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Frequency noise suppression in $GdVO_4$ Raman laser for linewidth narrowing

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Raman lasers make use of inelastic, third-order nonlinear light-matter interaction and inherent phase matching to shift optical frequencies and enhance beam quality by transferring pump energy into the cavity's fundamental mode. These processes have a linewidth-narrowing effect, expected to reduce laser linewidth by up to eight orders of magnitude, outperforming Brillouin lasers, with reported reductions from hundreds of MHz-GHz to approximately 1 kHz in certain systems, with pulsed configurations approaching their Fourier limit [1,2]. However, many applications in precision metrology, next-generation atomic clocks, high-resolution spectroscopy, and enhanced qubit manipulation in quantum technologies, benefit from much narrower linewidths and increased wavelength options.

We report the development of a single-longitudinal-mode Raman laser operating at 1164 nm and/or 1174 nm, using the two primary Raman modes (834 cm^{-1} and 882 cm^{-1}) of $GdVO_4$ as the Raman medium and a 1064 nm pump laser. We obtain first order Stokes emission at a threshold power of 1.3 W. We implement Pound-Drever-Hall (PDH) locking of the cavity to the Stokes resonance to ensure stable single-frequency operation. Further, we plan to characterize the frequency noise damping and linewidth using a short delay self-heterodyne interferometric technique. We expect to measure exceptionally large noise damping and linewidth reduction due to the use of a broad-linewidth pump and a lower noise floor measurement system. We aim to show that the laser concept is promising for simultaneously satisfying the linewidth, power, and wavelength requirements of ultra-narrow linewidth applications.

[1] Pahlavani, R. L., et al. "Linewidth narrowing in Raman lasers." APL Photonics 10.7 (2025).

[2] Chen, Hui, et al. "High-power, ultra-low-noise cascaded diamond Raman lasers with spectrum compression." High Power Laser Science and Engineering 12 (2024): e82.

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