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Recent Progress in the Ultranarrow Linewidth Multiwatt Diamond Raman Lasers in the Visible

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Lasers with ultra-narrow linewidths, stable single-frequency operation, exceptional beam quality, and high power in the visible spectrum are indispensable for applications such as artificial guide star generation and optical lattices in next-generation clocks. Diamond Raman Lasers (DRLs) represent a compelling solution, as they enable access to spectral regions that are otherwise challenging for conventional laser technologies. Their excellent thermal conductivity allows power scaling without degrading beam quality, while their intrinsic phase-noise suppression outperforms traditional Brillouin lasers [1, 2]. Despite these advantages, achieving long-term stable single-frequency performance remains a central challenge. We have recently demonstrated free-running single-mode operation sustained for 35 minutes, highlighting the feasibility of extended operation when both the diamond and LBO crystals are carefully temperature-stabilized, and optimization of cavity parameters has been considered [3, 4]. For guide star and quantum applications, however, frequency locking to an external atomic reference is essential. Here, we demonstrate, for the first time, frequency locking of a DRL to the sodium D2a transition at 589 nm.

[1] E. Granados et al., ‘Spectral synthesis of multimode lasers to the Fourier limit in integrated Fabry–Perot diamond resonators’, *Optica*, vol. 9, no. 3, p. 317, (2022).

[2] R. L. Pahlavani, et al ‘Linewidth narrowing in Raman lasers’, *APL Photonics*, vol. 10, no.7 (2025)

[3] O. Terra, et al., “Towards Stable, Low-Phase-Noise, and Multi-Watt Single Frequency Diamond Lasers in the Visible,”(CLEO/Europe-EQEC), Munich, Germany, 2025, pp. 1-1, doi: 10.1109/CLEO/Europe-EQEC65582.2025.11109760

[4] A. Sharp et al., “Optimising Single-Frequency Intra-Cavity-Doubled Diamond Raman Lasers,” (CLEO/Europe-EQEC), Munich, Germany, 2025, pp. 1-1, doi: 10.1109/CLEO/Europe-EQEC65582.2025.11111260.

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