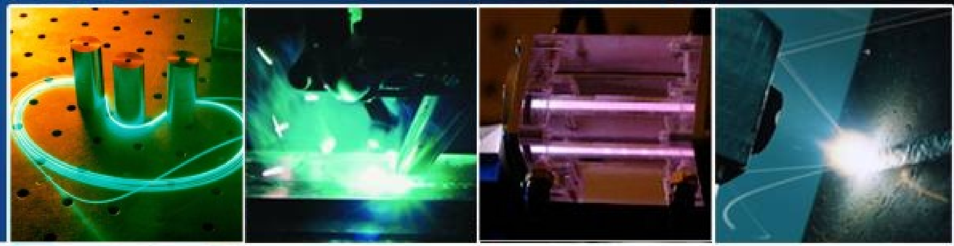
PEOPLE MATTER

research
development
consulting



LASER ZENTRUM HANNOVER e.V.

Passively Q-Switched Nd:YAG Laser for Spaceborne Laser Altimetry – Bepi Colombo (Mercury) Altimeter

J. Neumann, S. Hahn, R. Huß,
R. Wilhelm, M. Frede, D. Kracht

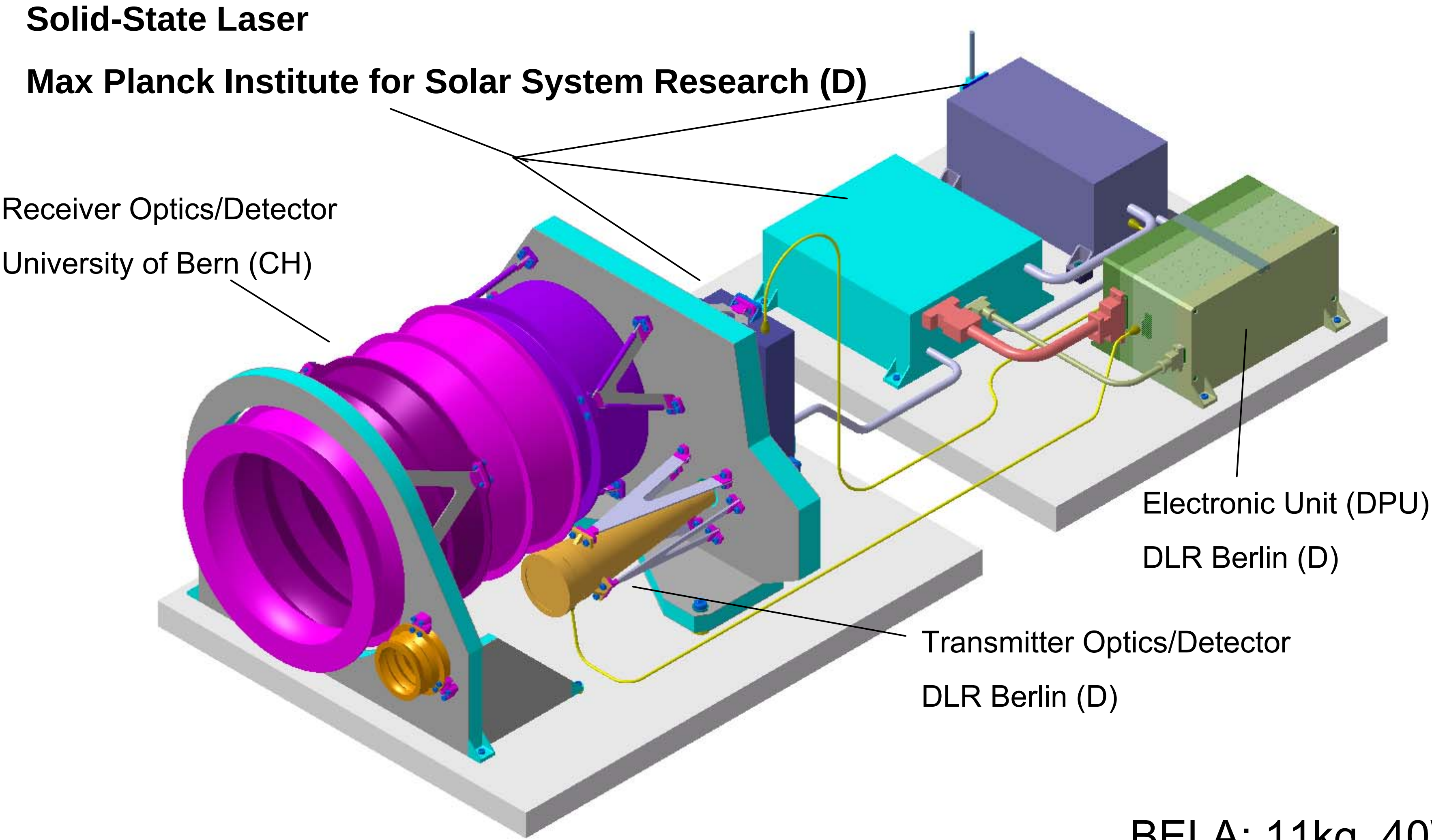
Overview

- BELA laser requirements & conceptual laser design

- Testbed setup for feasibility study
  - Laser performance
  - Temperature dependencies

- Optical & mechanical design of prototype models (PM)

BELA - BepiColombo Laser Altimeter



BELA: 11kg, 40W

BELA Diode Pumped Solid-State Laser

Pump Diode Unit

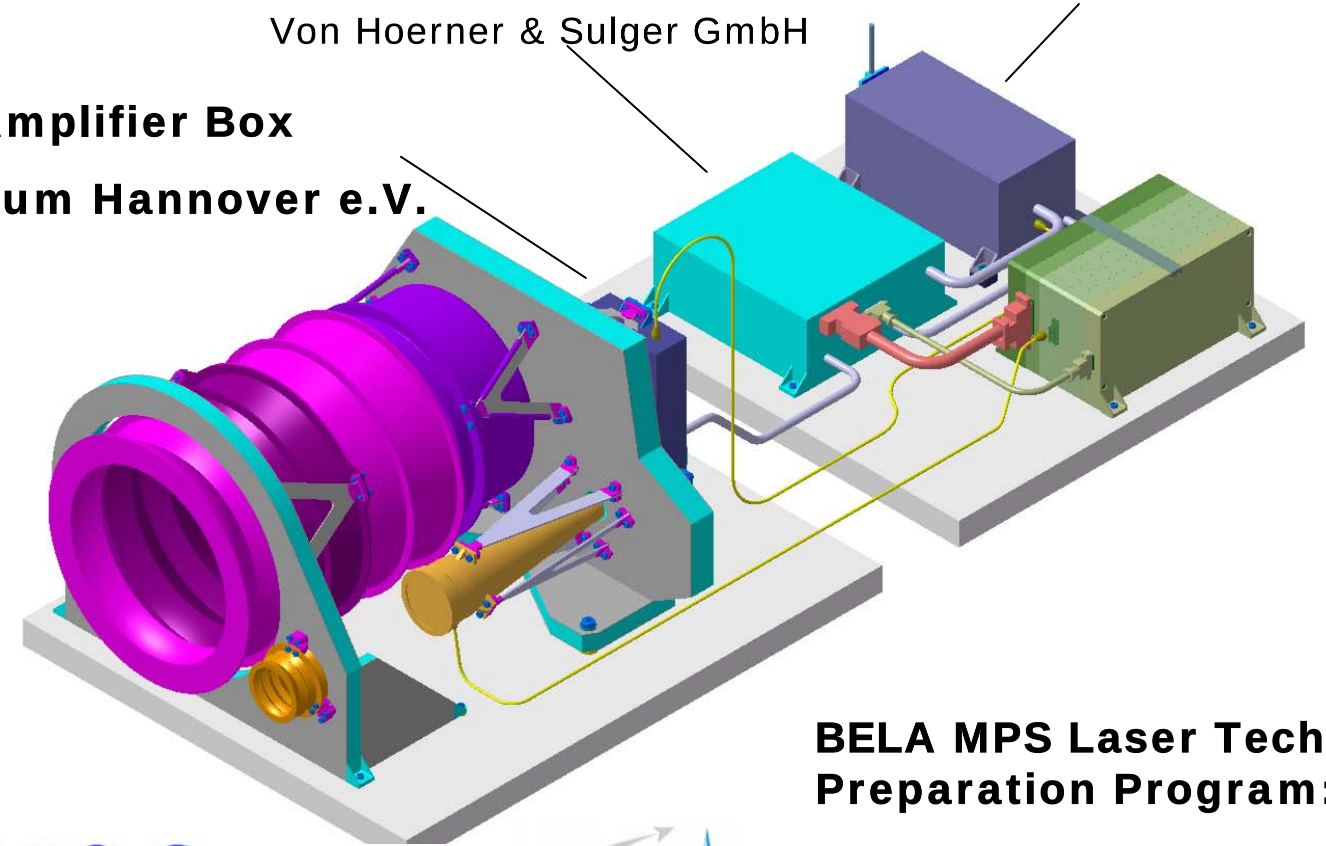
DILAS Diodenlaser GmbH

Laser Electronic Unit

Von Hoerner & Sulger GmbH

Oscillator Amplifier Box

Laser Zentrum Hannover e.V.



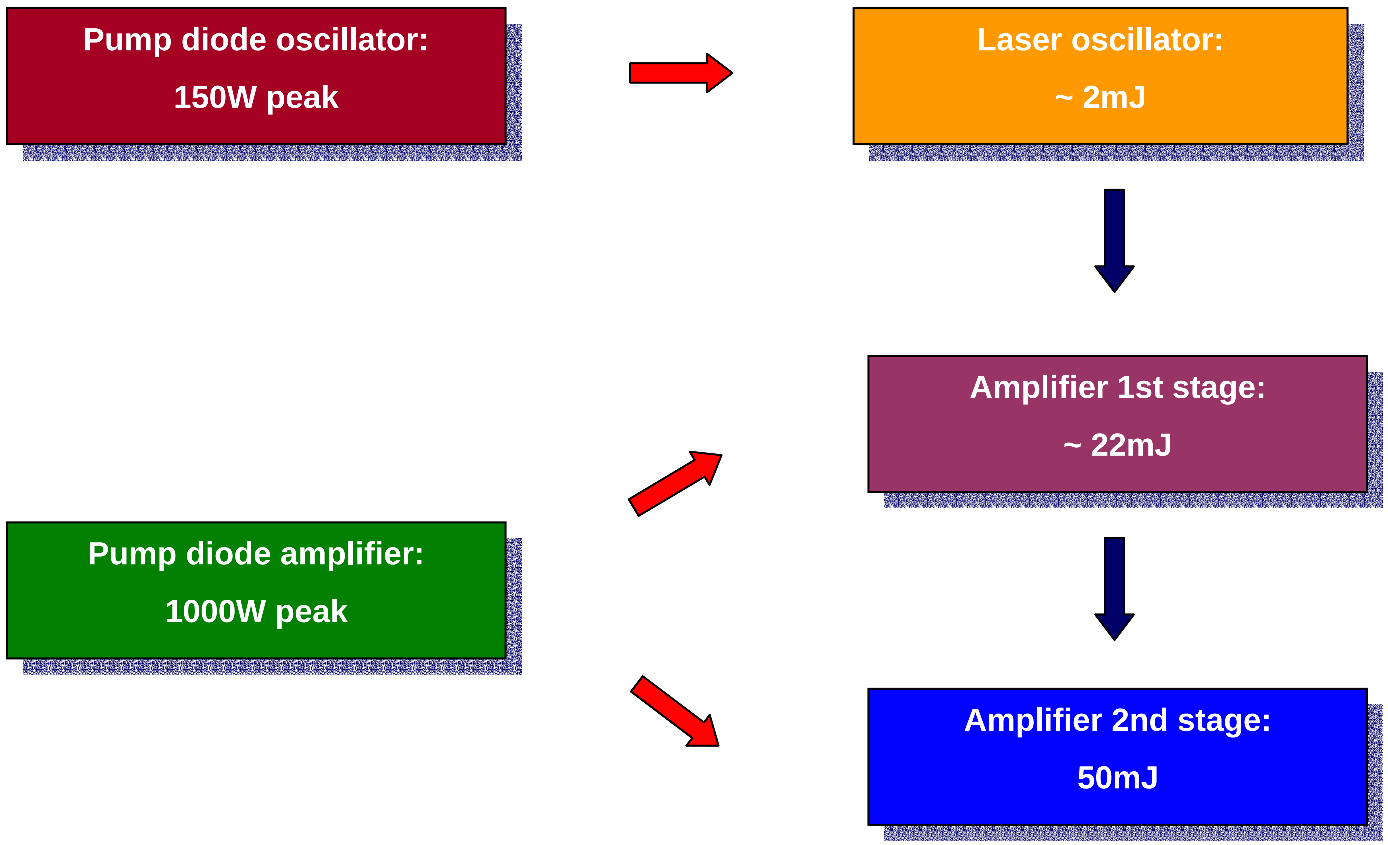
BELA MPS Laser Technology Preparation Program:

vH&S LZH EADS DILAS Diodenlaser GmbH **for** MPS

BELA Laser Requirements

– Pulse energy	>50mJ
– Pulse duration	<10ns
– Beam quality	$M^2<1.6$
– Repetition rate	10Hz
– Wavelength	1064nm
– Radiation	100krad
– Op. temperature	20-45°C (laser head)
	18-33°C (pump diodes)

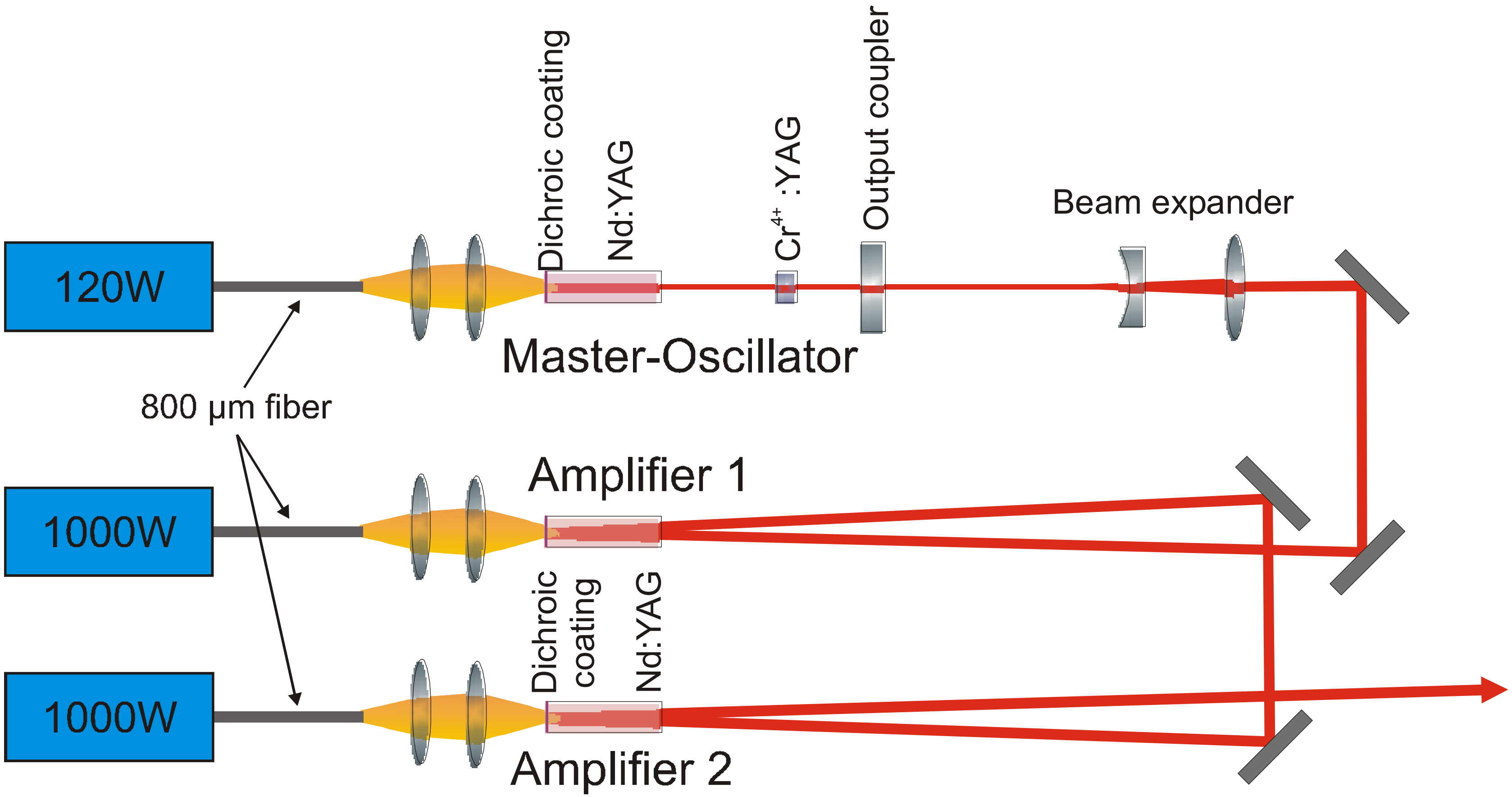
BELA Laser System Concept



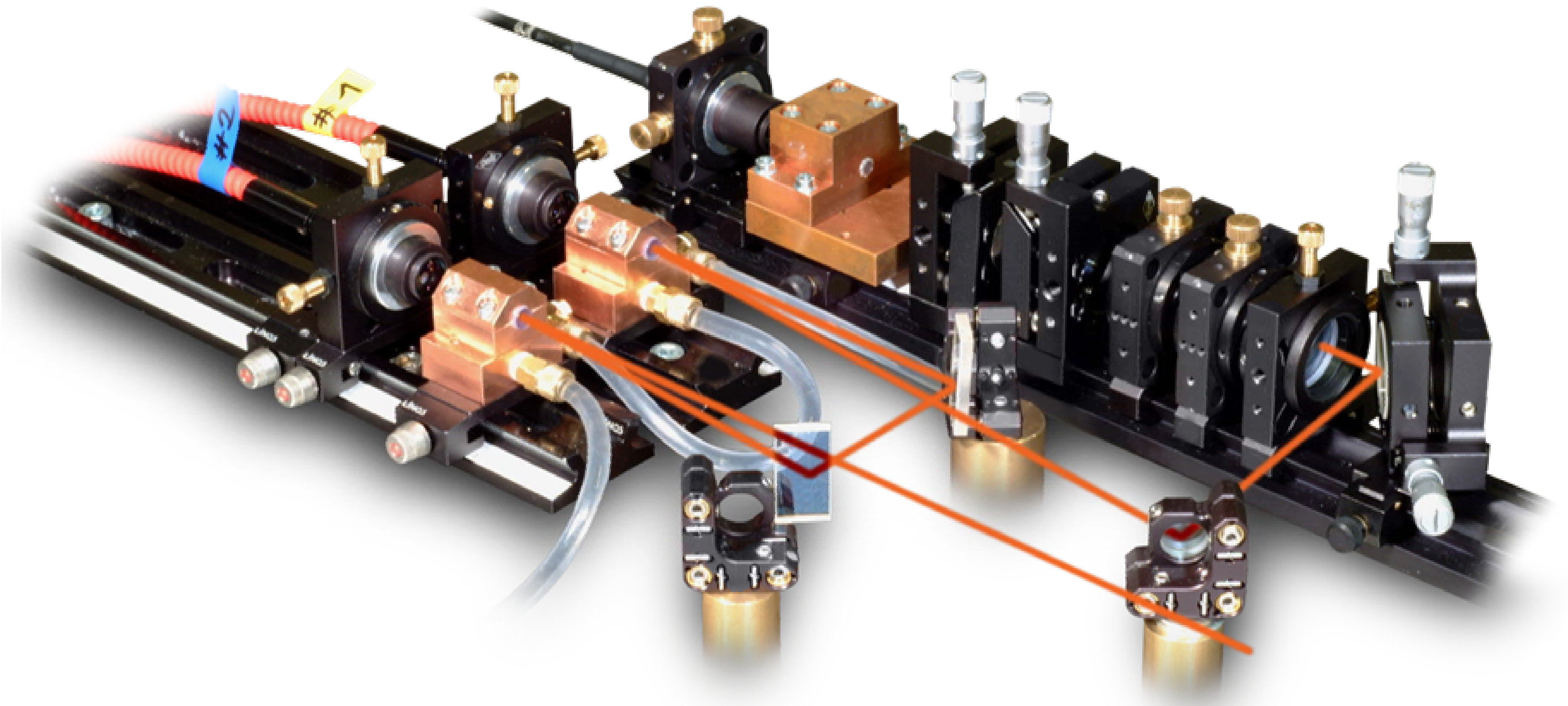
BELA Laser Design Concept

- Fiber coupled pump diodes
  - Separation of pump source and laser head
- Longitudinal pumping scheme
  - Optimized overlap pump beam / laser mode
  - Higher efficiency
  - Long absorption path in laser crystal
- q-cw pumping
  - 200µs pump pulse duration as a trade off between efficiency and output energy
- Passive Q-switching with saturable absorber Cr^{4+}:YAG
  - Simplicity
  - Low mass
  - Low power consumption
- 2-stage amplifier
  - Splitting of energy into 2 stages to avoid self-lasing

Master Oscillator Power Amplifier (MOPA)

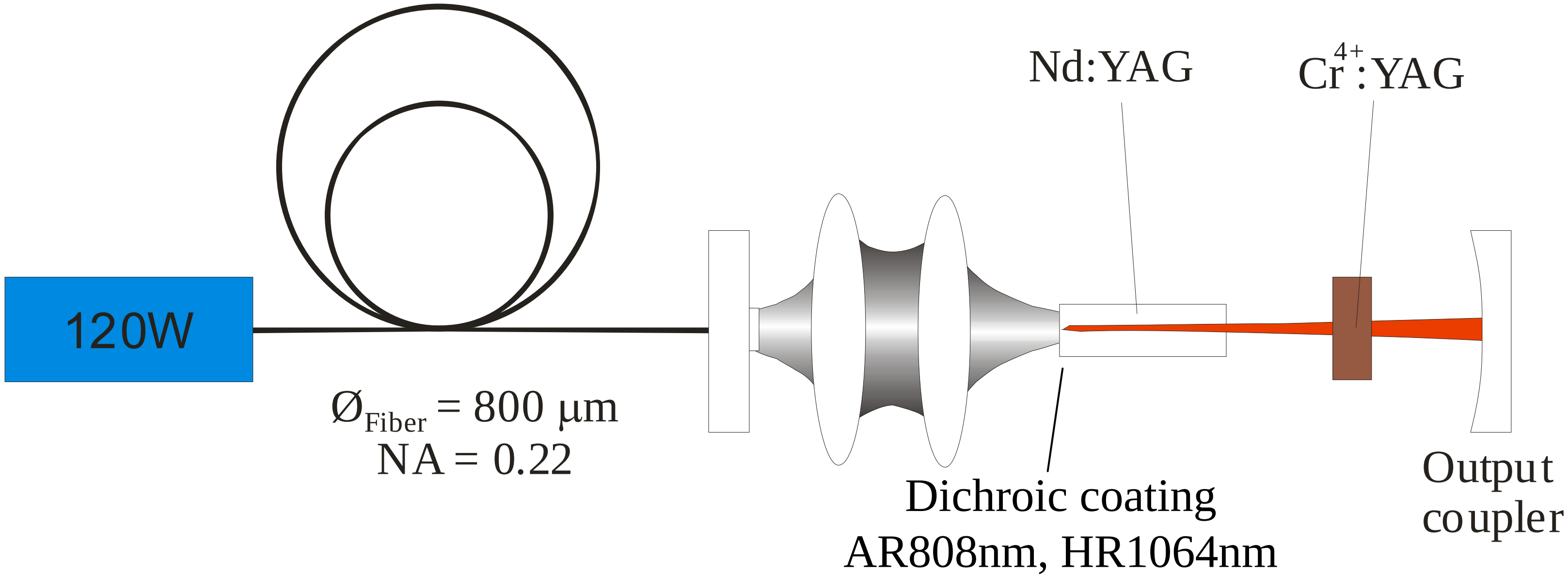


Miniaturized Testbed



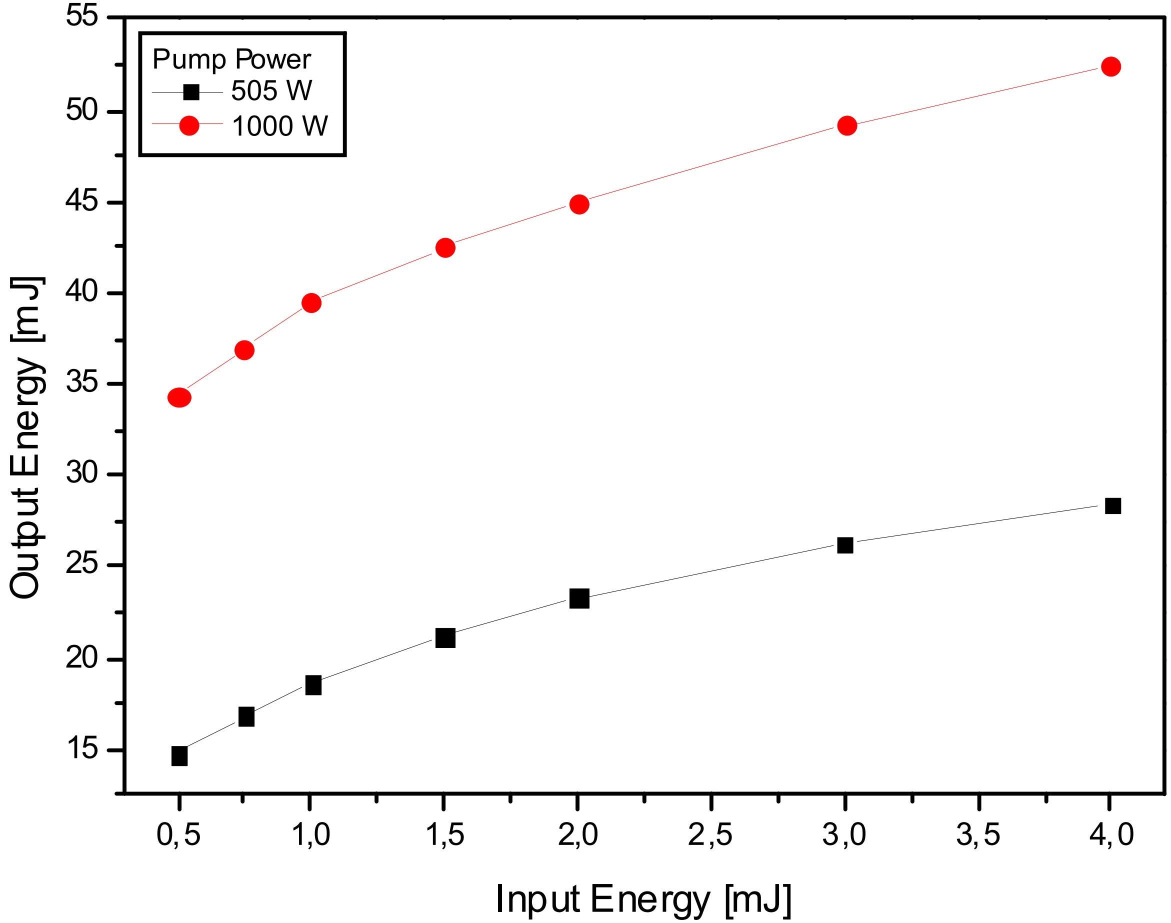
Mass of optical components ca. 40g

Laser Oscillator



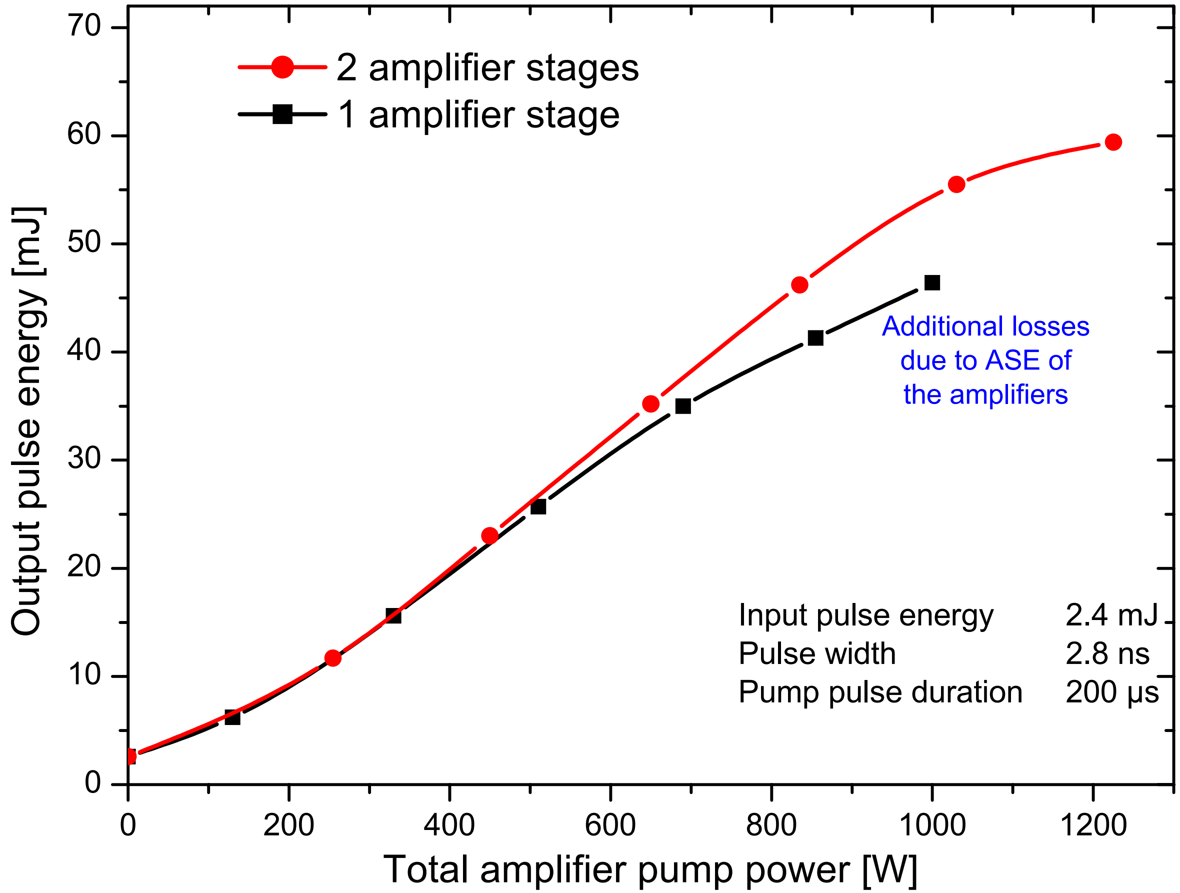
- Pulse energy: 2.4 mJ
- Pulse duration: 2.8 ns
- Beam quality: M^2=1.2
- Peak-pump power: 104 W
- Pump duration: 200 µs
- Opt.-opt. efficiency: 12 %

Amplifier: 1st Stage



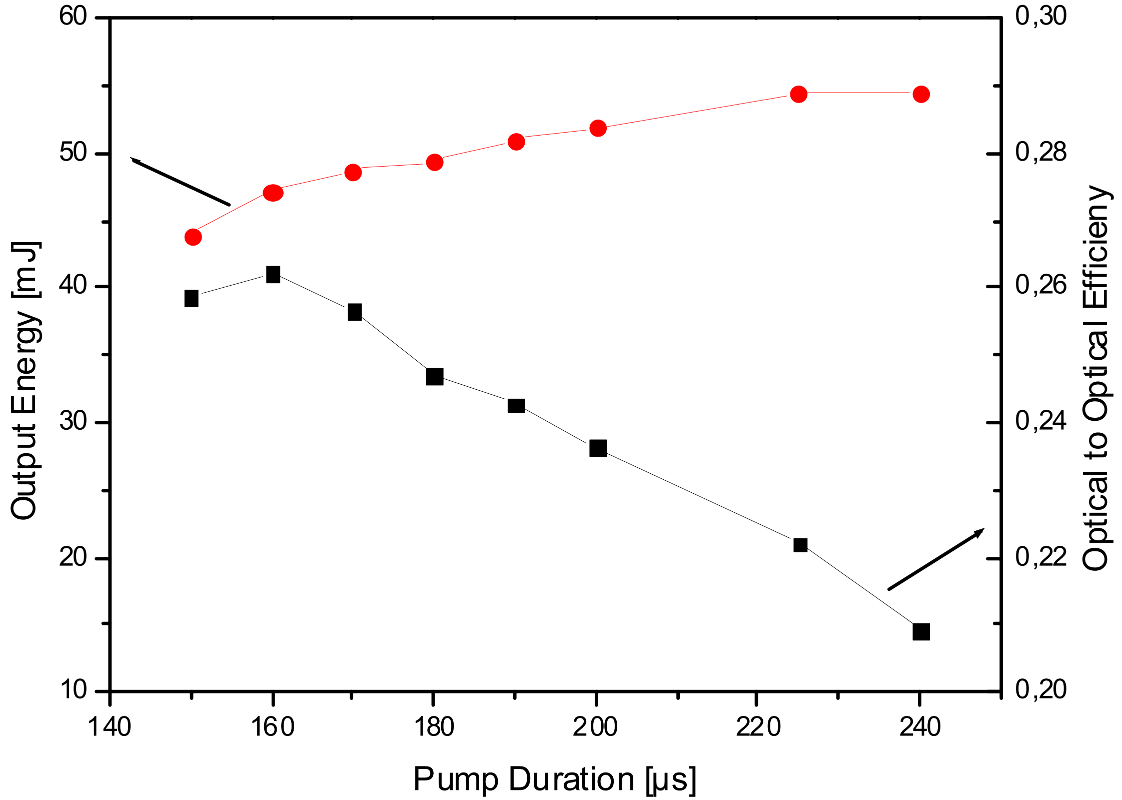
Saturated effective amplification @ > 2 mJ seed energy

Power Amplifier



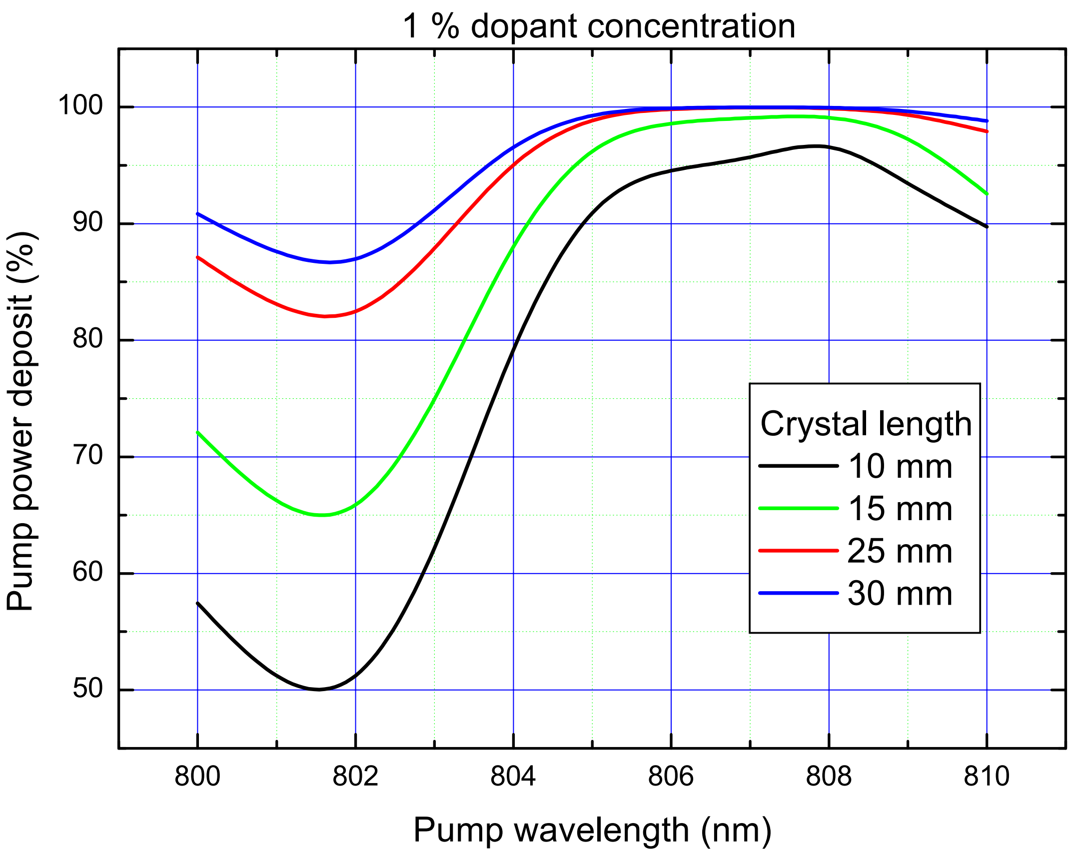
>50mJ @ 2 x 550 W, $M^2 < 1.5$

Optical-to-optical Laser Efficiency



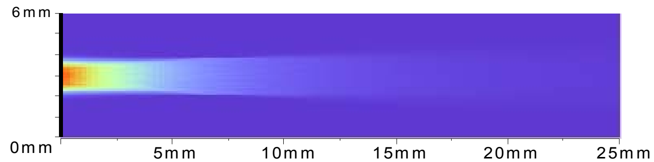
Optical-to-optical efficiency: ≈23% @ 200µs

Pump Light Absorption

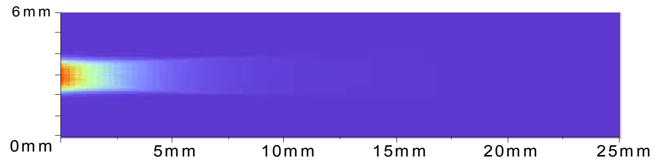


Pump diode shift: 0.25nm/K
-> 3.75nm for ΔT=15K

803 nm



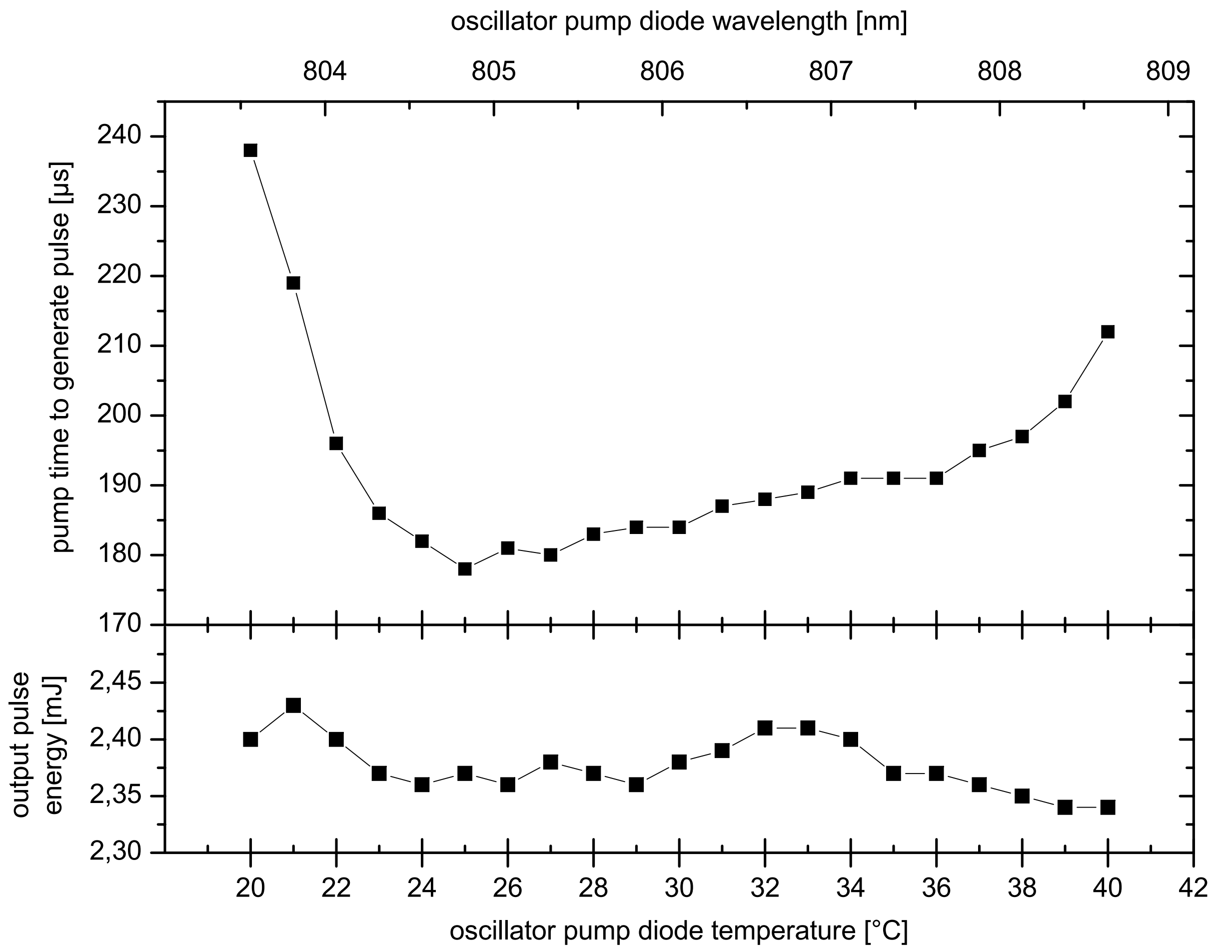
807 nm



$\Delta\lambda$(FWHM) = 2.5 nm

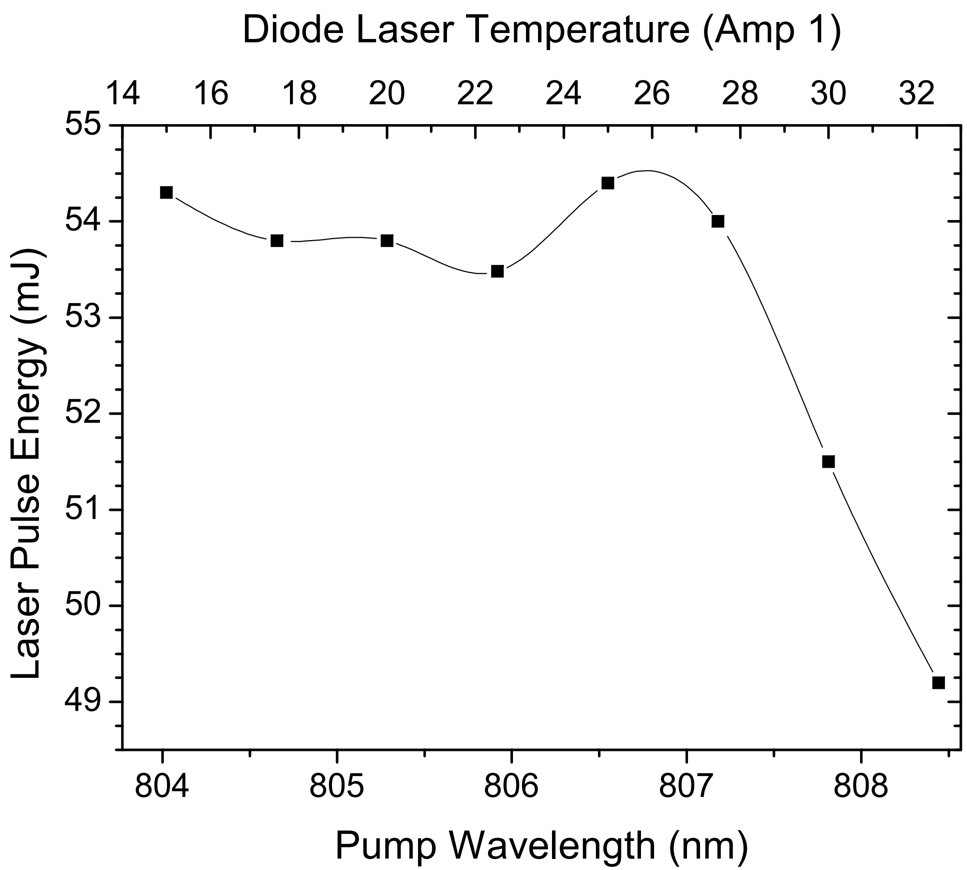
Absorption > 95% between 804nm and 809nm for 25mm crystal

Temperature Range: Oscillator Pump Diodes



Temperature acceptance range: $\Delta T > 15K$

Temperature Range: Amplifier Pump Diodes



Temperature acceptance range: ΔT > 15K

Testbed Laser Performance

✓ Pulse energy	54mJ
✓ Pump energy	245mJ
✓ Pump power	2x 550W +100W
✓ Pump duration	200µs
✓ Beam quality	$M^2 < 1.5$
✓ Pulse duration	2.8ns

✓ Temperature acceptance range for pump diodes $\Delta T > 15K$

Requirements for Flight Model

• Mass (laser system)	4kg
Laser head	<1.3kg
• Total ionizing radiation dose	100krad
• Vibration level (Sojuz)	$26g_{rms}$
• Operating temperature	20-45°C
• Non-operating temperature	-40-60°C

- Sealed pressurized box to avoid contamination of optics

Mass of optical components approx. 40g

Most of the mass due to housing in sealed box

2 Prototype Models

- Prototype I

  Optical functionality for integration in BELA instrument prototype

- Prototype II
  - Laser operation during thermal cycling
  - Verification of thermal model
  - Vibration tests of subcomponents

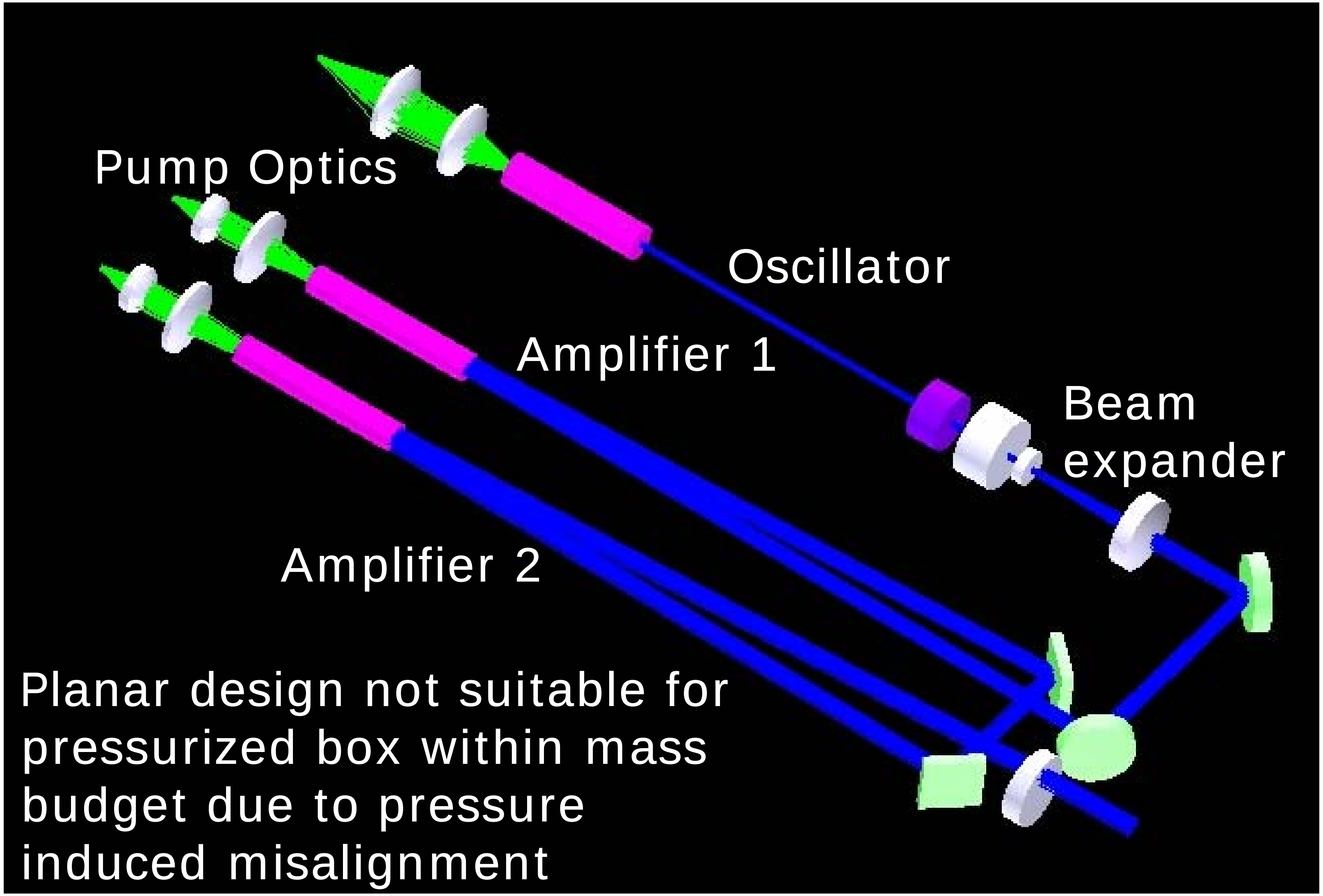
Modular concept: reversible screw joints / O-ring sealed -> easy replacement of non-adequate parts

Prototype Model Optical Materials

• Mirrors, lenses, windows	fused silica
• Aspheric lenses in pump optics	Co550
• Laser crystals	Nd^{3+}:YAG
• Passive Q-switch	Cr^{4+}:YAG

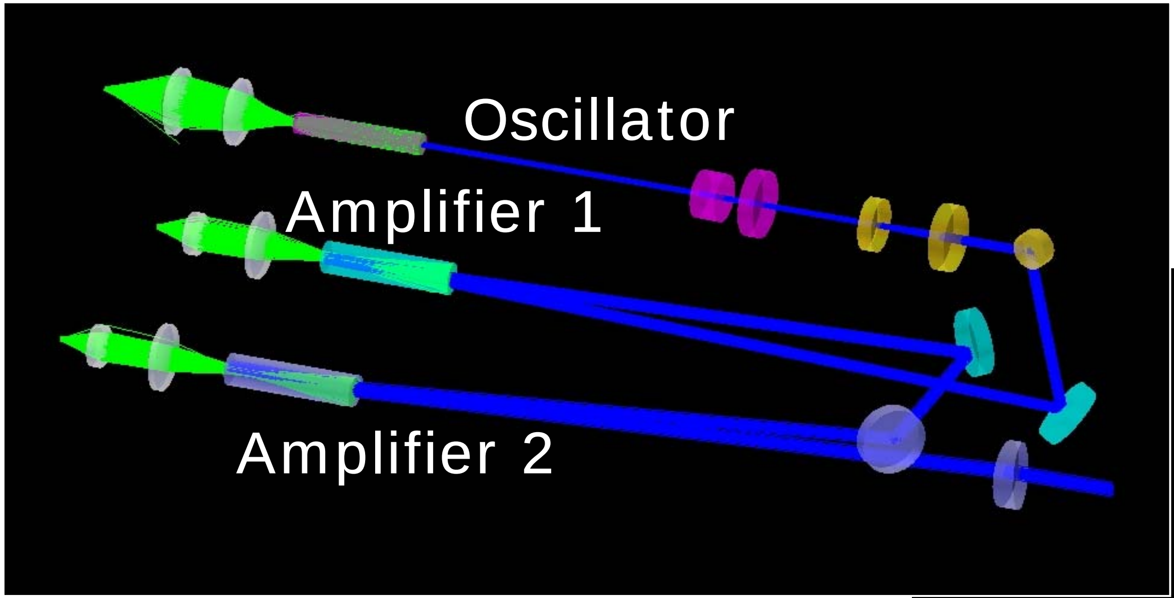
→ Materials already used for other space missions, i.e. can be made radiation hard

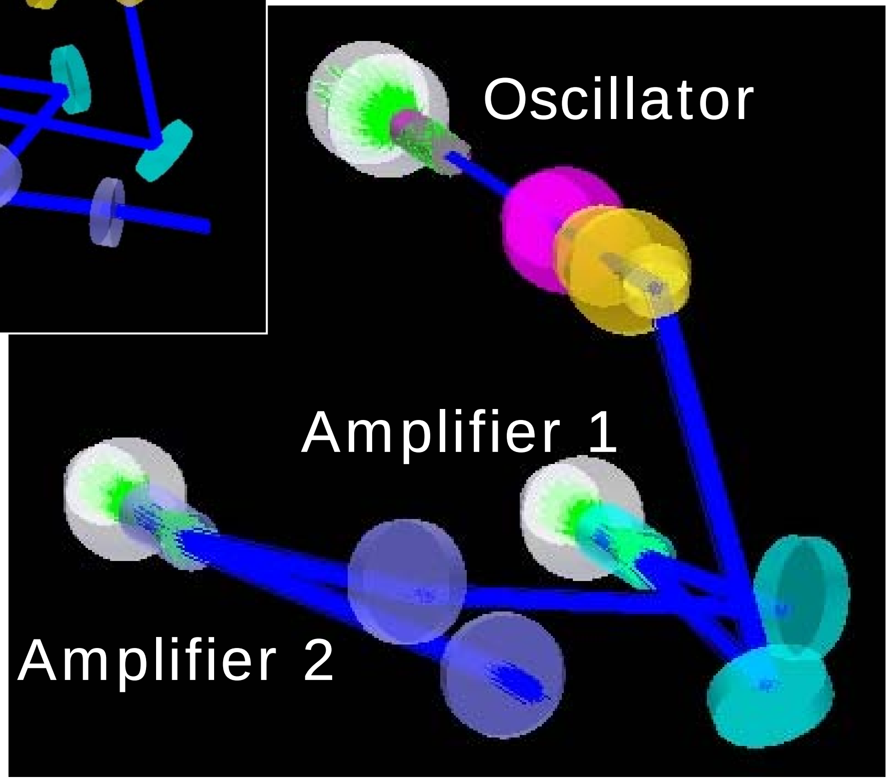
Planar Testbed



Planar design not suitable for pressurized box within mass budget due to pressure induced misalignment

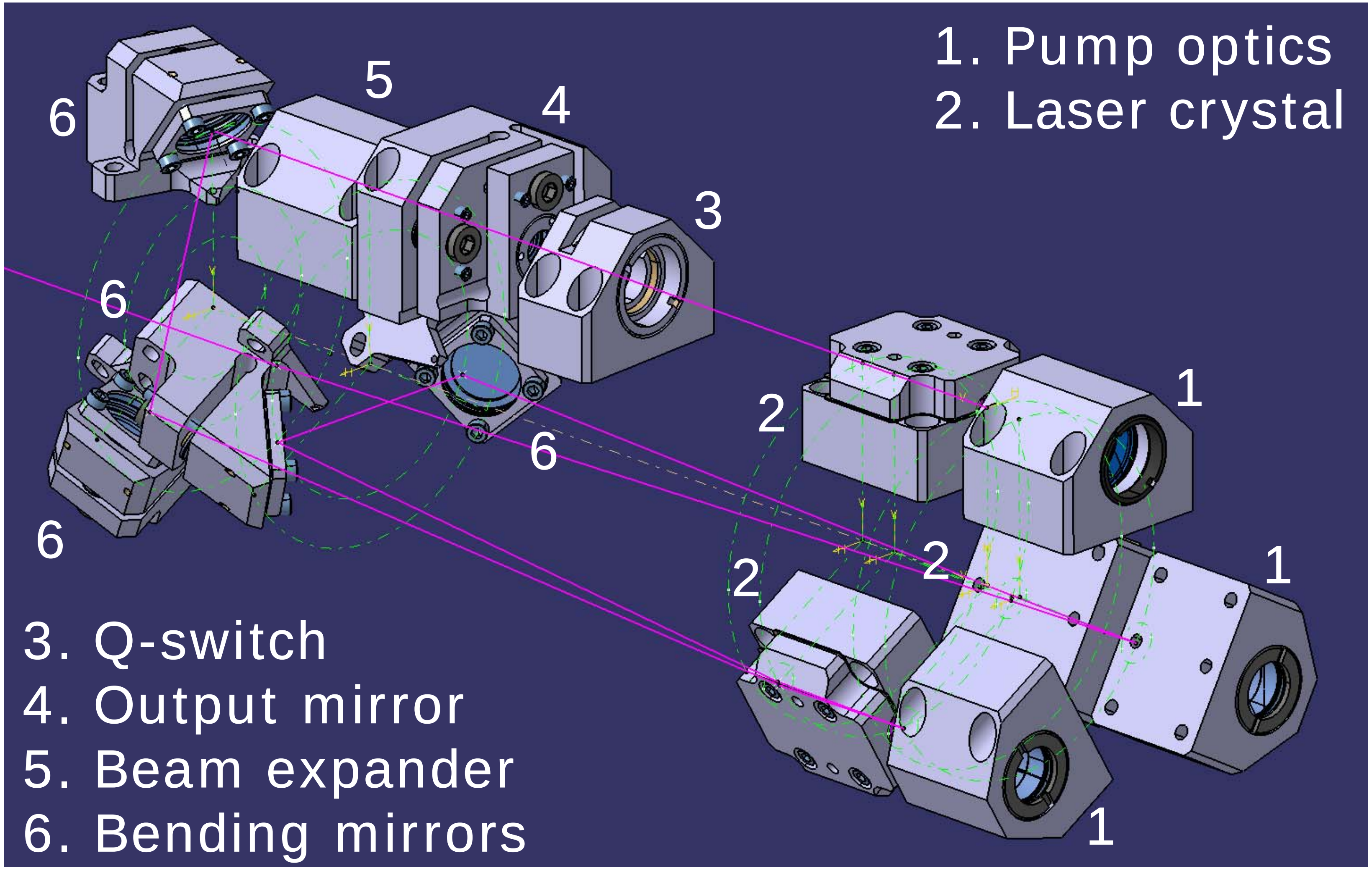
Optical Design for Prototype



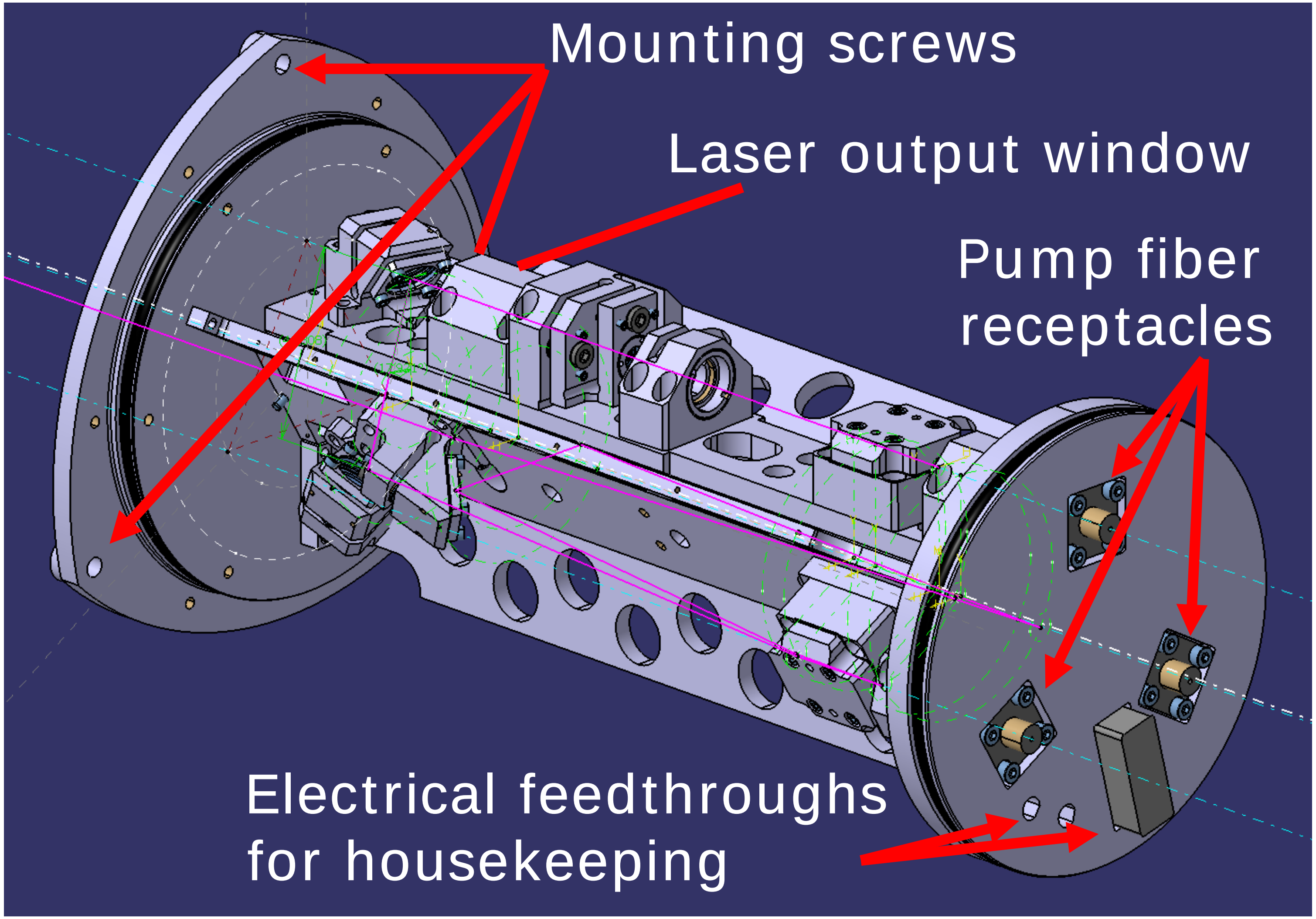


- 3D Optical Design (Zemax)
- Only reflection angles at bending mirrors have changed compared to testbed

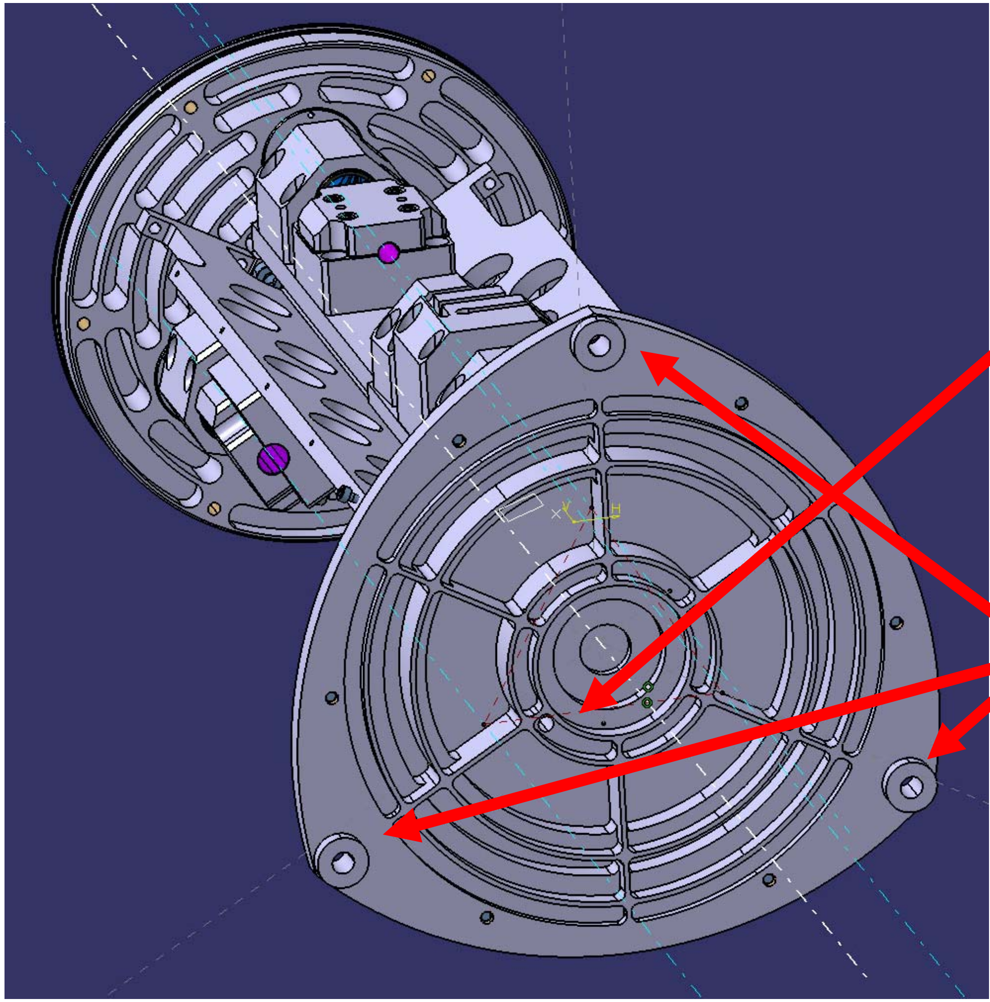
Mechanical Mounts for Optics



Optical Bench



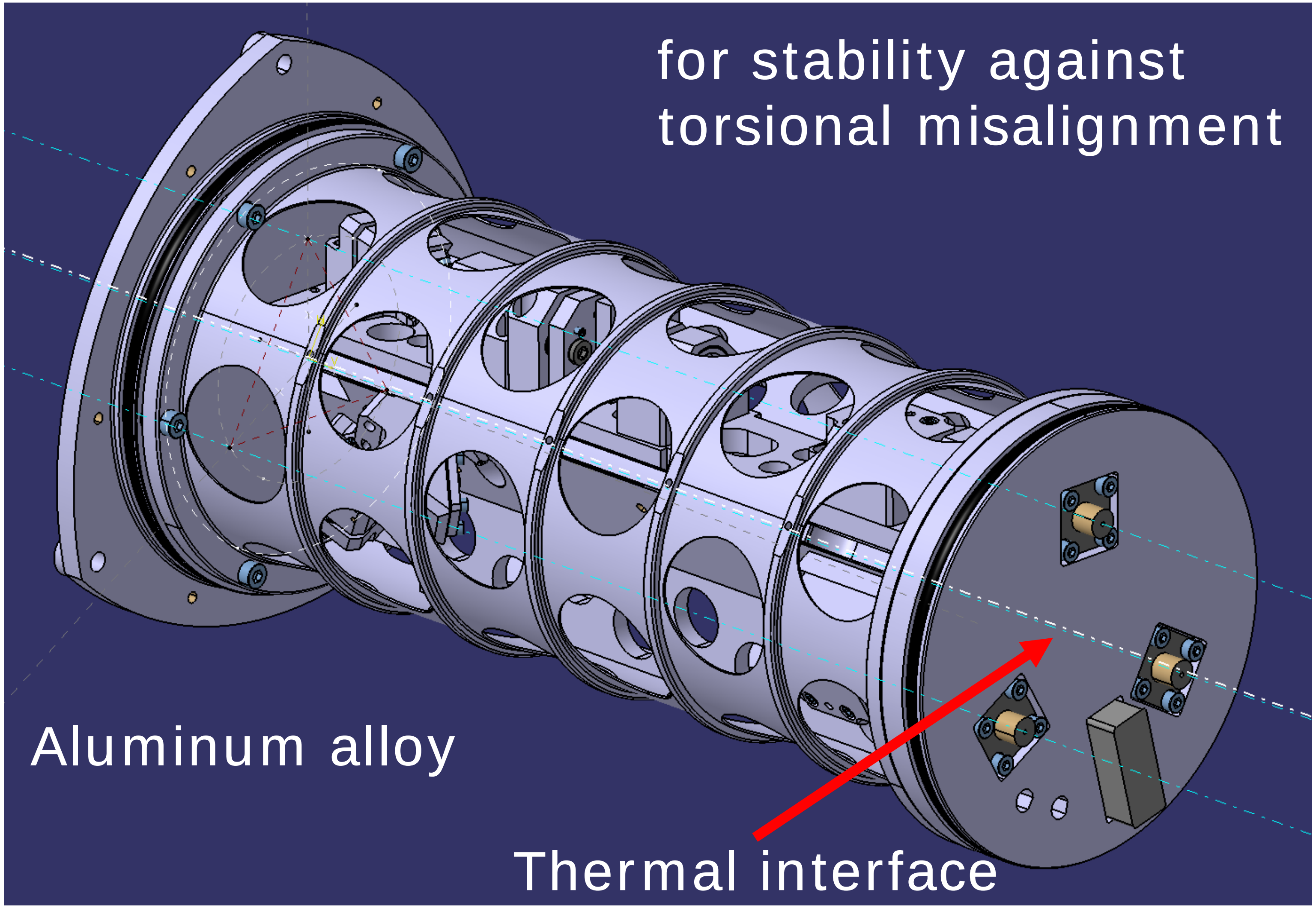
Mounting



Laser output window

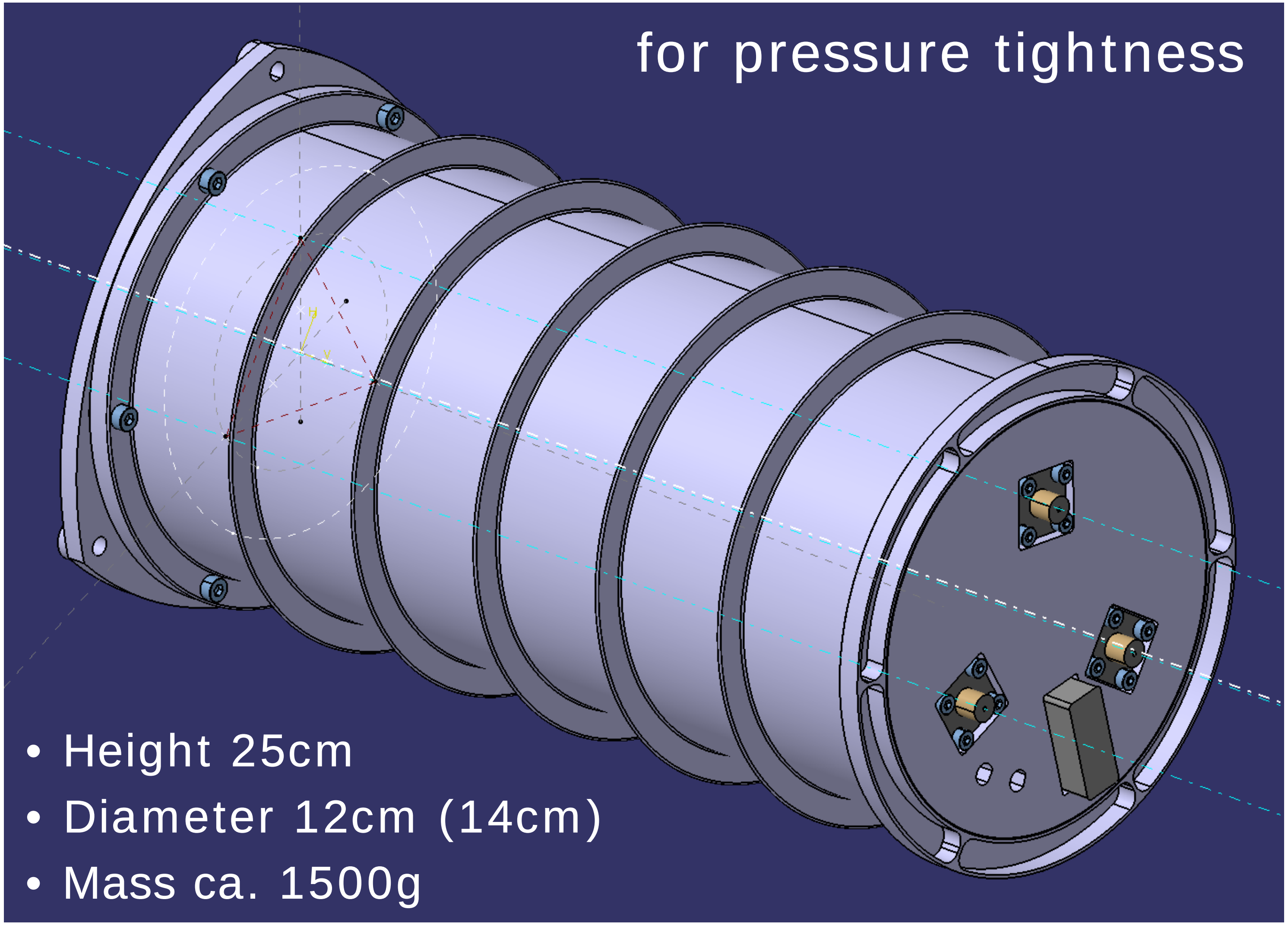
Mounting by
M4 screws

Stabilizing Jacket



Sealing Jacket

for pressure tightness



- Height 25cm
- Diameter 12cm (14cm)
- Mass ca. 1500g

Mechanical Design

- Good volume to surface ratio -> low mass for pressurized box
(Prototype Model ~1.5kg, Flight Model <1.0kg)

- Rugged optical bench due to highly symmetrical design (mainly symmetrical radial forces induced by pressure difference)

- Low thermally induced optical misalignment due to almost symmetrical thermal load

- Transport of dissipated heat via massive optical bench

Future Work

- Thermal cycling test end of 2006
- Vibration tests of critical subcomponents
- Radiation hard optical components

- Mechanical redesign after thermal cycling / vibration tests
- Replacement of screw joints by irreversible joining techniques (welding, soldering, etc.)

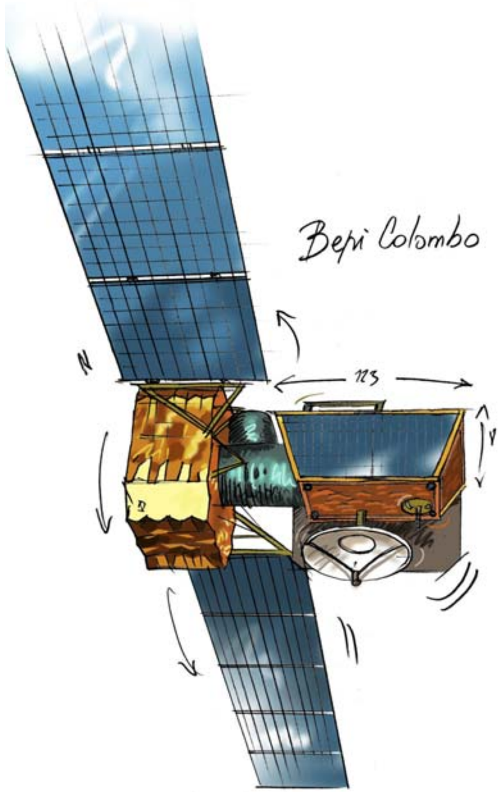
→ Qualification procedure

This work was funded by

- German Aerospace Center (DLR)
- Max Planck Institute for Solar System Research (MPS)

and performed within the framework of the BELA Laser Industrial Team

vH&S LZH EADS DILAS Diodenlaser GmbH for MPS



Contact:

Laser Zentrum Hannover e.V.
Jörg Neumann
Hollerithallee 8
D-30419 Hannover
Germany

E-mail: **j.neumann@lzh.de**