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Numerical study of a bi-directional in-band pumped dysprosium-doped fluoride fiber laser at 3.2 μm

Key words: Mid-infrared laser; Fiber laser; Bi-directional pumping

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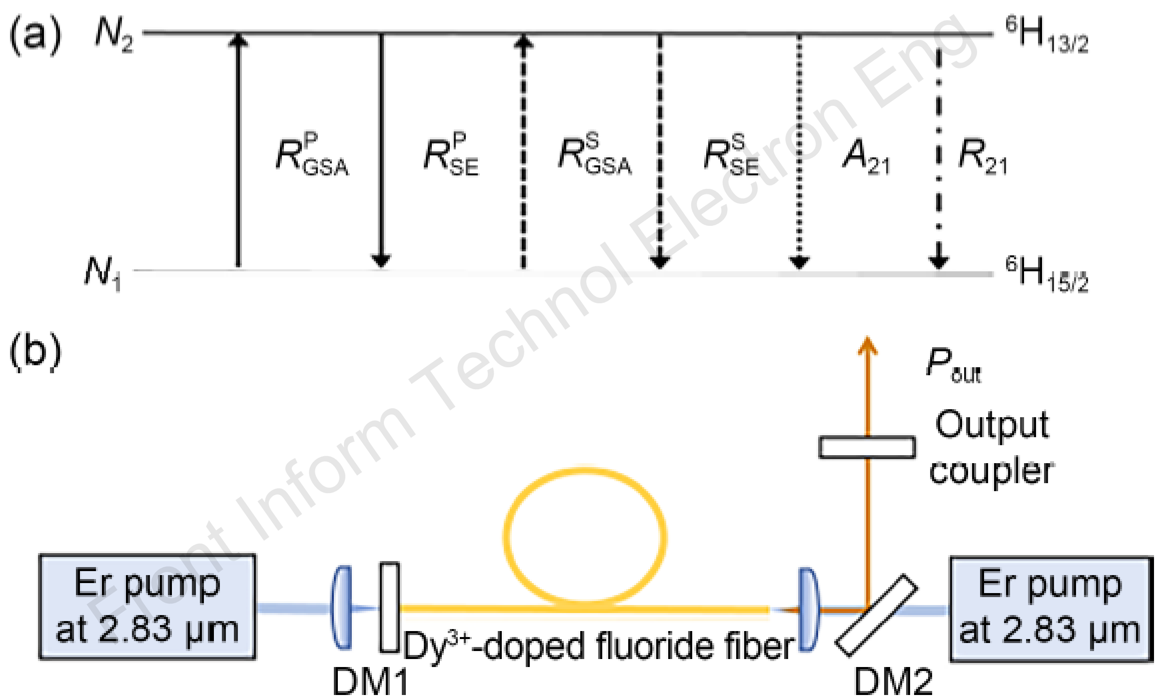
Motivation

- Achieving a high-efficiency and high-power Dy^{3+}-doped fluoride fiber laser in the mid-infrared (mid-IR) region over 3 μm is a scientific and technological frontier. Typically, Dy^{3+}-doped fluoride fiber lasers use a unidirectional pumping method, which suffers from the drawback of high thermal loading density on the fiber tips, thus limiting power scalability.
- Systematically investigate the bi-directional in-band pumping scheme for the Dy^{3+}-doped fluoride fiber laser is excepted to enhance the laser output efficiency.

Main idea

- To address the limitation of output power scaling and enhance the efficiency of the Dy^{3+}-doped fluoride fiber laser at 3.2 μm, we propose a bi-directional in-band pumping scheme.
- We explore the impact of gain fiber length and reflectivity of the output coupler on the laser's performance.
- We aim to achieve high-efficiency Dy^{3+}-doped fluoride fiber laser by optimizing the fiber and cavity parameters.

Framework



The overall framework of this work. First, we propose a schematic of the Dy^{3+}-doped fluoride fiber laser. After that, the simulation model of the fiber laser is established. Finally, the output performance of the fiber laser is investigated numerically.

Method

To address the limitation of output scaling and enhance the efficiency of the Dy^{3+}-doped fluoride fiber laser, we propose a bi-directional pumping scheme and numerically investigate the laser performance based on rate equations and propagation equations.

Results

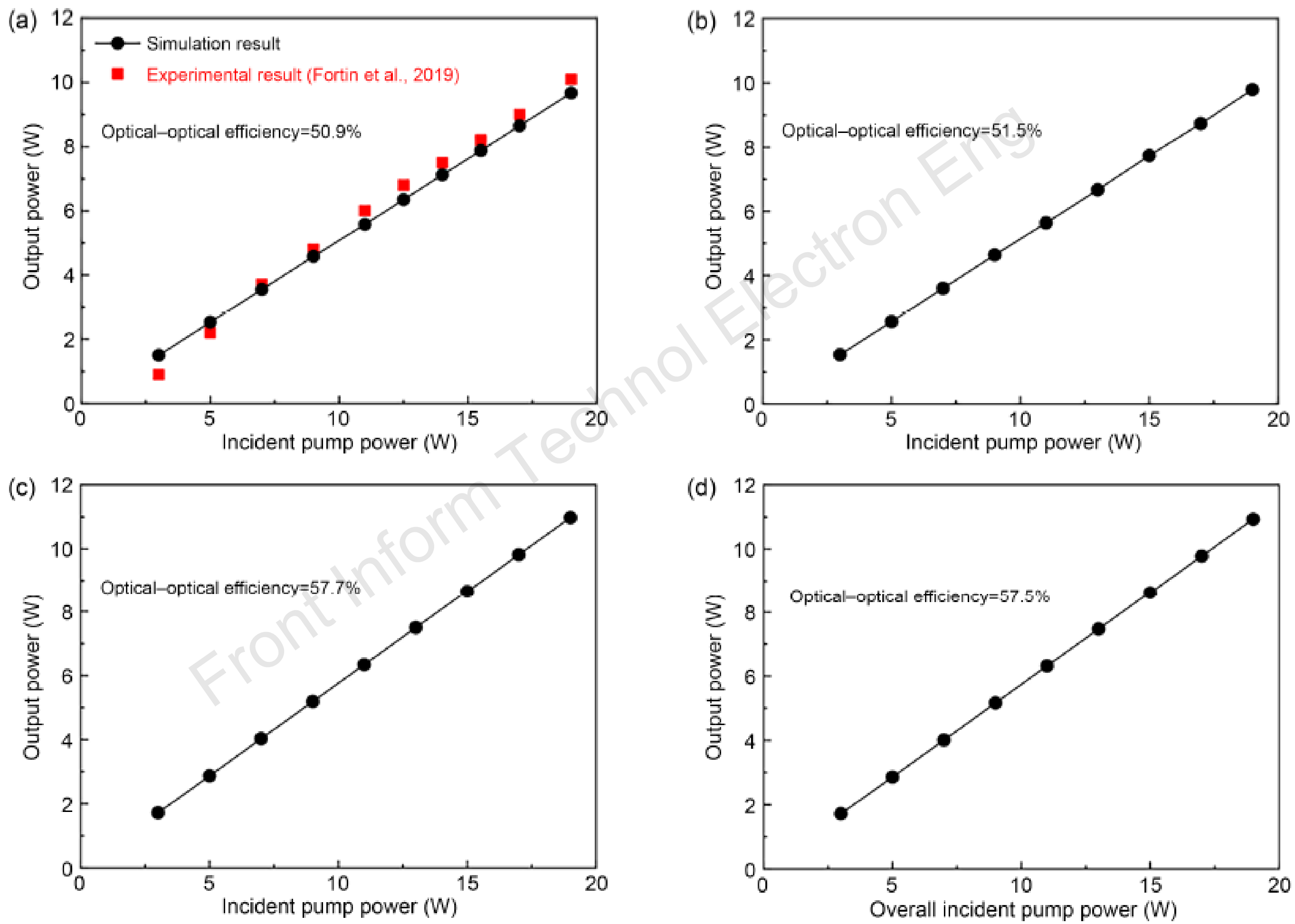


Fig. 2 Comparsion of the simulation results and experimental results from Fortin et al. (2019) (a) and simulated output power of the Dy^{3+}-doped fluoride fiber laser as a function of the incident pump power with different pumping methods: forward pumping (b), backward pumping (c), and bi-directional pumping (d)

Results

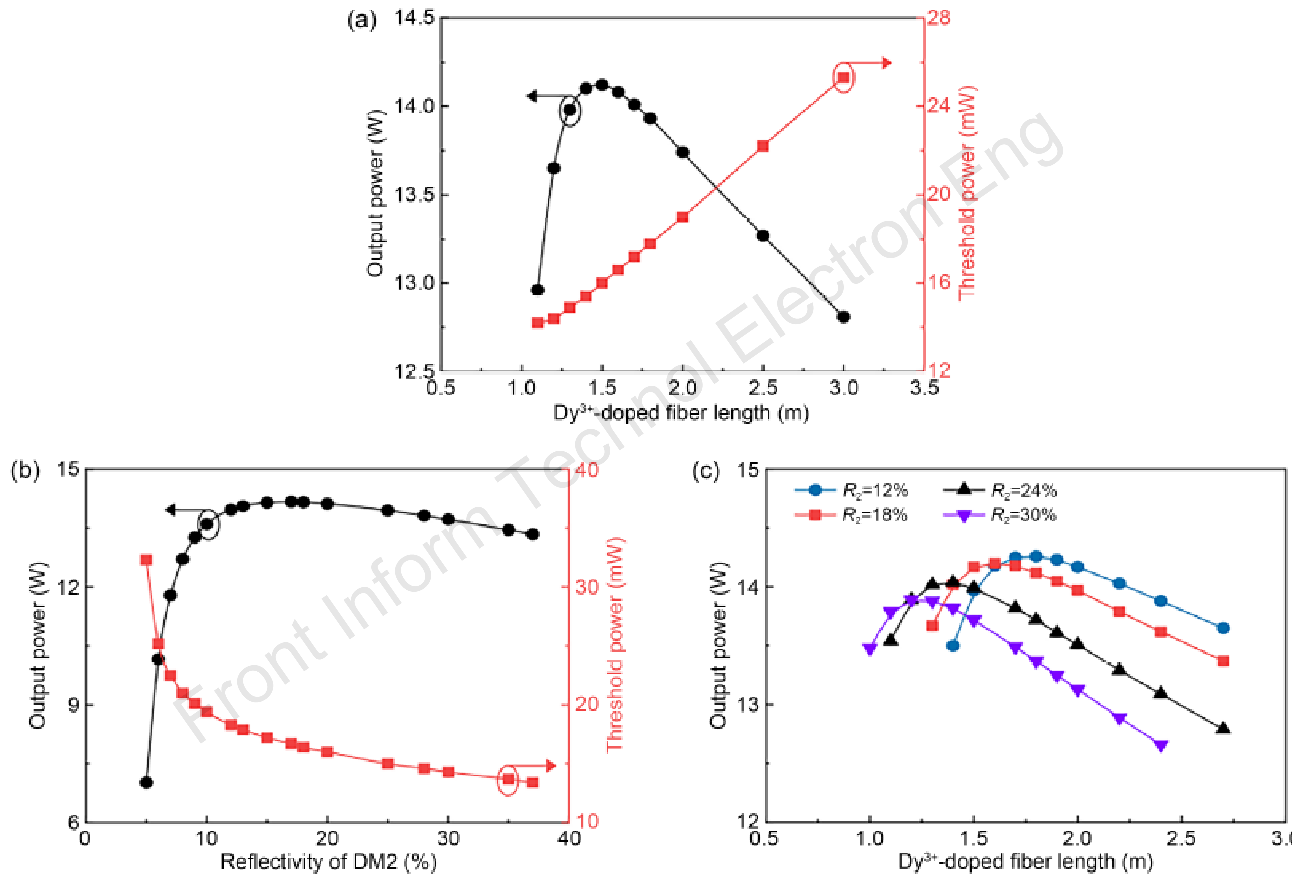


Fig. 3 Simulated output power and threshold power of the bi-directional pumped Dy^{3+}-doped fluoride fiber laser as a function of Dy^{3+}-doped fiber length (the overall incident pump power is 19 W and the output coupler reflectivity is 20%) (a), simulated output power and threshold power of the bi-directional pumped Dy^{3+}-doped fluoride fiber laser as a function of R_2 (the overall incident pump power is 19 W and the fiber length is 1.5 m) (b), and simulated output power of the bi-directional pumped Dy^{3+}-doped fluoride fiber laser versus the fiber length for R_2 values of 12%, 18%, 24%, and 30% (the overall incident pump power is 19 W) (c)

Results

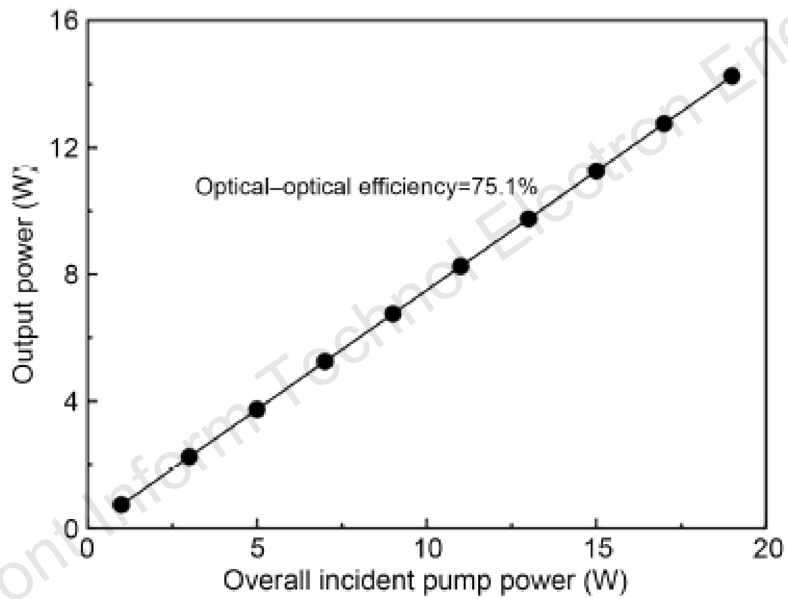


Fig. 4 Simulated output power of the bi-directional pumped Dy^{3+}-doped fluoride fiber laser as a function of the overall incident pump power under R_2=12% and L=1.8 m

Conclusions

In summary, a bi-directional pumping scheme to address the limitation of output power scaling and to enhance the efficiency of the Dy^{3+}-doped fluoride fiber laser at 3.2 μm was investigated numerically based on rate equations and propagation equations. The simulations focused on exploring the impact of gain fiber length and reflectivity of the output coupler on the laser's performance. Detailed simulation results demonstrated that a maximum optical–optical efficiency of 75.1% with respect to the overall incident pump power can be achieved by optimizing the fiber and cavity parameters. Moreover, we identified the potential for further efficiency improvement by appropriately increasing the dopant concentration of Dy^{3+}.

Yuchen WANG received BS and MS degrees in electronics engineering from Politecnico di Milano (Milan, Italy) in September 2012 and October 2015, respectively, and PhD degree in Physics from Politecnico di Milano (Milan, Italy) in February 2019. From November 2018 to November 2019, he has been a postdoctoral researcher at Italian National Research Council (IFN-CNR). From November 2019 to April 2021, he has been a postdoctoral researcher at Aalto University. He is currently a researcher at Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai. His research interest includes mid-IR lasers, ultrafast lasers, and nonlinear optics.

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