Optimized temperature/bandwidth operation of cryogenic Yb:YAG composite thin-disk laser amplifier

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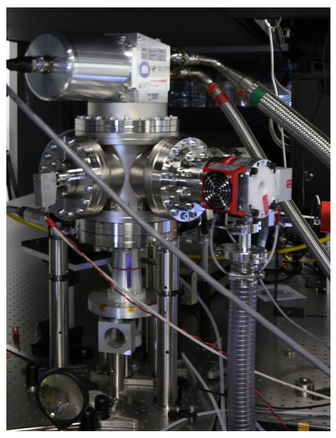
Motivation

- High-energy picosecond lasers are needed for
  - Pumping of Optical Parametric (Chirped Pulse) Amplifiers
  - Supporting efforts in sub-cycle pulse synthesis and coherent X-ray sources

→ Solution: Cryogenic composite-thin-disc YAG multipass amplifier in strict relay imaging geometry

- Aim at 100 mJ, low repetition rate (100 Hz – 1 kHz)

→ For sub-ps pulses: Optimization of bandwidth vs. power required



Experimental set-up

- **(1) Multi-mode cavity for the power extraction and bandwidth characterization**
- **(2) Multi-pass amplifier**
- **Characteristics:**

Cavity:
- Lens: f = 300 mm
- 10% output coupler

Crystals:
- Composite thin-disc, 1% doped Yb:YAG
- Thickness: 1 mm

Pump:
- Fiber coupled laser diode NA=, MFD = 1000 µm
- Wavelength λ = 938 nm stabilized
- Maximal pump power PP = 500 W

Where is b) and c)

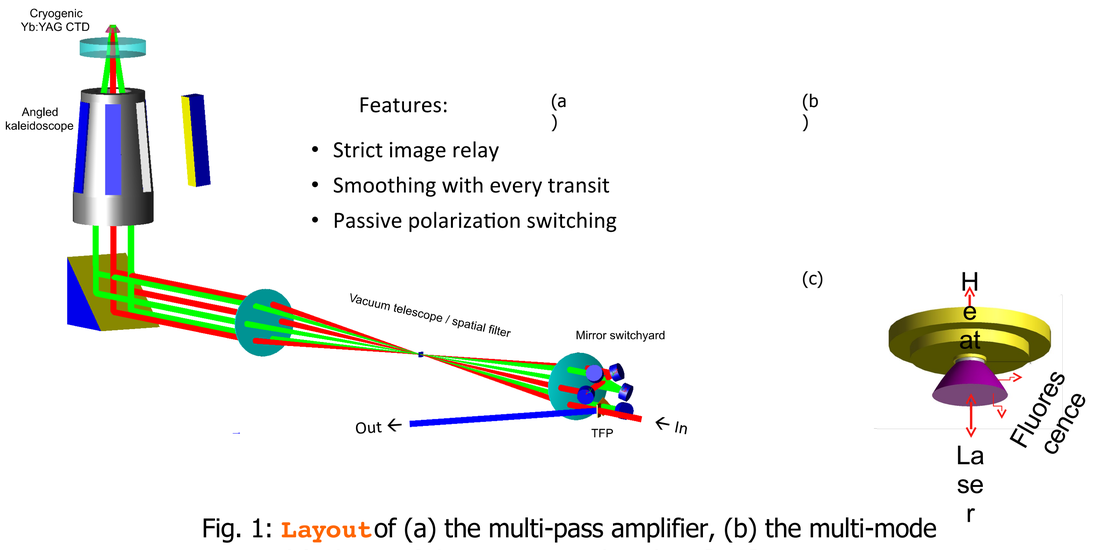


Fig. 1: Layout of (a) the multi-pass amplifier, (b) the multi-mode cavity. (c) Shape of the composite thin-disc. [1,2]

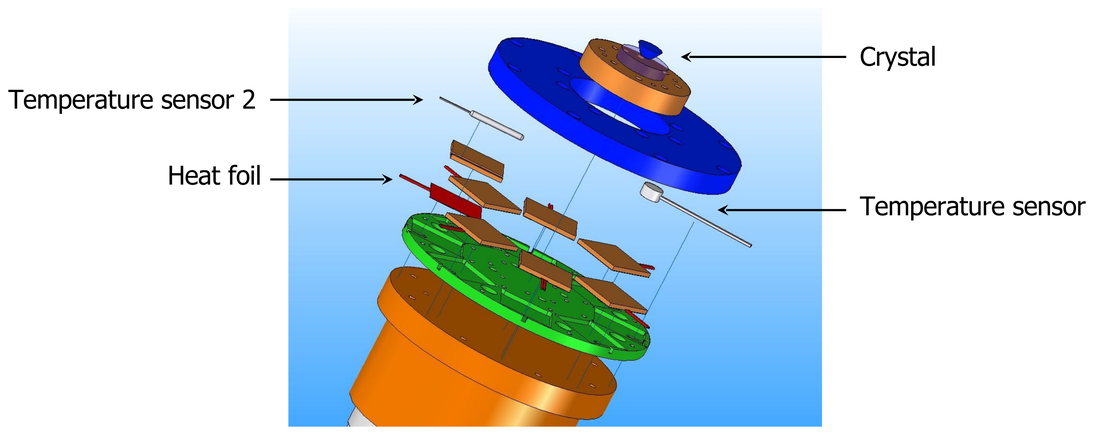


Fig. 2: Drawing of the cold head with the heat foils for temperature adjustments.

	Yb:YAG @300K[4]	Yb:YLF @80K[3,4]	Yb:YAG @80K[3]
κundoped [W/m/K]	11	4	40
σemission [10-20 cm2]	2.1	1.8	11
σabsoption [10-20 cm2]	0.8	1	1.7
τ [µs]	951	2000	1000
Δλemission [nm]	1025-1035	1005-1035	1029

Tab. 1: Material properties.

[1] L. E. Zapata, H. Lin, H. Cankaya, A.-L. Calendron, W. Huang, K.-H. Hong, and F. X. Kaertner, "Cryogenic composite thin disk high energy pulsed, high average power, diffraction limited multi-pass amplifier," ASSL Conference Proceedings, AF3A (2013)
[2] L. E. Zapata, "Edge-Facet Pumped, multi-aperture, thin-disk laser geometry for very high Average Power Output Scaling," U. S. Patent 6,834,070 B2 December 21, 2004. Inventor: under DOE contract No. W-7405-ENG-48 with the University of California.
[3] T. Y. Fan, D. J. Ripin, R. L. Aggarwal, J. R. Ochoa, B. Chann, M. Tilleman, J. Spitzberg, „Cryogenic Yb3+ - Doped Solid-State Lasers", IEEE JSTQE **13** (3), 448 (2007)
[4] Altechna webiste: http ://www.altechna.com/product_details.php?id=1050&product_name=Yb%3ALiYF4+Crystals

Experimental results

Fluorescence measurements:

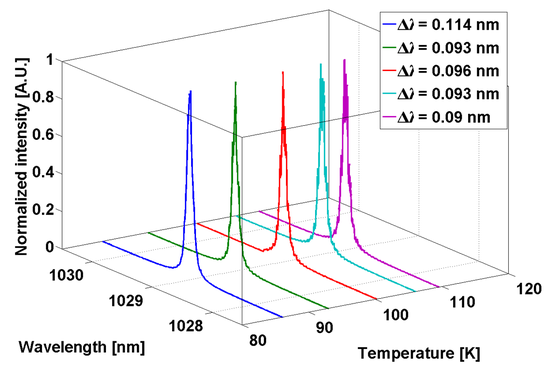


Fig. 3: Fluorescence measurements vs temperature.
Pump settings: frep = 10 Hz, Tpumping = 1 ms, Pav = 1 W

Multi-mode cavity operation:

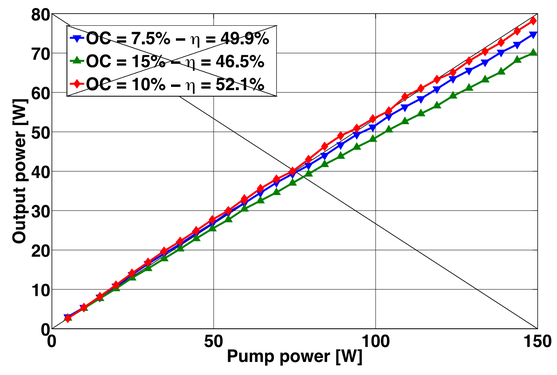


Fig. 4: Slope efficiency.
T = 85 K

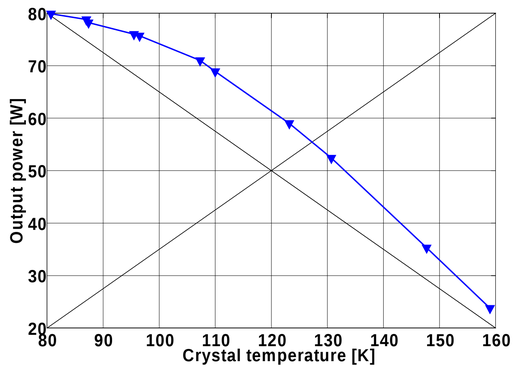


Fig. 5: Output power dependancy with temperature.
Pump settings: frep = 10 Hz, Tpumping = 30 ms, Pav = 150 W

Seeded operation:

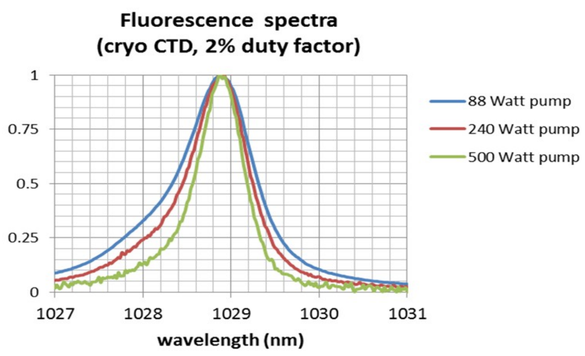


Fig. 6: Gain narrowing during amplification of 1 mJ seed.

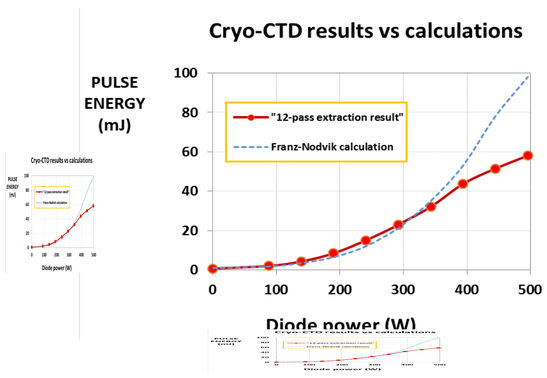


Fig. 7: Energie after multi-pass amplification in composite thin-disc and Franz-Nodvik simulations.

Conclusions

- 78 W extracted from composite thin-disc in a multi-mode cavity pumped with 150 W and at 80 K
- Measurement of fluorescence spectra at different temperatures
- Measurement of gain narrowing during the amplification of 1 mJ seed pulses
- Extraction of 60 mJ from the multi-pass amplifier, limited by a damage due to lack of stretching
- Outlook:
  - Increase of the stretching ratio
  - Amplification to higher repetition rates
  - Compression of the pulses after amplification