Erbium-doped thin-film lithium niobate waveguide amplifier achieves >10 dB on-chip net gain

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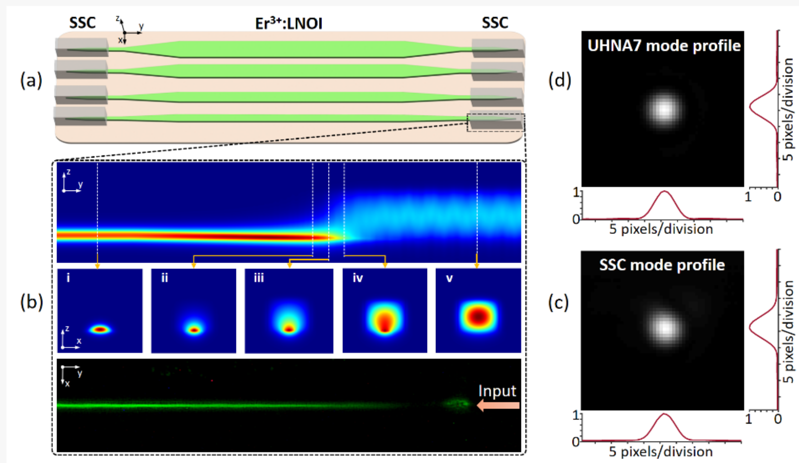

Fig. 1 Design & modal evolution of the SSC-integrated EDWA chip. (a) the schematic of the SSC-integrated EDWA chip, (b) the simulated modal evolution in the SSC region with the insets (i-v) showing the cross-section modal distribution at different propagation positions.

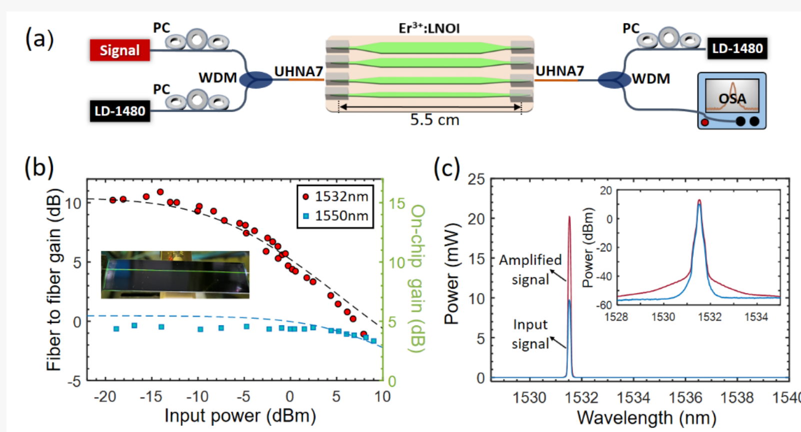

Fig. 2 Gain characterization of the EDWA chip. (a) the experimental schematic, (b) the fiber-to-fiber net gain curves measured at two different signal wavelengths, (c) the input and output signal spectra measured at 10 dBm input power. The insets in (c) s

CHENGDU, SICHUAN, CHINA, July 15, 2025 /EINPresswire.com/ -- With the rapid development of optical communications, quantum computing, and related fields, there is an increasing demand for high-performance integrated photonic devices. As a key component of next-generation integrated photonic systems, on-chip erbium-doped waveguide amplifiers have attracted widespread attention in recent years. Thin-film lithium niobate (TFLN), known for its excellent electro-optic and nonlinear properties, is considered an ideal platform for photonic integrated circuits. Over the past two years, erbium-doped TFLN waveguide amplifiers have been successfully demonstrated and reported by multiple research groups worldwide. However, due to the significant refractive index and mode-field mismatch between TFLN waveguides and external optical fibers or fiber lenses, high facet coupling losses have resulted in low or even negative on-chip net gain (fiber-to-fiber) in previously reported erbium-doped

TFLN waveguide amplifiers. This limitation has greatly hindered their practical applications. In this study, we employ an adiabatic mode-field converter-based waveguide facet coupler to achieve high net gain and high-power amplification in waveguide amplifiers, providing a critical solution for high-density photonic integrated systems.

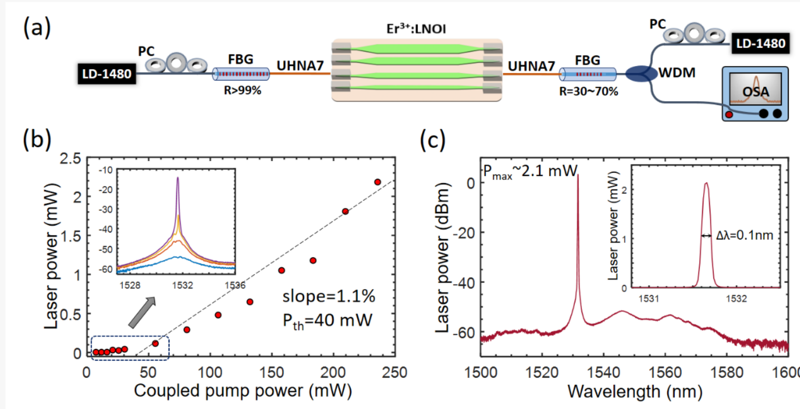

Fig. 3 (a) schematic of the laser setup integrating the EDWA chip with a fiber Bragg grating (FBG), (b) the generated laser powers vs coupled pump powers, with the laser spectra evolution around the pump threshold shown in the inset. (c) the laser spectru

The research group of Prof. Ya Cheng from East China Normal university introduce the highest reported fiber-to-fiber net gain in an erbium-doped lithium niobate waveguide amplifier (EDWA) to date. This groundbreaking work, titled “High fiber-to-fiber net gain in erbium-doped thin film lithium niobate waveguide amplifier as an external gain chip”, has been published in Opto-Electronic Science (Issue 4, 2025).

To address the mode-field mismatch between lithium niobate (LN) waveguides and optical fibers, researchers employed a structure combining inverse-tapered waveguides with a silicon oxynitride (SiON) cladding. By precisely controlling the adiabatic tapering of the waveguide mode, the optical field is smoothly transformed from a submicron-thick LN waveguide into a 3-μm-thick SiON waveguide, thereby achieving efficient mode matching between the thin-film lithium niobate (TFLN) waveguide facet and ultra-high numerical aperture (UHNA) fibers, as illustrated in Figure 1. Experimental results demonstrate that this mode-field converter achieves a coupling efficiency exceeding 75%, with a single-facet coupling loss as low as -1.2 dB. Compared to conventional end-face polished butt-coupling methods, the coupling efficiency is improved by more than sevenfold. This approach successfully enables highly efficient and stable coupling between TFLN waveguides and optical fibers.

By monolithically integrating the high-efficiency mode-field converter with an erbium-doped waveguide amplifier, and employing bidirectional pumping in a 5.5-cm-long $Er:LiNbO_3$ waveguide, the researchers achieved an on-chip net gain exceeding 15 dB, corresponding to a fiber-to-fiber (off-chip) net gain of >10 dB at around 1532 nm. The noise figure remained as low as 6.8 dB. Furthermore, the maximum amplified output power measured at the fiber reached over 20 mW (with a fiber input power of ~10 mW), as demonstrated in Figure 2.

The researchers further demonstrated the integrated waveguide amplifier chip’s critical application as an efficient gain medium. By incorporating an external fiber Bragg grating as a reflective mirror, they successfully constructed a Fabry-Pérot external cavity laser. Under bidirectional optical pumping, this configuration achieved narrow-linewidth continuous-wave lasing with a maximum fiber-coupled output power of 2.1 mW.

Professor Ya Cheng's Research Team at East China Normal University has long been dedicated to advancing the fundamental innovation, scientific research, and industrial applications of ultrafast laser micro/nanofabrication technologies. The team has pioneered a series of groundbreaking techniques, including femtosecond laser slit-shaping waveguide direct writing, three-dimensional electrode fabrication, lithium niobate (LN) photonic chips, and ultrahigh-precision 3D printing.

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Ya Cheng, Professor and Doctoral Supervisor at East China Normal University and Researcher at the Shanghai Institute of Optics and Fine Mechanics (SIOM), Chinese Academy of Sciences, has served as Chief Scientist for major research projects under the National Key Basic Research Program (973 Program) and the National Key R&D Program of China. He has been honored with the National Science Fund for Distinguished Young Scholars, the National "Ten Thousand Talents Program" Leading Talent Award, Shanghai Leading Talent, and Shanghai Outstanding Academic Leader, among other distinctions.

He is a Fellow of The Optical Society (OSA) and the Institute of Physics (IOP), UK. Professor Cheng's research focuses on the mechanisms of ultrafast laser-matter interactions and micro/nanofabrication technologies. His work has led to significant advancements in femtosecond laser processing techniques and the development of high-performance LN photonic devices. He holds over 20 authorized Chinese patents and 8 U.S. patents, and has published more than 200 SCI-indexed papers, which have been cited over 10,000 times in the Web of Science (h-index ~60). He has authored five English monographs (including one sole-authored, two co-authored, and two co-edited volumes) under invitations from Pan Stanford Publishing and Springer London, as well as one Chinese monograph published by Science Press. Professor Cheng has delivered over 150 invited talks at major international conferences in photonics and optoelectronics and has been recognized with Shanghai's top natural science prize and China's national disruptive technology award for pioneering contributions.

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