Title: "GaN-diode-pumped AlGaInP VECSEL for strontium optical clocks"

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Vertical-external-cavity surface-emitting lasers (VECSELs) are interesting for quantum technologies based on cold atoms/ions, providing high brightness and low noise at specific transition frequencies. Here we report diode-pumped AlGaInP-based VECSELs developed for the second cooling transition of strontium, achieving 300mW at 689nm, and 170mW single-frequency, locked to a reference. The VECSELs were optically-pumped with GaN laser diodes, now widely available. The VECSEL gain structure was designed for short pump absorption at blue wavelengths, and a ten-fold increase in output power was achieved compared to previously reported blue-diode-pumped VECSELs. We compare narrow linewidth performance with similar VECSELs pumped with low-noise green lasers.

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Vertical-external-cavity surface-emitting lasers (VECSELs) are of significant interest for quantum technologies based on cold atoms/ions, providing high spatial and spectral brightness and low noise at specific transition frequencies; however, the portable quantum devices currently under development require very compact laser sources, and for optically-pumped lasers this generally means diode-pumping. Diode lasers are routinely used to pump infrared VECSELs; however, for direct visible emission, high power has previously only been achieved via pumping with multi-Watt frequency-doubled infrared solid-state and semiconductor lasers, with diode-pumped visible VECSELs pump-power-limited to <20mW.

Recently we have demonstrated a single frequency AlGaInP-based VECSEL at 689nm with sub-kHz linewidth and relatively high power (200mW) via optical pumping with a low noise green VECSEL (Coherent Verdi G). Such performance has allowed this laser to be implemented in a neutral strontium optical clock setup, targeting the narrow second stage cooling transition. With multi-Watt GaN-based diode lasers now widely available the overall volume of the clock system can be reduced further, leading to a more portable device, if the VECSEL gain structure can be designed to accommodate the very short pump absorption length for blue wavelengths. Here we report the design, characterisation and performance of an AlGaInP-based VECSEL pumped with a high-power diode laser system at 447nm, achieving output power up to 300mW at 689nm. With intracavity filtering we achieve 170mW single-frequency and we have achieved active locking to an external reference at the Sr transition frequency. We compare narrow linewidth performance with similar VECSELs pumped with low-noise green lasers.

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Jennifer E. Hastie