Single-Longitudinal-Mode Diamond Raman Lasers in the Near-Infrared Spectral Region

***Oliver Lux*[1,2], *Soumya Sarang*[1], *Ondrej Kitzler*[1], *David J. Spence*[1], *Robert J. Williams*[1], *Richard P. Mildren*[1]**

1. MQ Photonics Research Centre, Department of Physics and Astronomy, Macquarie University, New South Wales 2109, Australia

2. Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen 82234, Germany

Lasers operating in single-longitudinal-mode (SLM) are of great importance for high-precision measurements in nonlinear optics and spectroscopy as well as for applications in remote sensing, laser cooling and the flourishing field of gravitational wave detection. However, stable SLM in standing-wave inversion lasers is impeded by spatial hole burning which causes mode instability and can only be overcome at the expense of power limitations and/or higher complexity of the laser system, e.g. by means of injection-seeding, ring or microchip laser designs.
As an alternative approach, we demonstrate that the nonlinear optical process of stimulated Raman scattering provides a spatial hole burning free gain which enables the generation of SLM output that is intrinsically stable [1]. The underlying mechanism was harnessed for the development of two compact Raman laser configurations which were realized as external standing-wave cavities, without use of any mode-selective elements, and containing only the CVD diamond Raman-active gain medium. Efficient frequency conversion of a tunable Yb-fiber-amplified distributed feedback (DFB) laser emitting around 1064 nm to the first- and second-order Stokes components produced SLM output in the near-infrared spectral region at powers up to 7 W, while wavelength tuning over a range of 700 GHz was accomplished by varying the temperature of the DFB pump laser, as depicted in Fig. 1a.
The first Stokes diamond Raman laser provided tunable SLM output around 1240 nm with frequency stability of 80 MHz. Without cavity length stabilization, output powers up to 4 W could be achieved stably for several tens of seconds. Heating in the diamond was found to play an important role in longitudinal mode competition, as it introduces a change in Raman frequency but more importantly alters the optical cavity length through thermal expansion and the thermo-optic effect. In a next step, active stabilization of the cavity length using the Hänsch-Couillaud method [2] was used to maintain SLM operation over longer periods and increase the maximum SLM output power to more than 7 W.
Selective amplification of the second-order Stokes component in a further standing-wave Raman laser generated narrowband output in the eye-safe spectral region around 1486 nm. Here, the implementation of a volume Bragg grating, which provided optical feedback into the Raman cavity, improved the frequency stability to 50 MHz (Fig. 1b). The second Stokes Raman laser was successfully employed for water vapor detection, thus confirming the feasibility of the developed concept for light detection and ranging (LIDAR) applications [3]. Hence, SLM Raman lasers represent a promising alternative to existing OPO/OPA and erbium-based laser sources currently applied for active remote sensing. In general, the results foreshadow a novel approach for greatly extending the power and wavelength range of SLM sources.

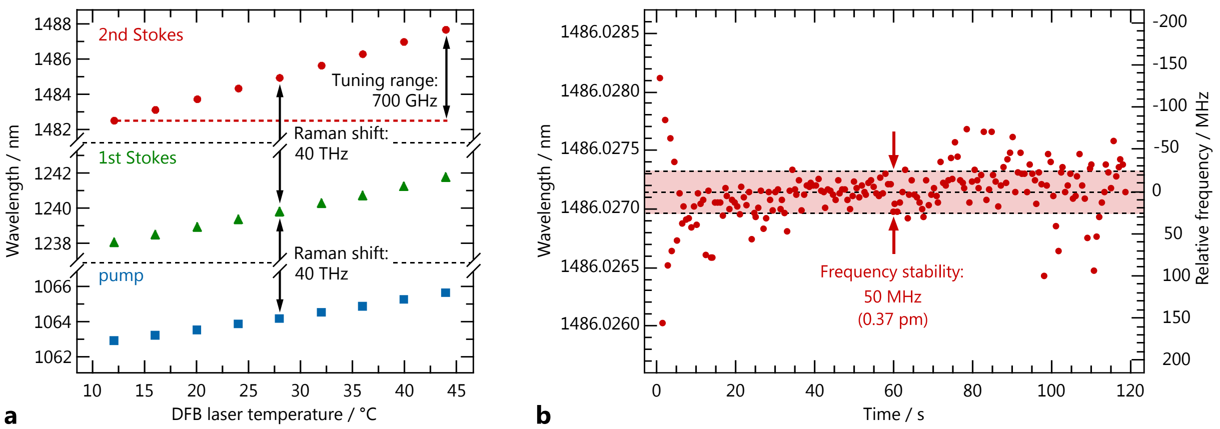

Fig. 1. a Temperature-tuning of the DFB pump laser and resulting output wavelengths of the first and second-order Stokes SLM diamond Raman lasers. **b** Wavelength stability of the second-order Stokes SLM diamond Raman laser over two minutes.

References

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