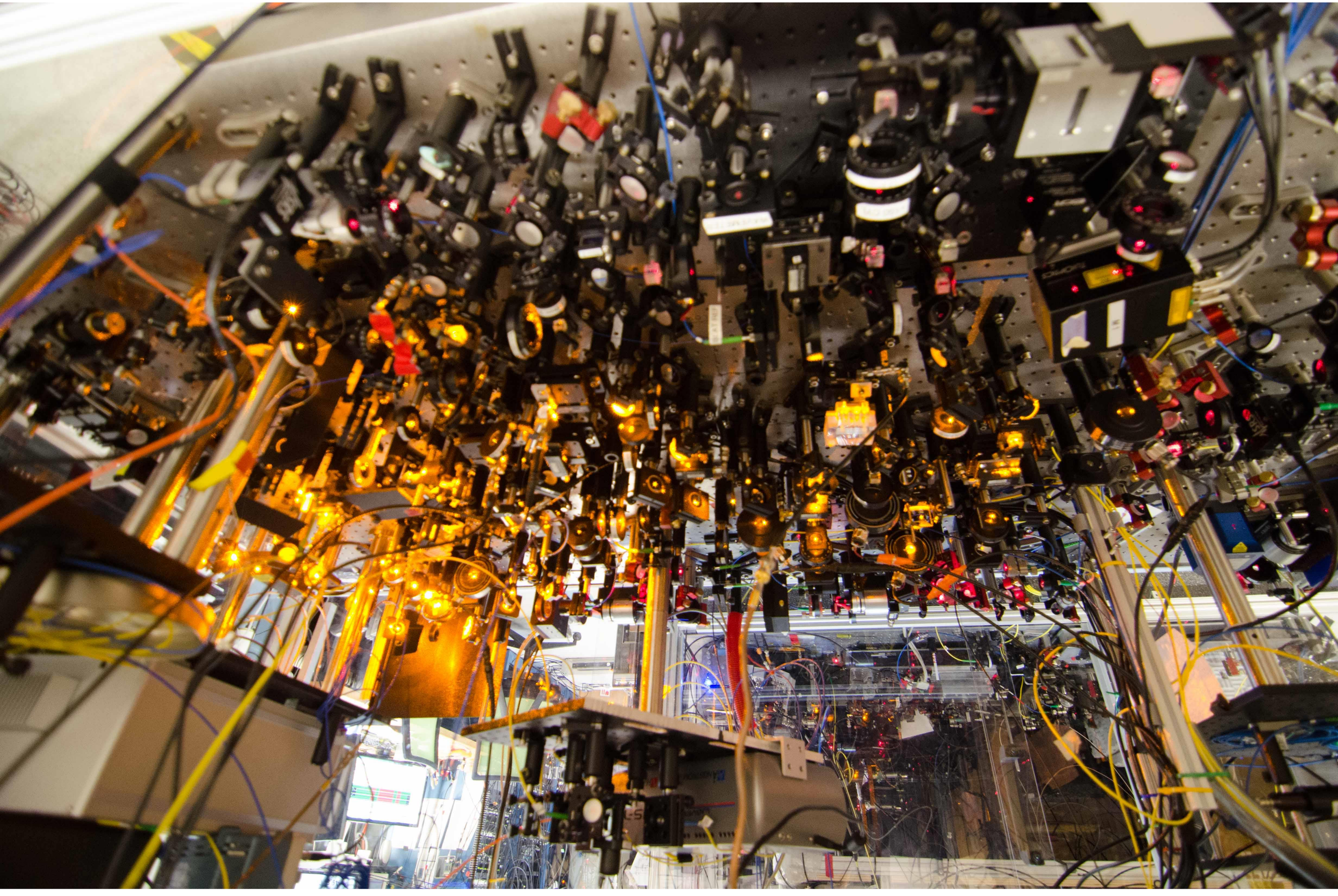

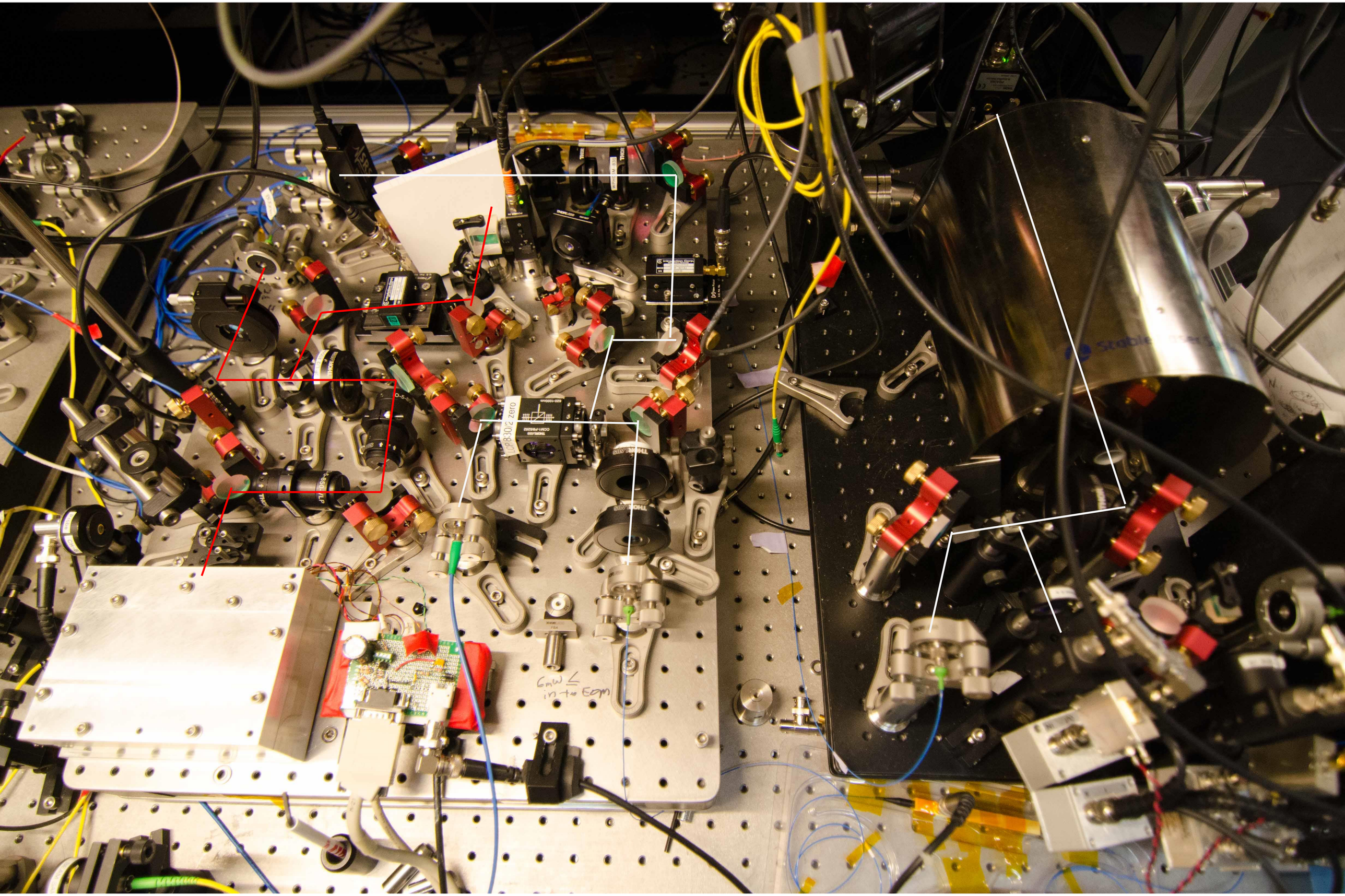
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