Single-frequency praseodymium doped YLF laser design and operation with extended wavelength coverage in the visible

Paul White[1], Alan J. Kemp[2], Loyd J. McKnight[1]

1. *Fraunhofer Centre for Applied Photonics, Technology and Innovation Centre, 99 George Street, Glasgow, Scotland, UK*
2. *Institute of Photonics, University of Strathclyde, Technology and Innovation Centre, 99 George Street, Glasgow, Scotland, UK*

Single-frequency operation of a diode-pumped praseodymium-doped YLF laser has been demonstrated using an elegant cavity design. Over 100 mW of single-frequency operation has been achieved from 687 nm to 705 nm with one cavity arrangement. This laser system is well suited for applications in atomic cooling and spectroscopy and this laser system targets use in neutral strontium optical clocks[1].

A 5W GaN diode laser was used as a pump laser and was temperature controlled to ensure maximum absorption in the crystal. A combination of cylindrical and spherical beam-shaping optics were used to compensate for varying beam quality and astigmatism between fast and slow axis to result in a near-circular pump spot size of 70um. A V-shaped cavity was carefully designed to ensure maximum output power using a pump-through mirror, 75mm ROC HR mirror and 1% output coupler with coatings selected for operation in the red-NIR wavelength range. Tuning was achieved with a birefringent filter (BRF). Output powers from 200-400 mW were obtained with single-transverse mode multi-longitudinal mode operation.

Single-frequency operation was achieved with careful selection of an uncoated YAG etalon and confirmed using a scanning fabry-perot interferometer. In combination with filter effects from the crystal etalon and BRF single-frequency operation could be achieved without substantially compromising power. Our analysis of the cavity design partially shown in Fig 1 has shown we can compensate for spatial hole burning [2] with appropriate etalon selection for maximum output power. The low-gain from 687-696 nm would otherwise prevent laser operation with this pump power in ring-laser cavities and other cavity designs due to the loss induced from intracavity filter and tuning elements. Our design is carefully optimised to minimise loss whilst providing sufficient filtering. Tuning was achieved from 687 nm to 705 nm as shown in Fig 1. and through tuning of the BRF, etalon, crystal temperature and cavity length any frequency could be selected within that range. Frequency stabilisation to external reference cavities has been achieved with feedback a cavity mirror mounted on a piezo.

The single-frequency power levels across this broad wavelength range provides a versatile platform for many applications in this spectral range in particular for neutral strontium optical clocks. This platform offers advantages over semiconductor sources due to the low-levels of noise from carrier dynamics and the long-lifetime of the gain crystal.

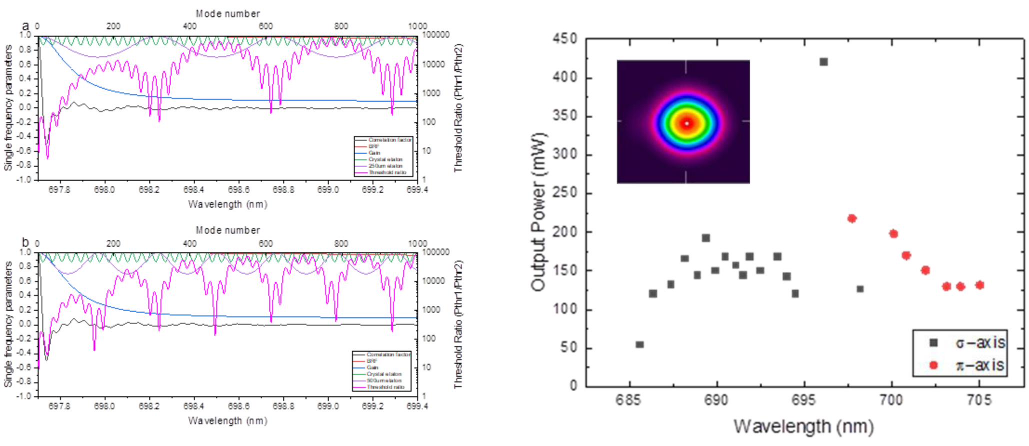

Fig. 1 (left) Analysis of the frequency selective components used to achieve singe-frequency operation and the threshold ratio of the second longitudinal mode compared to the first. (right) measured single-frequency power with beam quality measurement inset (M2 <1.1)

References

[1] A. Sottile, E. Damiano, A. Di Lieto, and M. Tonelli "Diode-pumped solid-state laser platform for compact and long-lasting strontium-based optical clocks", Optics Letters Vol. 44, Issue 3, pp. 594-597 (2019)
[2] J. J. Zayhowski "Limits imposed by spatial hole burning on the single-mode operation of standing-wave laser cavities", Optics Letters Vol. 15, Issue 8, pp. 431-433 (1990)