Conditioning of laser light for optical qubit control

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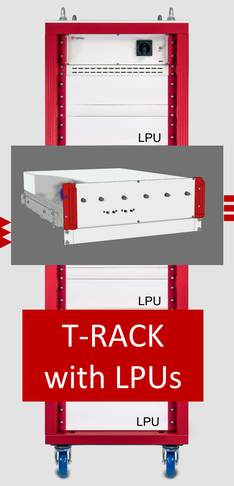
TOPTICA's role in ATIQ

The ATIQ project will produce three quantum computing demonstrators based on different ion trap technologies. For each demonstrator, laser light with well-controlled frequency, intensity, and switching capabilities is needed to manipulate the experimental system and perform the essential operations of a quantum computer. TOPTICA will leverage a modular platform designed for light processing and perform research to extend this platform to include the wavelengths and functionalities necessary to produce rack-mounted light processing units adapted to the needs of each demonstrator. In addition, TOPTICA will contribute a rack-mounted solution that prepares laser light for qubit addressing of multiple ion zones for one of the demonstrators.

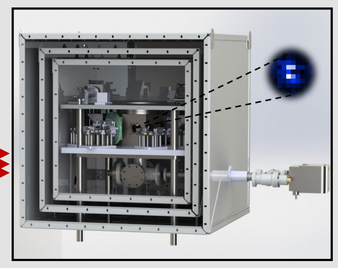
Laser Beam Conditioning

Fibers



Fibers

Trapped ion quantum computer experiment at JGU Mainz



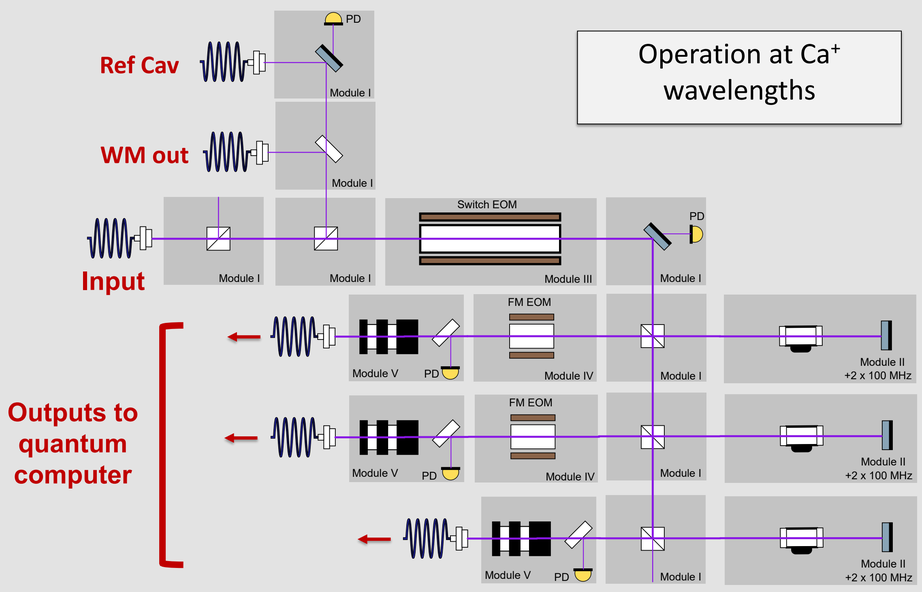
Quantum Computer

Full solution for laser beam conditioning in a rack mounted solution, including:

- Beam routing and switching
- Frequency shifting, sidebands (AOM/EOMs)
- Phase and polarization control

Modular platform: Light Processing Units

Prototype designed in project IQuAn (quantum processor):



Operation at Ca^+ wavelengths

Light Processing Unit (LPU) – example configuration

Modules

I. **Interface Cube**
   - Polarization cleaning
   - Beam splitting, folding
   - Power monitoring

II. **Double pass AOM**
   - Frequency shifts
   - Intensity modulation
   - Switching

III. **Switch EOM**

IV. **Sideband EOM**

V. **Automated Fiber Coupling**

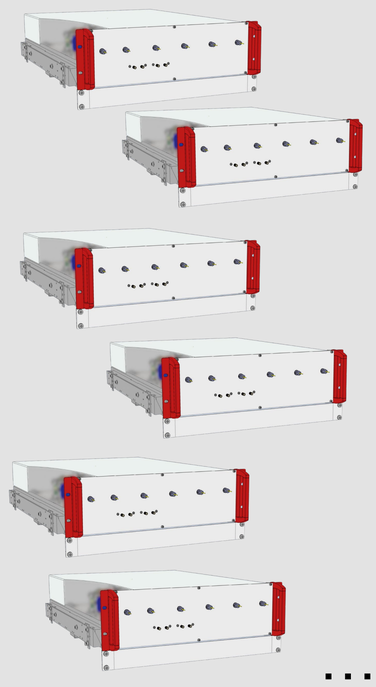
Rack based solution:

- Compact and hands-off
- Fully fiber coupled
- Modular construction
- Passive stability
- Cable management
- Thermal management

Expansion of wavelengths and functionalities

Goal of research within ATIQ project:

- Extension beyond Ca+ wavelengths
- Investigation of added functionalities
  - Shutters
  - Beam combining
- Diverse configurations
  - 3 demonstrator approaches
  - 4 species
- Delivery of **25-30 custom LPUs** in total



Ion	Wavelengths in use
Yb+	369 nm, 399nm, 760 nm, 935 nm
Ba+	413nm, 493nm, 614 nm, 650 nm, 1762 nm
Sr+	405 nm, 422 nm, 461 nm, 1033 nm, 1091 nm
Ca+	375 nm, 397 nm, 422 nm, 729 nm, 854 nm, 866 nm

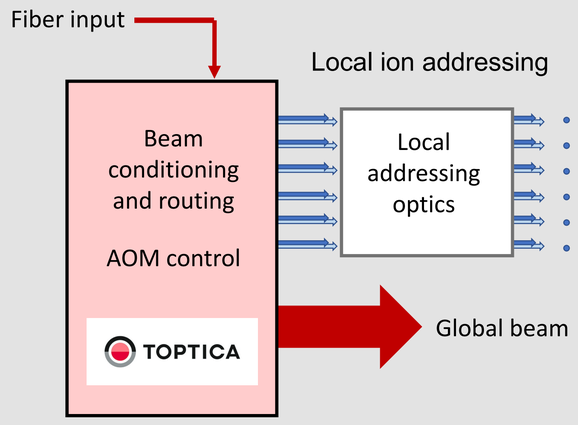
Leibniz Universität Hannover — Ca^+, Sr^+

Johannes Gutenberg Universität Mainz — Ca^+, Sr^+

Universität Siegen — Yb^+, Ba^+

Multiple-zone Raman addressing unit

Goal: Manipulation of ground state qubits with Raman transitions for quantum processor in Mainz (JGUM)



- Up to 16 addressing beams
- Frequency, intensity, polarization, phase control
- High passive stability required for performing gates

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