



Advanced solid state lasers: feature issue introduction

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This joint issue of *Optics Express* and the *Journal of the Optical Society of America B* (JOSA B) features 61 peer-reviewed articles, many of which are contributed by authors who participated in the International Conference of Advanced Solid State Lasers, held in Osaka, Japan, from October 20 to 24, 2024. This introduction provides a concise overview of the featured articles, which highlight recent advances in laser science, ultrafast optics, and nonlinear optics. The collection covers a broad range of topics in solid-state lasers, from material development to laser source engineering, and from design of innovations to their emerging applications. Together, these contributions reflect the dynamic developments in both fundamental research and applied photonics technologies. © 2025 Optica Publishing Group. All rights, including for text and data mining (TDM), Artificial Intelligence (AI) training, and similar technologies, are reserved.

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The Advanced Solid State Lasers (ASSL) conference continues to serve as a premier international forum for the dissemination of cutting-edge research in solid-state laser materials, architectures, and source technologies. The 2024 ASSL conference, held in Osaka, Japan, from October 20 to 24, 2024, upheld this tradition by highlighting significant advances in laser performance aimed at addressing the evolving needs of both scientific and industrial applications. As in past years, materials science remains a cornerstone of the conference, reflecting the central role that gain media—crystalline, ceramic, glass, or composite—play in defining the operational boundaries of laser sources. This year's contributions span a wide range of novel gain media, including ceramics, crystals, glasses, and 2D materials, along with enabling components such as saturable absorbers (SAs), nonlinear crystals, and microresonator structures. These developments support improved power scalability, spectral agility, and ultrashort pulse generation, while also introducing new functionalities in areas like structured light and dual-comb generation. The laser sources reported encompass diverse operational regimes, from continuous-wave (CW) operation to few-optical-cycle pulse generation, with spectral coverage ranging from the visible to the mid-infrared.

The 61 peer-reviewed articles selected for the ASSL-2024 Joint Feature Issue of *Optics Express* and JOSA B reflect the breadth and depth of innovation presented at the conference. Together, these contributions span laser materials, source architectures, nonlinear optics, and structured laser beams. We extend our sincere thanks to all contributing authors for sharing their most recent works, and to the reviewers for their critical insights, which ensured the high quality of this issue. We are also grateful to the editorial team at Optica Publishing Group—especially Carmelita Washington—for their dedicated support throughout the review and production process.

Laser gain materials and nonlinear crystals are at the core of solid-state laser technology. The focus is on the characterization of new materials and providing highly accurate material properties of both new and established crystals, glasses, and ceramics which are essential for optimizing and designing future laser sources. Laser gain media engineering continues to expand the operational limits of laser sources. Studies in this issue present detailed spectroscopic characterizations. Parameters such as absorption and emission cross-sections, thermal conductivity, and excited-state lifetimes are systematically examined to support future device optimization. This collection includes several noteworthy contributions that explore new host materials,

energy transfer mechanisms, and thermal engineering strategies for improving gain media performance.

The study by J. Demaimay *et al.* reports on the crystal growth, polarized spectroscopy and laser operation of Sm:LiYF₄ crystal [1]. A 465-nm blue diode-pumped Sm-laser delivers 23.9 mW output power in the CW regime at a central wavelength of 605 nm. This work demonstrates the potential of samarium-doped fluoride crystals as compact visible laser sources for biomedical and display applications.

Building on this direction, A. Sureshkumar *et al.* developed Dy³⁺-doped silica microspheres exhibiting yellow stimulated emission using whispering gallery modes. The microspheres were fabricated by fiber fusion splicing and pumped directly by blue GaN laser diodes, achieving narrow-linewidth emission and validating a compact strategy for visible microresonator-based laser sources [2]. Their work highlights a promising pathway for narrow-linewidth visible microlasers based on fiber fusion splicing and rare-earth doping.

Thermal management, a critical factor in high-power lasers, is addressed by Y. Sato *et al.*, who proposed a distributed face-cooled composite laser medium using interlayer surface activated bonding (il-SAB) [3]. Their work shows that such an approach significantly enhances the effective thermal conductivity of Nd:YAG-based composites, enabling the power scaling of compact lasers with transparent heat sinks.

A. Pirri *et al.* reported on (Dy,Tb):LuAG transparent ceramics as promising yellow-emitting gain media. Through detailed Judd–Ofelt analysis, low-temperature spectroscopy, and energy transfer studies, they confirmed that Tb³⁺ co-doping enhances the Dy³⁺ emission efficiency and proposed a model to explain emission dynamics under various excitation pathways [4].

The work by S. Liu *et al.* shifts attention to near-infrared spectral range around 2 μm, relevant for eye-safe laser applications. They established a quantitative model for Tm:CaF₂ crystals, revealing how Tm³⁺ doping governs cluster formation and cross-relaxation, with both reaching saturation above 2 at.% Tm concentration [5]. They also provided critical guidance for optimizing Tm:CaF₂ in high-energy pulsed lasers.

Building on the discussion of Tm³⁺ emission around 2 μm, N. Q. H. Nguyen *et al.* conducted a comparative spectroscopic investigation of low-phonon Ho³⁺-doped MF₂ (M = Ca, Sr, Ba) crystals for potential applications in 2–3 μm lasers [6]. The study demonstrates that Ho:CaF₂ offers the broadest gain bandwidth near 2.1 μm, while Ho:BaF₂ shows extended excited-state lifetimes and reduced multi-phonon relaxation rates, making it promising for 3 and 3.9 μm tunable and mode-locked (ML) lasers.

X. Yu *et al.* demonstrated the first CW laser operation at 2.3 μm from Tm³⁺-doped disordered Tm:(Y, Sc)₂O₃ and Tm:(Lu, Sc)₂O₃ crystals [7]. Pumped by a 793 nm fiber-coupled laser diode, they achieved output powers of 665 mW and 872 mW with slope efficiencies of 9.5% and 16.1%, respectively, laying a foundation for future 2.3 μm femtosecond ML lasers.

Attention has also been drawn to Er³⁺-doped sesquioxides emitting at 2.8 μm. W. Hou *et al.* systematically studied Er³⁺:Y_xSc_{1-x}O₃ crystals grown by the optical floating zone method, revealing their broad absorption/emission spectra and favorable thermal conductivity. Notably, the Er:Y₂O₃ crystal

yielded a maximum CW output power of 972 mW at 2.8 μm with a slope efficiency of 10.4%, highlighting its potential for high-power MIR laser applications [8].

Efforts have pushed rare-earth lasers toward longer wavelengths in the mid-IR. P. Schlosser and V. Savitski demonstrated Dy:KPB₂Cl₅ and Dy:PbGa₂S₄ lasers emitting at ~4.45 μm with >1 mJ pulse energy under diode pumping, where Dy:PGS achieved a record wavelength of 4.68 μm for this crystal under 1.7 μm diode pumping and Dy:KPC showed superior Q-switching efficiency for airborne N₂O sensing [9].

Expanding the range of ceramic laser hosts, Y. Sato and T. Taira demonstrated Nd³⁺-doping into α-Al₂O₃ via hot isostatic pressing and low-temperature sintering, enabling the formation of Nd:Sapphire ceramics with distinct crystal-field-split fluorescence [10]. Their approach offers a viable route to fabricate bulk-shaped Nd:Sapphire gain media using conventional ceramic processes.

Beyond rare-earth-doped ceramics and crystals, innovative theoretical and computational approaches have been explored to optimize luminescent materials. Y. Wang *et al.* employed a synergistic MD–FDTD method to investigate Ag nanoparticle aggregation in Bi-doped glasses, achieving a 60% emission enhancement at 1300 nm and a 40 nm red-shift in peak wavelength [11].

Nonlinear optical crystals are essential components in frequency conversions, ultrafast lasers, and quantum optics, where their mechanical and optical damage properties critically influence performance and device longevity. G. Exner *et al.* systematically investigated the nanoindentation and laser-induced damage behavior of CdSe crystals, revealing strong wavelength-dependent surface damage thresholds and highlighting the influence of spot size and repetition rate under tight focusing conditions [12]. Their results provide benchmark mechanical data and intrinsic damage limits that can guide future nonlinear material design and high-intensity applications.

K. Kato *et al.* reported for the first time accurate Sellmeier equations for AgInS₂ and combined them with recently derived equations for AgGaS₂. Their results provided accurate phase-matching condition predictions for mixed AgGa_{1-x}In_xS₂ crystals at room temperature for nonlinear three-wave mixing across the 0.62–10.59 μm range. The new model accurately reproduces experimental optical parametric oscillator (OPO) phase-matching conditions and supports mid-IR generation via femtosecond-pumped nonlinear processes [13].

K. Kato *et al.* further presented accurate Sellmeier and thermo-optic dispersion formulas for CdGeAs₂, enabling precise prediction of second harmonic generation (SHG) and sum-frequency generation (SFG) phase-matching conditions for CO₂ lasers from 2.65 to 10.59 μm at 20–140°C [14]. Their results facilitate temperature-tuned mid-IR conversion in arsenic-based chalcopyrites and pave the way for broader application of CdGe(As, P)₂.

The following article explored advanced nanostructured materials and their modal properties, offering new insights into threshold engineering via subwavelength graphene-based gratings. F. O. Yevtushenko *et al.* presented a theoretical investigation of threshold conditions for H- and E-polarized modes in a microsized graphene strip grating on gain substrates using eigenmode analysis based on quantum conductivity models.

Their results reveal that the lowest thresholds are associated with lattice modes whose gain indices are highly tunable via graphene's chemical potential, offering precise control of lasing conditions [15].

Two articles have focused on exploring novel SAs to enable compact and efficient passively Q-switched (PQS) laser operation. R. Du *et al.* reported a stable PQS all-fiber Er laser using a self-fabricated BiVO₄ SA, achieving 25.2 mW average output power and a pulse energy of 331 nJ [16]. S. Zhang *et al.* demonstrated that Fe,Cr:ZnS crystals serve as efficient SAs for 2.7 μm PQS lasers, achieving sub-80 ns pulses [17]. The dual-ion doping enables enhanced modulation via Cr²⁺-sensitized energy transfer to Fe²⁺ ions.

Ultrafast lasers continue to drive scientific and technological progress, with innovations in mode-locking techniques, dispersion control, and frequency comb stabilization. Nine articles report ML solid-state and fiber lasers in a variety of host materials. Q. Lu *et al.* proposed a figure-9 ML fiber laser using liquid crystal variable retarders, enabling flexible control of the mode-locking state through tunable splitting ratios and non-reciprocal phase shifts [18]. Experimental results confirmed that this scheme offers a conservative yet robust mapping of mode-locking regimes, paving the way for intelligent ultrafast fiber laser designs.

W. Li *et al.* reported a narrowband, chirp-free passively ML Er fiber laser using a single-walled carbon nanotube SA, generating 323 ps pulses at 1546.61 nm with only 166 longitudinal modes phase locked [19]. The low modulation depth and narrow filter bandwidth enabled stable pulses generation with a transform-limited 8 pm linewidth, highlighting SA and filter design as key factors in long-pulse operation.

Y. Wang *et al.* demonstrated a 1.2 GHz nonlinear polarization rotation ML Yb fiber laser that directly generated 38 fs stretched pulses with over 1 W average output power, enabled by a compact Faraday rotator and a shortened cavity length [20]. This design also supports octave-spanning supercontinuum generation without amplification, making it suitable for high-precision applications like frequency combs and ultrafast metrology.

In addition to fiber lasers, ML solid-state lasers have also demonstrated impressive mode-locking performance with high peak power and short pulse duration. For instance, H. Iliev *et al.* reported 1.6 ps pulses from an in-band pumped Nd:LuVO₄ laser using a χ²-lens-based passive mode-locking mechanism, achieving Watt-level average output power [21].

W. Huo *et al.* reported a quad-wavelength synchronously ML laser based on two Yb:SYB/Yb:CNGS crystals with Fabry–Perot structure, simultaneously operating at 1042.6, 1044.7, 1046.9, and 1049.1 nm, demonstrating the potential of single-cavity multi-wavelength ultrafast sources for high-order wave-mixing and quantum photonics [22].

Additionally, Yb³⁺-doped compositionally “mixed” crystals have shown promise for sub-60 fs pulse generation via SESAM mode-locking, with prospects for further improvement via Kerr-lens mode-locking (KLM) techniques [23]. L. Liu *et al.* reported the first diode-pumped ML laser based on Yb:YScO₃ crystal generating 48 fs soliton pulses at 1056.4 nm with an average output power of 45 mW [24]. This “mixed” sesquioxide

crystal exhibits broad emission bandwidth and high slope efficiency, making it a promising candidate for high-power ultrafast lasers.

Shorter pulses could be achieved via KLM. H. Y. Nie *et al.* demonstrated 23 fs soliton pulses generation at 1082.3 nm from a diode-pumped Yb,Gd:YAP laser via soft aperture KLM, representing the shortest pulses ever reported from any Yb³⁺-doped perovskite-type crystal [25].

Moving beyond bulk geometries, S. Kitajima *et al.* achieved 48 fs pulses from the KLM thin-disk Yb:KLuW laser, indicating the viability of highly anisotropic sesquioxide crystals in thin-disk architectures [26].

Solid-state lasers encompass high-power and spectrally versatile sources based on rare-earth-doped crystals, glasses, and ceramics. Efficient CW and Q-switched operation had been realized across a broad spectral range, spanning from the visible to short-wave infrared. L. Kotov *et al.* reported on both CW and actively Q-switched operation of a Tb:YLF laser at 587 nm, achieving a record-high CW output power of 1 W and Q-switched laser operation with 0.5 mJ pulse energy and 100 ns pulse duration [27], marking the first demonstration of an actively Q-switched orange Tb laser, with a strong potential for DIAL applications.

Y. Kaneda *et al.* realized diode-pumped Sm³⁺:YLF lasers operating at 605 nm and 648 nm, reaching output powers of 263 mW and 548 mW, and slope efficiencies of 11% and 22%, respectively [28]. These results highlight quasi-three-level behavior at 605 nm and suggest further optimization routes through controlling doping and pump parameters.

J. Yang *et al.* developed a diode-pumped microchip laser based on Nd³⁺-doped calcium borosilicate glass (NdCBS06), yielding 4.53 mW at 1062.69 nm and showcasing its suitability for broadband glass lasers due to its 20-nm-wide, thermally tunable absorption band [29].

H. Huang *et al.* achieved 45.8 W average output power at 1937 nm from an acousto-optically Q-switched Tm:YAP laser, benefiting from a thermal-lens compensated cavity, broad cavity-length tolerance, and dual-end LD pumping to ensure high stability [30].

K. Li *et al.* introduced a machine learning-driven-guided approach to optimize thermal lens compensation in multi-segment bonded Tm:YAG lasers, enabling accurate focal length prediction and robust output stabilization under varying pump conditions, advancing thermal control strategies for 2 μm lasers [31].

Z. Li *et al.* realized an intra-cavity pumped Ho:Y₂O₃ ceramic laser with 5.1 W output power at 2116 nm and additional multi-wavelength emissions below 2100 nm, emphasizing its broad spectral tunability and flexible cavity design [32].

M. Glasset *et al.* achieved a record-high output power of 2.7 W at 2.3-μm from a Tm:YLF laser using an off-resonance intracavity upconversion pumping scheme, with only ~5% pump absorption, made possible by strategic thermal load balancing between Nd:YVO₄ and Tm:YLF gain crystals, and careful optimization of doping and output coupling [33].

S. Slimi *et al.* reported a multi-watt CW Ho:KLu(WO₄)₂ laser in-band pumped at 1959 nm, generating 2.7 W output power at 2078 nm with a slope efficiency of 33.5% and a broad tuning range of 117 nm. These results are promising for the

realization of soliton mode-locking by adding cavity elements with negative group-velocity dispersion [34].

J. Huang *et al.* revealed that the beat-frequency signal of a CW Nd:YAG laser can be polarization-locked and coherently transferred during extra-cavity SHG, offering a new mechanism for improving SHG efficiency and polarization control [35].

Among the most important applications of nonlinear crystals is the frequency conversion of solid-state lasers, which enables access to spectral regions far beyond the native gain bandwidth. The following five papers in this feature issue focus on recent advances in nonlinear frequency conversion. H. Zhao *et al.* demonstrated a high-peak-power nanosecond red laser at 657 nm by intracavity frequency doubling in a Nd:YLF dual-crystal configuration with a type-I phase-matched BIBO crystal. With optimized resonator design and polarized pumping, up to 77 kW peak power and 6.3 W average power were achieved, representing a record for nanosecond red lasers at this wavelength [36].

H. Zheng *et al.* investigated the influence of gain competition on pulse evolution in cascaded nanosecond diamond Raman lasers, revealing a novel method for tailoring pulse compression through deliberate control of Stokes-order dynamics. Their work demonstrates efficient multi-wavelength Raman emission with distinct waveform features and paves the way for optimizing high-power short-pulse generation in diamond Raman lasers [37].

S. Das *et al.* developed a high-efficiency, non-resonant optical parametric oscillator (NRO) based on periodically poled LiNbO₃ (PPLN), producing 11.4 W average output power with 63% conversion efficiency and sub-nanometer spectral narrowing using a volume Bragg grating (VBG) [38].

Y. Zhang *et al.* demonstrated a mid-infrared ultra-short pulse-burst laser at 2.94 μm based on difference frequency generation (DFG) in MgO:PPLN, with adjustable burst parameters and up to 1.33 W average output power, offering a promising solution for soft tissue ablation due to its high efficiency and low thermal damage [39].

M. Piotrowski *et al.* presented a comparative study of high-power OPOs based on CdSiP₂ (CSP) and ZnGeP₂ (ZGP) crystals, pumped by a nanosecond Ho:LLF laser at 2.06 μm . The CSP OPO produced over 8 W average output power in the mid-IR with good beam quality, outperforming ZGP in terms of bandwidth and damage threshold [40].

N. Ming *et al.* reported on a systematic study of the dependence of THz frequency upconversion detection performance on the pumping pulse energy using a lithium niobate crystal. They identify an optimal pump energy that maximizes the upconverted Stokes signal-to-background ratio, supported by both experimental results and theoretical modeling [41].

Fiber lasers maintain strong momentum due to their scalability, robustness, and integration potential. They have been integral to ASSL since their inception, serving both as stand-alone sources and as pump engines for more complex laser systems. W. Cheng *et al.* numerically optimized the key cavity parameters of Nd fiber (NDF) oscillators, achieving a maximum output power of 143.2 W at 920 nm and a broad wavelength tuning range of 870.2–926.4 nm [42]. These results demonstrate the potential of 0.9 μm NDF lasers for high-power

applications such as blue-green light generation and solid-state laser pumping.

Y. Yao *et al.* demonstrated a narrowband, high-energy 1550 nm picosecond polarization-maintaining fiber laser based on a self-starting Figure-9 Er oscillator [43]. By employing FBG filtering and large-core EYDCF amplification, they achieved 546 nJ pulses at 1.5 MHz with a 0.2 nm spectral linewidth and excellent beam quality.

J. Pokorný *et al.* demonstrated a highly efficient 2.1 μm holmium silica fiber laser achieving a record slope efficiency of 81% and an output power up to 22.5 W under core-pumping at 1.94 μm using an in-house drawn fiber with 3850 mol ppm Ho³⁺ doping. With resonator optimization, they further achieved 35.4 W output power with a laser efficiency of 79%, and numerical simulations suggest the feasibility of scaling to 250 W output with 80% efficiency using a pedestal-cladding-pumped geometry [44].

J. Zhang *et al.* demonstrated an efficient 2.8- μm all-fiber Er laser utilizing a low optical feedback cavity, achieving a maximum output power of 12.5 W and a total optical efficiency of 22.1% [45]. Their approach, which avoids conventional high-reflector components, significantly lowers lasing thresholds and is extendable to other mid-IR fiber lasers including Ho lasers.

P. Wang *et al.* reported the first mid-infrared laser emission from a heavily Er³⁺-doped ZBYA glass fiber, achieving 6.74 W output at 2.8 μm with a slope efficiency of 15.4% under dual-end pumping [46]. This work provides a robust solution for powerful mid-IR fiber lasers and demonstrates the feasibility of using ZBYA fibers for high-performance 3 μm emission.

Y. Jung *et al.* proposed a compact and scalable all-fiber SMF-SCF structure capable of generating configurable multi-spot lattice beam arrays, such as 2×2 to 4×4 , by simply tuning the SCF length [47]. This beam-shaping approach demonstrates excellent stability and minimal power loss at 1060 nm and shows great promise for high-precision applications like laser processing and biomedical imaging.

Ultrafast pulse amplification and post-compression provide essential pathways to achieving few- or even single-cycle pulse durations with high peak powers, enabling advanced applications in attosecond science, strong-field physics, and high-harmonic generation. J. Takano *et al.* developed a Watt-level femtosecond fiber amplifier based on Pr³⁺:ZBLAN, achieving 1.33 W average power and 367 fs pulse duration at 1300 nm, with potential for sub- μJ pulse energy and three-photon imaging applications [48].

Z. Y. Zhan *et al.* demonstrated a microjoule-level nanosecond pulse amplification system based on a 1.7 μm all-fiber Tm fiber laser, where a noise-like seed pulse was amplified to 11.2 μJ with an average output power of 3.24 W at 288.4 kHz, exhibiting an optical efficiency of 32.4% and potential for biomedical imaging applications [49].

M. Bock *et al.* presented a Ho:YLF chirped pulse amplification (CPA) system emitting 75 mJ pulse energy at 2050 nm and a pulse repetition rate of 1 kHz, compressed to 2.2 ps with 31 GW peak power, paving the way for sub-100 fs pulse generation at $\sim 2 \mu\text{m}$ [50].

Z. Gao *et al.* demonstrated a high-energy nonlinear pulse post-compression scheme using a hybrid bulk-air multi-pass cell (MPC), achieving 45 fs pulse duration at an average power

of 130 W and a pulse repetition rate of 200 kHz, reportedly the highest pulse energy from any solid-state MPC system, by managing air nonlinearity and mode-matching to preserve beam quality at several hundred μJ level [51].

Structured laser beams offer powerful capabilities for enhancing resolution, precision, and functionality across a wide range of photonic applications. This joint feature issue brings together one review article and eight cutting-edge contributions that collectively highlight the rapid advances in structured beam generation and control from lasers. Together, these works span novel laser architectures, intracavity engineering strategies, and diverse beam shaping techniques aimed at tailoring amplitude, phase, polarization, and spatial mode content directly from the source.

J. Wang *et al.* provided a comprehensive review of optical vortex lasers, covering their fundamental principles, beam shaping strategies, and recent advances across bulk, fiber, and chip-scale platforms, while outlining key challenges and opportunities in dynamic control, mode purity, and high-order orbital angular momentum generation [52].

J. Hao *et al.* demonstrated tunable high-order vortex beam generation from an Yb:YAG thin-disk laser by converting Hermite–Gaussian beams into Laguerre–Gaussian beams via an external astigmatic mode converter [53]. They achieved mode orders from the 1st to the 10th with output powers exceeding 10 W, enabling the generation of high-order vortex beams with tunable topological charges and offering a scalable platform for structured laser beam generation.

H. Zhu *et al.* reported a diode-pumped Nd:YVO₄ laser that generates petal-like laser beams with tunable topological charge from 1 to 35, enabled by axial adjustment of the axicon-lens pump configuration [54].

Q. Cui *et al.* demonstrated an Yb:YAG thin-disk regenerative amplifier that produces high-energy ultrafast vortex pulses with 10 mJ pulse energy at a pulse repetition rate of 1 kHz via external astigmatic mode converter, representing the highest pulse energy from any optical vortex laser to date [55].

J. C. Tung *et al.* investigated vortex–antivortex (V–AV) dynamics in SHG of Hermite–Gaussian beams under astigmatic transformation, demonstrating that the total topological charge is conserved despite complex V–AV interactions and phase transitions induced by the rotation of an external astigmatic mode converter [56].

D. Li *et al.* demonstrated direct generation of ultrafast Bessel beams from a ML Yb:KGW laser using an axicon as an output coupler, achieving 105 fs pulses with 1.1 W average power and tunable diffraction-free propagation [57].

H. S. Charehjaloo *et al.* analyzed a linear axicon-based thin-disk laser resonator and derived a parameter related to the separation between the axicon and the thin disk to thoroughly investigate the characteristics of the generated near-ideal Bessel beam. They demonstrated that the near-ideal Bessel beam can be sustained as an eigenmode without requiring a curved output mirror, offering a simplified and robust cavity design for high-quality Bessel beam generation [58].

K. Chen *et al.* reported an all-fiber high-power cylindrical vector beam laser using leaky-mode resonance and THB coupling to enable efficient LP₀₁ – LP₁₁ mode conversion, achieving 2.93 W output power and 97.9% CVB purity. This

compact system provides a tunable and efficient HOM source for advanced photonic applications [59].

H. C. Liang *et al.* experimentally realized orthogonally dual-polarization nonplanar circular modes in a diode-pumped Nd:YVO₄ laser with a strictly degenerate cavity, and theoretically reconstructed their polarization-resolved patterns using a Gaussian wave packet framework [60]. Y. F. Chen *et al.* established a quantum–classical connection in the Fock–Darwin system, demonstrating that stationary coherent states manifest as spatially entangled vortex arrays and bridge Laguerre–Gaussian modes with hypotrochoid orbits through a generalized integral formula [61]. This work provides a unified theoretical framework connecting Laguerre–Gaussian modes with hypotrochoid orbits, offering new insights into quantum degeneracies and spatial mode symmetries, with broad implications for structured laser beam, cavity quantum electrodynamics, and mesoscopic quantum systems.

We hope this feature issue offers readers a timely and comprehensive overview of the latest advances in solid-state lasers and nonlinear optics. The breadth and depth of the 61 featured articles underscore the dynamic progress in material development, device engineering, and fundamental laser physics. We are grateful to all authors, reviewers, and Optica staff members whose dedication made this collection possible. We are optimistic that the continued momentum in this vibrant research community will inspire new directions and collaborations, and we look forward to witnessing these developments in future ASSL conferences.

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