Laser Systems for Atomic Quantum Processors

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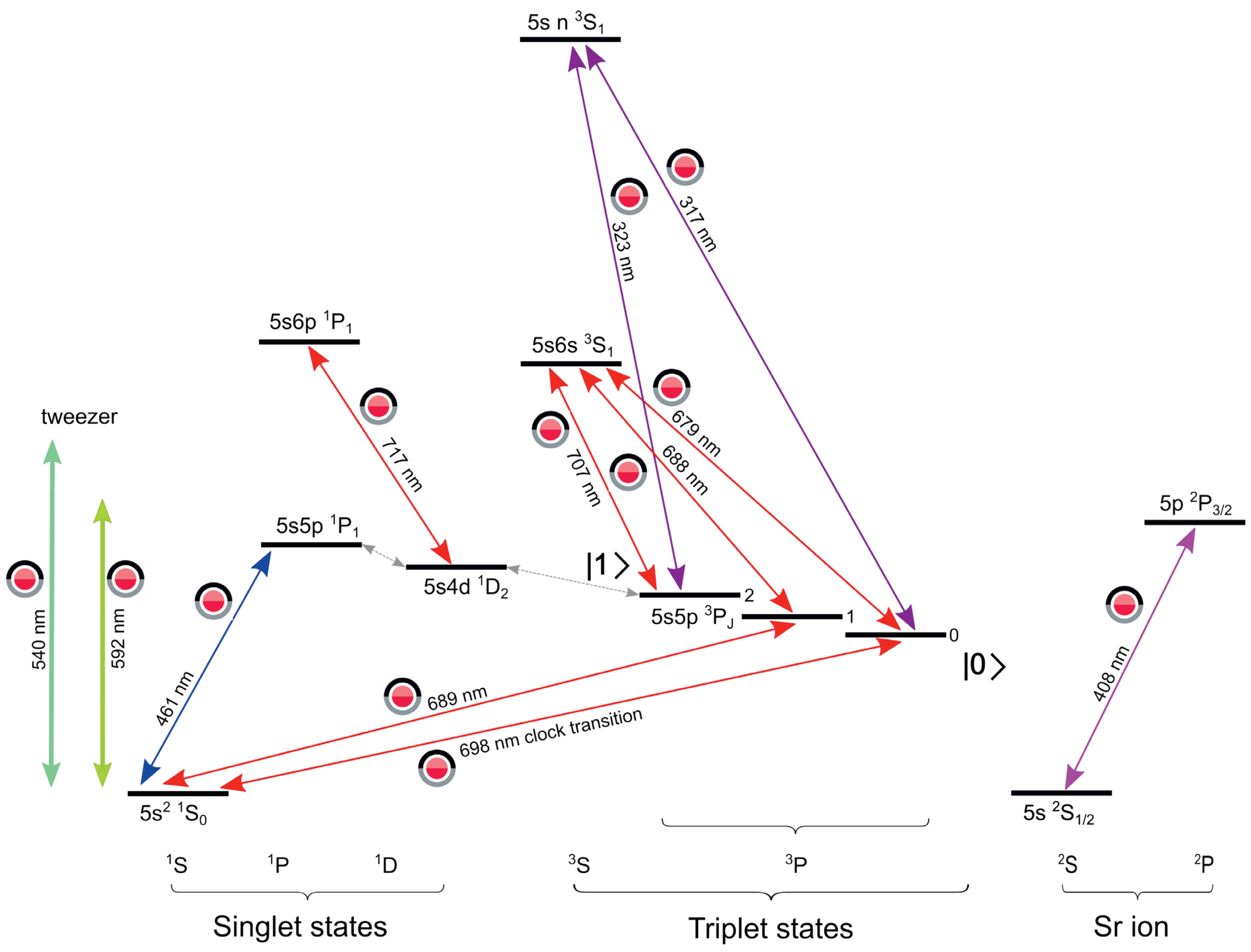
QRyd[Demo] In the project QRydDemo, a neutral atom quantum processor is being developed. It will be based on laser-cooled strontium atoms in dynamic optical tweezer arrays. Two fine-structure states of the metastable ^{3}P manifold represent the qubit. Single-qubit rotations are performed using Raman transitions while Rydberg transitions are used for two-qubit gates.

TOPTICA will perform research on and provide a system comprising all required lasers for cooling, repumping, optical tweezers, qubit initialization, single-qubit rotation, Rydberg excitation, and detection. This includes laser frequency stabilization, linewidth narrowing or phase-noise reduction.

Laser system for Sr Rydberg quantum computing

λ [nm]	Type*)	Locked to	Use
317	ECDL-FHG	Optical frequency comb	Rydberg excitation
323	ECDL-FHG	Optical frequency comb	Rydberg excitation
408	ECDL	Wavelength meter	Autoionization detection
461	ECDL	Optical frequency comb	Cooling 1st stage
540	ECDL-SHG	Wavelength meter	Tweezer I
592	ECDL-SHG	Wavelength meter	Tweezer II
665	ECDL	Optical frequency comb	Raman blue
673	ECDL	Optical frequency comb	Raman blue
679	ECDL	Wavelength meter	Repump
688	ECDL	Optical frequency comb	Qubit init. & readout
689	ECDL	Optical frequency comb	Cooling 2nd stage
690	ECDL	Optical frequency comb	Raman blue
698	ECDL	Ultrastable cavity	Optical Qubit, comb-lock
707	ECDL	Wavelength meter	Repumping
717	ECDL	Wavelength meter	Repumping
1550	FL	GPS	Comb-lock

*) External Cavity Diode Laser (ECDL), Fourth-Harmonic Generation (FHG), Second-Harmonic Generation (SHG), Fiber Laser (FL)

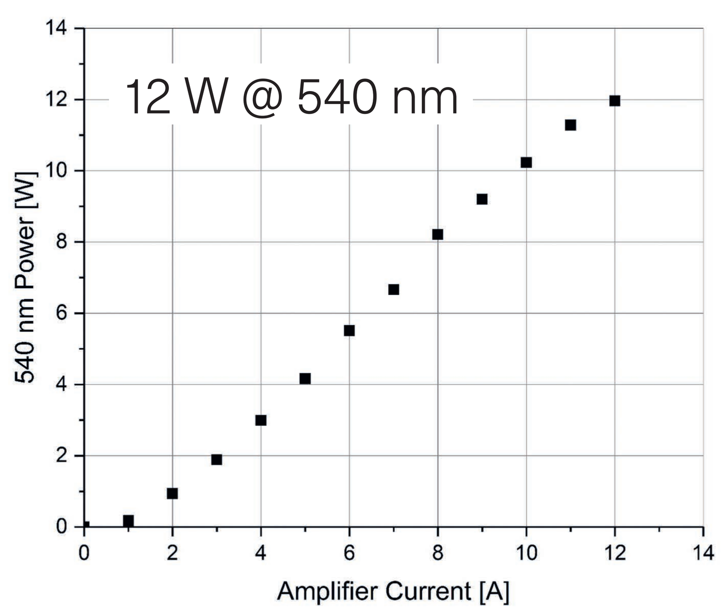


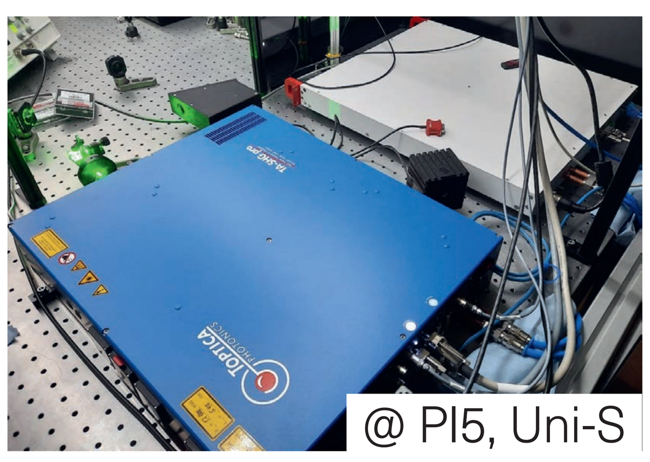
- Lasers for repumping, autoionization detection, and tweezers are locked to wavelength meter
- Lasers for cooling and qubits are locked to f_{ceo}-free optical frequency comb
- Optical frequency comb is locked to
  - Fiber laser that is locked to GPS (1st phase, 1-10 kHz)
  - ECDL that is locked to ultrastable high finesse cavity (2nd phase, 1-10 Hz)

Research on high-power laser systems for optical tweezer arrays (ongoing)

We investigate methods to generate tweezer lasers withthe following charateristics:

- Magic wavelength: 540 nm (1st generation)
- Triple magic wavelength: 592 nm (2nd generation)
- High power (multiwatt)
- Low RIN
- Coarse tuning of a few nm
- Frequency stabilization to the MHz level





Research on low-noise external cavity lasers for atomic qubits (ongoing)

We investigate methods to realize external cavity diode lasers with the following characteristics:

- Low phase-noise
- Low RIN
- Improved ASE suppression
- Solutions applicable for many wavelengths

Methods:

- Broadband ASE filtering with optical elements
- Low phase-noise ECDLs via fast electronic feedback
- Narrow-band frequency filtering with optical cavities
- Low phase-noise ECDLs via optical feedback

Lasers of the QRydDemo quantum processor demonstrator can be upgraded with the best-suited solution.

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https://www.project.uni-stuttgart.de/qryddemo