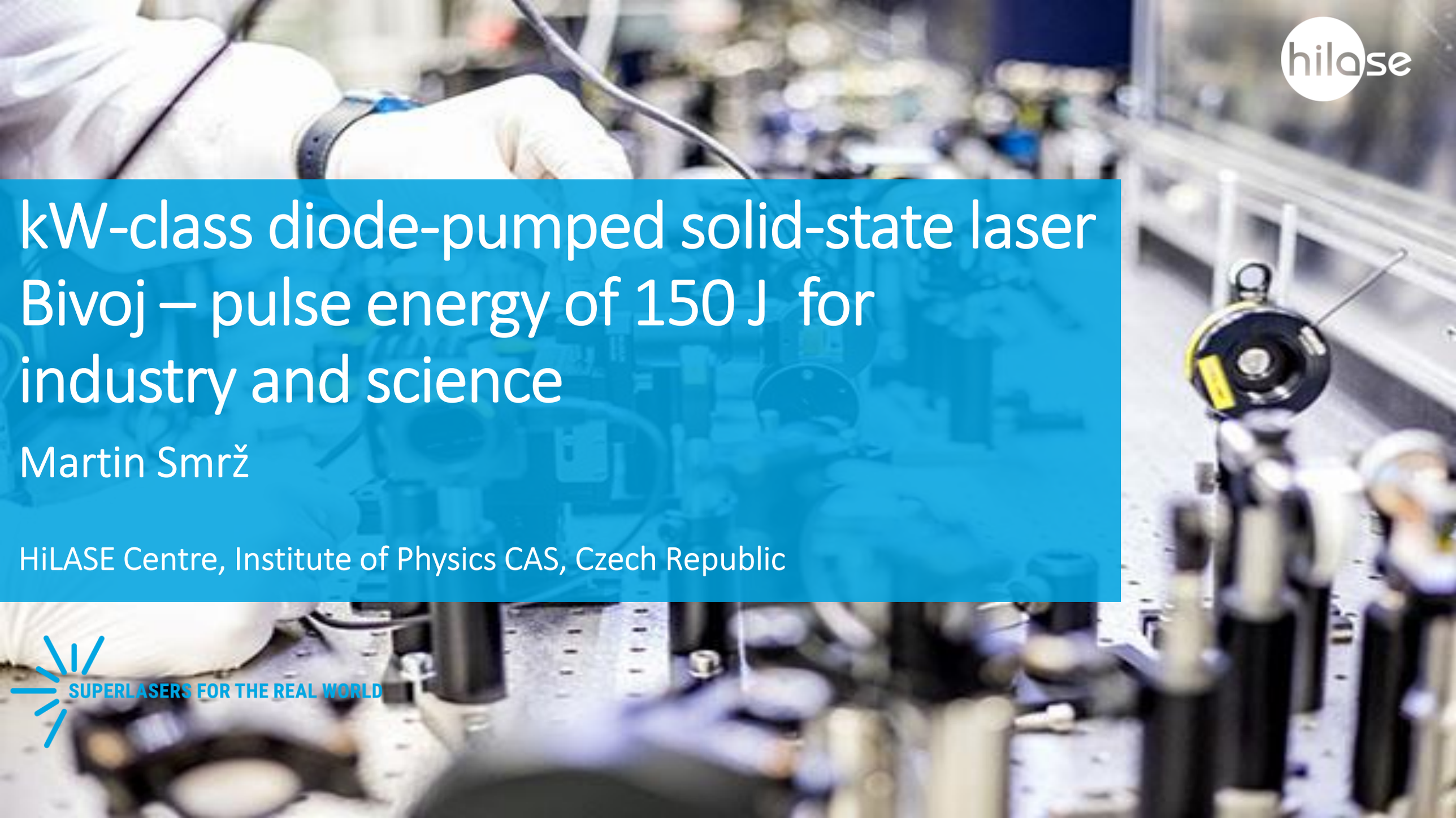

kW-class diode-pumped solid-state laser Bivoj – pulse energy of 150 J for industry and science

Martin Smrž

HiLASE Centre, Institute of Physics CAS, Czech Republic

SUPERLASERS FOR THE REAL WORLD

Dolní Břežany, Czech Republic

LOCATION OF HiLASE CENTRE

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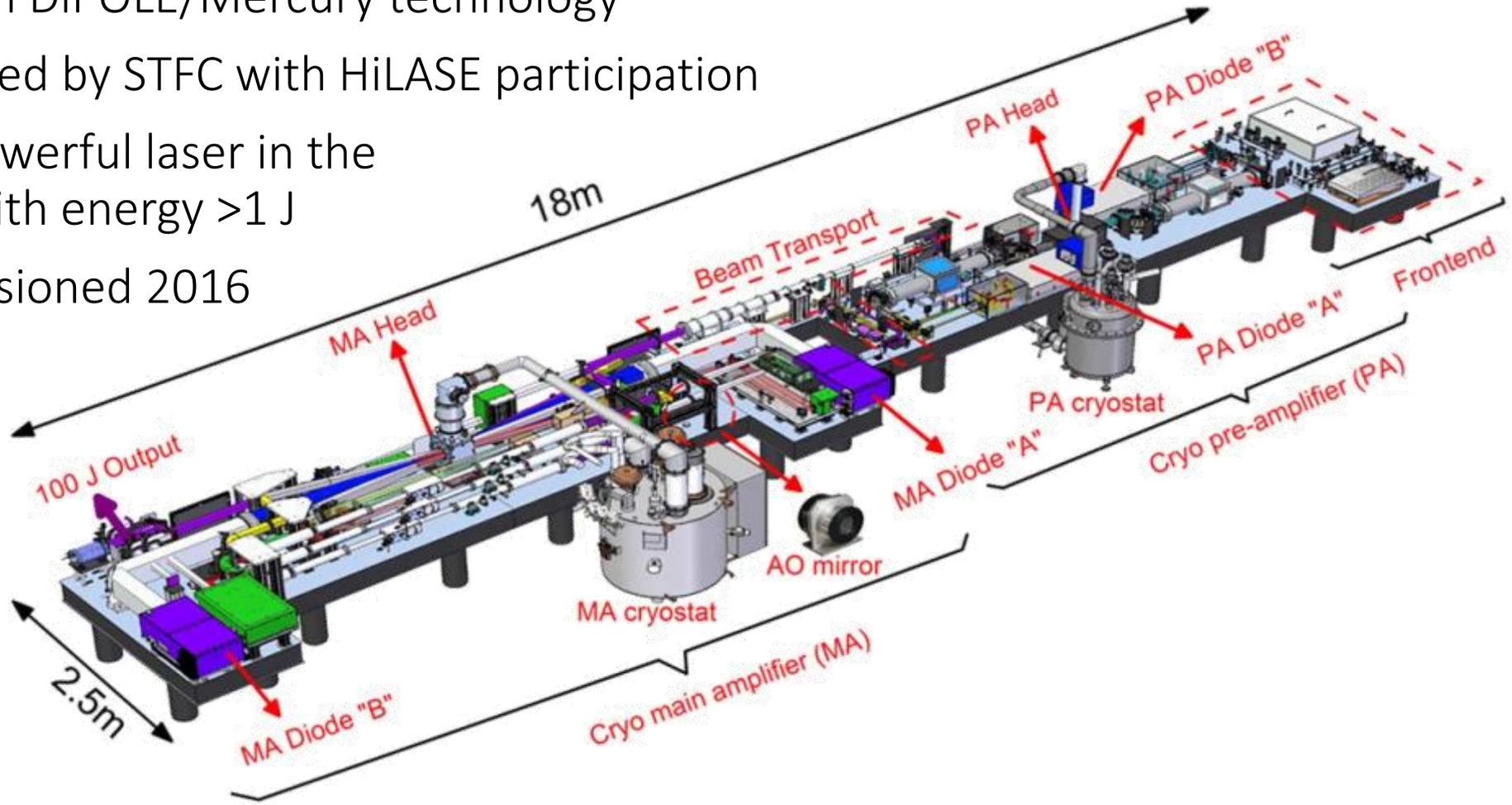
Outline

- Diode-pumped Yb:YAG solid-state laser Bivoj
- High energy harmonic frequency conversion to 515 and 343 nm
- Demonstration of a unique Faraday isolator device
- Applications for the real world

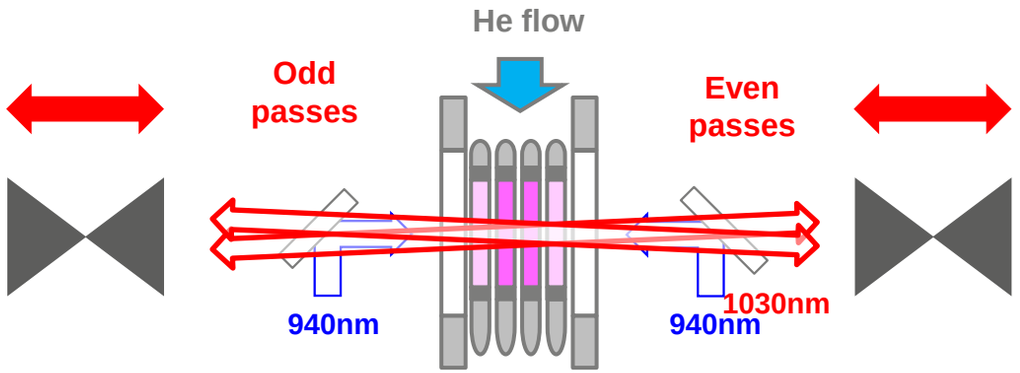
Cryogenically-cooled DPSS laser Bivoj

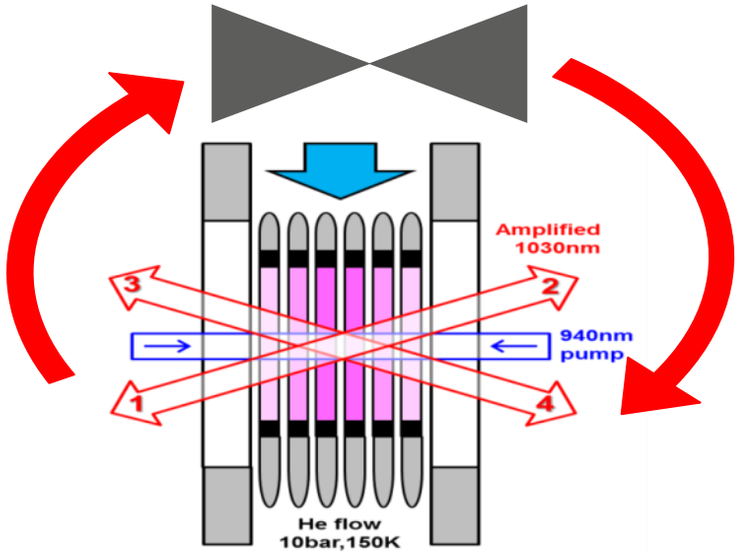
- Bivoj system – DPSSL – 150 J, 10 Hz, 2-14 ns, 1.5 kW square flat top beam, shaped pulses, multi-slab
- Based on DiPOLE/Mercury technology
- Developed by STFC with HiLASE participation
- Most powerful laser in the world with energy >1 J
- Commissioned 2016



Power amplifiers

Properties	10 J preamplifier
Beam	20 x 20 mm^2
Yb:YAG Size	D45 mm x 5 mm
4 slabs	7 passes
Pump	60 kW, 1 ms, 10 Hz
Cooling	He, 150K, 16 g/s, 7 bar





Properties	100 J preamplifier
Beam	75 x 75 mm^2
Yb:YAG Size	100 mm x 100 mm x 8.5 mm
6 slas	4 passes
Pump	500 kW, 1 ms, 10 Hz
Cooling	He, 150K, 180 g/s, 10 bar

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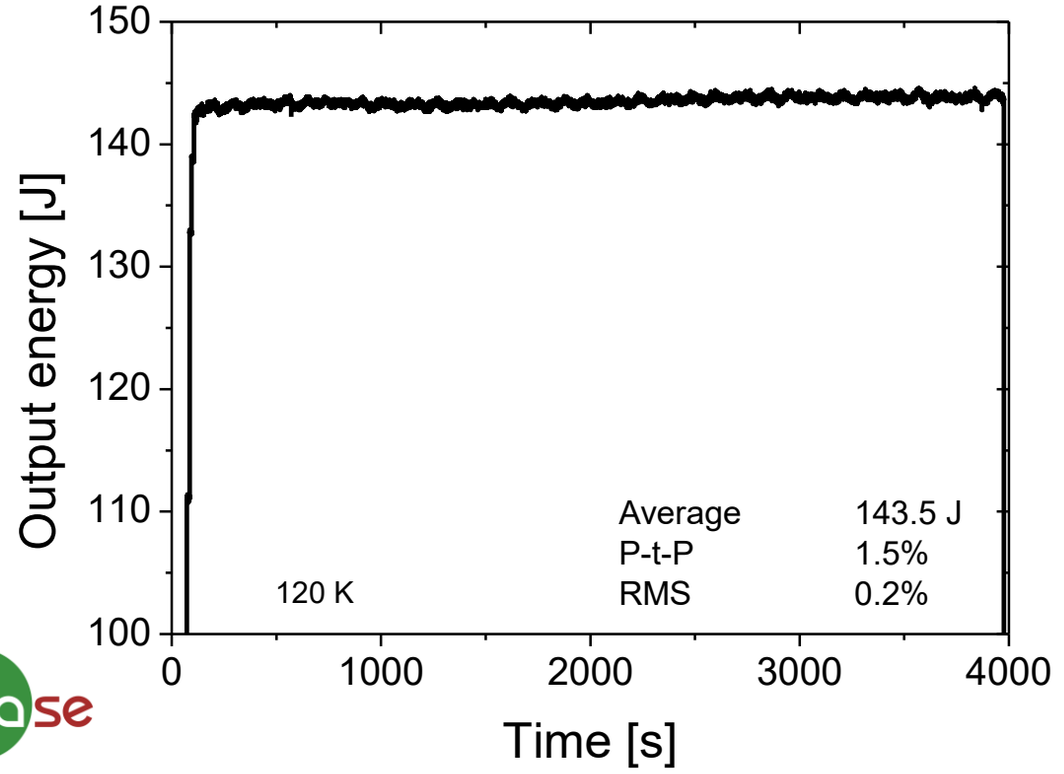
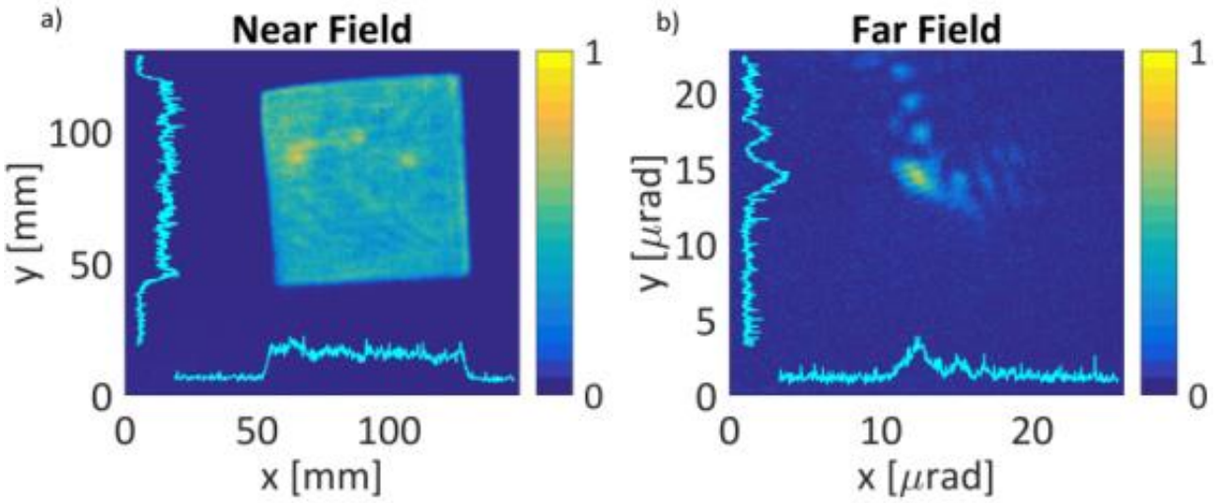
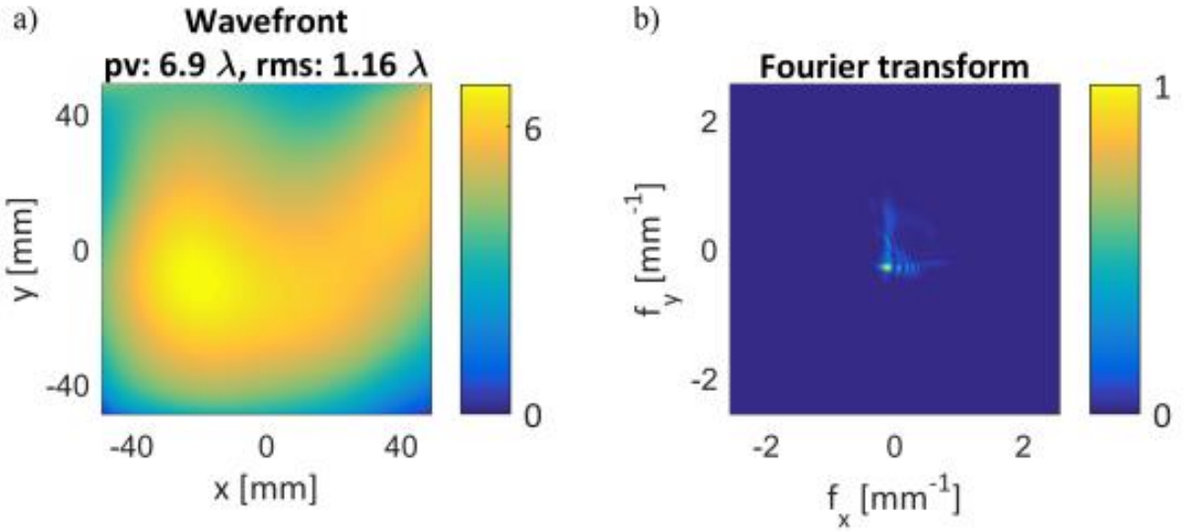
143 J @ 10 Hz for 60 mins

- 143 J for 60 mins
- 30% optical – to – optical efficiency
- without deformable mirror
- No damage, no power drop

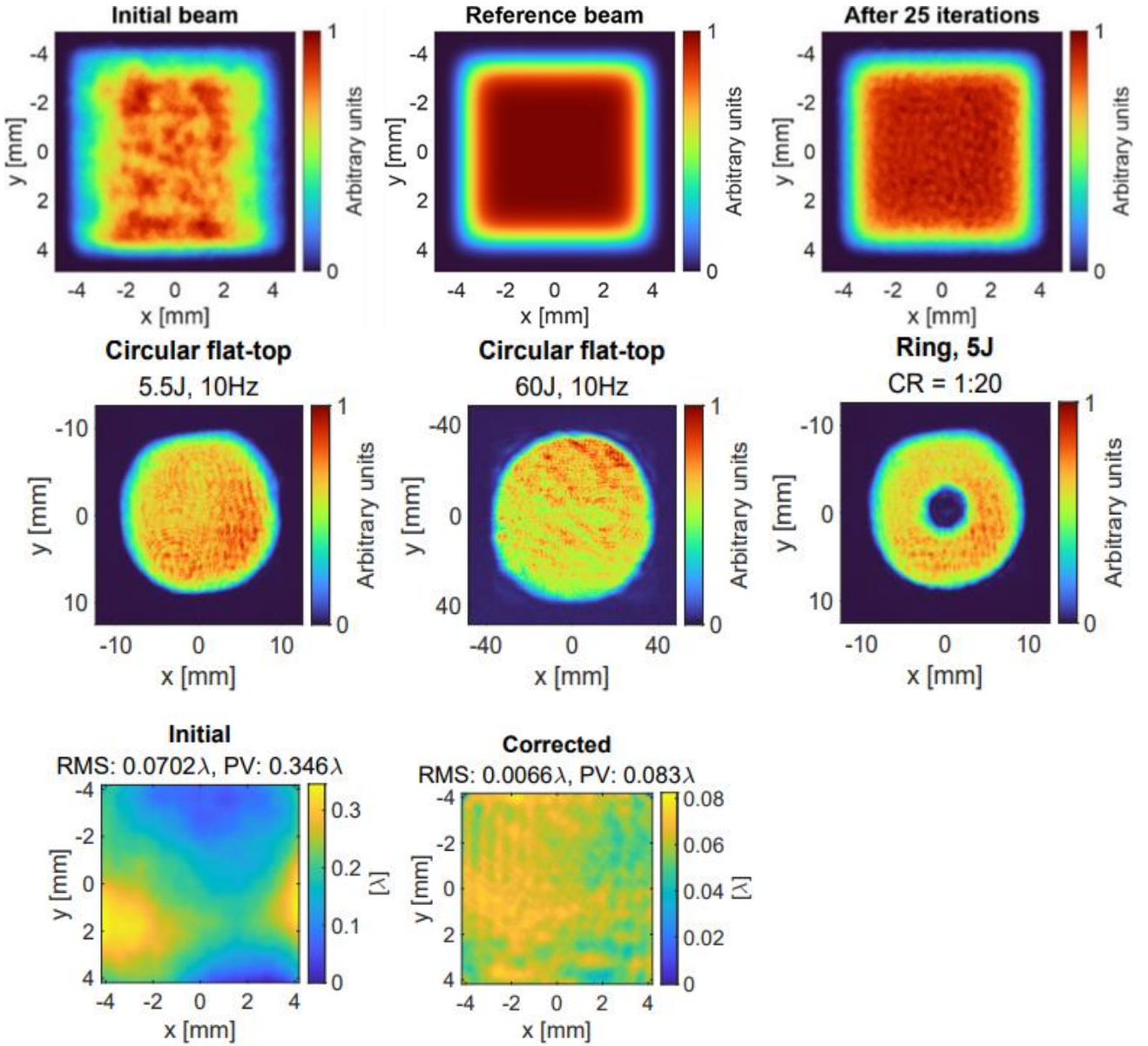






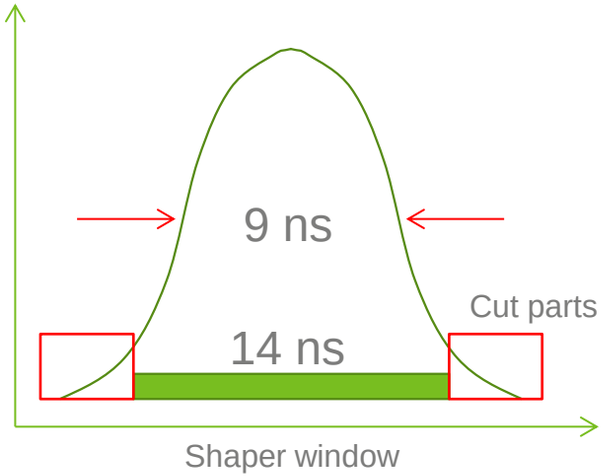
Arbitrary shaping of Bivoj laser beam

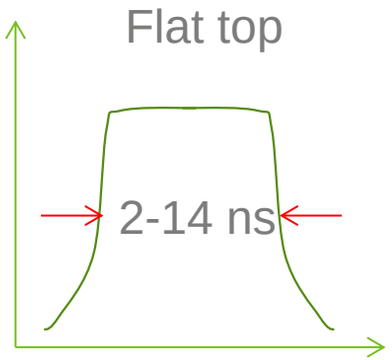
- Improved beam quality
- Creates custom shapes
- Improves wavefront

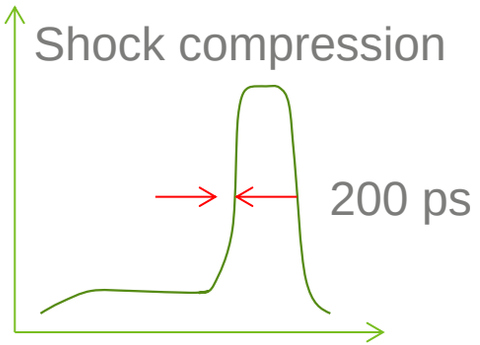


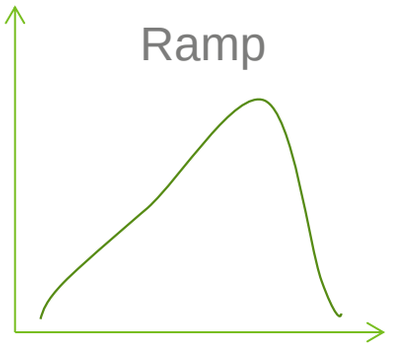
Tailoring pulse shape of Bivoj pulses

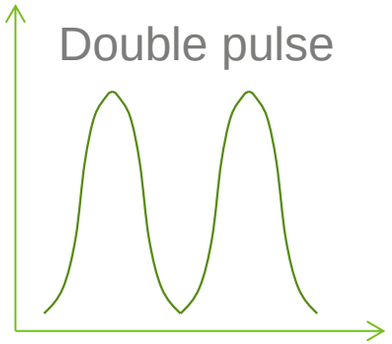
- Arbitrary pulse shaping in front-end
- Window 14 ns (clipped outside), resolution 150 ps
- Rise/fall times 200 ps
- LIDT limited by peak intensity – shorter pulses -> limited energy





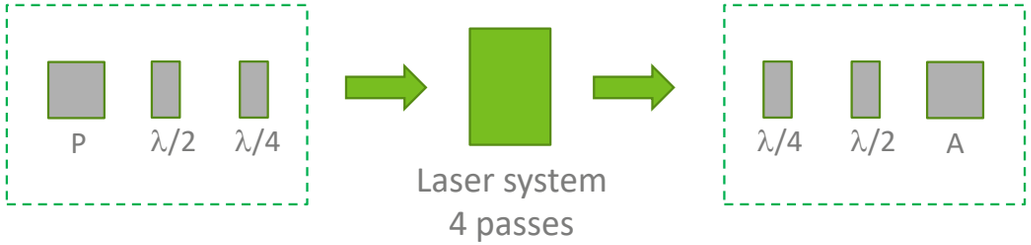




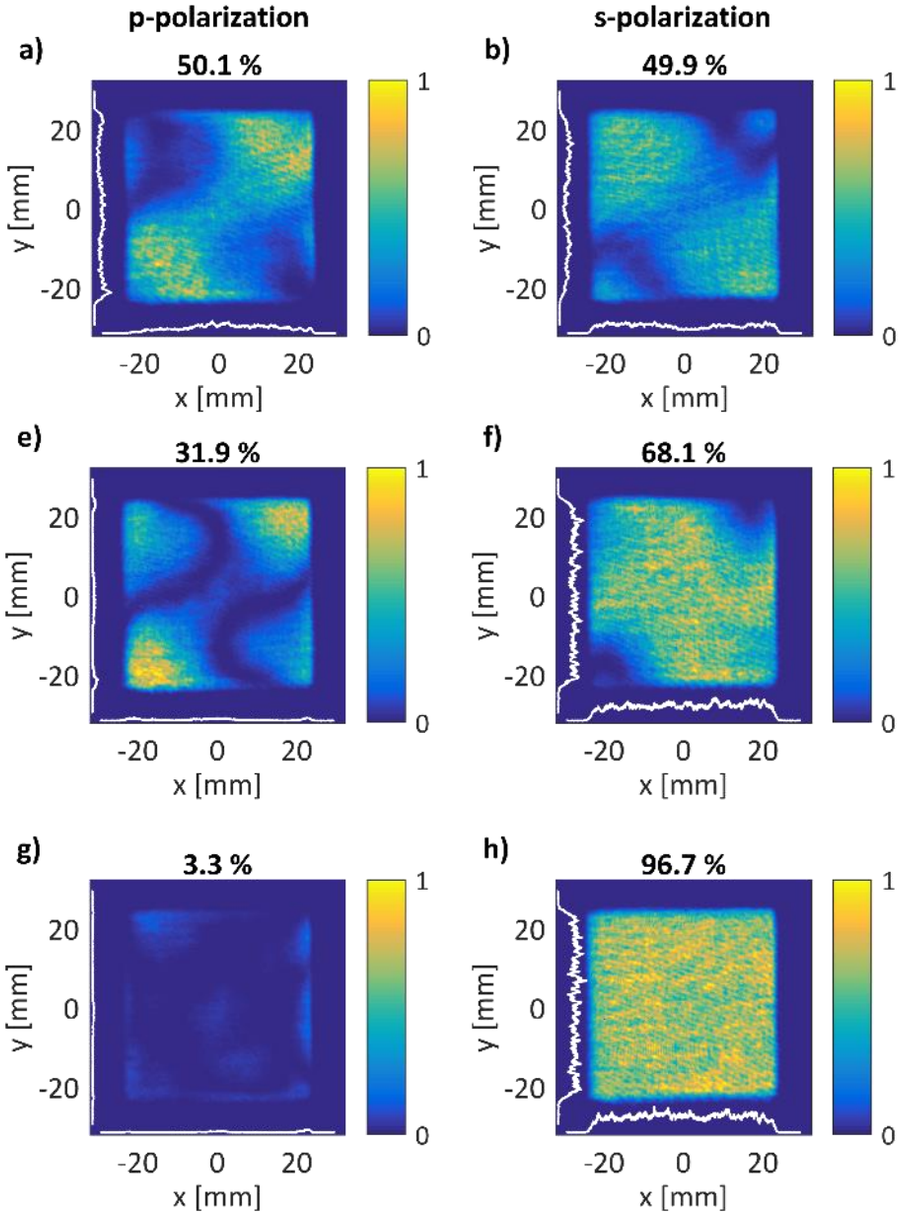


Supression of depolarization losses in Bivoj setup

- We obtain full information about polarization properties of the system by polarimetry

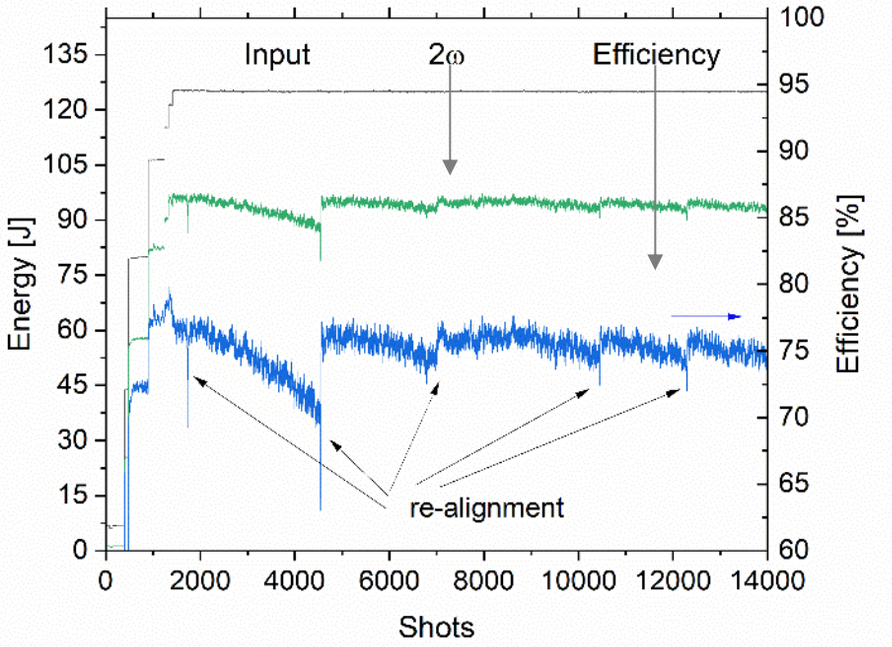


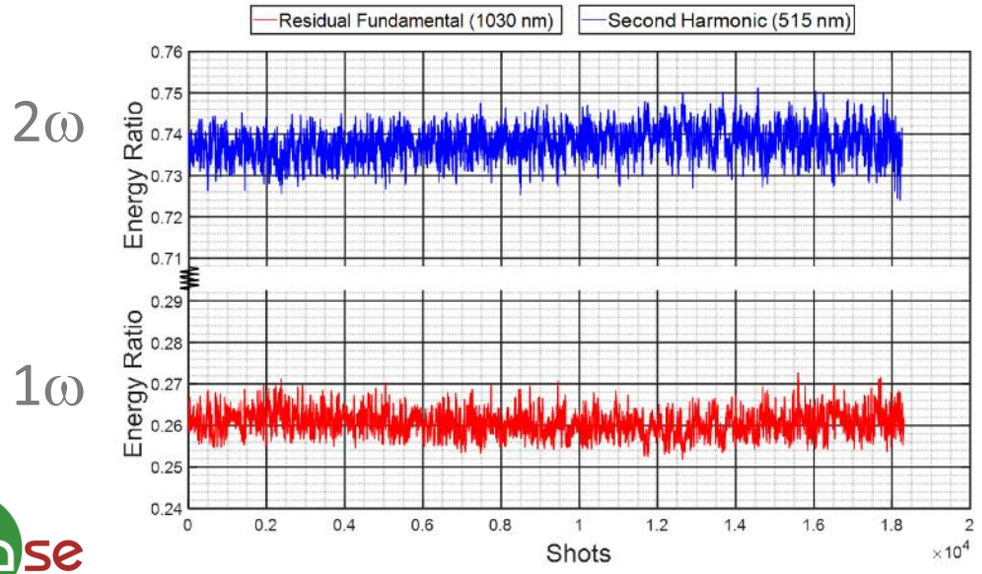
- Numerically find the best input and output polarization to minimize polarization losses
- Polarization losses
  - ➢ Unoptimized – 50%
  - ➢ Post compensation – 32%
  - ➢ Input/output optimization – 3%

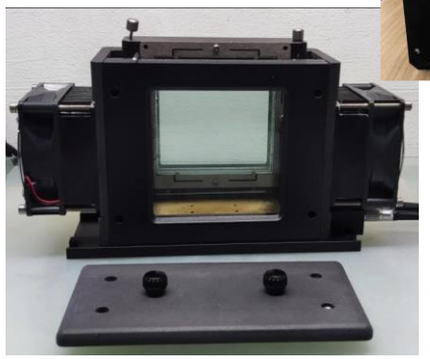


Second harmonic generation

- SHG 515 nm, 10 Hz
- Output 95 J (world record power for > 1 J)
- Efficiency >75% (peak 80%)
- After thermalization, excellent stability
- 0.5% RMS, 2% P-t-P
- LBO crystal 60x60x13mm^3, Type I, 30°C







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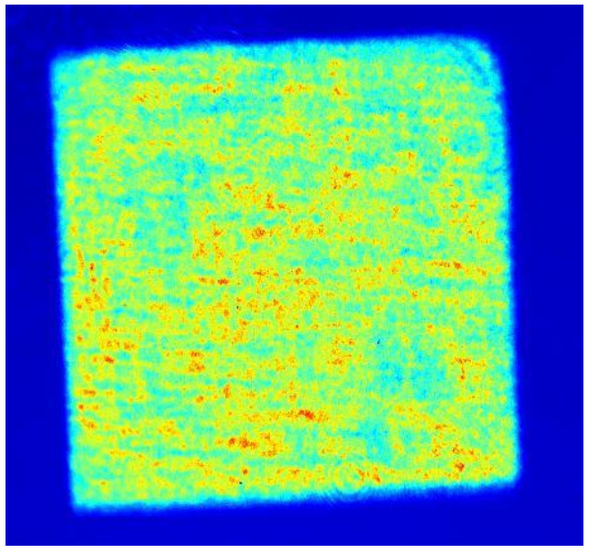
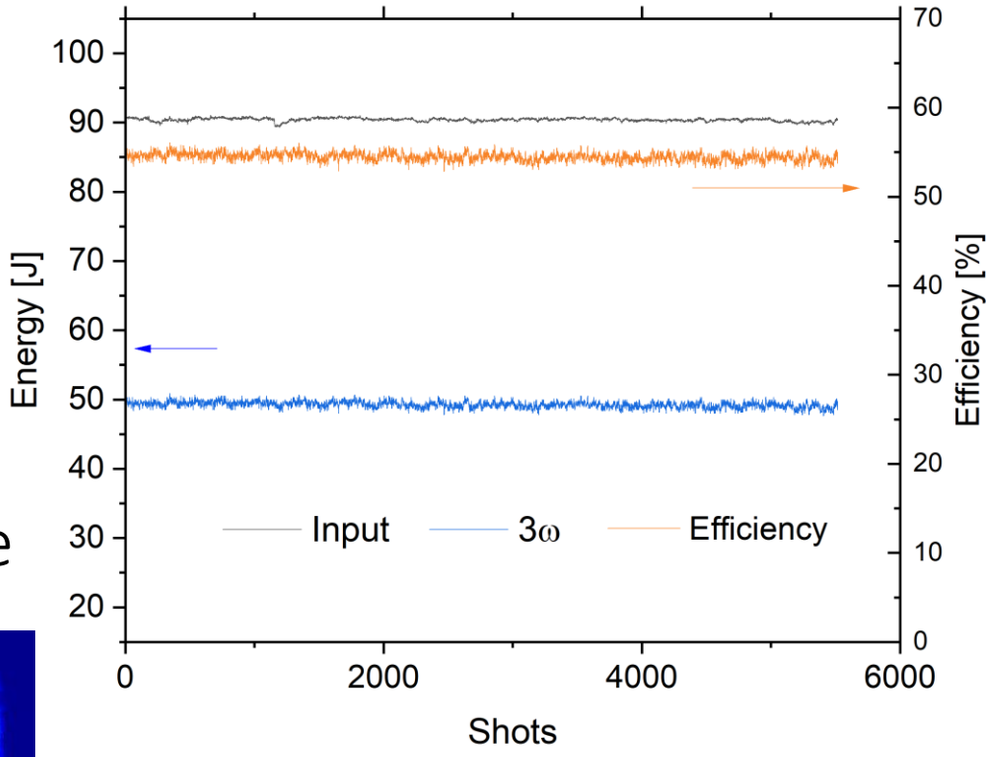


Third harmonic frequency generation

- THG 343 nm, 10 Hz
- Output 49.5 J (4x world record power)
- Efficiency >55% (peak 60%)
- After thermalization, good stability
- 1% RMS, 6% P-t-P, but bad homogeneity
- LBO crystal used for SFM, 60x60mm^2 aperture



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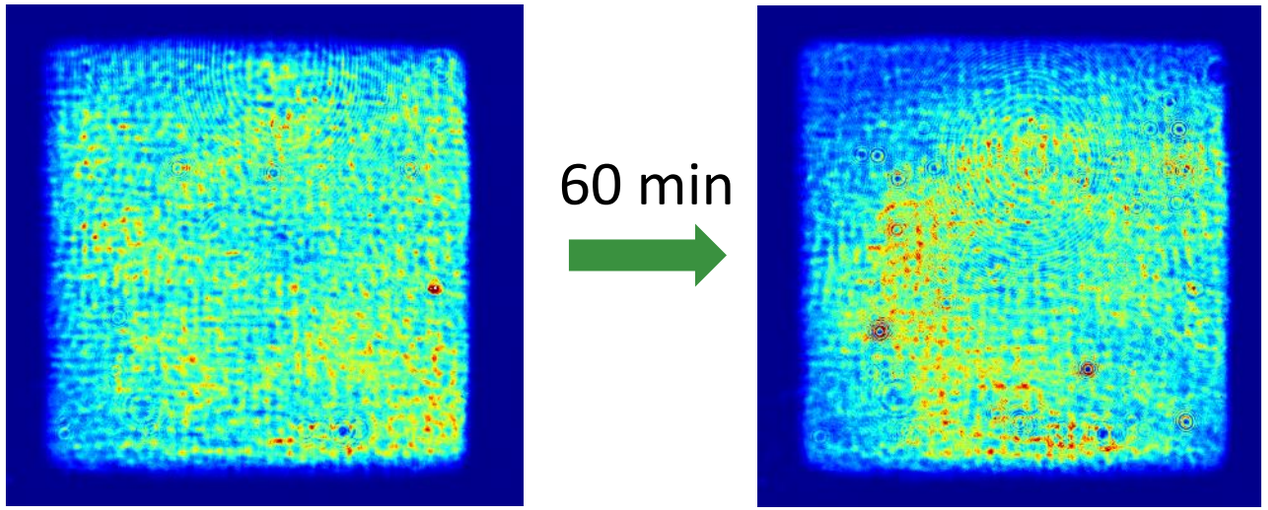
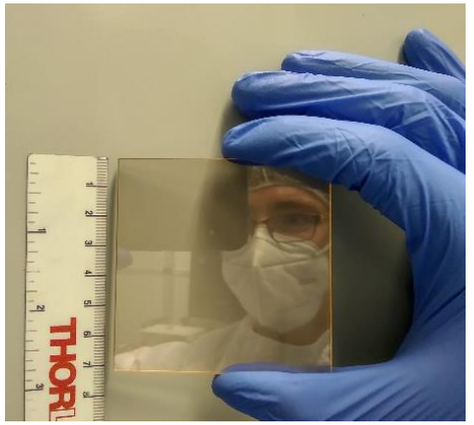


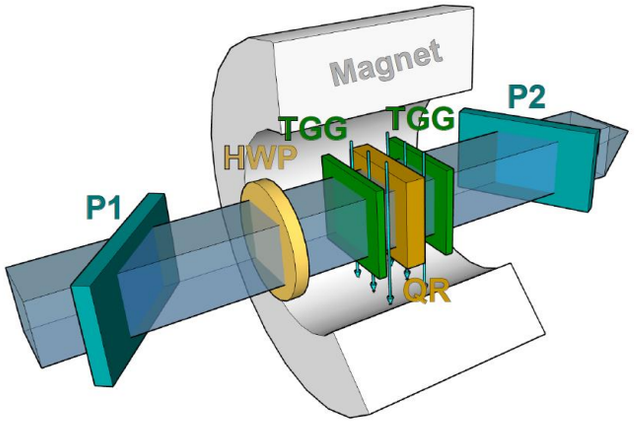
60 min

Faraday isolator

- 100J/kW power Faraday isolator for pulsed beam with large aperture
- >30 dB isolation ratio for 1 kW
- Beam size 60 x 60 mm^2
- Based on TGG material



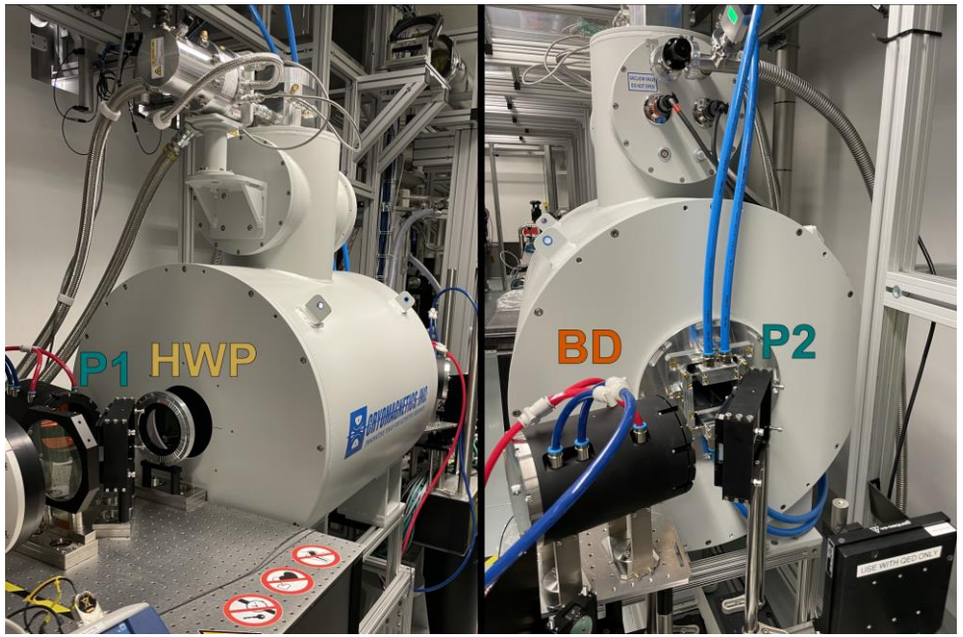
Two 69 x 69 x 3.6 mm^3
TGG ceramics/crystals



Compensation & suppression of the thermal effects

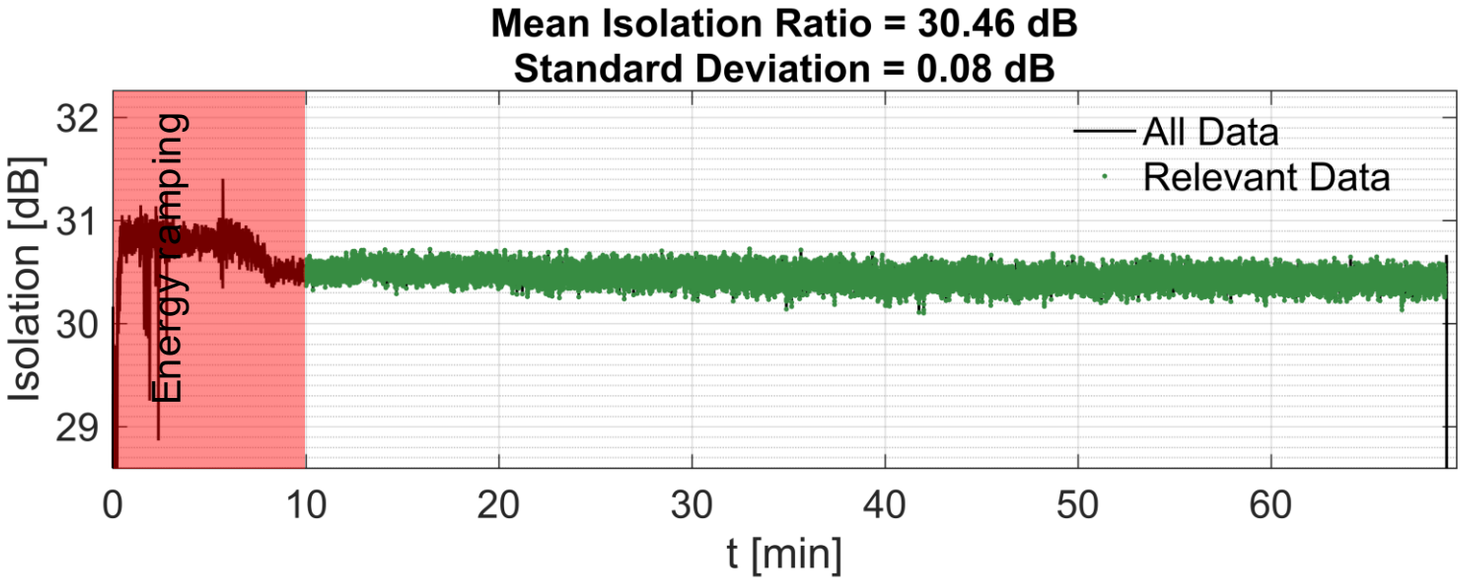
Thermal stress induced birefringence (photo-elastic effect)

1. Partial compensation via suitable optical layout with 67.5° quartz rotator
2. Cooling provided by forced airflow through the thin ducts between the QR and TGGs
3. Numerical modeling



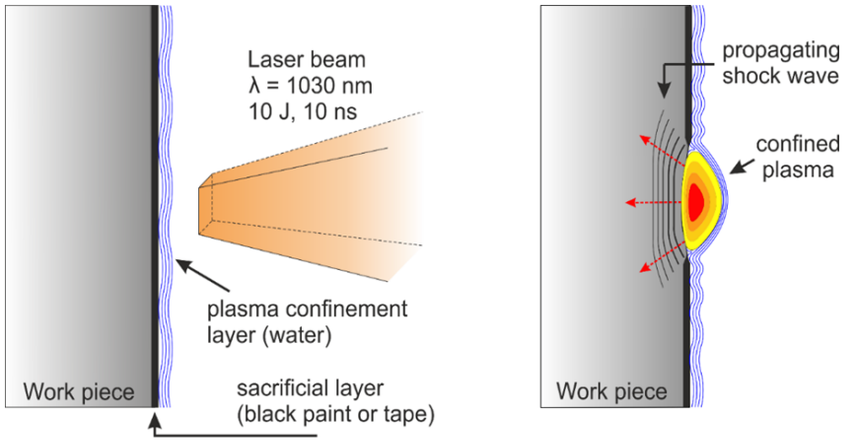
Operation with crystalline TGG

- Tested for 100 J/10 Hz output from the final amplifier
- TGG crystal slabs installed
- Air flow set on maximal tested velocity (≈35 m/s)
- Isolation ratio of >30 dB recorded during an hour long testing run, without any decrease due to the thermal effects

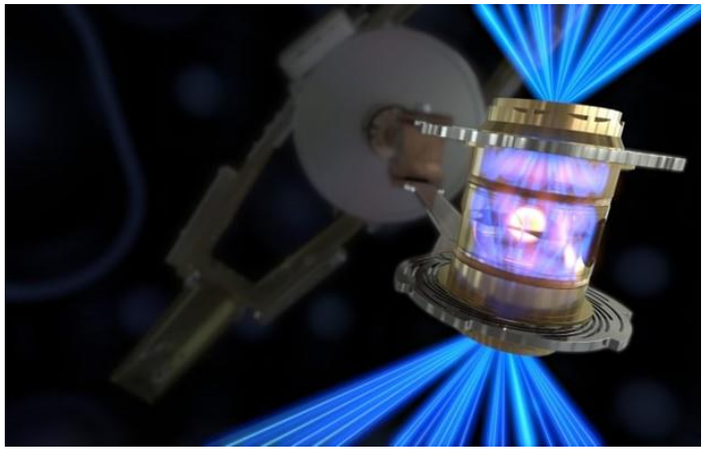


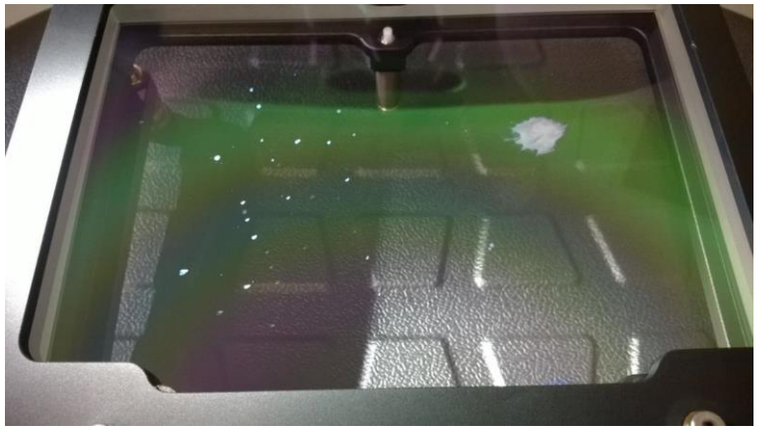
Applications

- Driver for high-energy fs OPCPA
- Tool for industrial LSP process
- Analysis of Laser Induced damage threshold
- Nuclear fusion driver (upscaling)



LSP mechanism





Summary

- Long-term operation of Yb:YAG Bivoj laser at 143 J@10 Hz
- 95 J@10 Hz at 515 nm reached with 75% conversion effciency
- Almost 50 J @ 10 Hz demonstrated at 343 nm
- Unique Faraday isolator with >30 dB ratio comissioned

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THANK YOU FOR ATTENTION!

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Institute of Physics of the CAS

Za Radnici 828
252 41 Dolni Brezany