Compact Laser Systems for Implementing a Strontium Rydberg Quantum Computer

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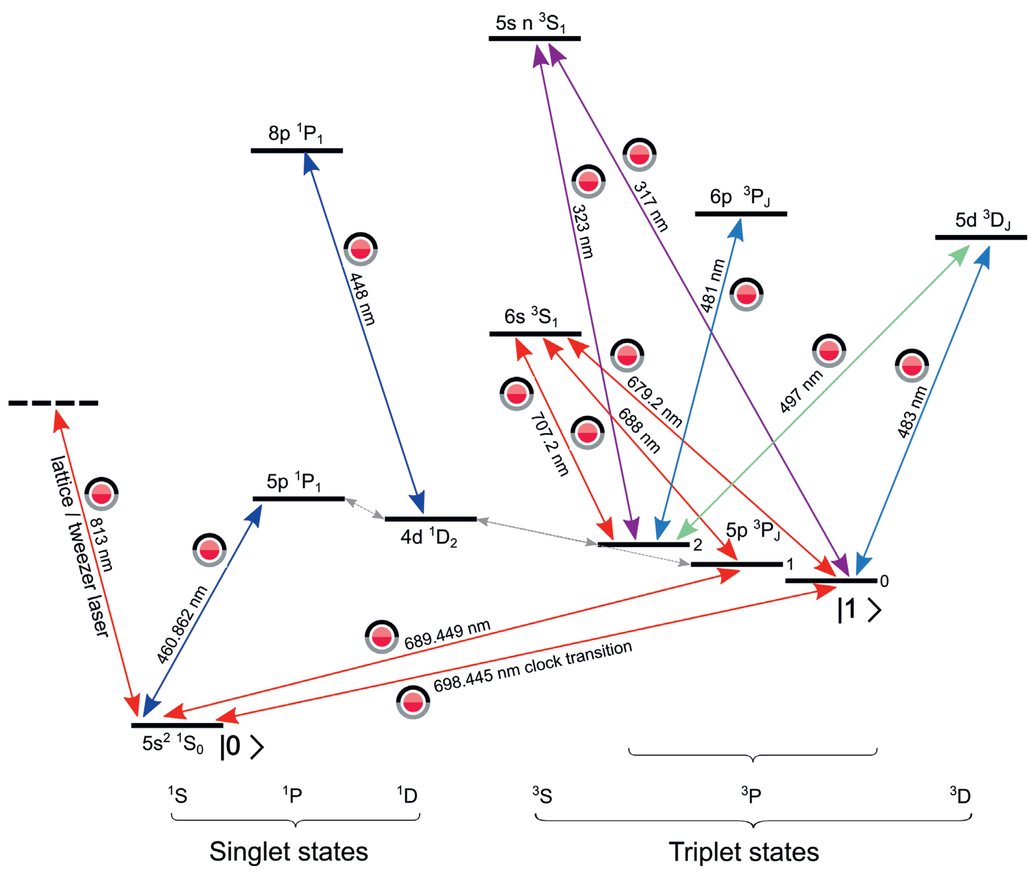
The MUNIQC-ATOMS project is dedicated to the realization of neutral atom based quantum processors. Individual atoms are trapped in optical tweezers and addressed and coherently manipulated by laser beams. Rydberg-Rydberg interactions between the atoms enable fast two- or multi-qubit quantum gates. The goal is to realize prototypes of quantum processors with up to 400 qubits characterized by high gate fidelities. TOPTICA's main tasks within the scope of the project consist of research into concepts for modularization, scaling and compactification of single-frequency laser sources for addressing strontium atoms. The focus lies on significantly increasing their robustness and operating time with the aim of maximum uptime of the laser systems with minimum user intervention.

Qubit of Choice: Strontium

- The qubit is encoded in the atomic levels $^1S_0$ and $^3P_0$, the fine structure of the ^3P_J state or the hyperfine structure of the $^1S_0$ state
- Qubit-qubit coupling is implemented via Rydberg blockade



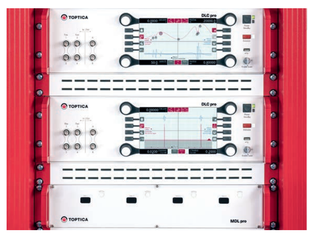
Specifications of related TOPTICA products

Wavelength [nm]	Type	Output Power	Linewidth*	Coarse tuning	MHFTR
317 / 323	DLC FHG pro	up to 3 W	300 kHz	± 0.5 nm	> 20 GHz
461	DLC DL pro HP	250 mW	150 kHz	- 5 nm +2 nm	> 20 GHz
448 / 481 / 483	DLC DL pro	200 / 70 / 70 mW	150 kHz	± 2 nm, ± 3 nm	> 20 GHz
679	DLC DL pro	45 mW	80 kHz	+ 10 nm, - 0 nm	> 20 GHz
689	DLC TA pro	250 mW	80 kHz	-10 nm	> 20 GHz
698	DLC DL pro	35 mW	100 kHz	± 9 nm	> 20 GHz
707	DLC DL pro	25 mW	100 kHz	+ 3 nm, - 11 nm	> 20 GHz
813	DLC TA pro	3 W	100 kHz	± 7 nm	> 20 GHz

* free-running, 5µs delay

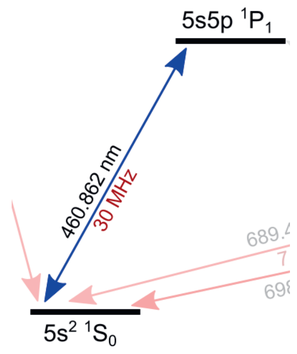
Miniaturization

- Integrate four single-frequency lasers including control electronics into modular rack inserts
- Maintain opto-mechanical stability
- Turn-key operation with active mode hop suppression
- 24/7 operation



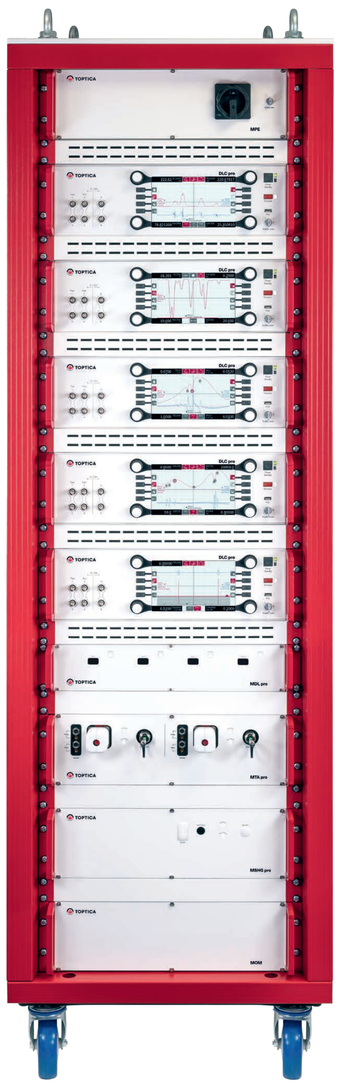
Power Scaling

- High power, narrow linewidth laser system for addressing the cooling transition
- Focus on opto-mechanical stability
- Active suppression of mode hops



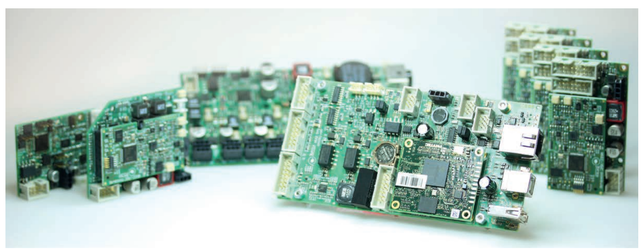
Rack Integration

- Integration of all modules into a 19 inch rack
- Optimize cooling concept with focus on minimization of acoustic and vibrational noise
- Enable stable long-term operation of the laser sources
- Ensure scalability via modular approach
- Minimize service down time via professional cable and fiber management



Control Electronics and Stabilization Solutions

- Realization of compact and efficient driver solutions
- High performance lock modules



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