Compact hybrid Ho:YLF picosecond amplifier system exceeding 100 mJ pulse energy

CLASS 5
10 YEARS Transforming Light into Innovation

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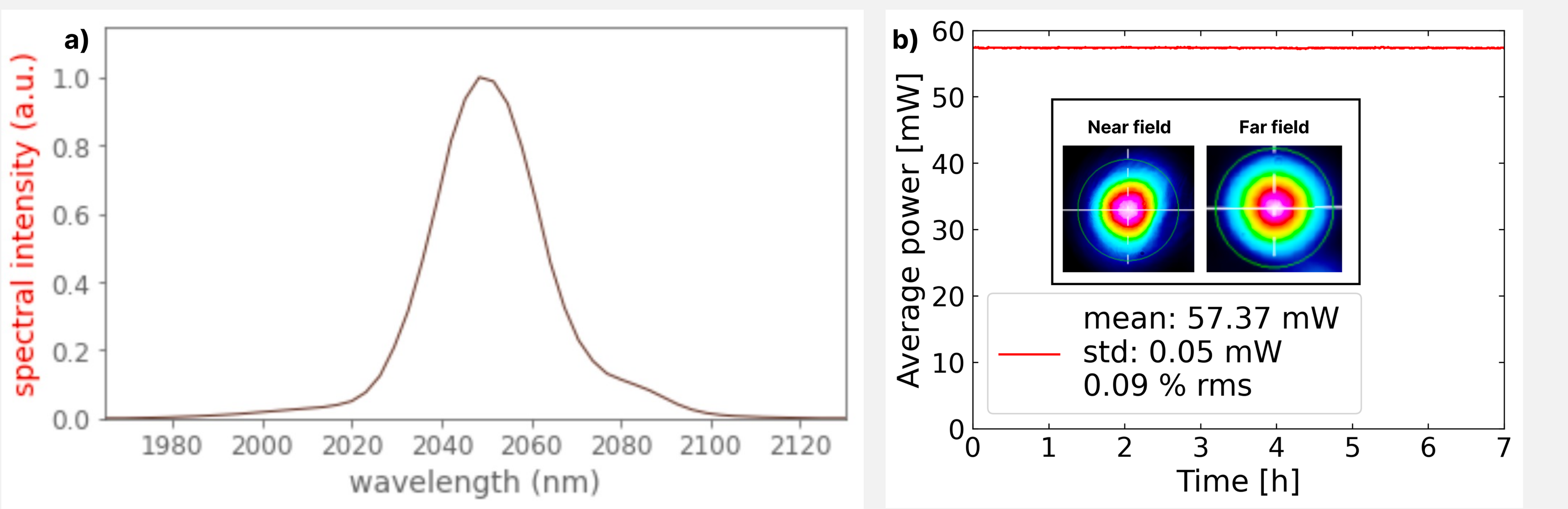
GW-level 2 µm Ho:YLF Compact Laser

High peak power (tens of GW) laser in the short-wavelength infrared (SWIR, 1.4 – 3 µm) region show promising application as secondary sources [1]; generating mid-infrared using OPCPA [2], terahertz radiation [3], as well as generating HHG down to the 'water window' [4]. In this poster, we present a compact hybrid Ho:YLF amplifier system, combining a microjoule-level Yb:fiber-driven OPA front-end with a Ho:YLF regenerative amplifier. This hybrid system reduces complexity and optimizes bifurcation dynamics. In the subsequent booster stages, the amplifier geometry and thermal effects are optimized to scale the pulse energy above 100 mJ for MIR OPCPA pumping between 3 – 11 µm. For example, such MIR drivers allow the generation of femtosecond X-ray pulses around 8 keV particularly important for time-resolved material studies [5].

[1] Chang, Z., et al., Intense infrared lasers for strong-field science, *Adv. Opt. Photonics* **14**(4), 652 (2022)
Tate, J., et al. Scaling of wave-packet dynamics in an intense midinfrared field. Phys. Rev. Lett. 98(1), 013901 (2007)
[2] Sanchez, D. et al., 7 µm, ultrafast, sub-millijoule-level mid-infrared optical parametric chirped pulse amplifier pumped at 2 µm, Optica 3(2) 147 (2016); von Grafenstein, L. et al., 2.05 µm chirped pulse amplification system at a 1 kHz repetition rate—2.4 ps pulses with 17 GW peak power, *Opt. Lett.* **45**(14), 3836 (2020).
[3] Clerici, M. er al., Wavelength Scaling of Terahertz Generation by Gas Ionization, *Phys. Rev. Lett.* **110**, 253901 (2013).
[4] Cousin, S. L., et al., High-flux table-top soft x-ray source driven by sub-2-cycle, CEP stable, 1.85-µm 1-kHz pulses for carbon K-edge spectroscopy, *Opt. Lett.* **39**(18), 5383.
[5] Koc, A., et al., Compact high-flux hard X-ray source driven by femtosecond mid-infrared pulses at a 1 kHz repetition rate. *Opt. Lett.* **46**(2), 210 (2021)

Yb-fiber driven OPA Front-End

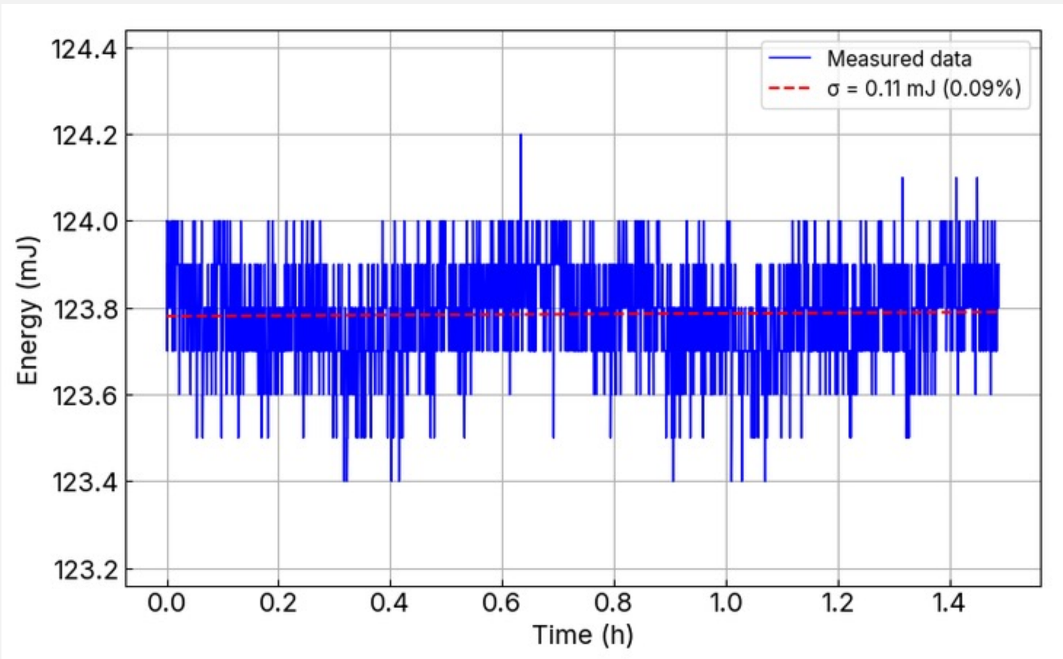


a) Spectrum and **b)** Beam characteristics of the Yb-fiber driven OPA Front-End

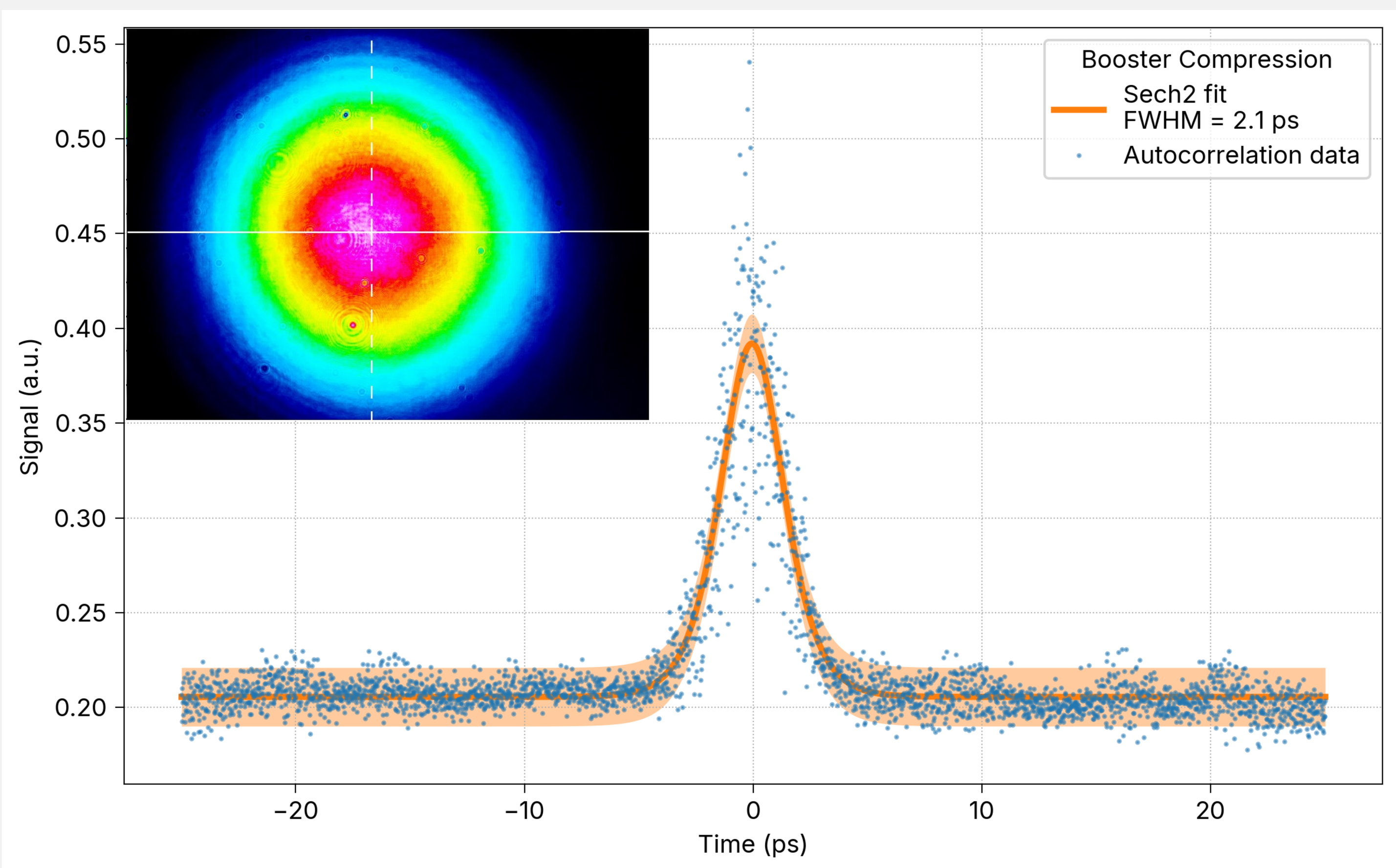
Recent Ho:YLF Booster Amplifier Improvements

We extended the booster by adding a third stage, with careful beam shaping using cylindrical lenses to counteract the non-uniform thermal lens of Ho:YLF. This optimized pump–seed overlap while respecting saturation fluence and damage thresholds. Laser parameters are summarized below.

Thora System	
Energy	110 mJ (0.09% rms)
Pulse Duration	2.1 ps
Rep. Rate	1 kHz
Peak Power	46 GW
Footprint RA +Booster	1x1.2 m 1.25x0.875 m

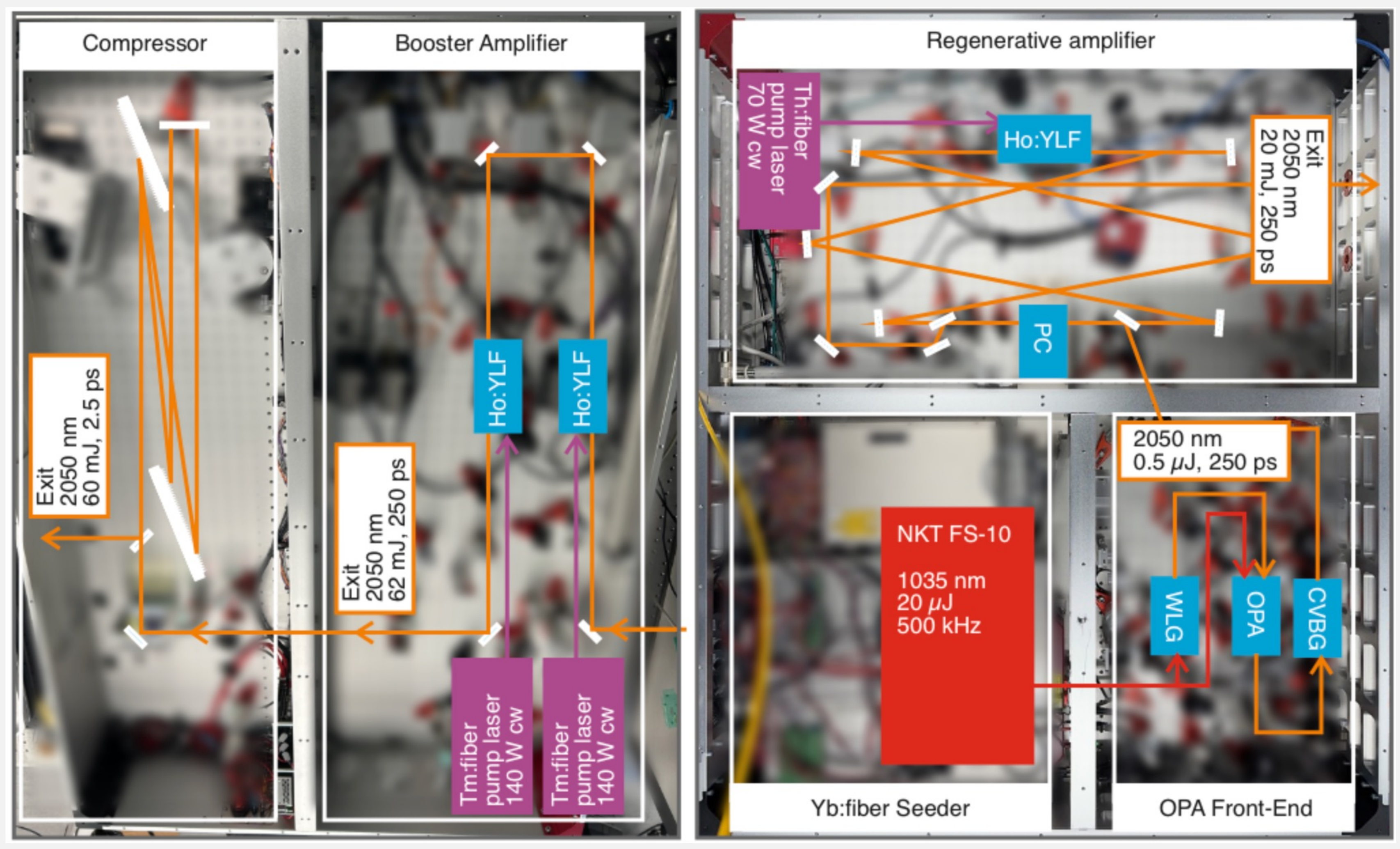


Pulse energy of final booster stage with energy > 100 mJ showing a warm up period of 1 hour and a fluctuation of 0.09% rms.



Part of the ouput of booster was compressed to 2.1 ps (FWHM) with excellent beam quality.

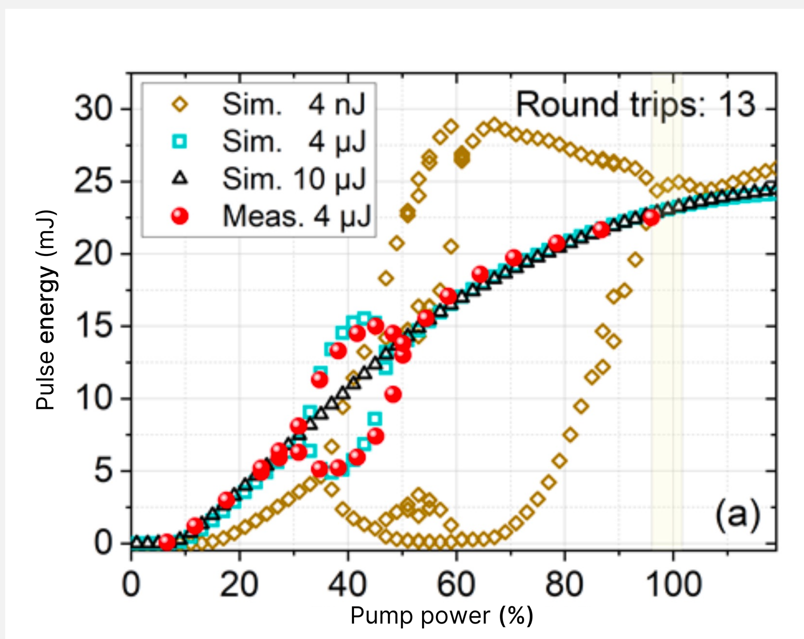
System Overview



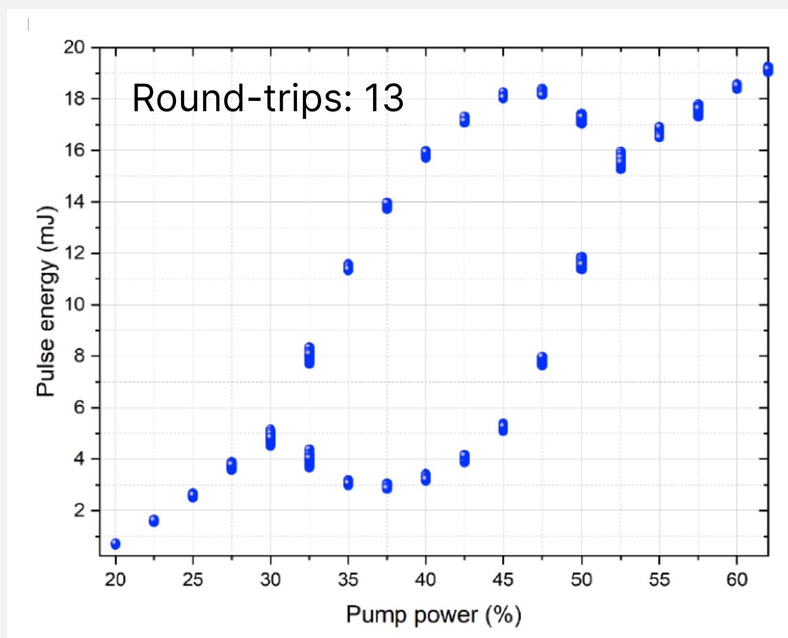
Ho:YLF Regenerative Amplifier and Dynamics

Recently, a 22 mJ at 1 kHz regenerative amplifier system has been realized [6]. Moreover, energy scaling up to 60 mJ has been demonstrated with thermo-electric cooling [7]. Despite the relatively compact architecture of the Ho:YLF amplifiers, all to date systems involve complex front-end designs, either based on fiber amplifier chains [2], or multi-stage parametric amplifiers [6,7]. We report a compact 100 mJ picosecond Ho:YLF amplifier system, seeded by a Yb:fiber driven single stage OPA, reducing the overall footprint to <3 m² an increasing stability.

[6] Bock, M., Ho:YLF regenerative amplifier delivering 22 mJ, 2.0 ps pulses at a 1 kHz repetition rate, *Opt. Express*, **32**(13), 23499 (2024)
[7] Zhou, F., et al., Enhancement of gain and efficiency of an Ho:YLF energy booster through deep thermoelectric cooling, *Opt. Continuum*, **1**(5), 1060 (2022)



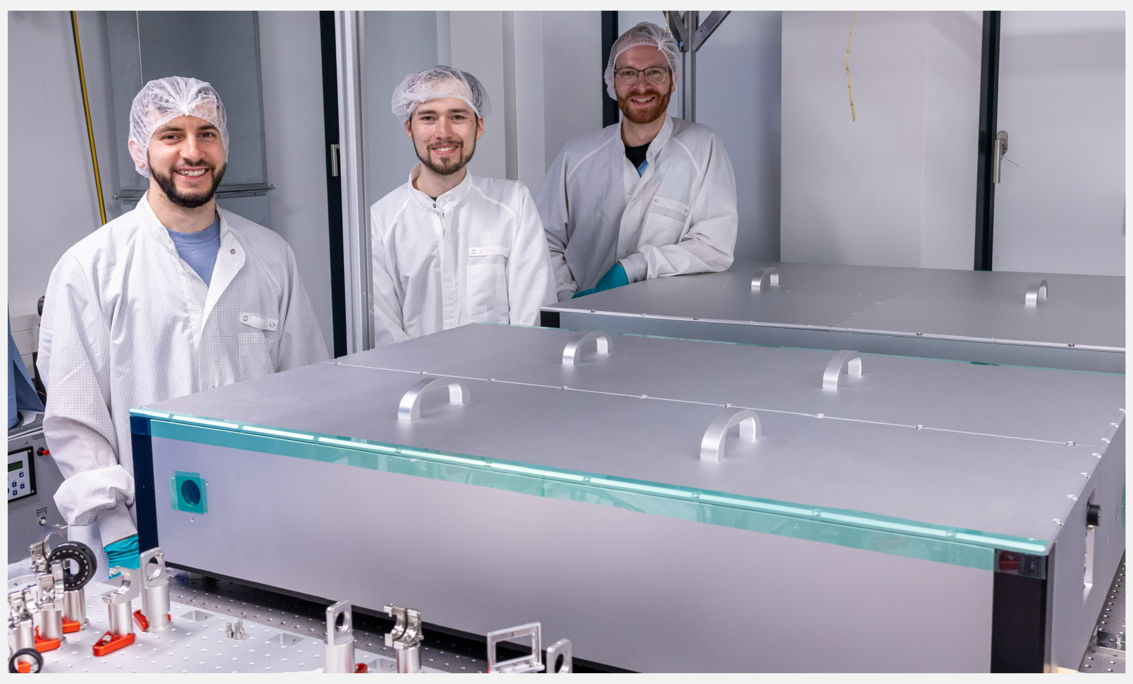
MBI Ho:YLF Regenerative Amplifier System demonstrating the bifurcation dynamics [6].



Class 5 Thora System demonstrating the bifurcation dynamics with the Yb-fiber driven OPA Front-End

Summary... Interested to learn more?

The system enables efficient pumping of a mid-IR OPCPA (3–11 µm), advancing research in laser–plasma interactions and strong-field physics. It also supports the generation of high-flux femtosecond X-ray pulses (~8 keV) in a compact table-top setup, opening opportunities for time-resolved material studies.



With **46 GW peak power**, the laser exceeds the self-focusing limit in air, enabling air filamentation and atmospheric studies. Further scaling is feasible through advanced cooling, optimized pumping, and additional amplifier stages

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