High Power Laser Science and Engineering, (2018), Vol. 6, e54, 5 pages.

doi:10.1017/hpl.2018.49

Editorial: HPLSE special issue on fibres for high-power lasers

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(Received 27 August 2018; accepted 21 September 2018)

Keywords: fibre laser; gain fibres; high-power fibre amplifier

In 2018, the journal *High Power Laser Science and Engineering* produced a Special Issue on Fibres for High Power Lasers. Nowadays, fibre-based laser sources have found extensive applications both in industry and in scientific research. The scope of the special issue was to span the latest developments on the fast developing fibre-based high-power lasers and amplifiers. The topics invited for inclusion were:

- Large mode area fibres for power scaling
- High-power fibre amplifiers
- Mid-IR fibre sources
- Mode instability mitigation in optical fibre
- Novel nonlinear phenomenon in optical fibre
- Specialty optical fibre fabrication
- Fibre devices, fibre components for high-power lasers

The guest editors of this special issue are: Yingying Wang, Beijing University of Technology, China and Seongwoo Yoo, Nanyang Technological University, Singapore.

Submissions for this special issue cover from the development of active fibres itself to the advances in fibre lasers and fibre amplifiers. Papers described research on high-power ytterbium-doped fibre lasers and amplifiers operating in continuous wave[1, 2], nanosecond regime[3], picosecond regime[4] and femtosecond regime[5]; erbium-doped tunable fibre amplifier[6]; Raman fibre laser[7, 8] and nonlinear amplifier[9]; high harmonic generation for UV wavelength[10] as well as a review of ytterbium-doped fibres[11].

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Ytterbium-doped Fibres

There is one review paper summarizing the development and prospect of Yb^{3+}-doped fibres for high-power fibre lasers where key issues for power scaling on the fibre side have been addressed and possible solutions are provided[11].

Ytterbium-doped fibre lasers and amplifiers

A range of papers have been focused on the power scaling of ytterbium-doped fibre lasers. Active tapered fibre allows kW-class output power in continuous wave (CW) regime[1]. Effectively suppressing stimulated Brillouin scattering (SBS) enables a 400 W level average power high beam quality linearly polarized nanosecond laser[3]. Optimizing the nonlinearity in the dissipative-soliton mode-locked fibre laser allows the scale up of the pulse energy in the sub-100 fs fibre lasers[5]. The thermal effect limiting the power scaling of fibre laser sources with high beam quality has also been investigated by a novel model[2].

High harmonic generation for UV emission

By building a hybrid fibre/solid-slab picosecond pulse laser system and utilizing third high harmonic generation (HHG) of LiB_3O_5 (LBO) crystals, a 15 μJ picosecond laser at 355 nm is generated for material processing[4]. Efficient HHG at 149 nm is enabled by external seeded femtosecond enhancement cavity (fsEC) for time-resolved photoemission spectroscopy applications[10].

Raman fibre lasers and nonlinear fibre amplifier

Raman fibre laser (RFL) is usually explored to achieve high-power output at specialized wavelengths. A 147.1 W output power at 1120 nm was achieved in Ref. [8]. In Ref. [7], simulation shows by combining the advantages of

the Tm-doped fibre lasers (TDFLs) at 2 μm and the tellurite fibre, hundreds of watts level mid-IR RFL at 2.35 μm and tens of watts level at 3 μm could be expected. Stimulated Raman scattering (SRS) effect could also be utilized to fully unleash the power-scaling potential of high-power fibre amplifier[9].

Erbium-doped fibre amplifier

A high-power, wavelength tunable and narrow linewidth 1.5 μm all-fibre laser amplifier was constructed based on a tunable diode laser and Er–Yb co-doped fibres[11].

Special issue content

1. kW-class high power fiber laser enabled by active long tapered fiber[1]
2. Numerical modeling of the thermally induced core laser leakage in high power co-pumped ytterbium doped fiber amplifier[2]
3. Monolithic high-average-power linearly polarized nanosecond pulsed fiber laser with near-diffraction-limited beam quality[3]
4. High pulse energy fiber/solid-slab hybrid picosecond pulse system for material processing on polycrystalline diamonds[4]
5. Nonlinearity optimization of dissipative-soliton fiber laser for generation of pulses with 350 kW peak power[5]
6. 10 watt-level tunable narrow linewidth 1.5 μm all-fiber amplifier[6]
7. Power scaling on tellurite glass Raman fibre lasers for mid-infrared applications[7]
8. Investigation on extreme frequency shift in silica fiber-based high-power Raman fiber laser[8]
9. Towards high power nonlinear fiber amplifier[9]
10. Efficient high harmonics generation by enhancement cavity driven with a post-compressed FCPA laser at 10 MHz[10]
11. Development and prospect of high-power Yb^{3+} doped fibers[11]

Abstracts

1. kW-class high power fiber laser enabled by active long tapered fiber

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High Power Laser Science and Engineering, Vol. 6, e16 (2018)

Abstract

Compared with traditional uniform fibers, tapered fiber has numerous unique advantages, such as larger mode area, higher pump absorption, suppression to nonlinear effects, and maintaining good beam quality. In this manuscript, we have constructed an all-fiberized fiber amplifier which is based on a piece of ytterbium-doped tapered double-clad fiber (T-DCF). The fiber amplifier is operated under continuous wave (CW) regime at 1080 nm wavelength. The M^2 factor of the amplifier at 1.39 kW output power is ~1.8. The maximum output power of the system reached 1.47 kW, which, to the best of our knowledge, is the highest output power of long tapered fiber based fiber laser system. Our result successfully verifies the potential of power scalability and all-fiberized capability of long tapered fiber, and the performance of our system can be further enhanced by fiber design optimization.

2. Numerical modeling of the thermally induced core laser leakage in high power co-pumped ytterbium doped fiber amplifier

Lingchao Kong[(a1) (a2) (a3)], Jinyong Leng[(a1) (a2) (a3)], Pu Zhou[(a1) (a2) (a3)], and Zongfu Jiang[(a1) (a2) (a3)]
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High Power Laser Science and Engineering, Vol. 6, e25 (2018)

Abstract

We propose a novel model to explain the physical process of the thermally induced core laser leakage (TICLL) effect in a high power co-pumped ytterbium doped fiber (YDF) amplifier. This model considers the thermally induced mode bending loss decrease and the thermally induced mode instability (TMI) in the coiled YDF, and is further used to reproduce the TICLL effect in the high power co-pumped step-index 20/400 fiber amplifier. Besides, the TICLL effect in the co-pumping scheme and counter-pumping scheme is compared. The result proves that the TICLL effect is caused by the combined effect of the thermally induced mode bending loss decrease and the TMI, and could be mitigated by adopting the counter-pumping scheme. To our best knowledge, this is the first theoretical explanation of the TICLL effect in high power fiber amplifier.

https://doi.org/10.1017/hpl.2018.49 Published online by Cambridge University Press

3. Monolithic high-average-power linearly polarized nanosecond pulsed fiber laser with near-diffraction-limited beam quality

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High Power Laser Science and Engineering, Vol. 6, e42 (2018)

Abstract

An all-fiberized high-average-power narrow linewidth ns pulsed laser with linear polarization is demonstrated. The laser system utilizes a typical master oscillator power amplifier (MOPA) configuration. The stimulated Brillouin scattering (SBS) is effectively suppressed due to the short fiber length and large mode area in the main amplifier, combined with the narrow pulse duration smaller than the phonon lifetime of SBS effect. A maximal output power of 466 W is obtained with a narrow linewidth of ~203.6 MHz, and the corresponding slope efficiency is ~80.3%. The pulse duration is condensed to be ~4 ns after the amplification, corresponding to the peak power of 8.8 kW and the pulse energy of ~46.6 μJ. Near-diffraction-limited beam quality with an M^2 factor of 1.32 is obtained at the output power of 442 W and the mode instability (MI) is observed at the maximal output power. To the best of our knowledge, this is the highest average output power of the all-fiberized narrow linewidth ns pulsed fiber laser with linear polarization and high beam quality, which is a promising source for the nonlinear frequency conversion, laser lidar, and so on.

4. High pulse energy fiber/solid-slab hybrid picosecond pulse system for material processing on polycrystalline diamonds

Wei Chen[(a1)], Bowen Liu[(a1)], Youjian Song[(a1)], Lu Chai[(a1)], Qianjin Cui[(a2)], Qingjing Liu[(a2)], Chingyue Wang[(a1)], and Minglie Hu[(a1)]
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High Power Laser Science and Engineering, Vol. 6, e18 (2018)

Abstract

We demonstrate an all polarization-maintaining (PM) fiber mode-locked laser seeded, hybrid fiber/solid-slab picosecond pulse laser system which outputs 40 μJ, 10 ps pulses at the central wavelength of 1064 nm. The beam quality factors M^2 in the unstable and stable directions are 1.35 and 1.31, respectively. 15 μJ picosecond pulses at the central wavelength of 355 nm are generated through third harmonic generation (THG) by using two LiB_3O_3 (LBO) crystals, in order to get better processing efficiency on polycrystalline diamonds. The high pulse energy and beam quality of these ultraviolet (UV) picosecond pulses are confirmed by latter experiments of material processing on polycrystalline diamonds. This scheme which combines the advantages of the all PM fiber mode-locked laser and the solid-slab amplifier enables compact, robust and chirped pulse amplification-free amplification with high power picosecond pulses.

5. Nonlinearity optimization of dissipative-soliton fiber laser for generation of pulses with 350 kW peak power

Han Chi[(a1) (a2)], Bowen Liu[(a1)], Youjian Song[(a1)], Minglie Hu[(a1)], Lu Chai[(a1)], Weidong Shen[(a3)], Xu Liu[(a3)], and Chingyue Wang[(a1)]
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High Power Laser Science and Engineering, Vol. 6, e27 (2018)

Abstract

We demonstrate a nonlinearity optimization method by altering distribution of passive fibers in a dissipative-soliton mode-locked fiber laser to level up output parameters. In the numerical simulation, we found that the passive fiber segment after gain fiber characterizes the highest average B-integral among fiber segments. By reducing the length of this fiber section and keeping the total passive fiber length as constant, the output pulse energy can be effectively scaled up while maintaining a short dechirped pulse duration, resulting in boosting peak power. With this method, 37-nJ pulses are generated from a dissipative-soliton mode-locked cladding pumped ytterbium-doped single-mode fiber laser in the experiment. The pulse can be dechirped to 66 fs with 350 kW peak power. Moreover, the pulse pedestal is suppressed by a vector-dispersion compressor.

6. 10 watt-level tunable narrow linewidth 1.5 μm all-fiber amplifier

Ni Tang[(a1) (a2) (a3)], Zhiyue Zhou[(a1) (a2) (a3)], Zhixian Li[(a1) (a2) (a3)], and Zefeng Wang[(a1) (a2) (a3)]
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https://doi.org/10.1017/hpl.2018.49 Published online by Cambridge University Press

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High Power Laser Science and Engineering, Vol. 6, e33 (2018)

Abstract

We report here a high-power, wavelength tunable and narrow linewidth 1.5 μm all-fiber laser amplifier based on a tunable diode laser and Er-Yb co-doped fibers. The laser wavelength can be precisely tuned from 1535 nm to 1580 nm, which covers many absorption lines of mid-infrared laser gases, such as C_2H_2, HCN, CO, and HI. The maximum laser power is >11 W, and the linewidth is about 200–300 MHz, which is close to the absorption linewidth of the above-mentioned gases. This work provides a suitable pump source for high-power wavelength tunable mid-infrared fiber gas lasers based on low-loss hollow-core fibers.

7. Power scaling on tellurite glass Raman fibre lasers for mid-infrared applications

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High Power Laser Science and Engineering, Vol. 6, e24 (2018)

Abstract

The power scaling on mid-infrared Raman fibre lasers (RFLs) is in demand for applications in health, environment and security. In this paper, we present the simulated laser behaviours of the tellurite glass RFLs pumped by 300-W Tm-doped fibre lasers (TDFLs) at 2 μm for the first time. By combining the advantages of the TDFLs and tellurite fibre, the output power at 2.35 μm has reached over hundreds of watts by first-order Raman shift. Moreover, the cascaded RFLs have been demonstrated with a wavelength extension greater than 3 μm and output power of tens of watts. To maximize the output power and the slope efficiency of the RFLs, we further analyse the interaction between the Raman gain and cavity loss, which are determined by fibre length and output reflectance of the laser cavity.

8. Investigation on extreme frequency shift in silica fiber-based high-power Raman fiber laser

Jiaxin Song[a1], Hanshuo Wu[a1], Jun Ye[a1], Hanwei Zhang[a1], Jiangming Xu[a1], Pu Zhou[a1], and Zejin Liu[a1]
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High Power Laser Science and Engineering, Vol. 6, e28 (2018)

Abstract

In this paper, we experimentally investigated the extreme frequency shift in high-power Raman fiber laser (RFL). The RFL was developed by using a pair of fiber Bragg gratings with fixed and matched central wavelength (1120 nm) combined with a piece of 31-m-long polarization maintaining (PM) passive fiber adopted as Raman gain medium. The pump source was a homemade high-power, linearly polarized (LP) wavelength-tunable master oscillator power amplifier (MOPA) source with ~25 nm tunable working range (1055–1080 nm). High-power and high-efficiency RFL with extreme frequency shift between the pump and Stokes light was explored. It is found that frequency shift located within 10.6 THz and 15.2 THz can ensure efficient Raman lasing, where the conversion efficiency is more than 95% of the maximal value, 71.3%. In addition, a maximum output power of 147.1 W was obtained with an optical efficiency of 71.3%, which is the highest power ever reported in LP RFLs to the best of our knowledge.

9. Toward high-power nonlinear fiber amplifier

Hanwei Zhang[a1], Pu Zhou[a1], Hu Xiao[a1], Jinyong Leng[a1], Rumao Tao[a1], Xiaolin Wang[a1], Jiangming Xu[a1], Xiaojun Xu[a1], and Zejin Liu[a1]
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High Power Laser Science and Engineering, Vol. 6, e51 (2018)

Abstract

Stimulated Raman scattering (SRS) effect is considered to be one of the main obstacles for power scaling in general-type fiber lasers. Different from previous techniques that aim at suppressing SRS, nonlinear fiber amplifier (NFA), which manipulates and employs the SRS for power scaling in rare-earth-doped fiber, is under intensive research in recent years. In this paper, the authors will present an all-round study on this new kind of high-power fiber amplifier. A theoretical model is proposed based on the rate equation and amplified spontaneous emission (ASE), with random noise taken into account. By numerical solving of the theoretical model, the power scaling potential, heat analysis and advantages in suppressing the undesired backscattering light are quantificationally analyzed for the first time. Then two different types of high-power NFAs are demonstrated individually. Firstly, a laser diode pumped NFA has reached kilowatt output power, and the results agree well with theoretical predictions. Secondly, a tandem-pumped NFA is proposed for the first time and validated experimentally, in which 1.5 kW output power has been achieved. The authors also briefly discuss several new issues relating to the complex

nonlinear dynamics that occur in high-power NFAs, which might be interesting topics for future endeavors.

10. Efficient high harmonics generation by enhancement cavity driven with a post-compressed FCPA laser at 10 MHz

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High Power Laser Science and Engineering, Vol. 6, e19 (2018)

Abstract

Efficient high harmonics generation (HHG) was demonstrated at 10 MHz repetition rate with an external femtosecond enhancement cavity, seeded by a ∼70 fs post-compressed 10 MHz fiber chirped pulse amplifier (FCPA) laser. Operation lasting over 30 min with 0.1 mW outcoupled power at 149 nm was demonstrated. It was found that shorter pulse was beneficial for alleviating the nonlinear plasma effect and improving the efficiency of HHG. Low finesse cavity can relax the plasma nonlinearity clamped intra-cavity power and improve the cavity-locking stability. The pulse duration is expected to be below 100 fs for both 1040 nm and 149 nm outputs, making it ideal for applications such as time-resolved photoemission spectroscopy.

11. Development and prospect of high-power Yb^{3+} doped fibers

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High Power Laser Science and Engineering, Vol. 6, e40 (2018)

Abstract

Ytterbium-doped fibers have become the optimum gain media of high-power fiber lasers thanks to a simple energy structure, which strongly reduces the excited state absorption, and a low quantum defect and a high optic–optic conversion efficiency, which means the low thermal load. In this paper, we take a review of the current state of the art in terms of Yb^{3+} doped fibers for high-power fiber lasers, including the development of the fabrication techniques. The research work to overcome the challenges for Yb^{3+} doped fibers, which affect the stability of output power and beam quality, will be demonstrated. Direction of further research is presented and the goal is to look for a fiber design, to boost single fiber output power, stabilize the laser power and support robust single-mode operation.

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https://doi.org/10.1017/hpl.2018.49 Published online by Cambridge University Press