Generation of color-tunable high-performance LG laser beams via Janus OPO

April 24 2023

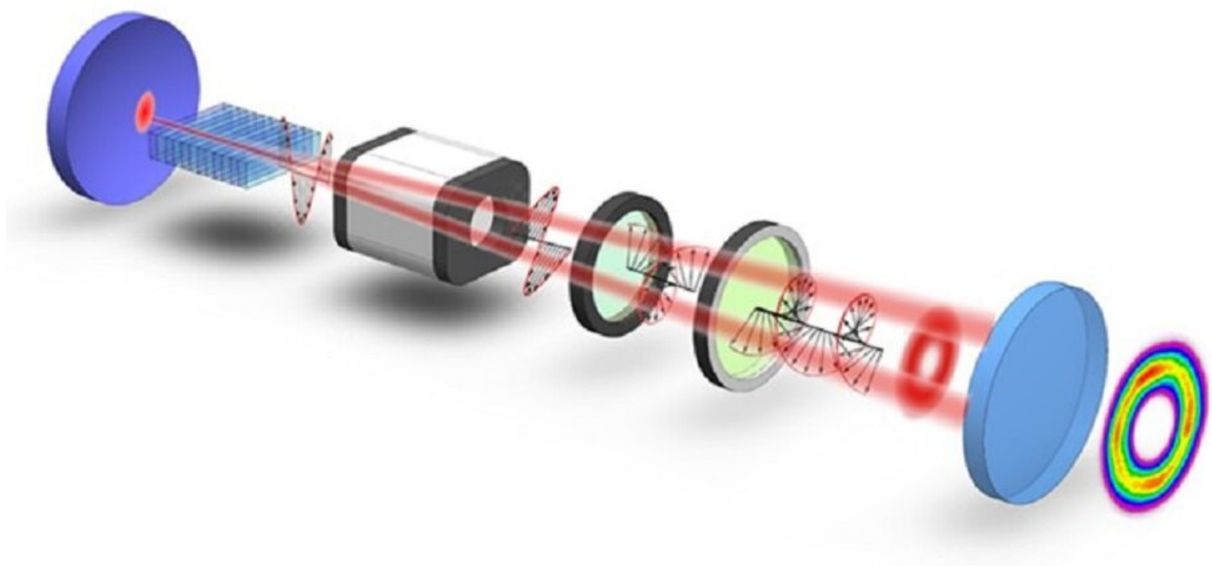

Diagram of Janus optical parametric oscillator. Credit: *Advanced Photonics Nexus* (2023). DOI: 10.1117/1.APN.2.3.036007

Laguerre-Gaussian (LG) modes are a type of light wave that can carry the external torque of photons as they move through space. They are useful in many fields, from optical communications to super-resolution imaging. Advanced developments in these and other applications demand reliable and color-tunable LG mode laser sources, which do not yet exist.

An optical parametric oscillator (OPO) is a device that can generate a wavelength-tunable laser beam, so it has been used to realize a color-tunable LG laser source—generally, in one of two ways. One way is to change a regular beam into an LG beam using a phase component outside the OPO, but this makes the LG beam less pure. The other way is to utilize higher-order resonator mode so that it can create LG at source directly, but this has been a work in progress.

As reported in *Advanced Photonics Nexus*, a team from Nanjing University and Sun Yat-Sen University recently developed a two-facing "Janus" OPO scheme for generating high-efficiency, high-purity broadband LG modes with tunable topological charge. The Janus resonator consists of two cavity mirrors, a periodically poled lithium niobate crystal, a Faraday rotator, a quarter wave plate, and a vector vortex wave plate.

Different from previous intracavity mode conversion schemes based only on self-reproductions of the phase and polarization, the Janus OPO introduces an additional imaging system into the resonator to assist self-reproduction of complex wavefront, which greatly improves LG OPO performance.

The Janus cavity mode is composed of two different modes that intersect. The mode at the front end of the resonator is a Gaussian-like pattern, which can better match the Gaussian pump light to obtain high gain. At the output end, the cavity mode gradually and smoothly evolves into a standard LG mode, which ensures high-purity LG beam output and effectively reduces the diffraction loss. On the other hand, the reconstruction of the intensity distribution during the imaging process actively forms a high-purity LG mode—rather than passive mode filtering—which further reduces resonator losses.

According to corresponding author Yong Zhang, Professor of Physics at

Nanjing University, "The Janus OPO largely reduces the loss of the resonator through imaging design and improves the efficiency and purity of the output LG beam." The output LG mode has a tunable wavelength between 1.5 µm and 1.6 µm, with a conversion efficiency above 15%, a controllable topological charge up to 4, and a mode purity as high as 97%.

Zhang notes, "The efficiency of the OPO can be further improved by double-passing the pump light, and the wavelength band of the output LG beam has the potential to expand to visible and ultraviolet, offering a powerful tool to explore the interaction between LG beams and matter, for potential applications like super-resolution imaging based on stimulated emission depletion (STED) microscopy and precise rotation sensing."

According to Dunzhao Wei, Associate Professor in the School of Physics at Sun Yat-Sen University and first author on the report, "The scheme of Janus OPO can be further expanded to vector beam output and entangled LG photon generation, directions that will play important roles in areas such as atomic ensemble spin-orbit interaction, laser fabrication, and higher-entanglement quantum sources."

More information: Dunzhao Wei et al, Generation of high-efficiency, high-purity, and broadband Laguerre-Gaussian modes from a Janus optical parametric oscillator, *Advanced Photonics Nexus* (2023). DOI: 10.1117/1.APN.2.3.036007

Provided by SPIE

high-performance-lg-laser.html