Direct Generation of Laguerre-Gaussian modes from a Nd:$GdVO_4$ self-Raman laser

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1. Introduction

Laguerre-Gaussian (LG) modes [1] possess an orbital angular momentum (OAM) of $\ell\hbar$ per photon and a ring-shaped spatial form, and they have been attracting much interest in various applications, including optical manipulation, optical/quantum communication, and super-resolution microscopes. Further extension of applications desires strongly the high quality LG mode laser sources with wavelength versatility. Self-Raman lasers enable us to realize ultra-compact laser systems with versatile wavelengths and excellent beam quality [2].

2. Experiment and Results

In this work, we demonstrate the direct generation of 1.108 μm and 1.173 μm LG modes from a self-Raman Nd:$GdVO_4$ laser by employing a shaped pumping geometry formed of an axicon and a focusing lens. Figure 1(a) shows a schematic diagram of self-Raman LG mode laser. The pump source was an 879 nm fiber-coupled laser diode, and its collimated output was focused by an axicon and a focusing lens (IL) to produce a pump beam with a central intensity dip, so as to achieve the good spatial overlap between the pump beam and the LG mode. An objective lens (OL) focused the pump beam onto an *a*-cut 0.3 at.% Nd:$GdVO_4$ crystal. A laser cavity consisted of the input crystal facet (R > 99.99 % for 1.0-1.2 μm), and a concave output coupler (OC) (R > 99.99 % for 1.063 μm, R = 99.99 % for 1.108 μm). This geometry allows us to achieve the 1.108 μm or 1.173 μm Stokes outputs by careful alignment OC. The fundamental output exhibited a high-order mixed transverse mode with a central dark spot. The Stokes outputs showed a perfect annular LG mode profile with a central dark spot in the near and far-fields owing to beam cleanup effects via the stimulated Raman conversion process (Figs. 1(b)-(e)) [3]. Furthermore, maximum LG mode output powers of 49.8 mW and 133.4 mW were achieved at 1.108 μm and 1.173 μm, respectively, for the pump power of 5.69 W.

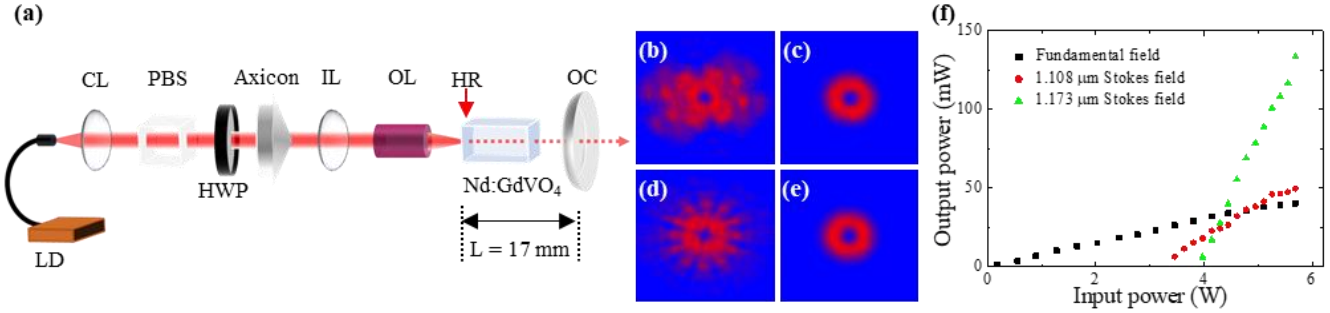

Fig. 1. **(a)** Experimental setup for a self-Raman Nd:$GdVO_4$ vortex laser. Spatial forms of **(b)** the fundamental (1.063 μm) and **(c)** 1.108 μm Stokes LG modes. Spatial forms of **(d)** the fundamental (1.063 μm) and **(e)** 1.173 μm Stokes LG mode. **(f)** Output powers of fundamental and LG modes as a function of input power.

3. Conclusions

We have successfully demonstrated the direct generation of LG mode outputs at 1.108 μm and 1.173 μm from a self-Raman Nd:$GdVO_4$ laser by shaping the pumping beam with the use of an axicon and a focusing lens. The maximum LG mode output powers at 1.108 μm and 1.173 μm were measured to be 49.8 mW and 133.4 mW at the absorbed pump power of 5.69 W, respectively.

References

[1] L. Allen, M. W. Beijersbergen, R. J. C. Spreeuw, J. P. Woerdman, "Orbital angular momentum of light and the transformation of Laguerre–Gaussian laser modes," Phys. Rev. A **45**, 8185–8189 (1992).
[2] T. Omatsu, K. Miyamoto, A. J. Lee, "Wavelength-versatile optical vortex lasers," J. Optics **19**, 123002 (2017).
[3] J. T. Murray, W.L. Austin, R. C. Powell, "Intracavity Raman conversion and Raman beam cleanup," Opt. Mater. **11**, 353-371 (1999).