Frequency control of diamond Raman lasers for guide star applications

AIPC /ANZCOP/COMMAD/WSOF

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High power lasers tuned to the Sodium (Na) resonance at 589 nm are becoming increasingly important in the field of space adaptive optics due to growth in the fields of space situational awareness and optical satellite communications, as well as in astronomy. The lasers are used to generate guide stars in the mesosphere for compensation of atmospheric distortions via an adaptive optical system. The minimum laser power requirement for creating sufficiently bright guide stars is around 10-20 W, with an optimal linewidth close to the natural linewidth (FWHM 9.79 MHz) at the peak Na resonance (589.15 nm). There is a need for brighter guide stars with reduced background and hence several approaches to higher-powered guide star lasers are being investigated [1, 2, 3].

We are investigating an approach based on diamond Raman lasers. Pumped using a 1018 nm Yb-fiber laser, the diamond Raman laser generates a Stokes wavelength at 1178 nm which is then converted to 589 nm using intracavity second-harmonic generation (Fig. 1). To date, 22 W of output power has been demonstrated with a laser linewidth lower than 8.5 MHz and is constrained to a single-longitudinal mode by exploiting effects particular to Raman gain in the presence of intracavity harmonic generation [1]. Wavelength tuning across the Na resonance and more broadly has been demonstrated. However, frequency locking/stabilization and laser linewidth are important considerations in guide star applications and are yet to be investigated in detail.

Here we report on a modified diamond guide star laser (DGSL) system that aims to increase power and provides the frequency stability required for guide star applications. Based on a 70 W seeded-fibre amplifier as the pump, it uses open-loop control of the pump frequency to within 1-2 GHz and closed-loop cavity length control using a wavemeter or sodium spectroscopy as a reference. This stabilization method provides coarse tuning via the seed laser frequency and fine frequency tuning via the cavity length. Continuous tuning over 6 GHz has been obtained over a period of tens of seconds. We will also report on the linewidth properties, the latest results in frequency locking and evaluate the potential for DGSLs in increasing power.

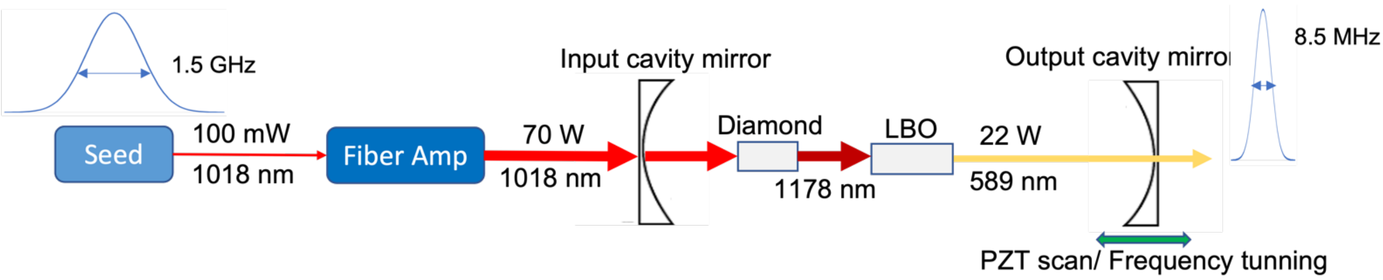

Fig. 1: The DGSL schematic showing the wavelength conversion from pump to Stokes and Stokes to the second harmonic generation. The retroreflection of the optical field inside the cavity is not shown for simplicity.

[1] Yang et al., Optics Letters **45**, 1898 (2020)

[2] Zhang et al., Laser and Photonic Review **8**, 889 (2014)

[3] Enderlein et al., SPIE Adaptive Optics Systems IV **9148**, 49 (2014)