Laser Output of Laguerre-Gaussian Mode with High Efficiency and High Purity

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Abstract: Laguerre-Gaussian (LG) modes have facilitated their potential applications in optical communication and quantum information processing. The evolving standards in practical applications such as super-resolution imaging and high-precision interferometer inevitably require high-quality LG laser beams. In this work, we demonstrate a low-threshold solid-state laser that can directly generate selected high-purity LG modes with high efficiency and controllability. The principle of our system can be understood as the intracavity spin-orbital angular momentum conversion of light.

1. Introduction

The rapid developments in generating Laguerre-Gaussian (LG) modes and orbital angular momentum of light [1] in recent years have facilitated their potential applications in optical communication, micromanipulation, and quantum information processing [2,3]. The evolving standards in practical applications such as super-resolution imaging and high-precision interferometer inevitably require high-quality LG modes. However, the most existing ways to generate LG modes using fork-grating, q-plate, and spiral phase plate actually generate the hypergeometric-Gaussian modes with a definite l index but an expansion in the p index, which decreases the mode purity and conversion efficiency of the desired LG mode. The effort in producing LG modes in a laser cavity has been impeded for the past ten years because the LG modes with opposite handedness (for example, l = 1 and l = -1 modes) have the same loss and become degenerate in an active optical cavity. It is a great challenge to efficiently generate bright, high-purity and controllable LG laser modes, which will be in high demands [4]. In this work, we have demonstrated a low-threshold solid-state laser that can directly generate selected high-purity LG modes with high efficiency and controllability [5].

2. Experimental results

The principle of our system can be understood as the intracavity spin-orbital angular momentum conversion of light. We put a vortex half-wave plate (VWP, Thorlabs, Inc.), a Faraday rotator (FR) and a quarter-wave plate (QWP) inside a Nd:YVO_4 laser cavity, which can achieve cavity mode reversibility through intracavity spin-orbital angular momentum conversion.

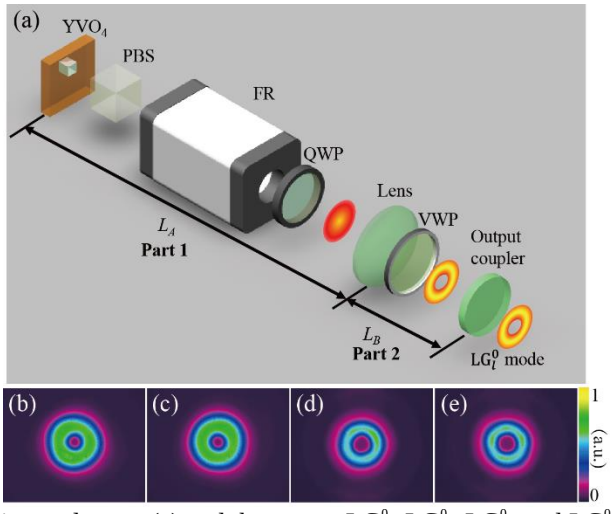

Fig. 1. Experimental setup (a) and the output LG^0_1, LG^0_{-1}, LG^0_2, and LG^0_{-2} modes (b-e).

In our experiment, the generated LG_1^0 & LG_2^0 laser modes have mode purities of ~97% & ~93% and slope efficiencies of ~11% & ~5.1%, respectively. The lasing thresholds for the lower-order LG modes are comparable to that of the Gaussian mode (~500 mW). The beam quality factor reaches 2.19 for the LG_1^0 mode, which is very close to the ideal value of 2. The mode stability at high pump power also shows excellent laser performance. In addition, our cavity design can be easily extended to produce higher-order Laguerre-Gaussian modes and cylindrical vector beams. In comparison to previous reports, our current experiment has demonstrated a much more practical laser system for generating high-quality LG modes, which can now meet the requirements of certain realistic applications.

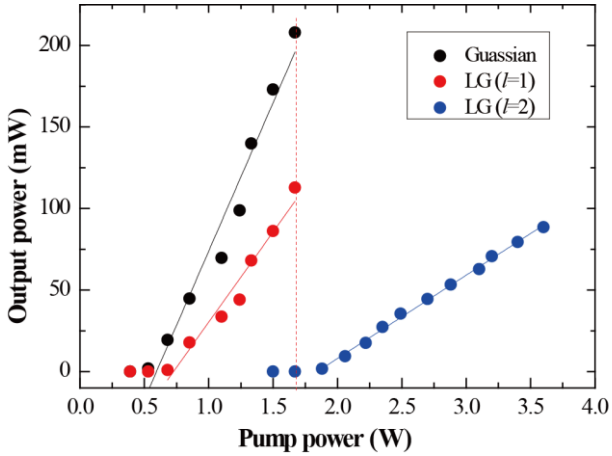

Fig. 2. Output powers versus the pump power.

3. References

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