BEC3 Lab

NaLi molecule experiment

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

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Dipolar Molecules with Spin

Why NaLi Triplet Molecules?

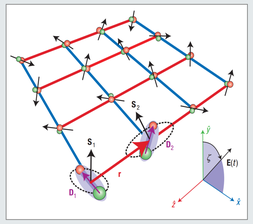
- Both electric & magnetic dipole moments (0.2 Debye, $2\mu_B$)
- Magnetic trapping, molecular and atom-molecule Feshbach resonances, spin-lattice Hamiltonian simulation
- Chemically reactive ($2NaLi \rightarrow Na_2 + Li_2$); possibility for quantum chemistry
- However, still long-lived since NaLi is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

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

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

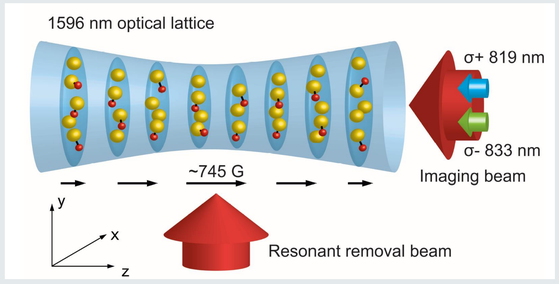
[Rvachov et al. PCCP, *20*.7 (2018) 4739-4745.]

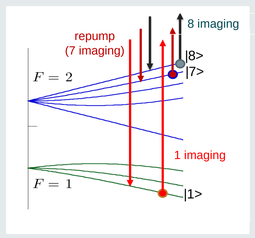
Lattice Spin Models



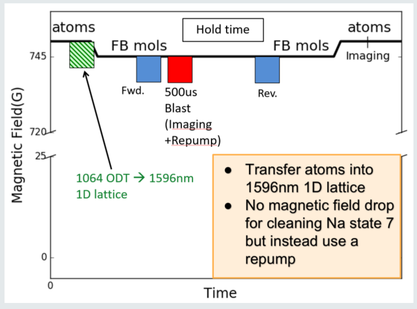
[A Micheli *et al.* Nat. Phys. (2006)]

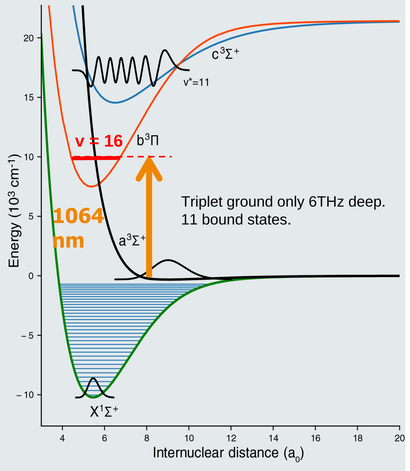
Forming Ground-State Molecules





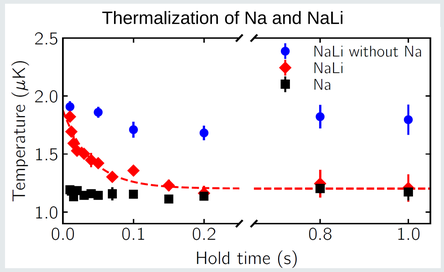
- 10^6 ^{23}Na and 10^6 ^{6}Li atoms in their lowest hyperfine states near quantum degeneracy (2uK) in 1D lattice (used to be 1319nm ODT)
- Magnetically associate Na & Li atoms to Feshbach molecules
- Transfer Feshbach molecules to the ground state using Stimulated Raman Adiabatic Passage (STIRAP)

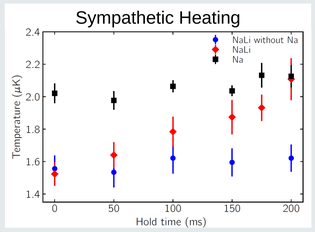


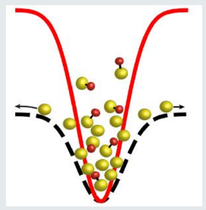


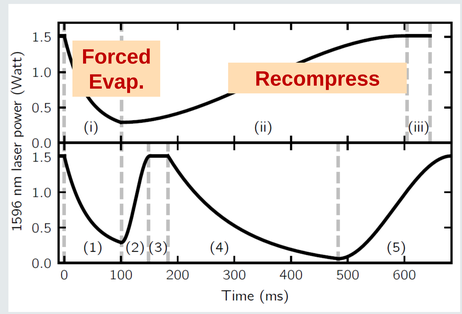
Sympathetic Cooling of Molecules

- 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

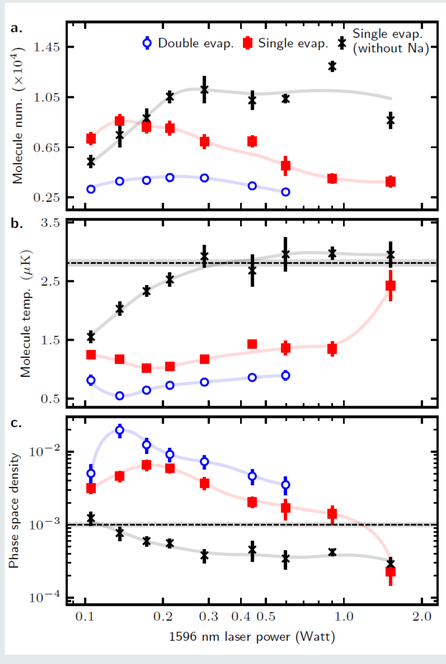






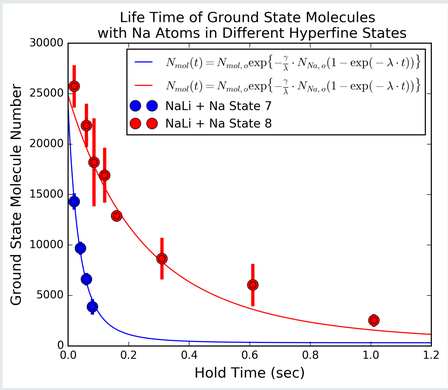


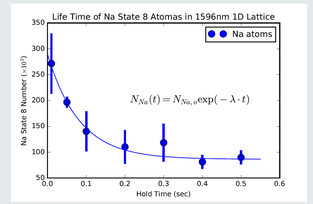
- After forced heating of Na atoms, the molecule temperature rises and reaches to the Na temperature as both particles thermalize
- Na atoms are forced evaporated by lowering the lattice depth and hold for the atoms to thermalize
- The lattice trap is recompressed for efficient thermalization between NaLi and Na
- Ground state molecules thermalize with colder Na state 8 atoms and become colder
- Phase Space Density (PSD) increases as Na atoms are further forced evaporate by decreasing the lattice depth
- Increase in PSD by a factor of 20 and temperature as low as 220nK can be reached by two stages of evaporation



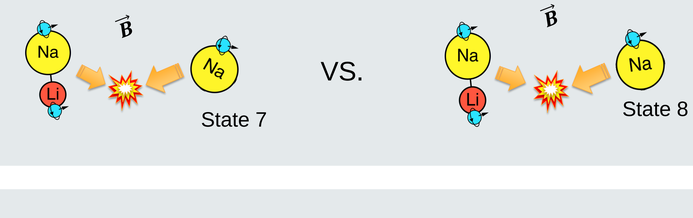
State Dependent Collision

- One body fit was done considering the fact that the Na atom number also decreases over the hold time (assumed exponential decay)
- Ground state molecules live long even in the presence of Na state 8 atoms
- Loss with Na 7 atoms is faster than with Na 8 by an order of magnitude.



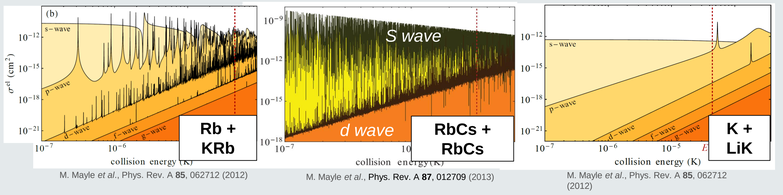


- $\frac{d}{dt}n_{mol}(t) = -\gamma\cdot n_{mol}n_{Na}$
- $n_{Na}(t) = n_{Na,o}\exp(-\lambda\cdot t)$



Prospects

- Pure magnetic trapping of the NaLi molecules
- Quantum degenerate molecules through evaporative cooling in a magnetic trap or a deeper 1550nm cross ODT
- Search for atom-molecule and molecule-molecule Feshbach resonances; low density of states can be favorable.
- Study Collisional properties between molecules and atoms in deferent magnetic fields



M. Mayle *et al.*, Phys. Rev. A **85**, 062712 (2012)

M. Mayle *et al.*, Phys. Rev. A **87**, 012709 (2013)

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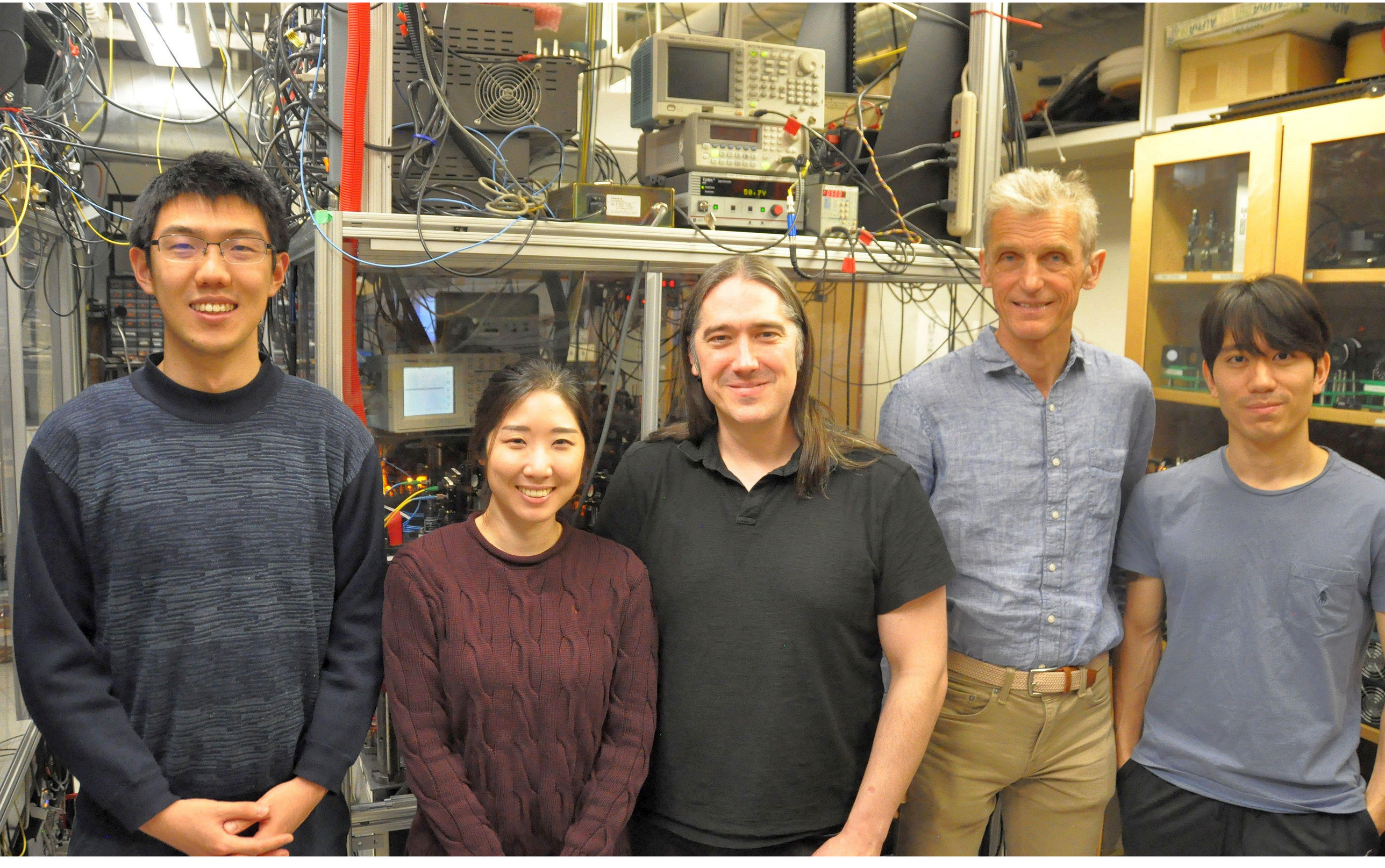

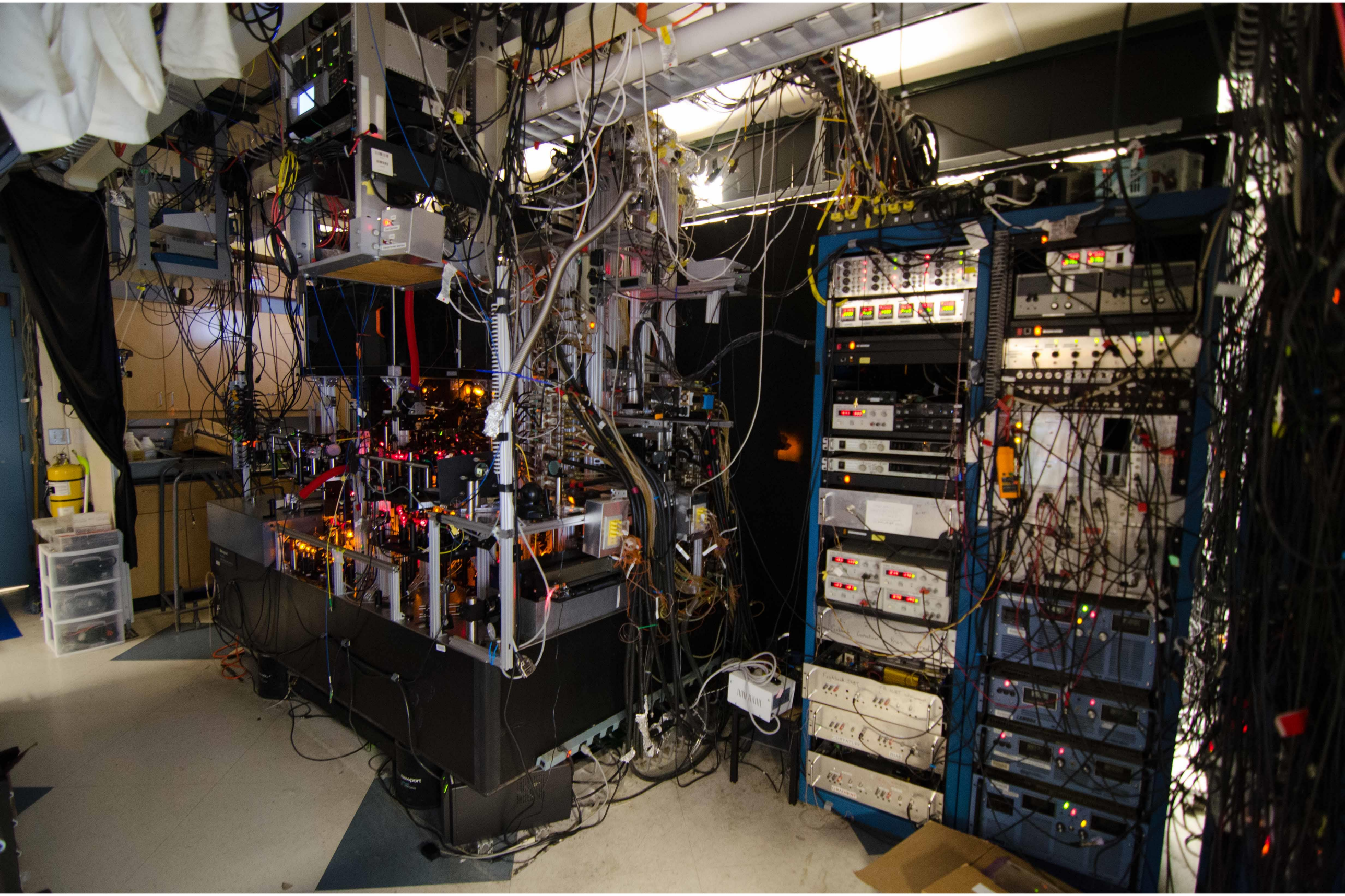

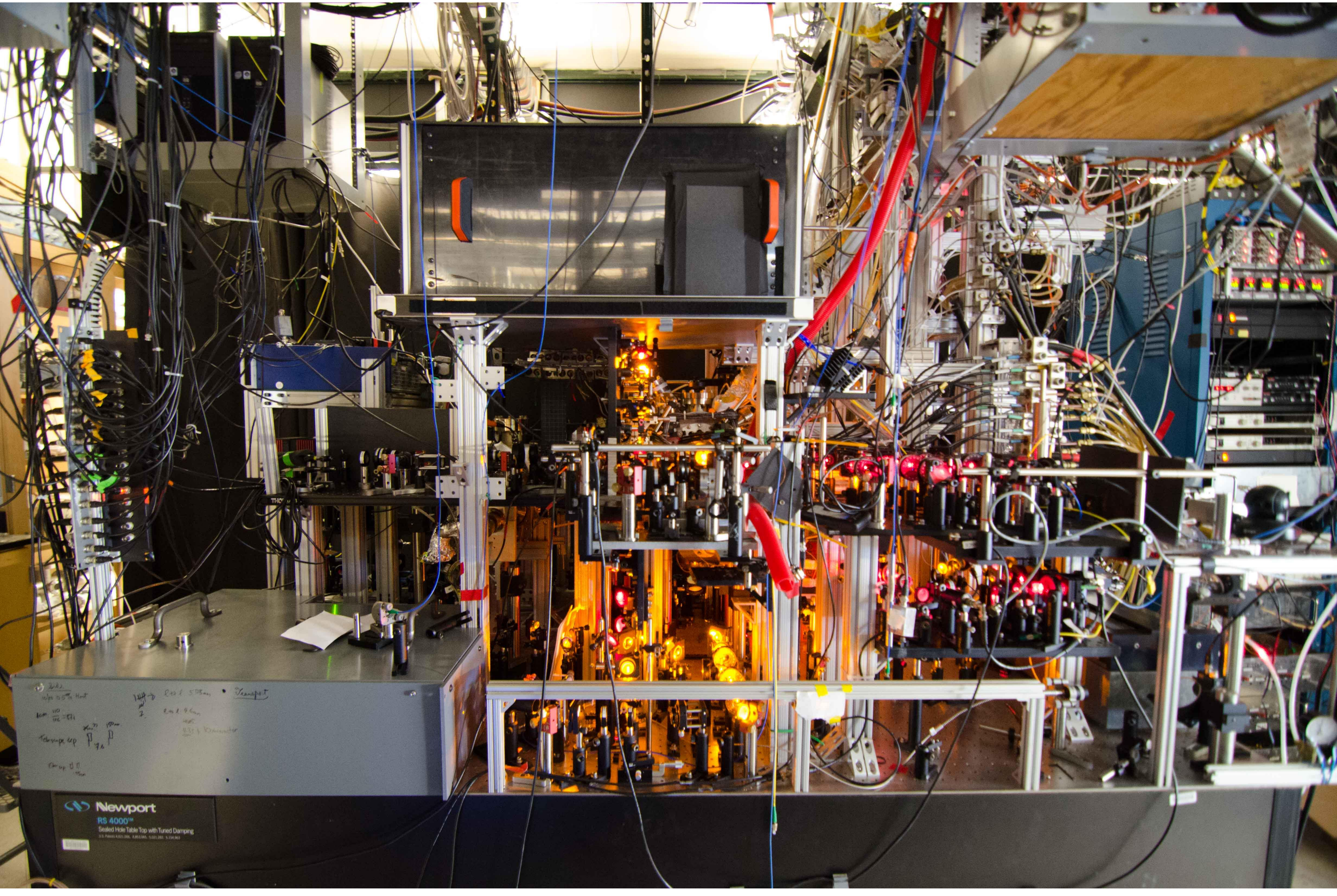
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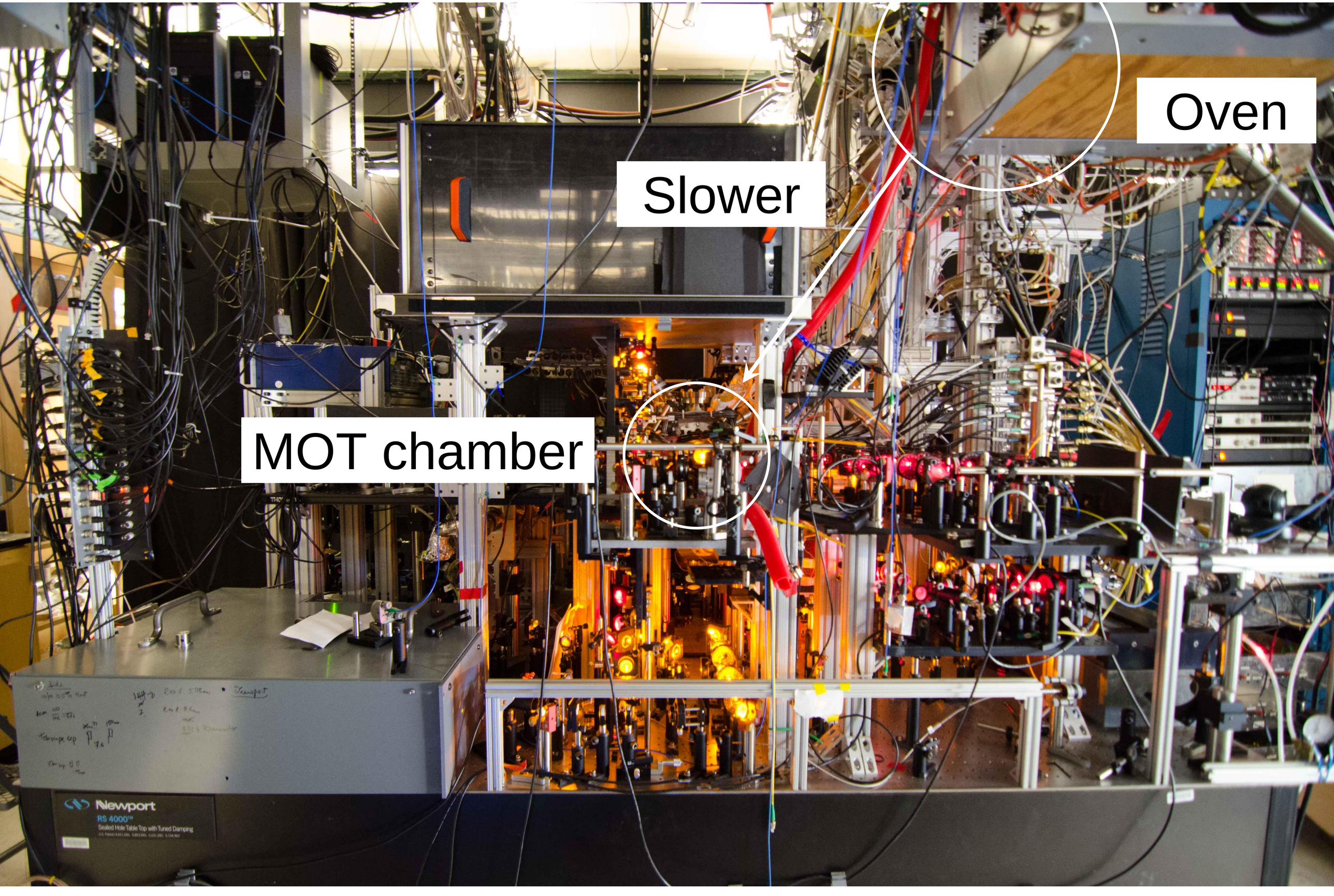
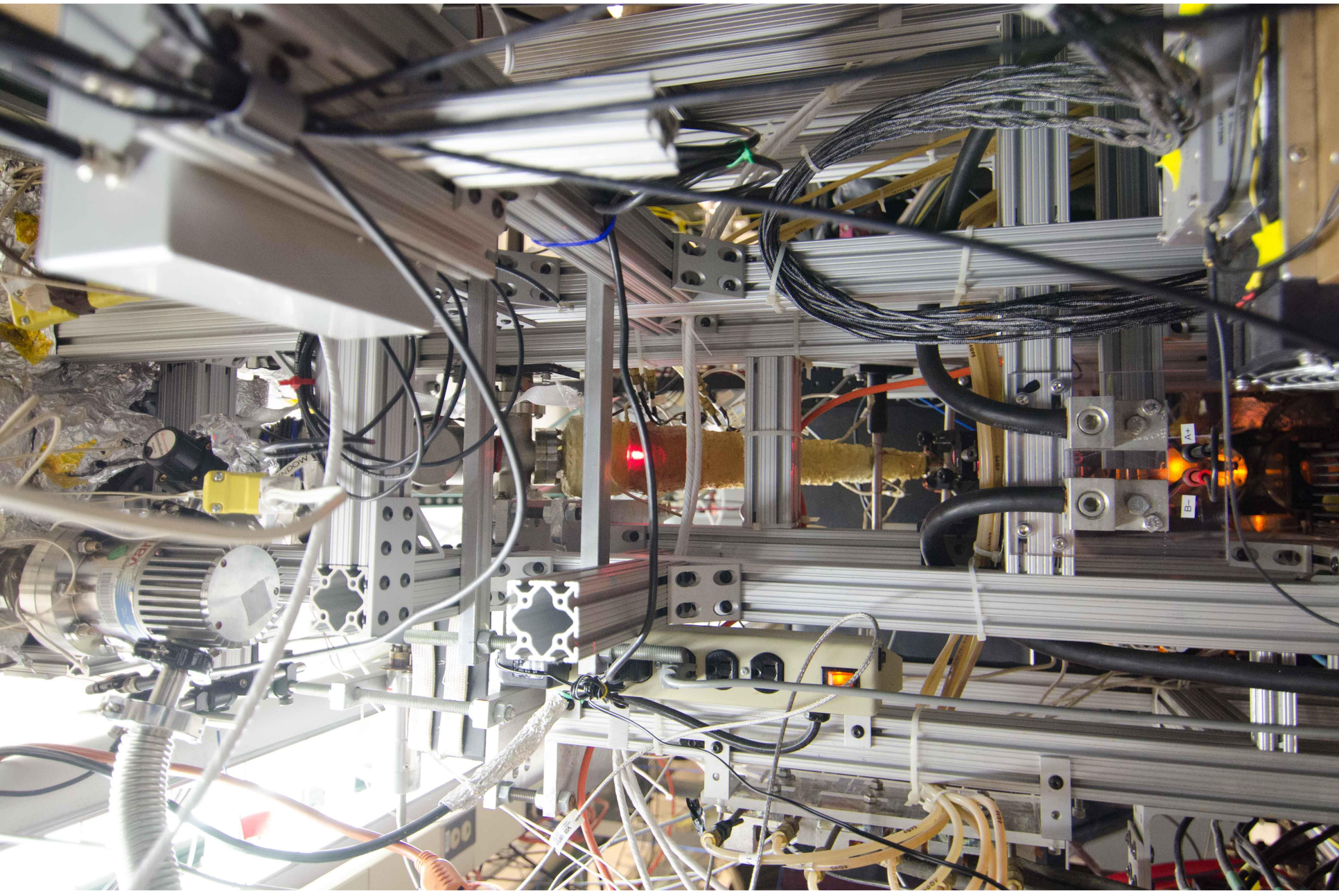
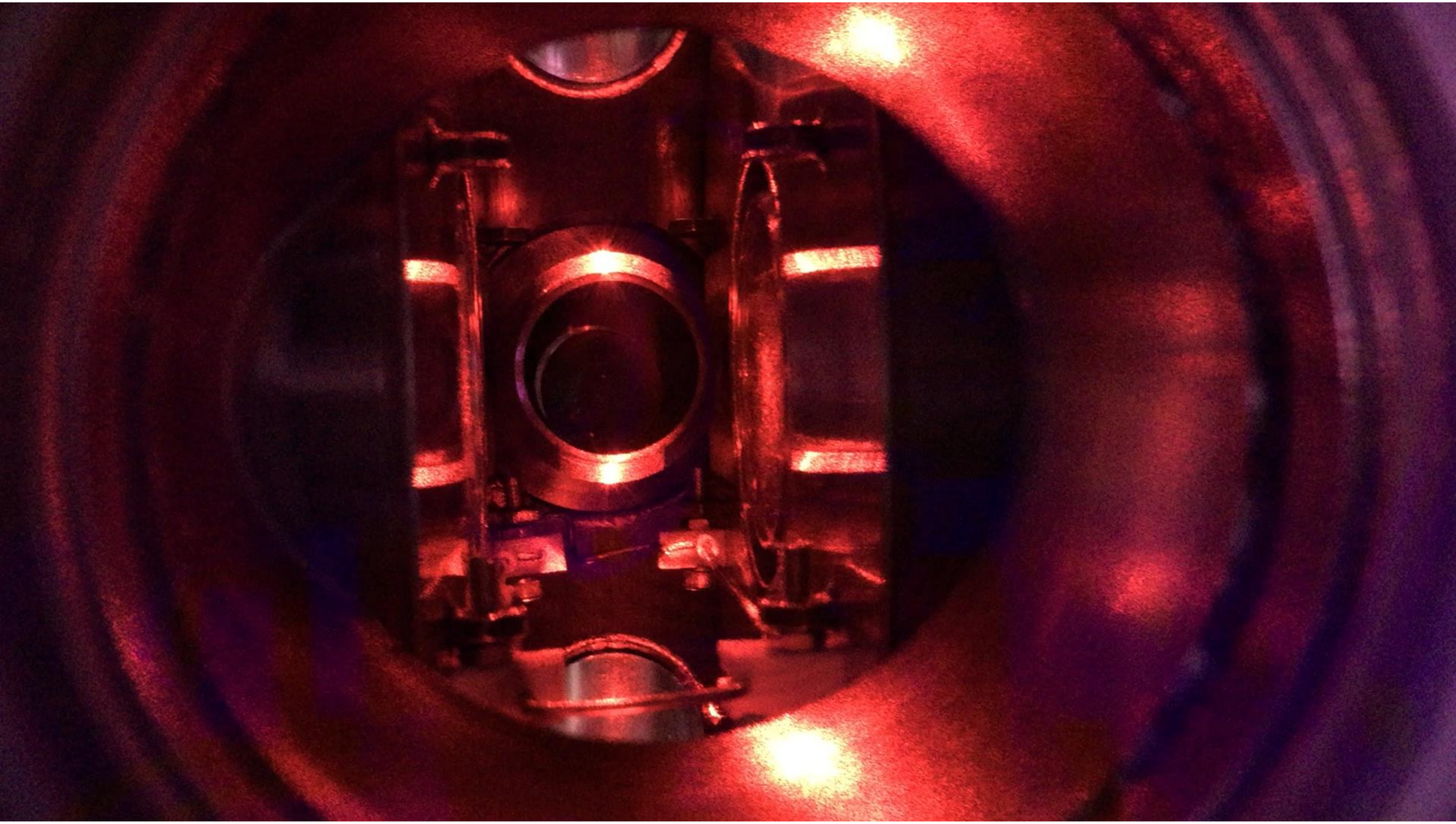
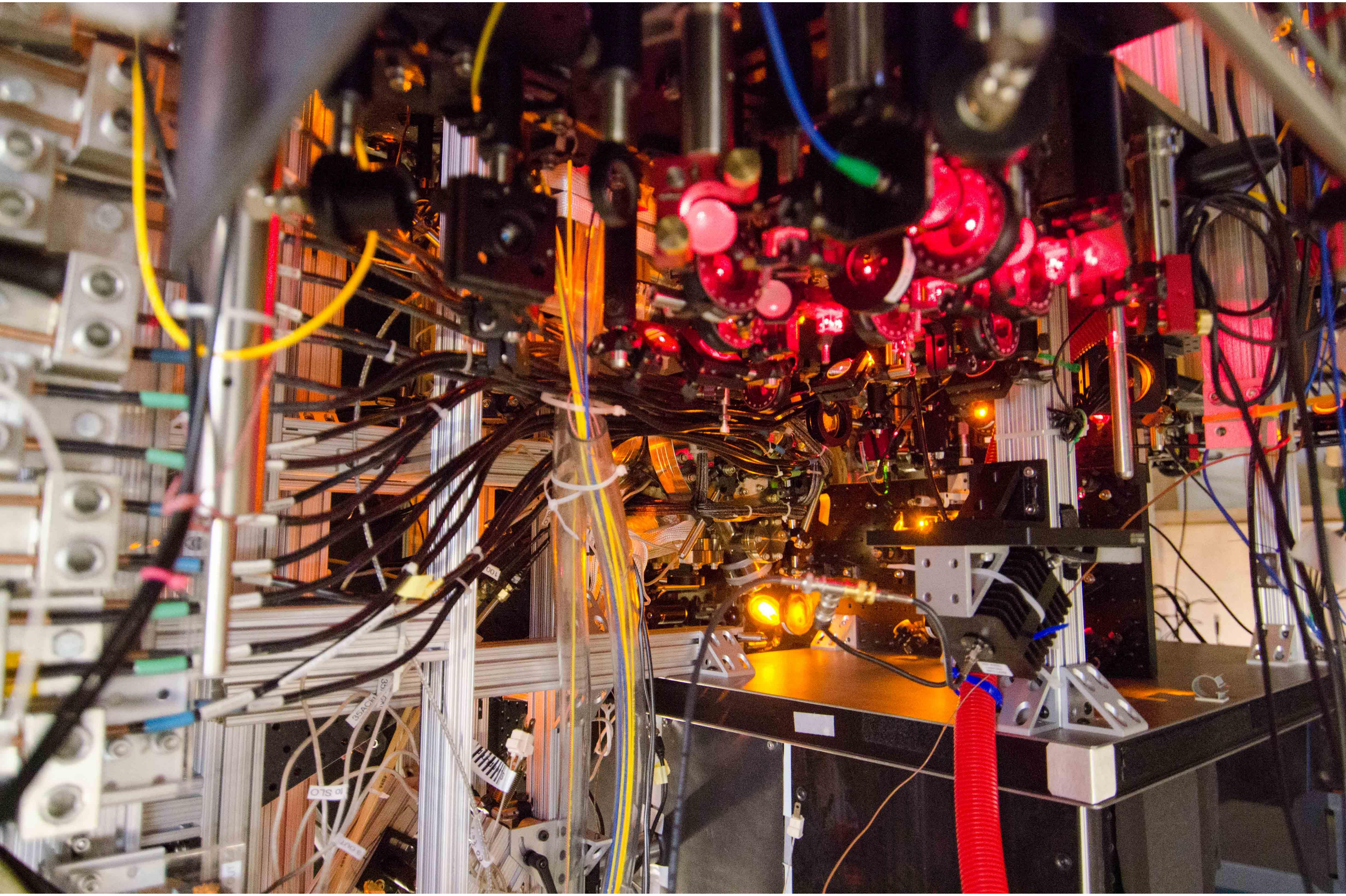
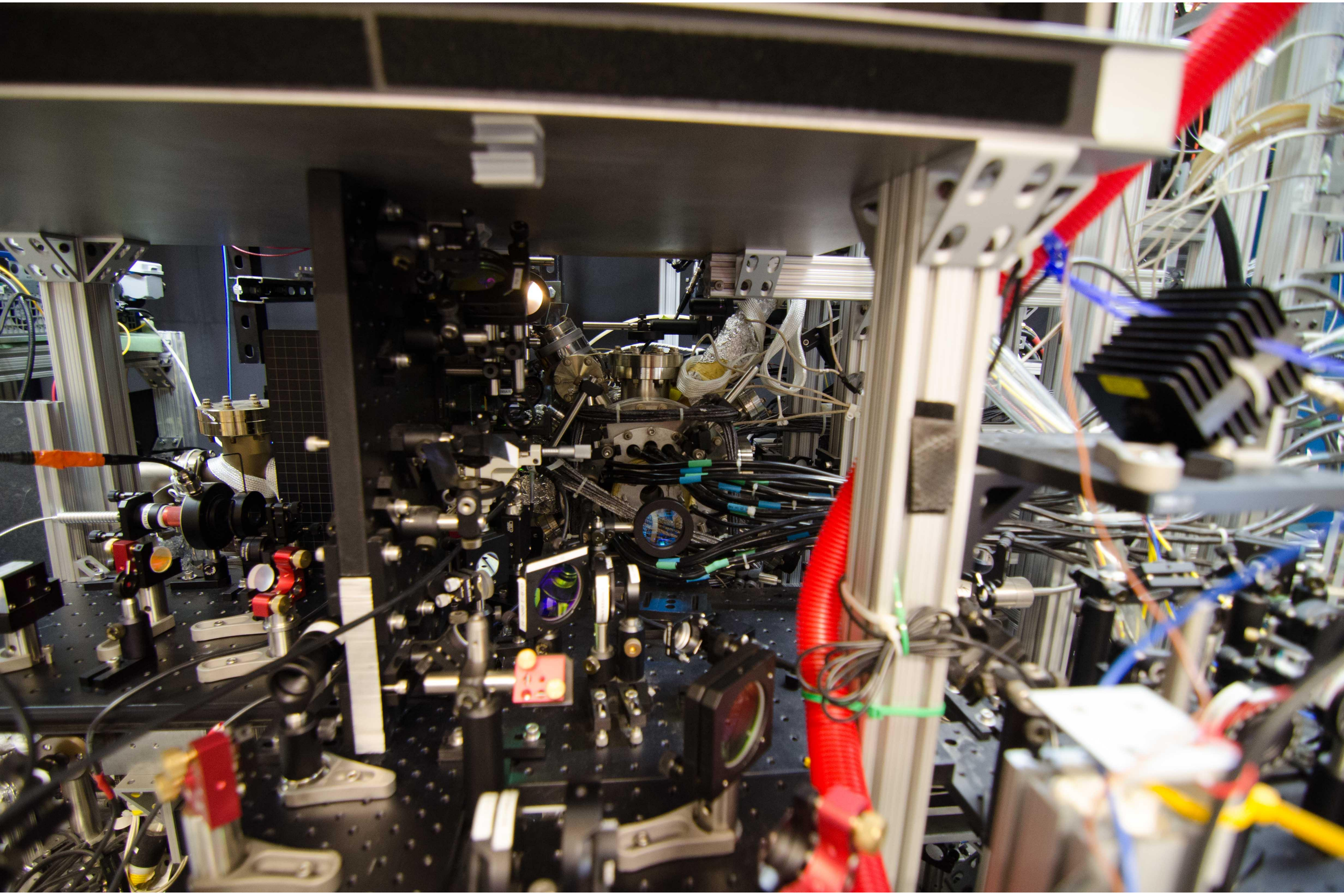
RS 4000™
Sealed Hole Table Top with Tuned Damping

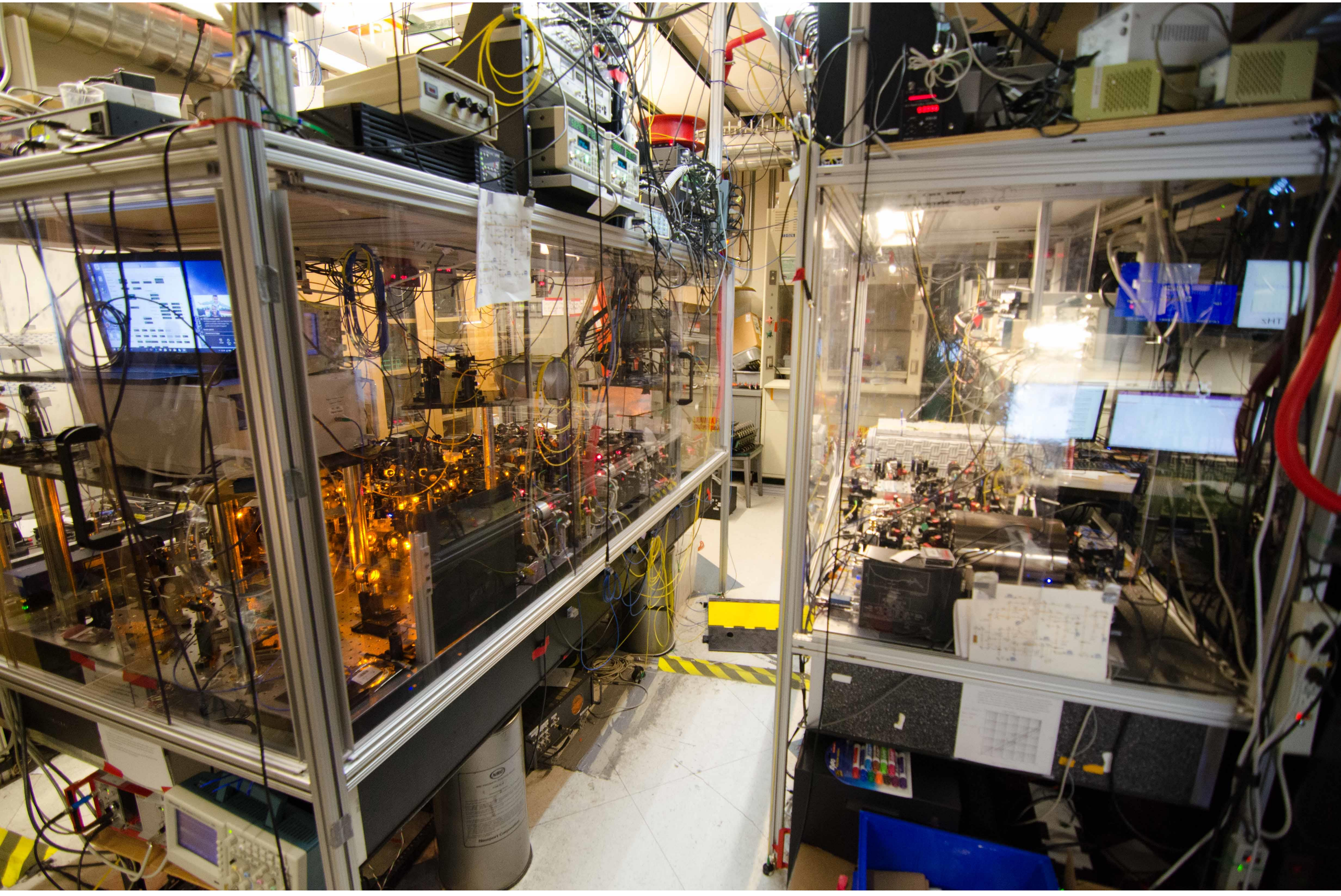

Oven
Slower
MOT chamber
Newport
RS 4000™
Sealed Hole Table Top with Tuned Damping

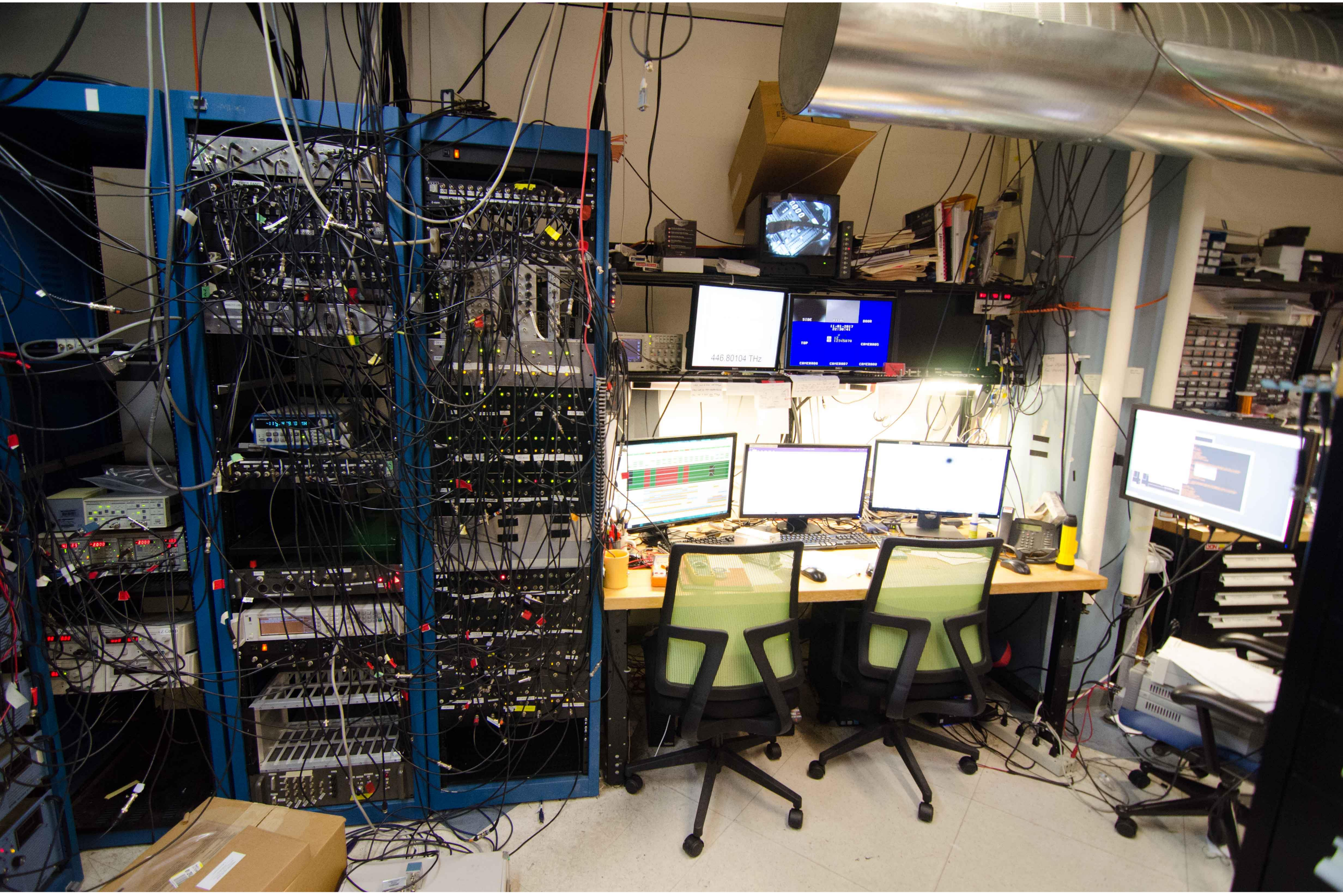








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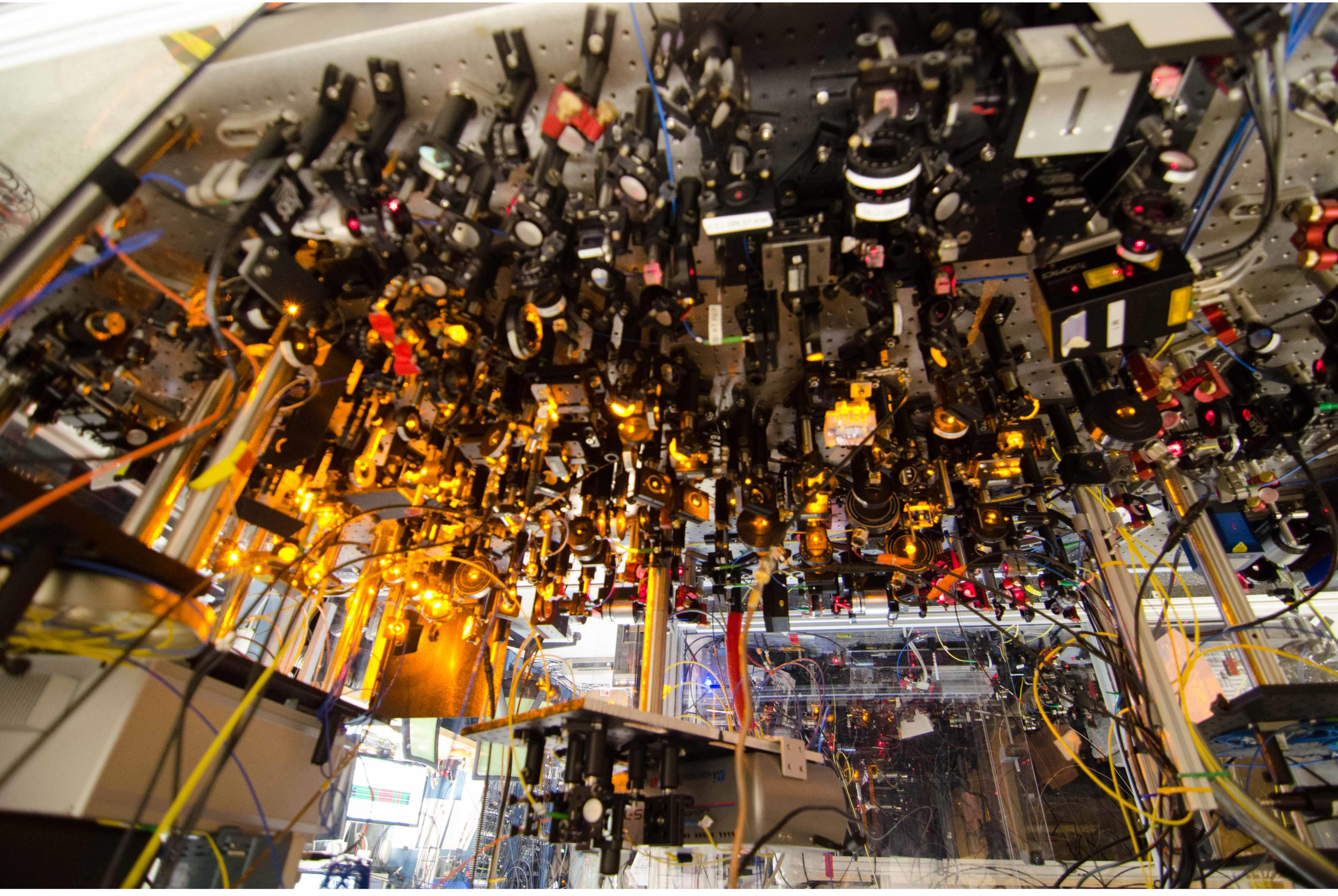

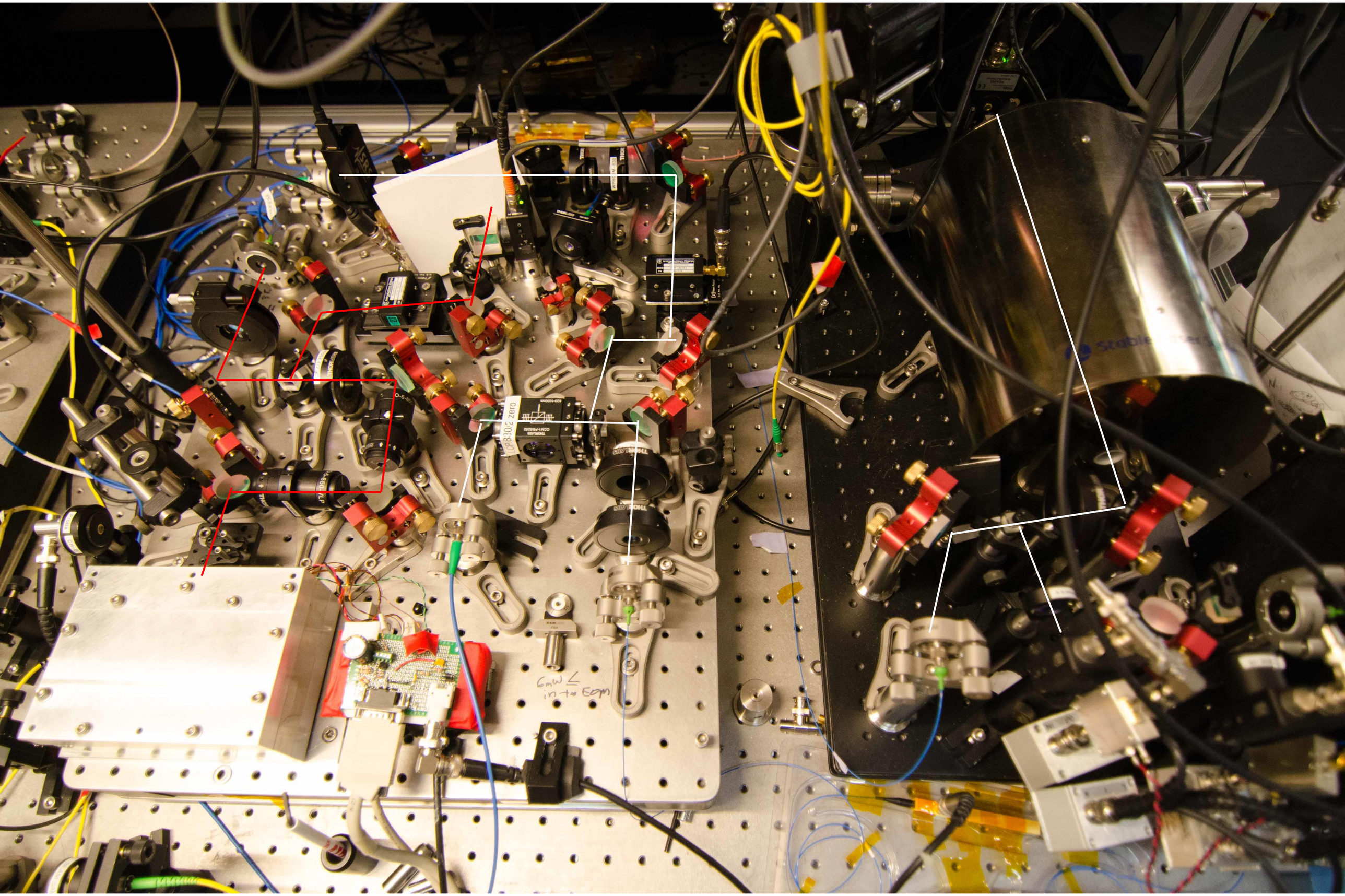
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