Harvard–QuEra-Style Neutral-Atom System: Layout and AOD Model

Dimensioned drawings tied to the published Methods of the Harvard/MIT/QuEra ^{87}Rb processors

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What this note shows. Three drawings in the style of the system layout in your Technology, Industry and Architecture note, but tied to published hardware: (1) a science-table layout in millimeters, (2) the atom-plane zone map in micrometers, and (3) a model of the crossed AA Opto-Electronic DTSX-400 AOD pair that the Harvard/MIT team has used in its major papers since 2021. Numbers taken from papers or vendor data are marked as published; table positions, relay focal lengths and the AOD's internal dimensions are engineering estimates, labeled as such.

1. The hardware lineage

QuEra Computing was co-founded by members of the Harvard and MIT groups of Mikhail Lukin, Markus Greiner and Vladan Vuletić, and the academic apparatus and QuEra's machines share one architecture: static tweezers from an LCoS SLM, moving tweezers from a crossed pair of AODs, a high-NA objective, and global 420 nm + 1013 nm Rydberg beams. The papers below report the hardware used here.

Paper	Atoms	Static traps	Moving traps	Objective	Notable
Ebadi et al., Nature 595, 227 (2021)	256	810 nm Ti:sapph, Hamamatsu X13138-02 SLM	809 nm, crossed DTSX-400 pair	Mitutoyo 50×, 0.5 NA	~1000 tweezers, 3 µm min spacing; 105 µm top-hat Rydberg sheets
Bluvstein et al., Nature 604, 451 (2022)	tens	830 nm SLM	828 nm, crossed DTSX-400 pair	0.5 NA	110 µm moved in 300 µs; cubic (constant-jerk) ramps
Bluvstein et al., Nature 626, 58 (2024)	280	852 nm SLM	850 nm, crossed DTSX-400 pair	Special Optics, 0.65 NA	Zoned architecture; 400 µm field of view; ORCA-Quest CMOS; ZCU102 FPGA
Bluvstein et al., arXiv:2506.20661 (2025)	448	852 nm, Hamamatsu X13138-02	852 nm, crossed DTSX-400 pair	Special Optics, 0.65 NA	Entangling zone 175 × 60 µm; reservoir refill; 795 nm lattice readout; 1529 nm shielding
Wurtz et al. (QuEra Aquila), arXiv:2306.11727 (2023)	256	SLM, ~600 traps	Two crossed AODs	not stated	75 × 76 µm user area, 4 µm min spacing; >99% sorting

2. Science-table layout

Figure 1 places the published components on a 1200 × 900 mm breadboard. Light reaches the atoms along four paths:

1. **Static tweezers (852 nm).** Fiber → collimator and expander (≈12 mm beam) → clean-up polarizer → λ/2 that aligns the polarization with the SLM's liquid-crystal director (horizontal on the X13138) →

Hamamatsu X13138-02 reflective LCoS SLM, used off-axis at about 5–7° so the input and output beams separate without a beam splitter → D-shaped pick-off mirror → 4f relay that demagnifies about 0.45× so the hologram fills the objective's 5.5 mm back aperture, with a block for the zero order in the Fourier plane → λ/2 that makes the beam s-polarized so the combining cube reflects it. There is no λ/4 in this arm: double-passing a λ/4 would turn the polarization 90° off the director and the SLM would no longer modulate it.

2. **Moving tweezers (852 nm).** Fiber → λ/2 that sets the AOD input polarization → crossed DTSX-400 pair → 4f relay (M ≈ 0.73, so the 7.5 mm AOD aperture maps onto the 5.5 mm pupil) → λ/2 that makes the beam p-polarized → polarizing beam splitter that transmits the moving traps and reflects the static ones onto a common axis.
3. **Local Raman beam (795 nm).** A separate 2D AOD steers a 1.9 µm spot; in the 2025 work this beam is displaced about 1.5 mm inside the 5.5 mm pupil.
4. **Imaging.** 780 nm fluorescence returns through the objective and a dichroic to a Hamamatsu ORCA-Quest C15550-20UP qCMOS camera. The 2024 and 2025 Harvard papers name this model and say it was chosen for its fast electronic readout; the 3,000-qubit paper gives its quantum efficiency at 780 nm as about 50%. The earlier Harvard/MIT machines (51 atoms in 2017, 256 atoms in 2021) used an EMCCD camera whose make is not stated. QuEra's Aquila paper says only "low-noise camera".

Around the cell: counter-propagating 420 nm and 1013 nm top-hat Rydberg sheets, MOT beams and coils, the $2D^+$ MOT atom source, a 1529 nm shielding beam and the 795 nm 1D lattice used for spin-to-position readout.

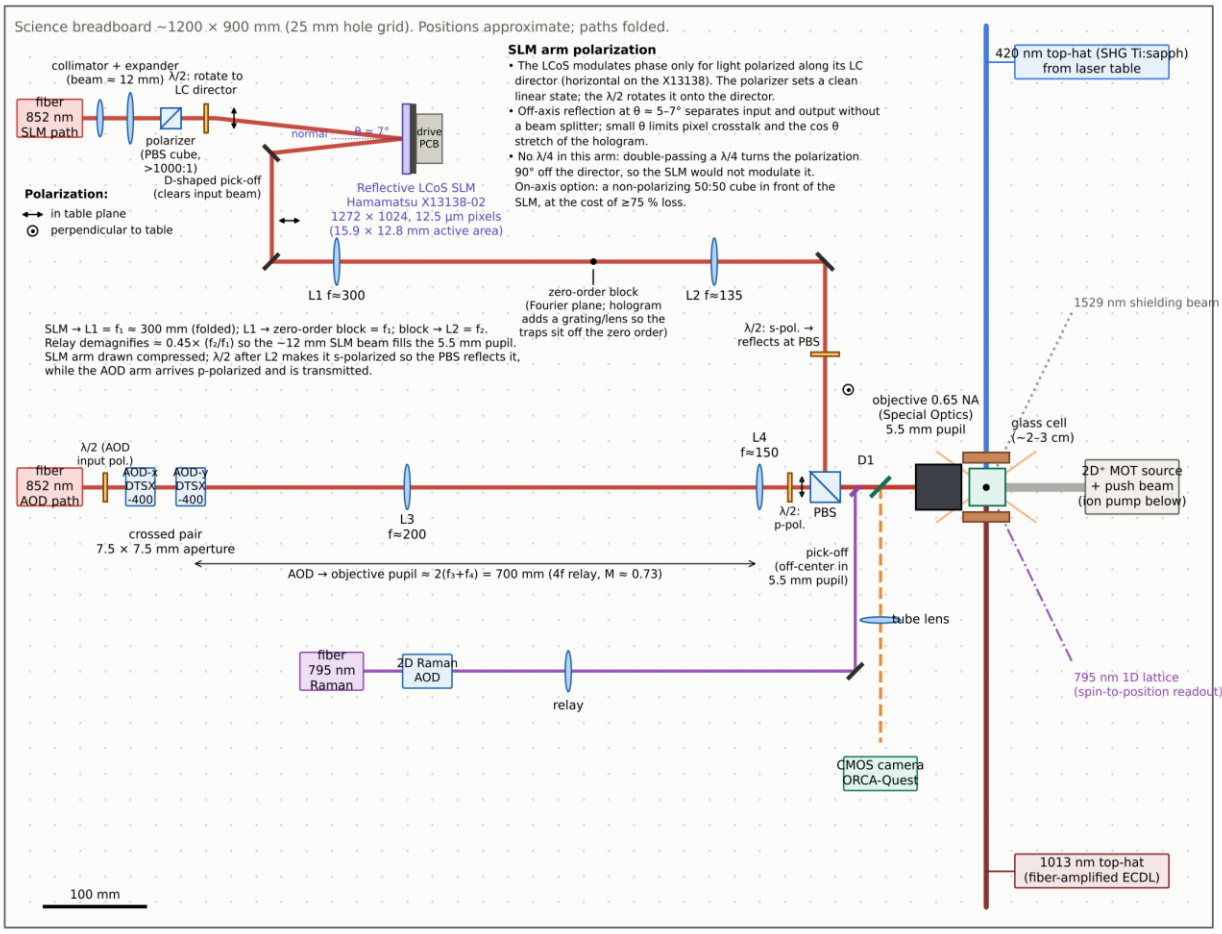


Figure 1. Science-table layout, top view, with a 100 mm scale bar. Component types, wavelengths and models are published; positions, fold geometry and relay focal lengths are estimates chosen to satisfy the published apertures (7.5 mm AOD, 5.5 mm objective pupil).

Consistency check: does the AOD reach match the published zone width?

The DTSX-400-850 scans 47 mrad. The relay magnification M ≈ 5.5/7.5 = 0.73 raises that to about 64 mrad at the objective pupil. A 0.65 NA objective with a 5.5 mm pupil has a focal length of about 5.5/(2 × 0.65) ≈ 4.2 mm, so the AOD reach at the atoms is roughly 4.2 mm × 64 mrad ≈ 270 µm. The 2024 paper states that the ~250 µm horizontal extent of its entangling region is set by the AOD deflection-efficiency bandwidth, which agrees.

3. Atom-plane zone layout

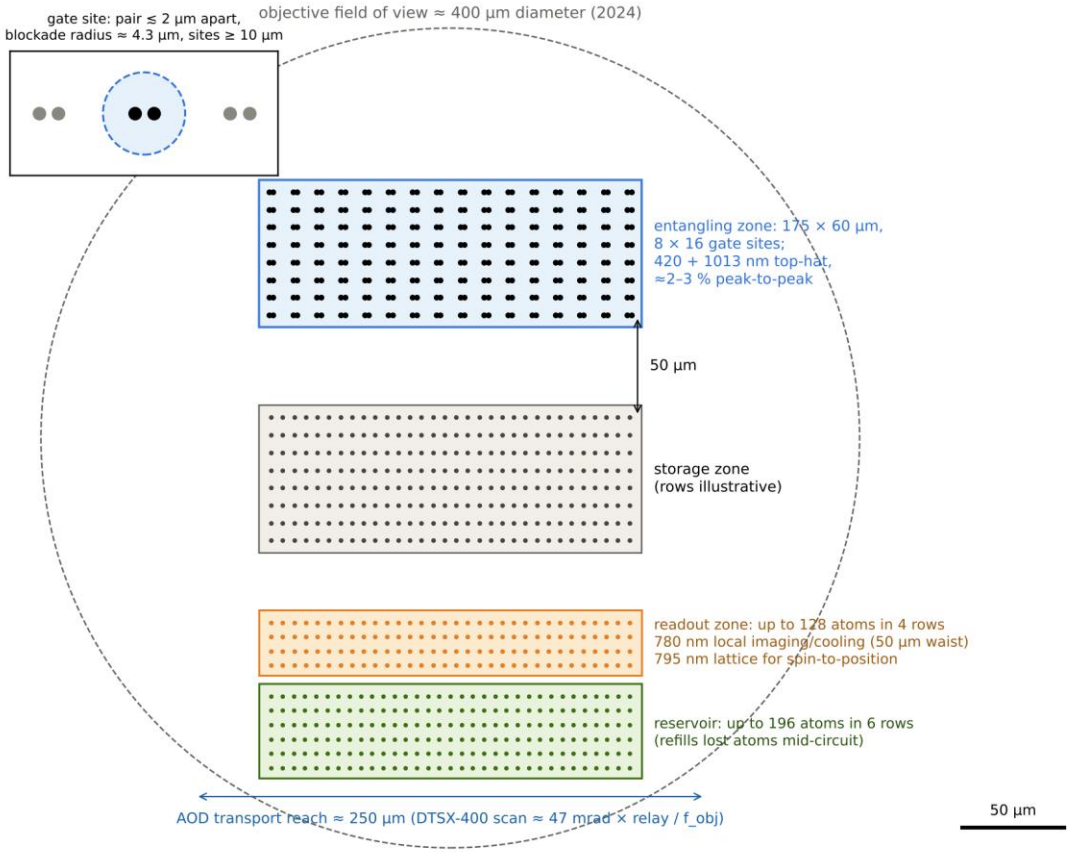


Figure 2. Atom-plane layout in micrometers. Entangling-zone size and gate-site count, the 50 µm storage offset, readout and reservoir capacities, the 400 µm field of view and the gate-site geometry are published (2024 and 2025 papers); the number of storage rows is illustrative.

Quantity	Published value	Source
Entangling zone (deep-circuit layout)	175 × 60 µm, 8 rows × 16 gate sites, up to 256 qubits	Bluvstein 2025
Storage to entangling zone	50 µm	Bluvstein 2025
Readout zone	up to 128 atoms in 4 rows	Bluvstein 2025
Reservoir	up to 196 atoms in 6 rows, below readout	Bluvstein 2025
Gate site	atoms ≲ 2 µm apart; sites ≥ 10 µm apart; blockade radius ≈ 4.3 µm	Bluvstein 2024
Rydberg beam uniformity	≈2–3 % peak-to-peak (top-hat)	Bluvstein 2025
Objective field of view	≈ 400 µm diameter	Bluvstein 2024
Local Raman spot	1.9 µm waist; neighbors ≳ 6 µm away unaffected	Bluvstein 2024
QuEra Aquila user area	75 × 76 µm, 4 µm minimum spacing	Wurtz 2023

4. AOD model: crossed DTSX-400 pair

Each Harvard/MIT paper above moves atoms with two independently driven DTSX-400 deflectors from AA Opto-Electronic, one per axis. Each unit is a single-axis TeO_2 slow-shear (off-axis) deflector in a 57.1 × 27.6 × 22.3 mm package. The second unit is rotated 90° about the beam so its sound travels perpendicular to the first. Because each axis flips the polarization by 90°, the rotated second unit receives the polarization it needs without an extra wave plate.

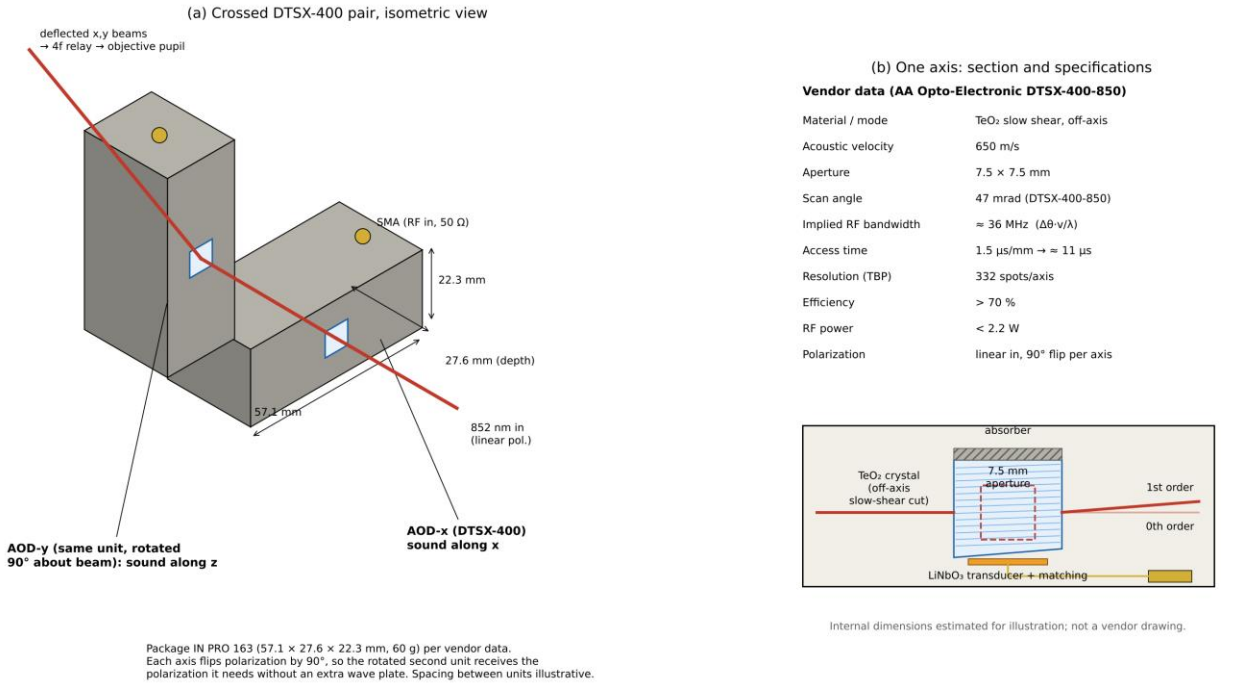


Figure 3. (a) Isometric model of the crossed pair with package dimensions from vendor data. (b) Section through one axis showing the TeO_2 crystal, $LiNbO_3$ transducer and absorber (internal dimensions estimated), with the vendor specifications.

Specification (DTSX-400-850)	Value	Notes
Material / mode	TeO_2 slow shear, off-axis	Anisotropic Bragg diffraction (wide band)
Acoustic velocity	650 m/s	Vendor value
Active aperture	7.5 × 7.5 mm	
Scan angle	47 mrad	Implies ≈ 36 MHz RF bandwidth (Δθ·v/λ)
Access time	1.5 µs/mm	≈ 11 µs across the full 7.5 mm aperture
Resolution	332 spots per axis	Time–bandwidth product
Diffraction efficiency	> 70 %	Per axis; ≈ 50 % or more for the pair
RF power	< 2.2 W	Driven from a Spectrum AWG + Mini-Circuits ZHL-5W-1 amplifiers (2022 paper)
Polarization	Linear in, 90° flip per axis	
Package	IN PRO 163, 57.1 × 27.6 × 22.3 mm, 60 g	

Drive electronics. The 2021 and 2022 papers drive the pair from a dual-channel Spectrum Instrumentation M4i.6631-x8 arbitrary waveform generator, one channel per axis, each carrying the sum of the row or column tones. The 2025 work uses five synchronized Spectrum AWGs (<10 ns jitter), including two channels for the moving AODs and two for the Raman AOD.

Motion limits. Atoms survive moves of 110 µm in 300 µs with cubic (constant-jerk) frequency ramps; loss begins near 55 µm in 200 µs, a speed of about 0.55 µm/µs. Rows and columns are never allowed to cross, so moves are limited to stretches, compressions and translations of the grid.

5. Relevance to your LCoS-based design

- **The SLM is the backbone.** The static array in all of these machines comes from a single phase-only LCoS (Hamamatsu X13138-02), corrected for about 70 milliwaves of aberration. The design issues in your LCoS notes (fringing, flicker, flatness, zero order) apply directly to that path.
- **Match the apertures.** The relays are set by two numbers: the 7.5 mm AOD aperture and the 5.5 mm objective pupil. The SLM relay must demagnify the SLM beam to fill the same pupil.
- **Wavelength choice.** Moving from 810–830 nm (2021–2022) to 852 nm (2024–2025) keeps the trap light further from the 780/795 nm D lines, reducing scattering and differential light shifts.
- **AOD reach sets the processor width.** The roughly 250–270 µm reach of the DTSX-400 pair through a 0.65 NA objective is what limits the entangling zone to about 175–250 µm. A wider machine needs a larger-aperture or wider-band AOD, a lower-magnification relay, or several AOD pairs.

Sources

S. Ebadi et al., “Quantum phases of matter on a 256-atom programmable quantum simulator,” Nature 595, 227 (2021); arXiv:2012.12281 — https://arxiv.org/abs/2012.12281

D. Bluvstein et al., “A quantum processor based on coherent transport of entangled atom arrays,” Nature 604, 451 (2022) — https://www.nature.com/articles/s41586-022-04592-6

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H. Bernien et al., “Probing many-body dynamics on a 51-atom quantum simulator,” Nature 551, 579 (2017); arXiv:1707.04344 — https://arxiv.org/abs/1707.04344

N.-C. Chiu et al., “Continuous operation of a coherent 3,000-qubit system,” arXiv:2506.20660 (2025) — https://arxiv.org/abs/2506.20660

J. Wurtz et al., “Aquila: QuEra’s 256-qubit neutral-atom quantum computer,” arXiv:2306.11727 (2023) — https://arxiv.org/abs/2306.11727

AA Opto-Electronic DTSX-400-850 product data (via GoPhotonics) — https://www.gophotonics.com/products/acousto-optic-deflectors/aa-opto-electronic/83-1383-dtsx-400-850

Figures generated by harvard_quera_layout_figs.py (saved alongside this note). The vendor page does not list the DTSX-400 center frequency; the bandwidth quoted is derived from the published scan angle and velocity.