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Editorial: Advanced high power solid-state laser technology

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Editorial on the Research Topic
Advanced high power solid-state laser technology

Since the first demonstration of lasers, continuous progress in the development of laser technology, especially solid-state laser technology, has led to numerous new applications and capabilities. Solid-state lasers, including fiber lasers, crystal lasers, and ceramic lasers, have the unique advantage of high efficiency, reliability, flexibility and robust configuration. The rapid development of the solid-state laser technology has been enabled by the introduction of novel materials, components, advanced laser technology and system design. Tremendous new applications have been advanced, including the high order nonlinear physics interactions, free space and quantum communications, LIDAR for autonomous vehicles, beam projecting and steering, and materials processing. However, the onset of nonlinear effects, thermal effects, and laser-induced damages have limited the power scaling of various solid-state lasers, which limited the overall performance of the systems with the conjunction of the transmission optics and free-space laser beam propagation. Novel concepts and designs have been continuously proposed and demonstrated by global researchers to explore approaches circumventing the aforementioned limitations. This Research Topic aims to provide a comprehensive view of the latest advances in solid state laser development along with the most recent new applications.

After the initiating of this Research Topic, 8 high-quality papers has been accepted for publication, which are representative of the broad range of technology advances that this Research Topic strives to facilitate, and we trust readers will find them stimulating and enlightening. We are thankful to all authors and reviewers for their excellent contributions. We would also like to thank the Frontiers staff for their outstanding work throughout the launch of this Research Topic as well as the review and production processes.

High quality robust mid-infrared laser has broad scientific and practical application value, which can be achieved by optical parametric oscillator through pumping nonlinear frequency crystal with near-infrared solid state laser [1–3]. The 2.79 μm Er,Cr:YSGG crystal has been proven to be a high efficiency flash-lamp pumped laser medium [4], and Jiang et al. has designed a new type of lithium niobate ($LiNbO_3$) acousto-optic Q-switched Er,Cr:YSGG laser with pliane-convex resonator, where the laser performance has been improved significantly. When the laser operated at free running region, the maximum values of pulse energy was 160 mJ at 60 Hz, compared with the plane-parallel resonator, the pulse energy was increased by 2 times in the plane-convex resonator. When the $LiNbO_3$ Q-switched laser operated at 60 Hz, the maximum pulse energy was 8.5 mJ, and the minimum pulse duration was 60.8 ns, which generates the corresponding peak power of approximately 140 kW.

Fiber lasers and amplifiers are important branch of solid-state laser, which has attracted more and more attention since their inception, both as stand-alone sources and as parts for more complex lasers and systems [5]. Four articles on high power fiber lasers and their applications appear in this Research Topic. Fiber materials are at the core of the technology [6], and consequently fiber materials and its design continues to be central to this article group. An et al. focus on a common phenomenon in the modified-chemical-vapor-deposition-fabricated fibers, and present a numerical analysis of the dip effect on high-power-related parameters for the first time, which reveled that the dip offers a flexible way to suppress the non-linear effects and filter the higher-order modes by optimizing the dip parameters. The next two papers addressed the transverse mode instability (TMI), since this represent one of the primary obstacles to power scaling fiber laser systems with diffraction-limited beam quality [7, 8]. Chai et al. demonstrate a direct pump modulation to mitigate TMI in a 30 μm-core-diameter all-fiber laser oscillator while Lu et al. propose to mitigate TMI by controllable mode beating excitation with a photonic lantern, which increased the TMI threshold by nearly four times. Narrow linewidth fiber lasers are a hot Research Topic in fiber laser area [9, 10], and the last paper from Chu et al. reported a 3-kW PM fiber laser at <10 GHz linewidth with the polarization extinction ratio of 96% and beam quality of 1.156, which is the highest output power ever reported with approximately 10 GHz linewidth.

Optical vortices, finding a growing number of applications ranging from industrial laser machining to optical communications, have aroused ever-increasing interest among both scientific and engineering communities [11, 12], which opens new application avenue for the solid-state lasers. The next group of papers in this Research Topic focused on "generating of optical vortices." Lin et al. design a folded resonant cavity to generate a helicity and topological charge tunable vortex laser, and the $HG^{\theta}_{m,0}$ beam (m = 1 to 10 and $\theta = -90^{\circ}$–90°]) and the vortex beam (topological charge l from ±1 to ±10 and left/right helicity) were flexibly achieved. Li et al. investigated the power scaling of optical vortices, and reported 1.89 kW cylindrical vector beams by metasurface extra-cavity conversion of a narrow linewidth all-fiber linearly-polarized laser, which is the highest power of cylindrical vector beams generated from fiber laser.

The remaining one paper in this Research Topic is about one of the key technology in high power solid-state lasers-adaptive optics technology [13]. In the adaptive optics control of high-power laser systems, an indispensable part is deformable mirrors, which are commonly used as the corrector to correct wavefront aberration, and suffer performance degradation under high-power laser irradiation [14]. Zheng et al. introduce the dual magnetic connection deformable mirrors, which could effectively suppress the laser-induced distortion and maintain good wavefront correction capability.

In summary, one can see that significant progress has been made in high power solid-state laser area, and more and more exciting applications are expected in the future. This Research Topic collects the latest breakthrough of the community working in these fields, showing the still vivid and inspiring development of high power solid-state laser.

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