# Generating powerful optical vortices directly from a thin-disk laser oscillator

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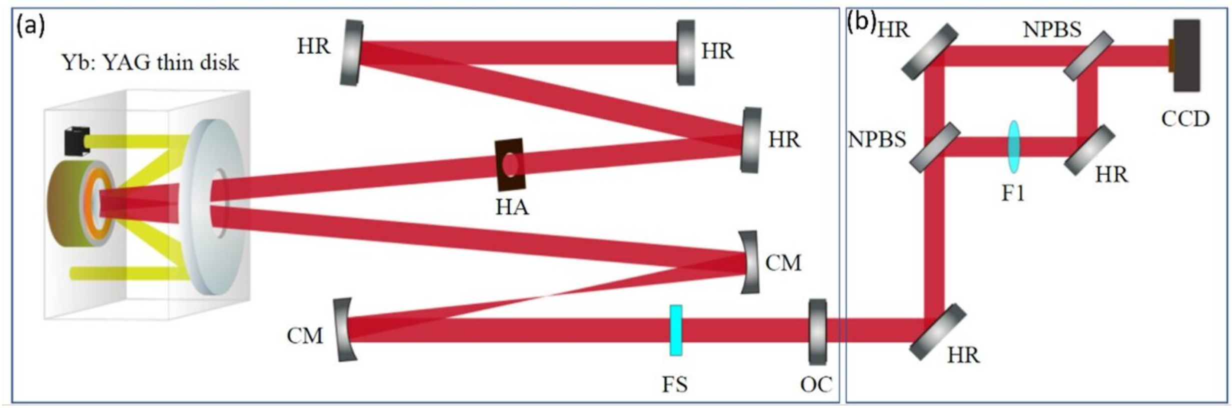



a, thin disk vortex oscillator which generated vortex beam. b, Mach-Zender interferometer which is used to detect the helical phase characteristics. Credit: Hongshan Chen, Qing Wang, Xin Liu, Heyan Liu, Xinhua Guo, Tingting Yang, Lisong Yan, and Jinwei Zhang

In recent years, optical vortices have attracted extensive attention in laser advanced manufacturing because of their annual intensity distribution and orbital angular momentum.

Compared with the Gaussian beam with basic transverse mode as the light source for laser ablation and fabrication, the vortex beam can generate a smoother ablative surface, and the orbital angular momentum carried by the vortex beam can be transferred to the machining material to fabricate the spiral micro-nano structure with adjustable hand properties.

High-power vortex beams play an important role in improving the efficiency of laser manufacturing and revealing the law of light-matter interaction under extreme conditions. How to explore a stable and reliable method to generate high power vortex light has become a research hot topic in related fields.

Currently it is difficult to generate high-power vortex light with high beam quality by using external-cavity mode conversion method due to the limitations of the operating wavelength band of the phase device, low power damage threshold and the device defect. A vortex beam generated directly in the cavity has the advantages of good transmission stability and high beam quality.

At present, vortex light generated by the intracavity method is mainly based on the all solid-state laser and fiber laser. Due to the thermal effect and low damage threshold, the output power of the generated vortex beam is mostly in the order of watts with the highest power up to ~30W. It requires to develop a new method of direct intracavity generation of the vortex beams with the high output power.

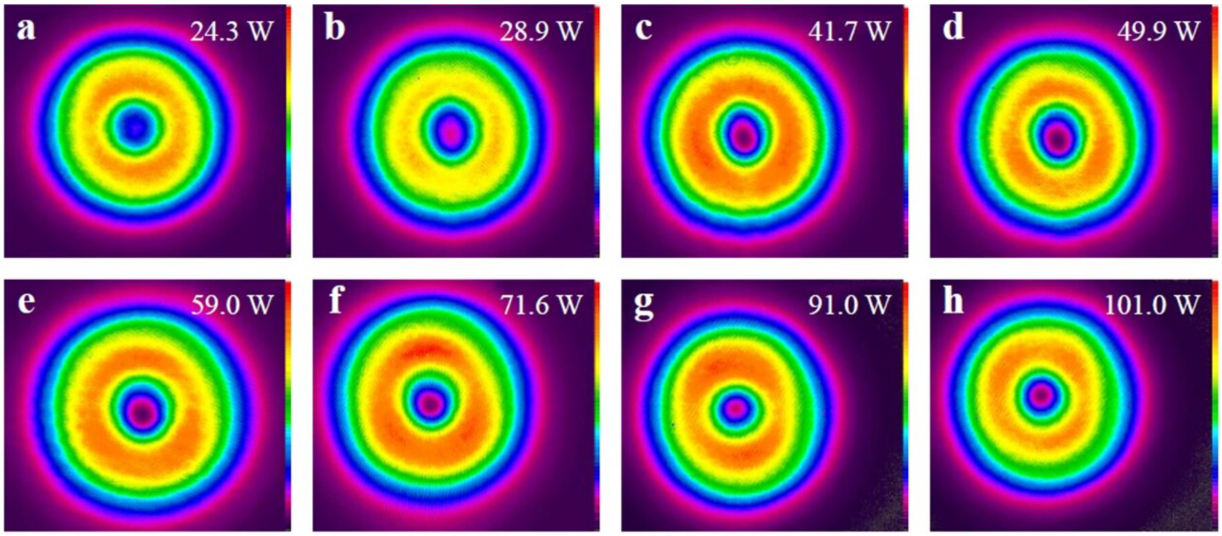
Thin disk laser shows great advantage in generating high power laser because of its special structure with large pumping spot area and high heat dissipation efficiency. The combination of thin disk technology and vortex light generation provides a new method to develop the vortex laser source with high performance.

In a paper published in *Light: Advanced Manufacturing*, a team of scientists, led by Professor Jinwei Zhang from School of Optical and Electronic Information and Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, China and co-workers, have built a thin disk oscillator to generate high power optical vortex beam based on the transverse mode competition and control.

By changing the size of the light spot in the cavity, high-order transverse mode oscillates first due to the low gain threshold and becomes dominant in the cavity, suppressing the oscillation of the fundamental mode. The experimental apparatus can be divided into two parts: the thin disk vortex oscillator which is used to generate vortex light with high output power, and the Mach-Zender interferometer which is used to detect the helical phase characteristics.

By changing the position of the stable region of the resonator, the size of the laser spot of fundamental mode on the disk can be adjusted. In this case, the gain of each order mode can be controlled.

In the experiment, the first-order Laguerre Gaussian (LG) mode was controlled to have the lowest oscillation threshold, which dominated the oscillation in the cavity and achieved a high power output. In order to achieve the control of chiral properties, a coated fused silica plate was added into the cavity to destroy the transmission symmetry of positive and negative chiral vortex light, enabling the control of chiral properties by tuning the angle of the plate.




Beam profiles of the $LG_{01}$ mode vortex delivered directly from the thin-disk vortex oscillator under different output powers. Credit: Hongshan Chen, Qing Wang, Xin Liu, Heyan Liu, Xinhua Guo, Tingting Yang, Lisong Yan, and Jinwei Zhang

The effect of spot size on mode competition was investigated by simulating the gain integral of each order transverse mode under different spot sizes on the disk.

The simulation results show that an LG beam of a certain order can have a higher gain integral than other order transverse modes by changing the size of the fundamental mode spot, and this mode dominates the cavity.

In the experiment, the first-order vortex light with the highest power of 100 W and excellent beam qualities were obtained, and the spiral phase properties were characterized. This high-power vortex laser will enhance the efficiency and flexibility of material processing and it paves the way for exploring new parameter space associated with structured light.

**More information:** Hongshan Chen et al, 100-W Yb:YAG thin-disk vortex laser oscillator, *Light: Advanced Manufacturing* (2023). DOI: 10.37188/lam.2023.040

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