

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

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

Technical note · October 24, 2026 · D. F. Hakala

**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, labelled 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 $\mu\text{m}$ min spacing; 105 $\mu\text{m}$ 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 $\mu\text{m}$ moved in 300 $\mu\text{s}$ ; 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 $\mu\text{m}$ 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 $\times$ 60 $\mu\text{m}$ ; 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 $\times$ 76 $\mu\text{m}$ user area, 4 $\mu\text{m}$ min spacing; >99% sorting                           |

## 2. Science-table layout

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

1. **Static tweezers (852 nm).** Fiber → expander ( $\approx 12$  mm beam) →  $\lambda/2$  → Hamamatsu X13138-02 LCoS SLM → 4f relay that demagnifies about  $0.45\times$  so the hologram fills the objective's 5.5 mm back aperture, with a block for the zero order in the Fourier plane.
2. **Moving tweezers (852 nm).** Fiber → crossed DTSX-400 pair → 4f relay ( $M \approx 0.73$ , so the 7.5 mm AOD aperture maps onto the 5.5 mm pupil) → polarizing beam splitter that merges the moving traps with the static ones.
3. **Local Raman beam (795 nm).** A separate 2D AOD steers a  $1.9\ \mu\text{m}$  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 CMOS camera.

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

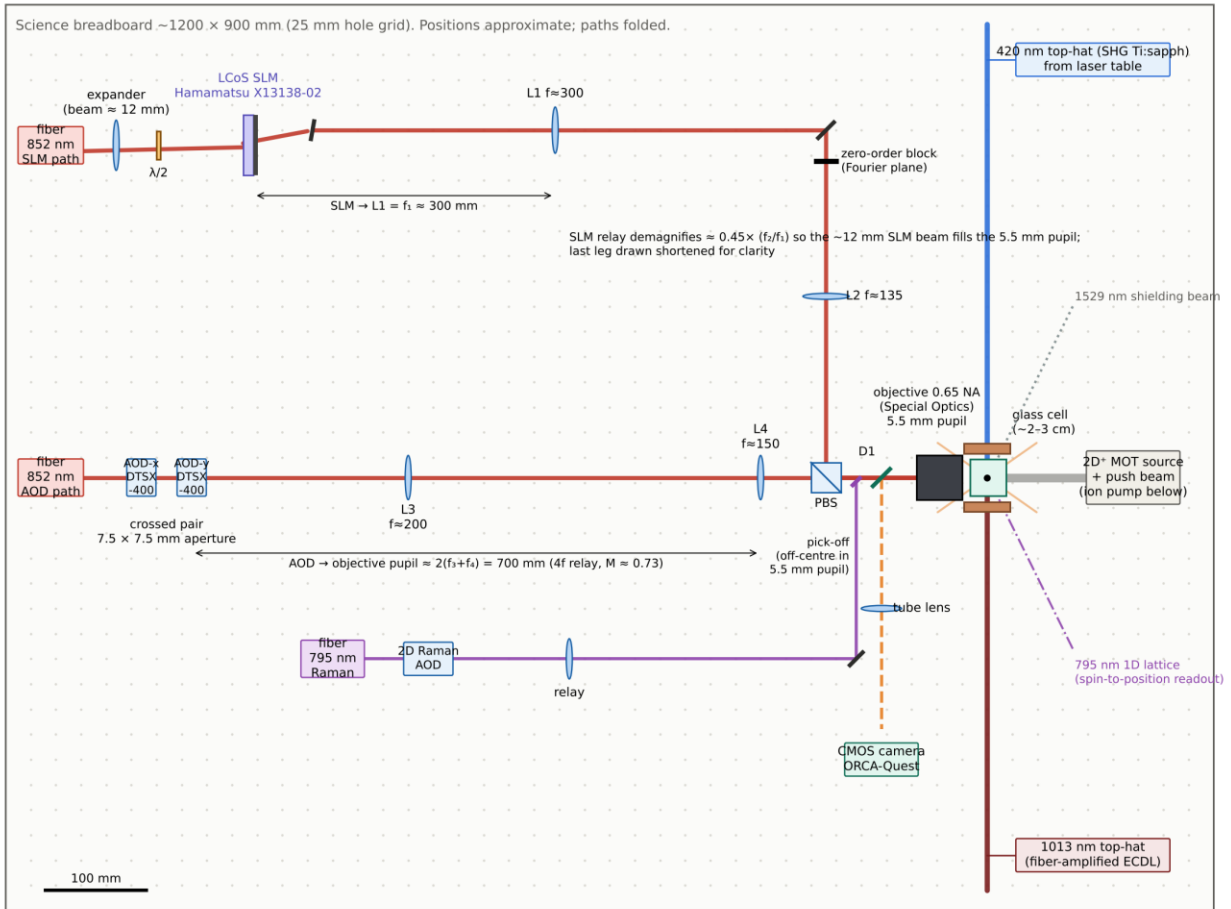


Figure 1. Science-table layout, top view, with a 100 mm scale bar. Component types, wavelengths and models are published; positions, fold geometry and relay focal lengths are estimates chosen to satisfy the published apertures (7.5 mm AOD, 5.5 mm objective pupil).

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

The DTSX-400-850 scans 47 mrad. The relay magnification  $M \approx 5.5/7.5 = 0.73$  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  $5.5/(2 \times 0.65) \approx 4.2$  mm, so the AOD reach at the atoms is roughly  $4.2\text{ mm} \times 64\text{ mrad} \approx 270\ \mu\text{m}$ . The 2024 paper states that the

~250  $\mu\text{m}$  horizontal extent of its entangling region is set by the AOD deflection-efficiency bandwidth, which agrees.

### 3. Atom-plane zone layout

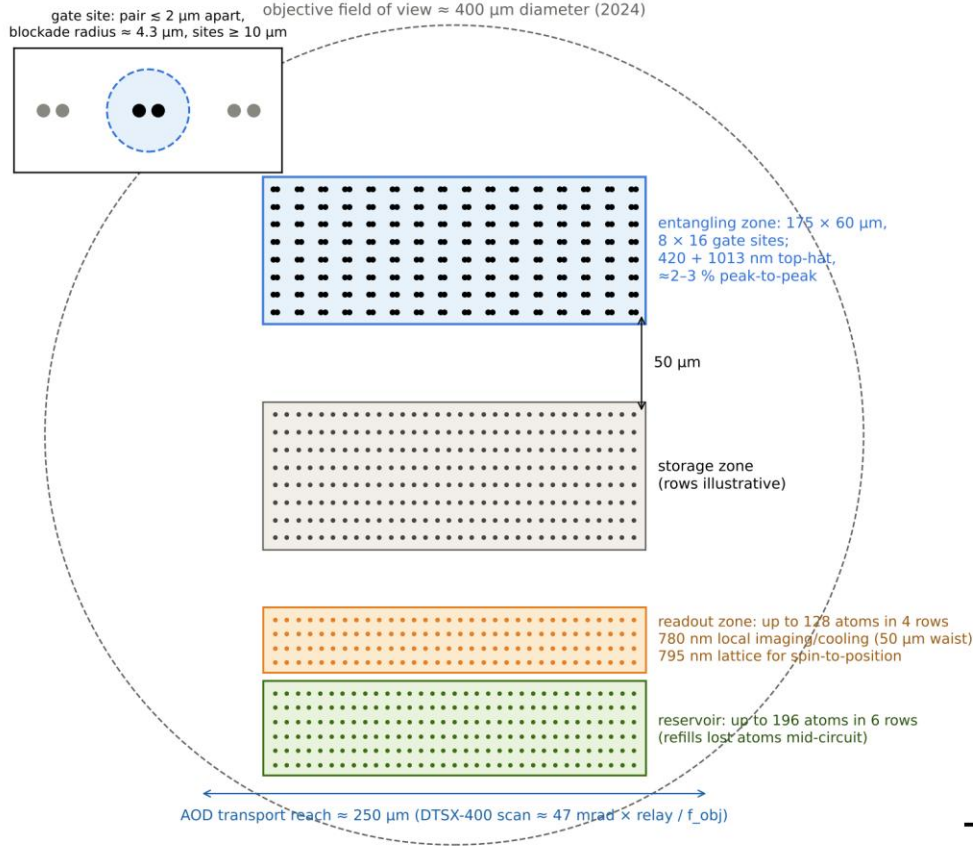


Figure 2. Atom-plane layout in micrometers. Entangling-zone size and gate-site count, the 50  $\mu\text{m}$  storage offset, readout and reservoir capacities, the 400  $\mu\text{m}$  field of view and the gate-site geometry are published (2024 and 2025 papers); the number of storage rows is illustrative.

| Quantity                              | Published value                                                                                                      | Source         |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------|----------------|
| Entangling zone (deep-circuit layout) | 175 $\times$ 60 $\mu\text{m}$ , 8 rows $\times$ 16 gate sites, up to 256 qubits                                      | Bluvstein 2025 |
| Storage to entangling zone            | 50 $\mu\text{m}$                                                                                                     | 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 $\leq$ 2 $\mu\text{m}$ apart; sites $\geq$ 10 $\mu\text{m}$ apart; blockade radius $\approx$ 4.3 $\mu\text{m}$ | Bluvstein 2024 |
| Rydberg beam uniformity               | $\approx$ 2–3 % peak-to-peak (top-hat)                                                                               | Bluvstein 2025 |
| Objective field of view               | $\approx$ 400 $\mu\text{m}$ diameter                                                                                 | Bluvstein 2024 |
| Local Raman spot                      | 1.9 $\mu\text{m}$ waist; neighbors $\geq$ 6 $\mu\text{m}$ away unaffected                                            | Bluvstein 2024 |
| QuEra Aquila user area                | 75 $\times$ 76 $\mu\text{m}$ , 4 $\mu\text{m}$ 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  $\text{TeO}_2$  slow-shear (off-axis) deflector in a  $57.1 \times 27.6 \times 22.3$  mm package. The second unit is rotated  $90^\circ$  about the beam so its sound travels perpendicular to the first. Because each axis flips the polarization by  $90^\circ$ , the rotated second unit receives the polarization it needs without an extra wave plate.

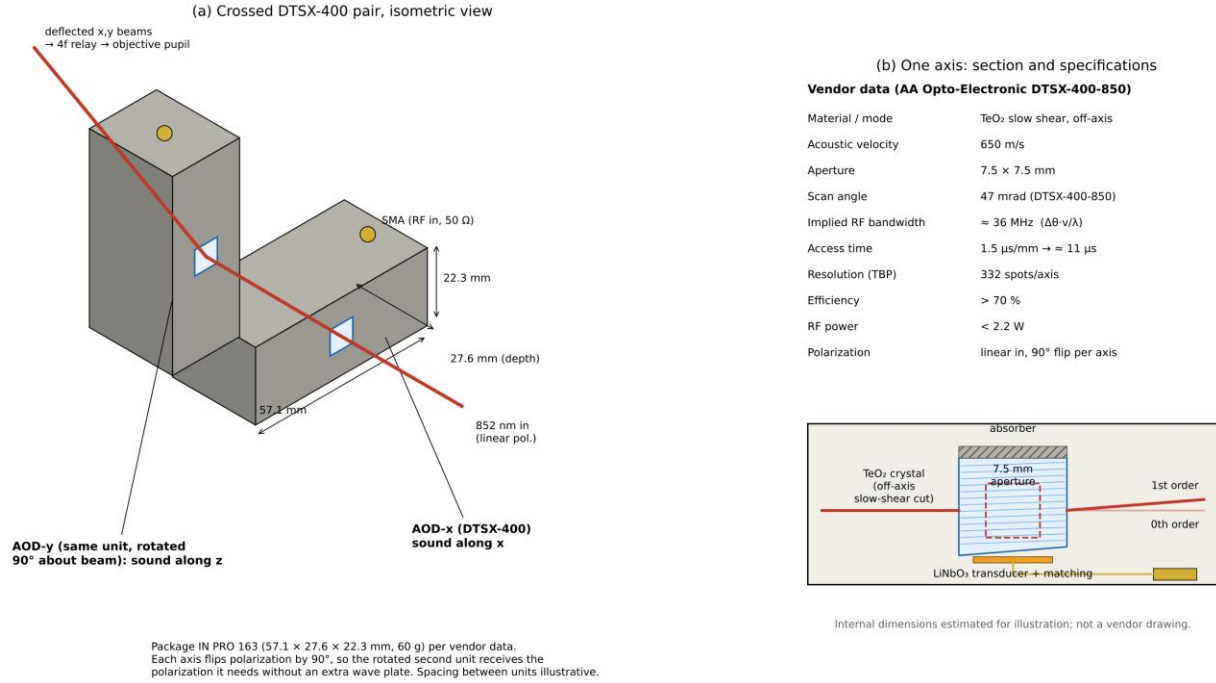


Figure 3. (a) Isometric model of the crossed pair with package dimensions from vendor data. (b) Section through one axis showing the  $\text{TeO}_2$  crystal,  $\text{LiNbO}_3$  transducer and absorber (internal dimensions estimated), with the vendor specifications.

| Specification (DTSX-400-850) | Value                                               | Notes                                                                       |
|------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------|
| Material / mode              | $\text{TeO}_2$ slow shear, off-axis                 | Anisotropic Bragg diffraction (wide band)                                   |
| Acoustic velocity            | 650 m/s                                             | Vendor value                                                                |
| Active aperture              | $7.5 \times 7.5$ mm                                 |                                                                             |
| Scan angle                   | 47 mrad                                             | Implies $\approx 36$ MHz RF bandwidth ( $\Delta\theta \cdot v/\lambda$ )    |
| Access time                  | $1.5 \mu\text{s}/\text{mm}$                         | $\approx 11 \mu\text{s}$ across the full 7.5 mm aperture                    |
| Resolution                   | 332 spots per axis                                  | Time–bandwidth product                                                      |
| Diffraction efficiency       | $> 70\%$                                            | Per axis; $\approx 50\%$ 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, $90^\circ$ flip per axis                 |                                                                             |
| Package                      | IN PRO 163, $57.1 \times 27.6 \times 22.3$ 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  $\mu\text{m}$  in 300  $\mu\text{s}$  with cubic (constant-jerk) frequency ramps; loss begins near 55  $\mu\text{m}$  in 200  $\mu\text{s}$ , a speed of about 0.55  $\mu\text{m}/\mu\text{s}$ . Rows and columns are never allowed to cross, so moves are limited to stretches, compressions and translations of the grid.

## 5. Relevance to 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  $\mu\text{m}$  reach of the DTSX-400 pair through a 0.65 NA objective is what limits the entangling zone to about 175–250  $\mu\text{m}$ . 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>
- D. Bluvstein et al., “Logical quantum processor based on reconfigurable atom arrays,” Nature 626, 58 (2024) — <https://www.nature.com/articles/s41586-023-06927-3>
- D. Bluvstein et al., “Architectural mechanisms of a universal fault-tolerant quantum computer,” arXiv:2506.20661 (2025) — <https://arxiv.org/abs/2506.20661>
- 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.*