

AlGaInP-based VECSEL for strontium clock transitions

Paulo Hisao Moriya*^a and Jennifer E. Hastie^a

^a Institute of Photonics, Department of Physics, SUPA, University of Strathclyde, 99 George Street, Glasgow G1 1RD, United Kingdom

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1. ABSTRACT TEXT FOR ONLINE AND/OR PRINTED PROGRAMS

Red-emitting optically-pumped vertical-external-cavity surface-emitting-lasers (VECSELs) are an interesting platform for compact, low noise, and high spatial and spectral brightness laser systems targeting narrow linewidth transitions used in strontium-based optical clocks. Recently, we have demonstrated sub-kHz linewidth operation at 689 nm when pumped by either green or blue lasers. Here we report the development and characterisation of an AlGaInP-based VECSEL targeting ionic and neutral strontium-based optical clock transitions at 674 and 698 nm, respectively. Both systems have single frequency output powers >100 mW in a circularly-symmetric transverse mode, achieving sub-200 Hz linewidth with low-loss, single-stage frequency-stabilisation.

2. ABSTRACT TEXT FOR TECHNICAL REVIEW PURPOSES

Red-emitting, optically-pumped AlGaInP-based vertical-external-cavity surface-emitting-lasers (VECSELs) are an interesting laser platform for the development of portable strontium-based optical clocks due to their wavelength tunability, low noise, high spatial and spectral brightness and ultra-narrow intrinsic linewidth; and their potential for system miniaturization by removing requirements for separate amplifiers, beam converters, frequency converters, and isolators. Recently, we achieved a linewidth of 125 Hz [1], record for this kind of laser, in an AlGaInP-based VECSEL designed to target neutral strontium cooling at 689 nm with output powers >100 mW and relative intensity noise of -153 dBc/Hz via optical pumping with a low noise green VECSEL (Coherent Verdi G). We also demonstrated narrow linewidth (<570 Hz) [2] with the same output power (>100 mW) for a VECSEL gain structure optimized for the shorter pump wavelength of a high power InGaN-diode at 448nm, allowing for potential pump laser integration and, consequently, miniaturization of the overall system size, weight, power and costs. Here we extend this platform with the development and characterisation of AlGaInP-based VECSELs targeting ionic and neutral strontium optical clock transitions at 674 and 698 nm, respectively. The two gain structures were optimized to achieve the two distinct required wavelengths when optically-pumped by a green light source. Both systems present single frequency operation with output power reaching the 100 mW-level with low noise, achieving sub-200 Hz linewidth when frequency stabilized to a reference cavity via the Pound-Drever-Hall technique. Finally, a comparison of the noise and linewidth performance with the VECSELs at 689 nm is performed.

References

- [1] P.H. Moriya et al., "Sub-kHz linewidth VECSELs for cold atoms experiments," *Opt. Express* 28, 15943-15953 (2020).
- [2] P.H. Moriya et al., "InGaN-diode-pumped AlGaInP VECSEL with sub-kHz linewidth at 689 nm," *Opt. Express* 29, 3258-3268 (2021).