From Oven to Tweezers: Atom Sources and MOTs for Alkali and Alkaline-Earth Arrays

System layouts, real equipment, physics and operating parameters for the front end of a neutral-atom processor

Technical note · October 25, 2026 · D. Hakala in Pa· SI units throughout (fields in mT, gradients in T/m, pressures)

What this note covers. Everything between the atom reservoir and a loaded tweezer: the oven or dispenser, slowing (Zeeman slower or 2D MOT), the 3D MOT, sub-Doppler or narrow-line cooling, transport to the science region, and tweezer loading. Two families are treated side by side: alkali atoms (^{87}Rb, ^{133}Cs; Harvard/MIT/QuEra and most academic groups) and alkaline-earth-like atoms (^{88}Sr, ^{87}Sr, ^{171}Yb; Atom Computing and the Sr/Yb tweezer groups). Equipment named in the drawings and tables is taken from papers or vendor datasheets, and each entry is attributed. Lasers labelled as 'common options' are typical commercial choices, not taken from a specific paper. The numbers in Section 4 come from mot_calculator.py, which is filed alongside this note.

1. The chain at a glance

Both families follow the same sequence: make a dilute atomic vapor, slow and collect atoms in a MOT, cool them further, bring them to the place where the tweezers are, and let single atoms fall into the tweezers. The physics of each stage differs between alkali and alkaline-earth atoms because of two facts. Alkali metals have a useful vapor pressure at room temperature; Sr and Yb need ovens at 400–500 °C. And alkaline-earth atoms have a narrow intercombination line that allow reaching microkelvin temperatures directly, where alkali atoms rely on sub-Doppler (polarization-gradient or gray-molasses) cooling.

Stage	Alkali (Rb, Cs)	Alkaline earth (Sr, Yb)
Source	Dispensers or reservoir at 20–60 °C; vapour ~10^{-5} Pa; UV-LED desorption to boost loading	Effusion oven 400–500 °C (≈ 0.03–0.5 Pa inside); collimating nozzle or microchannels; heated sapphire window
Pre-cooling / slowing	2D$^+$ MOT in a source cell (10^9 atoms/s at 10–20 m/s), or a MOT loaded directly from vapor	Zeeman slower on the broad line (0.3 m, ~70–90 mT), transverse cooling, often a 2D MOT
3D MOT	D2 line (780/852 nm), 0.1–0.3 T/m, 10^7–10^8 atoms, ~0.1–2 mK	Broad line (461/399 nm), ~0.5 T/m, ~1 mK
Final cooling	Polarization-gradient cooling or Λ-gray molasses on D1 → 10–20 µK	Narrow-line MOT (689 nm Sr: ~1 µK; 556 nm Yb: ~5–10 µK); broadband then single-frequency
Transport	Optional: optical conveyor belts (Harvard: ≈ 0.56 m in 71 ms)	Optional: moving lattice (Atom Computing: 0.3 m vertical in 100 ms)
Tweezer loading	Light-assisted collisions → ≈ 50 %; blue-detuned (gray-molasses) loading 80–90 %	≈ 50 % with light-assisted collisions; traps at magic wavelengths for the cooling/imaging line

2. Alkali implementation (^{87}Rb, ^{133}Cs)

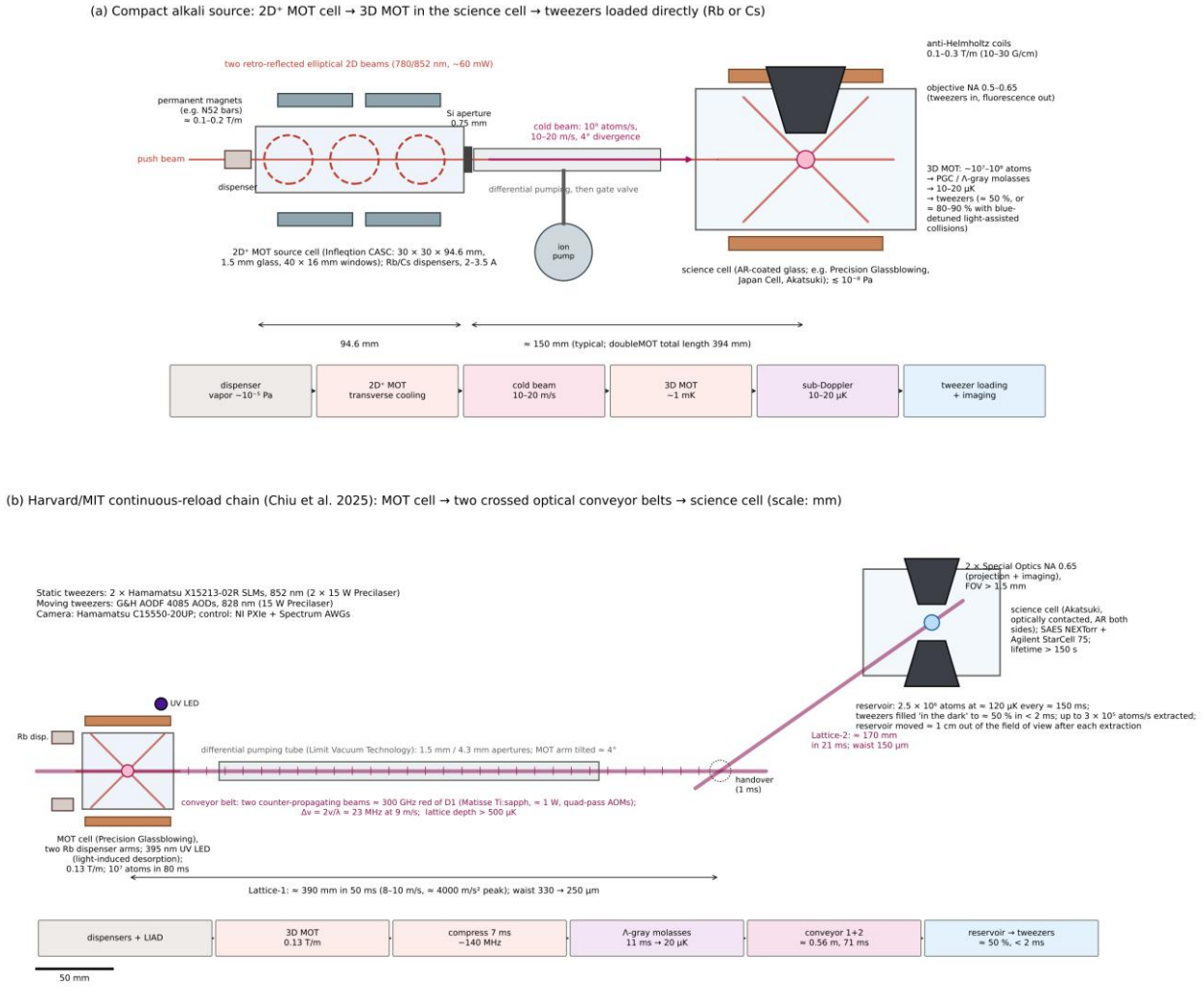


Figure 1. (a) Compact chain built from Infleqtion-type cells: 2D⁺ MOT source cell → 3D MOT in the science cell → direct tweezer loading. (b) The Harvard/MIT continuous-reload chain of Chiu et al. (2025), with published distances, times and component models. Cell and magnet positions in (a) are illustrative; lengths in (b) are published.

2.1 Source: dispensers, vapor and light-induced desorption

Rubidium and cesium are loaded from **alkali-metal dispensers**: resistively heated channels with an alkali salt and reducing agent. The Infleqtion source cells run them at 2.0–3.5 A; the compact Rb setup of arXiv:2604.12204 runs at 4.3 A. The vapor pressure follows equation (1) in Section 4. At 25 °C it is about 5×10^{-5} Pa for Rb and 2×10^{-4} Pa for Cs, which is enough for a 2D MOT in a glass cell. The Harvard machine adds a **395 nm UV LED** that desorbs Rb from the glass walls on demand (light-induced atomic desorption, LIAD). This raises the loading rate only while the MOT is loading, and the vacuum recovers in between.

2.2 Pre-cooling: the 2D⁺ MOT

A 2D MOT uses two pairs of elongated, retro-reflected beams and a linear quadrupole field (often from permanent magnets) to cool atoms transversely and confine them to a line. A weak **push beam** along the axis (the "+" in 2D⁺) drives them through a small aperture into the science chamber. The Infleqtion CASC cell is a representative commercial part: 30 × 30 × 94.6 mm glass, 40 × 16 mm side windows, a 0.75 mm silicon aperture for differential pumping, and a typical flux of 10^9 atoms/s at 10–20 m/s with 4° full divergence. The

compact setup of arXiv:2604.12204 makes its 2D-MOT field with four N52 neodymium bars (5 × 3 × 60 mm, 70 mm apart) and uses ~60 mW of cooling light.

2.3 The 3D MOT

The 3D MOT sits in the science cell (compact designs) or in a separate MOT cell (Harvard). Published operating points:

- **Harvard/MIT (Chiu 2025):** 0.13 T/m (13 G/cm) gradient; MOT light 23 MHz red of $F = 2 \rightarrow F' = 3$ with a repumper on $F = 1 \rightarrow F' = 2$; about 10^7 atoms in 80 ms; then a 7 ms compression with the light about 140 MHz red-detuned at lower intensity.
- **Compact Rb setup (arXiv:2604.12204):** 0.27 T/m at 3 A from 100-turn anti-Helmholtz coils driven by a Delta Elektronika ES015-10 supply; 15 mm beams, > 50 mW total; about 2×10^7 atoms with a 4 s loading time constant; 2.4 mK before sub-Doppler cooling.
- **Infleqtion doubleMOT:** a two-chamber package (12.7 × 12.7 × 39.4 cm, 3.9 kg) giving more than 5×10^8 atoms with a MOT lifetime of more than 40 s and a science-cell pressure below 0.8 nTorr (≈ 1×10^{-7} Pa).

2.4 Sub-Doppler cooling

The Doppler limit of the D2 line is 146 µK for Rb and 126 µK for Cs, too warm for reliable tweezer loading and imaging. Two methods go below it:

- **Polarization-gradient cooling (PGC).** Switch off the gradient, null stray fields with three pairs of compensation coils, and ramp the detuning far to the red while lowering intensity. The compact setup ramps −15 → −48 MHz over 16 ms and reaches 92 µK. Well-optimized PGC reaches 10–20 µK.
- **Λ-enhanced gray molasses on D1 (795 nm Rb, 895 nm Cs).** Blue-detuned light on $F = 2 \rightarrow F' = 2$ with a repumping sideband at two-photon (Raman) resonance creates dark states that atoms fall into as they slow. The Harvard chain uses 11 ms with the carrier 30 MHz blue of $F = 2 \rightarrow F' = 2$ and loads about 4×10^6 atoms at about 20 µK into its conveyor lattice.

2.5 Transport and tweezer loading

In a compact machine the tweezers are switched on inside the cooled cloud. Light-assisted collisions eject atoms in pairs, so each trap ends with 0 or 1 atom, about 50 % of the time (collisional blockade). Blue-detuned light (as in gray molasses) makes those collisions eject only one atom of the pair, and Brown et al. (2019) reached about 89 % loading in a single 0.63 mK tweezer and about 80 % in a 100-site array.

The Harvard 3,000-qubit machine separates the MOT from the processor so it can reload continuously. Lattice-1 (about 300 GHz red of D1 from a Spectra-Physics Matisse Ti:sapphire, ≈ 1 W, quad-pass AOMs) carries the cloud about 390 mm in 50 ms at 8–10 m/s. After a 1 ms handover, Lattice-2 carries it about 170 mm in 21 ms into the microscope field. The two belts cross at an angle and the MOT arm is tilted about 4°, so the hot line of sight from the MOT passes about 1 cm above the array. A reservoir of 2.5×10^6 atoms at about 120 µK arrives every 150 ms. Tweezers are filled from it without cooling light to about 50 % in under 2 ms, extracting up to 3×10^5 atoms/s, and the reservoir is then moved about 1 cm away.

3. Alkaline-earth implementation (Sr, Yb)

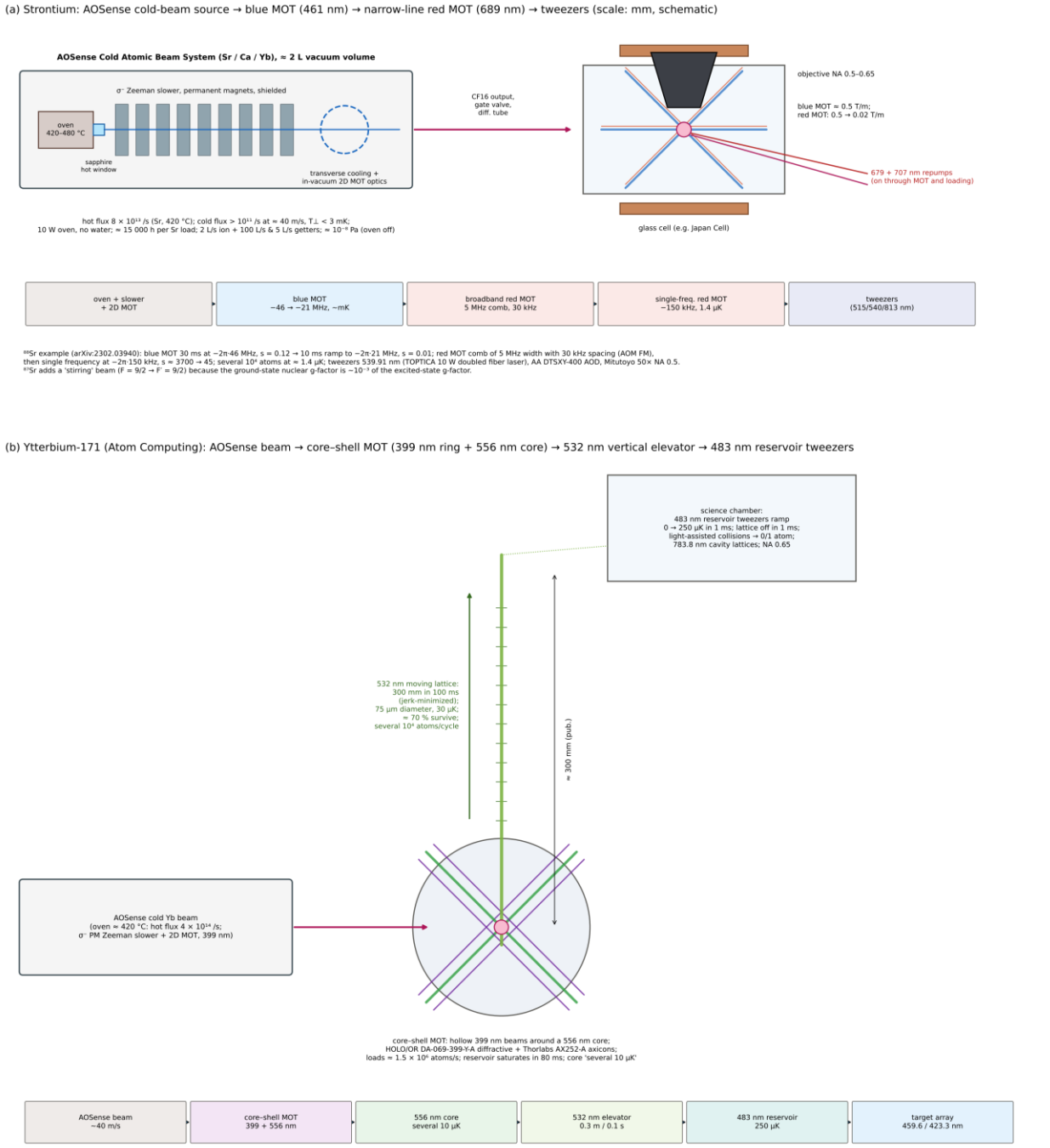


Figure 2. (a) Strontium chain with an AOSense cold-beam source, blue MOT and narrow-line red MOT (operating points from the ^{88}Sr tweezer work of arXiv:2302.03940). (b) The ^{171}Yb chain of Atom Computing (Norcia 2024): AOSense beam → core–shell MOT → 532 nm elevator → 483 nm reservoir tweezers.

3.1 Oven and atomic beam

Sr and Yb have negligible vapor pressure at room temperature (Figure 4a), so they come from an **effusion oven** at 400–500 °C. At 480 °C Sr has about 0.26 Pa of vapor; at 440 °C Yb has about 0.44 Pa. Bundles of microcapillaries or a needle nozzle collimate the output so that the atoms go towards the slower and not

onto the walls, and a heated window (sapphire in the AOSense unit) keeps the slowing beam's entry window from being coated. Both Atom Computing and the ^{88}Sr group of arXiv:2302.03940 buy the source as one unit:

AOSense Cold Atomic Beam System	Datasheet value
Species	Sr, Ca or Yb
Architecture	Effusion oven → σ^- Zeeman slower (permanent magnets, magnetic and thermal shields) → transverse cooling → in-vacuum 2D MOT optics; hot beam blocked from the output
Hot flux	Sr 8×10^{13} /s at 420 °C; Yb 4×10^{14} /s at 420 °C; Ca 4×10^{14} /s at 520 °C (tested to 650 °C)
Cold output	$> 10^{11}$ atoms/s, ≈ 40 m/s axial, $T\perp < 3$ mK
Power, life	10 W at 520 °C, no water cooling; ≈ 15 000 h per Sr load at 420 °C
Vacuum	≈ 2 L; 2 L/s ion pump + 100 L/s and 5 L/s getters; ≈ 1.3×10^{-8} Pa with the oven off, ≈ 9×10^{-6} Pa at 480 °C (before the output tube)
Interface	UHV gate valve → differential pumping tube → CF16 (1.33″) rotatable flange

A home-built alternative is the 2D-MOT source of Saskin et al. (2019, Yb): a needle-collimated oven at 440 °C feeding a 399 nm 2D MOT, with a 556 nm push beam sending atoms through a differential pumping tube to a narrow-line 3D MOT.

3.2 Zeeman slower

Atoms leave the oven at several hundred m/s. A counter-propagating beam on the broad $^1S_0$–$^1P_1$ line slows them at up to a_max (equation 3), and a tapered magnetic field keeps the changing Doppler shift compensated by a Zeeman shift (equation 5). For Sr this means a_max ≈ 9.4×10^5 m/s²; a slower designed at $\eta = 0.5$ for a 555 m/s capture velocity is about 0.33 m long with a peak field of about 86 mT (Figure 4b). Yb's heavier mass halves a_max, but its lower velocity at the same temperature gives a similar 0.28 m length. AOSense builds the field from shielded permanent magnets, which removes the tens of watts of heat and the power supplies of a wound coil slower.

3.3 Broad-line ("blue") MOT and repumpers

The first 3D MOT uses the broad line (Sr 461 nm, $\Gamma/2\pi = 30.5$ MHz; Yb 399 nm, 29 MHz). Its strong force captures atoms up to about 100 m/s, but its Doppler limit is about 0.7 mK. In the ^{88}Sr example the blue MOT loads for 30 ms at $\delta = -2\pi \times 46$ MHz and $s = 0.12$, then moves to $-2\pi \times 21$ MHz and $s = 0.01$ in 10 ms. Strontium's $^1P_1$ state leaks about 1 part in 5×10^4 to $^1D_2$, which decays to $^3P_1$ (harmless) and to the metastable $^3P_2$. A **707 nm repumper** returns $^3P_2$ atoms through 5s6s $^3S_1$; because $^3S_1$ can also decay into $^3P_0$, a **679 nm repumper** is kept on as well. Yb's leak is much weaker and Yb MOTs normally run without repumpers.

3.4 Narrow-line MOT

The intercombination line (Sr 689 nm, 7.5 kHz; Yb 556 nm, 182 kHz) has a Doppler limit of 0.18 µK (Sr) and 4.4 µK (Yb). Two problems must be managed, both quantified in Figure 4d:

- **Capture.** A 1 mK cloud from the blue MOT has a Doppler width of about 1 MHz on either narrow line, hundreds of linewidths. The laser is therefore **frequency-broadened**: the ^{88}Sr example drives the AOM with a frequency-modulated RF tone to make a 5 MHz-wide comb with 30 kHz spacing. The comb is then collapsed to a single frequency ($-2\pi \times 150$ kHz) while the gradient drops from about 0.5 to 0.02 T/m and the saturation parameter from about 3700 to 45, leaving several 10^4 atoms at about 1.4 µK.

- **Gravity.** For Sr the maximum radiation force is only R ≈ 16 times gravity (equation 8), so the atoms sag to the bottom of the MOT region where the Zeeman shift matches the detuning, and the cloud becomes a lens-shaped shell. Yb's broader green line gives R ≈ 245 and behaves more like an ordinary MOT. ^{174}Yb reaches 6.4 µK in Saskin 2019.
- **^{87}Sr needs a stirring beam.** In the fermion the ground state has only the tiny nuclear g-factor, while $^3P_1$ F′ = 11/2 has an electronic one, so the restoring force works only for some sublevels. A second 689 nm beam on F = 9/2 → F′ = 9/2 randomizes the ground sublevels fast enough to keep every atom trapped. ^{171}Yb (I = 1/2) does not need this in practice.

3.5 Atom Computing: the core–shell MOT and the elevator

Instead of switching from a blue MOT to a green MOT in time, Atom Computing runs both at once in space. Each MOT beam is a ring of 399 nm light around a 556 nm core, made with a HOLO/OR DA-069-399-Y-A diffractive axicon and a Thorlabs AX252-A refractive axicon. Fast atoms are caught by the broad-line shell, and atoms that reach the centre are cooled by the narrow-line core to several tens of µK. The MOT loads about 1.5×10^6 atoms/s, about twice a time-sequential MOT, and the 532 nm lattice reservoir saturates in 80 ms. Atoms then ride a 532 nm moving lattice 0.3 m upward in 100 ms (75 µm beam, 30 µK deep, about 70 % survive) and are handed to 483 nm reservoir tweezers ramped from zero to 250 µK in 1 ms.

3.6 Tweezer loading

Alkaline-earth tweezers are usually placed at a **magic wavelength** for the line used to cool and image in them, so that the trap does not shift that line. Examples are 532 nm (Yb, $^1S_0$–$^3P_1$), 515–540 nm (Sr $^3P_1$ magic conditions), 483 nm (Yb $^3P_1$), and 813.4 nm or 459.6 nm (clock-magic). Loading uses light-assisted collisions and gives about 50 %. Saskin 2019 measured 0.49 on average across 144 sites (lowest 0.35), with 30 ms of overlap with a compressed green MOT.

4. Physics and design equations

Vapor pressure (Alcock / CRC Handbook form), used to choose cell and oven temperatures:

$$\log_{10}\left(\frac{p}{\mathrm{Pa}}\right) = 5.006 + A + \frac{B}{T} + C\log_{10}T \tag{1}$$

with (A, B, C) = (4.857, −4215, 0) for solid Rb, (4.711, −3999, 0) for solid Cs, (9.226, −8572, −1.1926) for Sr and (9.111, −8111, −1.0849) for Yb (T in K).

Effusive flux through an oven aperture of area A_ap, and the mean thermal speed:

$$\Phi = \frac{1}{4}\, n\, \bar{v}\, A_{ap}, \qquad n = \frac{p}{k_B T}, \qquad \bar{v} = \sqrt{\frac{8k_B T}{\pi m}} \tag{2}$$

Slowing. The maximum scattering-force deceleration, the slower length for capture velocity v_0 and design fraction η, and the ideal field profile:

$$a_{max} = \frac{\hbar k\, \Gamma}{2m} \tag{3}$$

$$L = \frac{v_0^2 - v_f^2}{2\,\eta\, a_{max}} \tag{4}$$

$$B(z) = B_0\sqrt{1 - \frac{z}{L}} + B_{bias}, \qquad B_0 = \frac{\hbar\, v_0}{\lambda\, \mu'} \tag{5}$$

Here μ′ ≈ μ_B is the difference in magnetic moment between the upper and lower states of the cycling transition, and η ≈ 0.5–0.6 leaves margin for imperfect field profiles and beam intensity.

Saturation intensity, Doppler limit and recoil temperature:

$$I_{sat} = \frac{\pi h c\, \Gamma}{3\lambda^3}, \qquad T_D = \frac{\hbar \Gamma}{2k_B}, \qquad T_r = \frac{\hbar^2 k^2}{m\, k_B} \tag{6}$$

MOT force from each of a pair of counter-propagating beams with saturation parameter s, detuning δ and field gradient B′:

$$F_{\pm} = \pm \frac{\hbar k \Gamma}{2} \frac{s}{1+s+4(\delta \mp k v \mp \mu' B' z/\hbar)^2/\Gamma^2} \tag{7}$$

Expanding for small v and z gives a damping term (−βv) and a restoring term (−κz). Figure 4c plots the velocity dependence for Rb, Sr-blue and Sr-red.

Narrow-line force-to-gravity ratio (decides whether gravity reshapes the MOT):

$$R = \frac{\hbar k\, \Gamma}{2\, m\, g} \tag{8}$$

Moving-lattice velocity for a frequency difference Δν between the two lattice beams:

$$v = \frac{\lambda\, \Delta\nu}{2} \tag{9}$$

Harvard's 9 m/s at ≈ 796 nm needs Δν ≈ 23 MHz; Atom Computing's peak of ≈ 5.6 m/s at 532 nm needs ≈ 21 MHz.

Vacuum-limited lifetime (rule of thumb for room-temperature background gas):

$$\tau \approx \frac{C}{p}, \qquad C \approx (1-3) \times 10^{-6}\ \mathrm{Pa\,s} \tag{10}$$

This gives τ ≈ 30 s at 10^{-7} Pa and ≈ 300 s at 10^{-8} Pa. It matches the 30 s Atom Computing lifetime and the > 150 s Harvard lifetime.

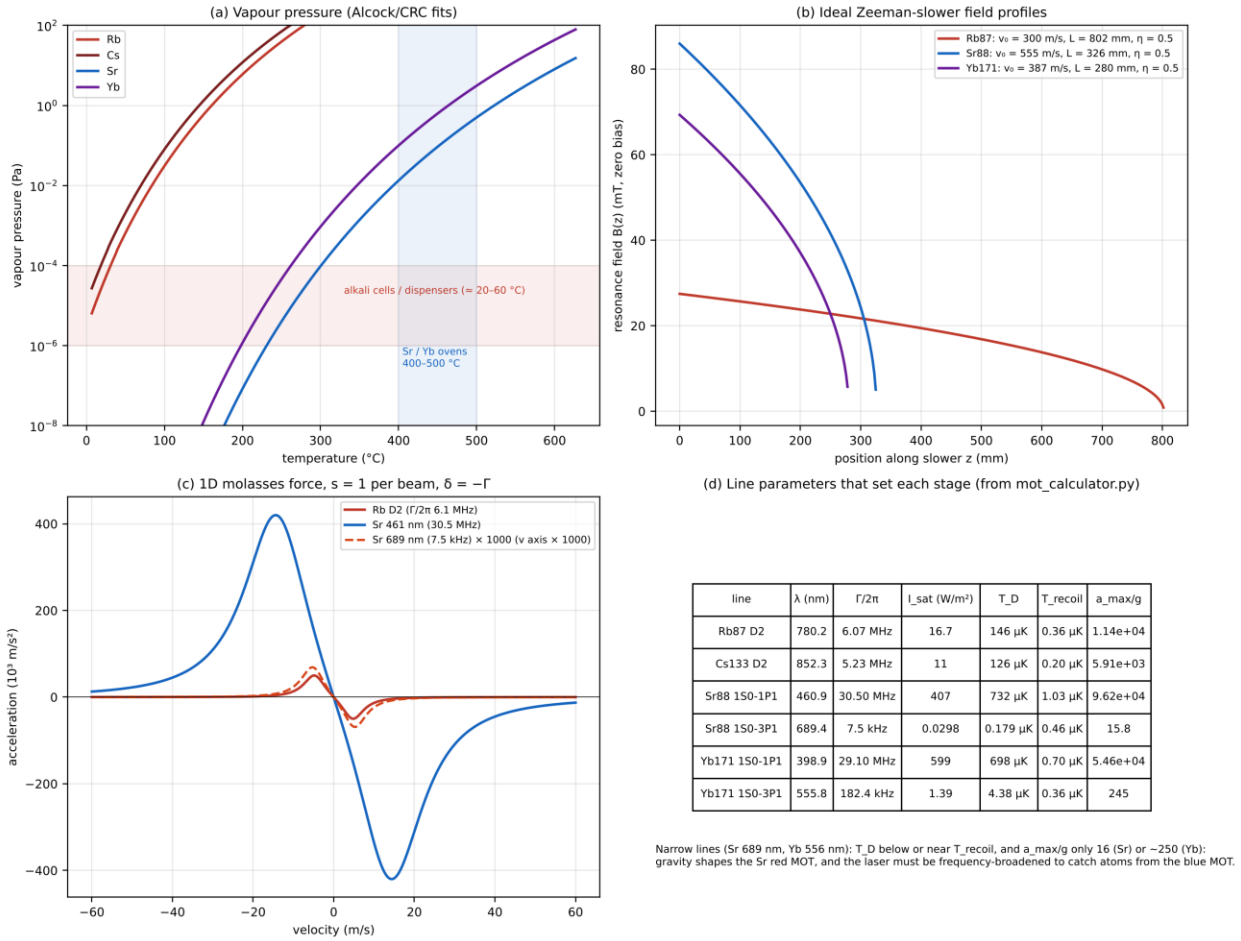


Figure 4. (a) Vapour pressure of Rb, Cs, Sr and Yb. (b) Ideal Zeeman-slower profiles. (c) 1D molasses acceleration versus velocity for broad and narrow lines. (d) Line parameters for each stage. All values computed by mot_calculator.py.

Calculator output	Rb (300 K)	Cs (300 K)	Sr (753 K)	Yb (713 K)
Vapor pressure (Pa)	6.5×10^{-5}	2.4×10^{-4}	0.26	0.44
Flux through 0.5 mm aperture (atoms/s)	2.1×10^{11}	6.3×10^{11}	5.3×10^{14}	6.6×10^{14}
a_max on broad line (m/s²)	1.1×10^{5}	5.8×10^{4}	9.4×10^{5}	5.4×10^{5}
Broad-line I_sat (W/m²)	16.7	11.0	407	599
Broad-line Doppler limit (μK)	146	126	732	698
Narrow-line Doppler limit (μK)	—	—	0.18 (689 nm)	4.4 (556 nm)
MOT capture velocity, 20 mm beams (m/s)	≈ 47	≈ 34	≈ 137	≈ 103

5. Loading sequences

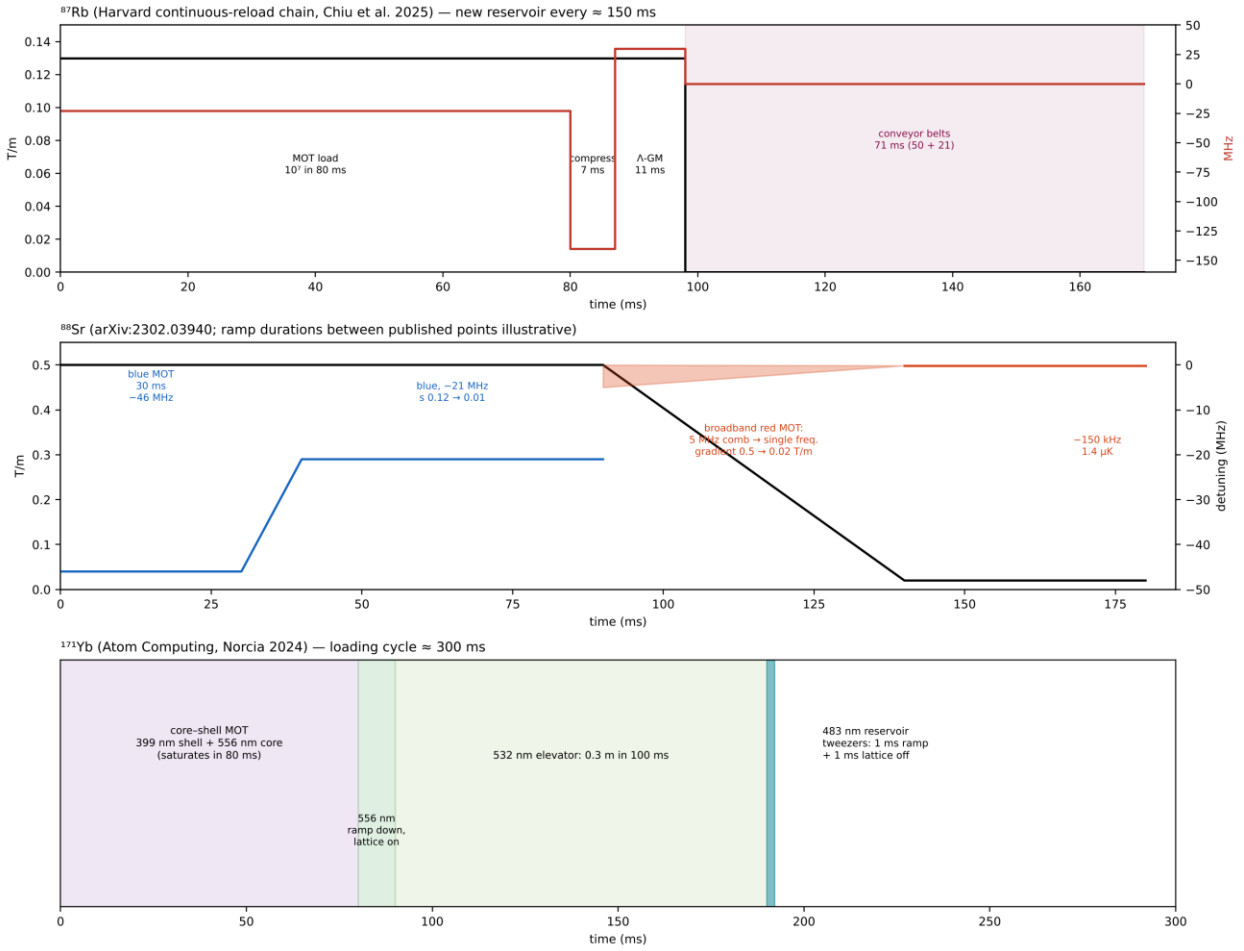


Figure 5. Loading sequences. Rb: Harvard continuous-reload chain (published durations and detunings). Sr: ^{88}Sr example (published end points; ramp shapes between them illustrative). Yb: Atom Computing core–shell MOT and elevator (published durations).

The cycle time sets how fast lost atoms can be replaced: about 150 ms per reservoir for the Harvard chain and about 300 ms per loading cycle for Atom Computing. In both machines the MOT runs while the processor works, which is the main reason for separating the two regions.

6. Lasers and frequency references

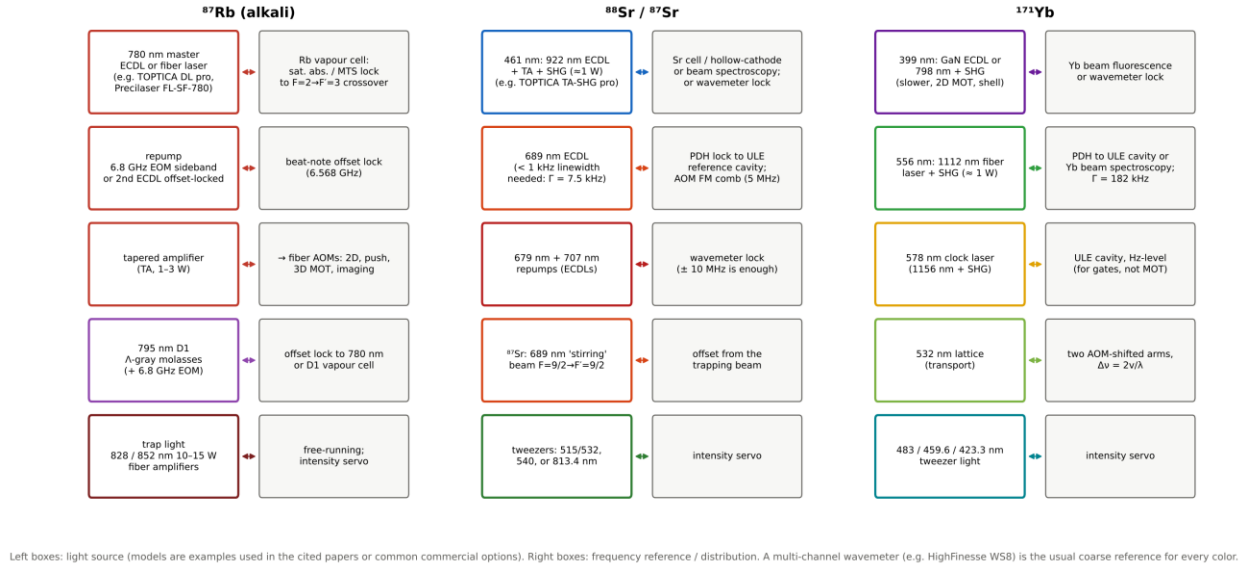


Figure 3. Laser sources (left of each pair) and frequency references or distribution (right) for Rb, Sr and Yb machines.

Light	Requirement	Published or common source
Rb 780 nm cooling + repump	$\lesssim$ 1 MHz linewidth; lock to Rb vapour; repump 6.568 GHz from cooler	Precilaser FL-SF-780-2-CW (2 W) + modulation-transfer lock + 6.58 GHz EOM (arXiv:2604.12204); TOPTICA DL pro + TA pro (common option)
Rb 795 nm D1 gray molasses	carrier + 6.8 GHz sideband at Raman resonance	ECDL + EOM, offset-locked (common option)
Conveyor / transport lattice	≈ 1 W, far detuned, two arms with controllable Δν	Spectra-Physics Matisse Ti:sapphire + quad-pass AOMs (Chiu 2025)
Sr 461 nm	≈ 1 W, few-MHz stability	922 nm ECDL + TA + SHG, e.g. TOPTICA TA-SHG pro (common option)
Sr 689 nm	linewidth well below 7.5 kHz	ECDL PDH-locked to an ULE reference cavity (common option); AOM frequency-modulated comb
Sr 679 / 707 nm	repumps, ± 10 MHz	ECDLs on a wavemeter lock (common option)
Yb 399 nm	slower, 2D MOT, MOT shell	GaN ECDL or 798 nm + SHG (common option)
Yb 556 nm	≈ 1 W; well below 182 kHz	1112 nm fiber laser + SHG (common option)
Tweezers	W-class, low intensity noise	Precilaser 15 W 828/852 nm (Chiu 2025); TOPTICA 10 W 540 nm doubled fiber laser (arXiv:2302.03940)

7. Vacuum and magnetic hardware

- **Pressure targets.** MOT/source region 10^{-7}–10^{-6} Pa is acceptable; the tweezer region needs $\lesssim 10^{-8}$ Pa for minutes of lifetime (equation 10). Differential pumping between the two (0.75 mm Si aperture in the Infleqtion cells; 1.5 mm / 4.3 mm tube from Limit Vacuum Technology in the Harvard chain) sustains a pressure ratio of about 10^{2}–10^{3}.

- **Pumps.** Combined NEG + ion pumps: SAES NEXTorr with an Agilent StarCell 75 (Harvard); 2 L/s ion + 100 L/s and 5 L/s getters inside the AOSense unit. Glass cells (Precision Glassblowing, Japan Cell, Akatsuki optically contacted) are baked to about 200 °C; the Infleqtion CASC allows 225 °C at 1 °C/min.
- **Gradients.** Alkali MOT 0.1–0.3 T/m; Sr/Yb blue MOT ≈ 0.5 T/m; narrow-line MOT 0.02–0.1 T/m. Coils are usually water-cooled pairs with fast switch-off (sub-millisecond, using an IGBT or MOSFET switch and a snubber) so that the field is gone before sub-Doppler cooling or tweezer imaging.
- **Compensation and bias.** Three pairs of shim coils null the background (Earth's field is about 0.05 mT) to the µT level for PGC and gray molasses. Qubit bias fields are added later (for example 50 mT for Atom Computing's Yb). Ion pumps add stray fields; the Infleqtion pump is specified below 0.05 mT.

8. Equipment referenced in this note

Item	Model / vendor	Key specification	Where reported
$2D^+$ MOT source cell (Rb/Cs)	Infleqtion CASC	10^9 /s, 10–20 m/s, 4°; 0.75 mm Si aperture; 30 × 30 × 94.6 mm	Infleqtion datasheet (2025)
Two-chamber MOT package	Infleqtion doubleMOT	> 5×10^8 atoms; < 1×10^{-7} Pa; 2 L/s ion pump; 12.7 × 12.7 × 39.4 cm	Infleqtion datasheet (2025)
Cold atomic beam (Sr/Ca/Yb)	AOSense Cold Atomic Beam System	> 10^{11} /s at ≈ 40 m/s; PM Zeeman slower; 2D MOT	AOSense datasheet; Norcia 2024; arXiv:2302.03940
MOT cell	Precision Glassblowing (two Rb dispenser arms)	with 395 nm UV LED for desorption	Chiu 2025
Science cell	Akatsuki Technology, optically contacted, AR both sides	lifetime > 150 s	Chiu 2025
Glass cell (Sr)	Japan Cell	blue + red MOT, tweezers	arXiv:2302.03940
Pumps	SAES NEXTorr + Agilent StarCell 75	pressure below ion-gauge range	Chiu 2025
Differential tube	Limit Vacuum Technology, custom	1.5 mm / 4.3 mm apertures	Chiu 2025
Coil supply	Delta Elektronika ES015-10	0.27 T/m at 3 A (100-turn coils)	arXiv:2604.12204
Hollow-beam optics	HOLO/OR DA-069-399-Y-A + Thorlabs AX252-A	core–shell MOT beams	Norcia 2024
Objectives	Special Optics NA 0.65 (×2); Special Optics NA 0.6; Mitutoyo G Plan Apo 50× NA 0.5	FOV > 1.5 mm (Harvard)	Chiu 2025; Saskin 2019; arXiv:2302.03940
Cameras	Hamamatsu C15550-20UP; Photometrics Prime BSI; Teledyne Kinetix	sCMOS / qCMOS	Chiu 2025; Saskin 2019; arXiv:2302.03940
Tweezer steering	G&H AODF 4085; Hamamatsu X15213-02R SLM; AA DTSXY-400	828/852 nm (Harvard); 540 nm (Sr)	Chiu 2025; arXiv:2302.03940

9. Relevance to neutral-atom arrays and LCoS design

- **Loading probability sets the hologram size.** With about 50 % loading, a target of N filled sites needs about 2N tweezers (or a reservoir that is reloaded). A 1,000-qubit array therefore needs an SLM

hologram of about 2,000 spots and the laser power to match. Enhanced loading (80–90 %) shrinks both by roughly 40 %.

- **Wavelength and coating.** Alkali machines use 828–852 nm; Sr and Yb machines use 483–540 nm or 813 nm. An LCoS panel, its cover glass and its relay must be specified for that wavelength and for stray MOT light (461/399 nm is close to many blue tweezer wavelengths and can reach the SLM through shared optics).
- **Separating MOT and tweezers protects the SLM path.** Conveyor belts and the vertical elevator move the hot MOT and its scattered light centimeters to tens of centimeters away from the array. This lets the objective sit close to the atoms and keeps MOT beams out of the SLM's field, at the cost of an extra transport stage.
- **Holographic beam shaping for the MOT itself.** The core–shell MOT already uses diffractive axicons to make hollow beams. A phase-only SLM could generate the same ring + core profile, or tune it during loading, but the 399 nm power and SLM damage threshold make a fixed diffractive element the practical choice today.
- **Cycle time drives rearrangement and refill.** Reservoir arrival every 150–300 ms means the SLM/AOD system must refill sites within that time; static SLM holograms do not need to refresh, but any SLM-based re-targeting must be faster than the reload cycle.

10. Software filed with this note

- **mot_calculator.py**: vapor pressure, effusive flux, beam velocities, a_max, Zeeman-slower length and field profile, I_sat, Doppler and recoil limits, capture velocity, narrow-line force/gravity ratio and Doppler width, conveyor detuning and vacuum lifetime. Run `python mot_calculator.py` for the summary or `python mot_calculator.py --species Sr87 --oven 753 --v0 450` for one design.
- **mot_layout_figs.py**: regenerates Figures 1–5 (imports mot_calculator.py, so keep the two files together).

Sources

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Figures generated by mot_layout_figs.py; numbers in Section 4 by mot_calculator.py (both saved alongside this note). Pressures quoted in Torr by vendors were converted to Pa (1 Torr = 133.3 Pa); gradients in G/cm to T/m (1 G/cm = 0.01 T/m).