An automated Ti:sapphire laser system with frequency comb reference for photoassociation spectroscopy

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We present an architecture of a fully automated, continuous-wave and tunable laser system, tightly referenced to a frequency comb. Here, it is demonstrated with a single Ti:Sapphire laser, but it can be easily scaled to multiple lasers for coherent multiphoton spectroscopy. It enables seamless and platform independent communication between all sub-systems – ranging from the laser cavity controller to the diffraction grating mount and frequency lock electronics – through dedicated servers that communicate in real-time, launching appropriate control algorithms to adjust, stabilize, and fine-tune the laser frequency.

The laser is locked to an optical frequency comb by a programmable RedPitaya PID controller, with all RF signals referenced to an atomic rubidium clock ensuring long-term stability and traceability. A motorized diffraction grating selects the desired spectral region of the comb [1] and is automatically aligned during wavelength tuning. The system supports fully remote operation and is capable of autonomous startup, calibration, and frequency stabilization without manual intervention.

The system monitors the frequency of the laser, automatically re-engages locks if lost, and logs diagnostics data for offline analysis. Such a level of automation significantly reduces the need for external intervention and enables stable long-term operation. The system is particularly suited for unattended experiments requiring robust frequency stability over long periods of time, such as photoassociation spectroscopy in ultracold atomic gases.

References

[1] J. Reichert, R. Holzwarth, Th. Udem and T.W. Hänsch, *Optics Communications* **172**, 1 (1999).