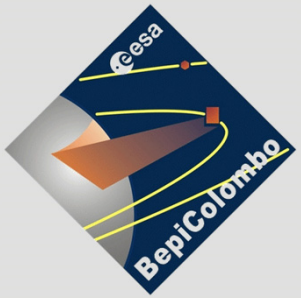
BELA Laser -
Qualifying a reliable laser source for planetary missions



Kai Weidlich, Product Manager High-Performance Optics
Airbus DS Optronics GmbH

24 April 2015

AIRBUS
DEFENCE & SPACE

Outline

Airbus DS Optronics: The Manufacturer of the BELA Laser System

The BELA Laser Design

BELA Laser Qualification Test Results

The Ganymede Laser Altimeter (GALA)

Background – Company Heritage

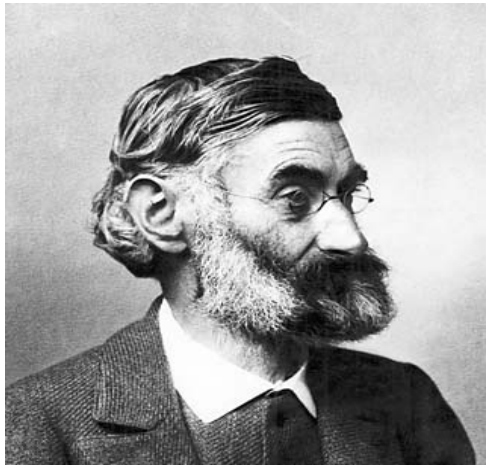
The Making of the Airbus Group - Airbus DS Optronics has its roots within Carl Zeiss

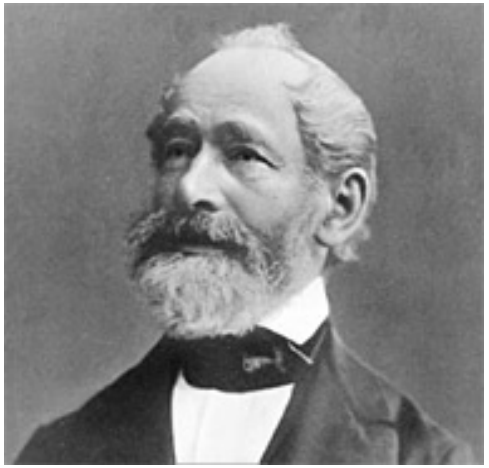
Heritage of Airbus DS Optronics

Carl Zeiss was founded in 1846 as a workshop for precision mechanics and optics

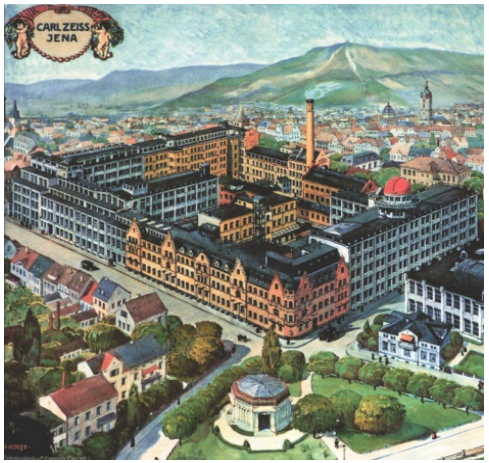
Airbus DS Optronics and Jena-Optronik originate both from the Carl Zeiss group in Jena

Carl Zeiss company has invented the Planetarium and supplies the space business for more than 50 years.





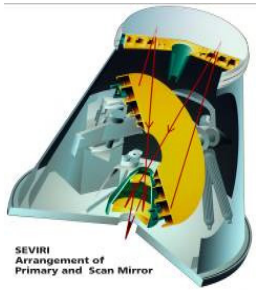
ZEISS



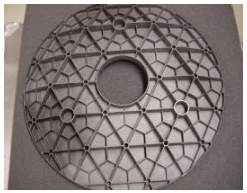
Heritage in High-Performance Optics for Space Applications

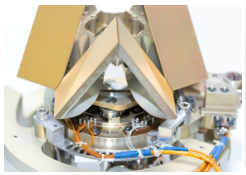
Telescope Systems

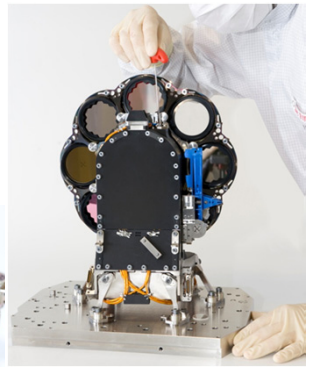
Earth Observation & Science Instruments



- **Spectrometers, spectrographs**
- **Optical telescopes**
- **Precision Optical Components**

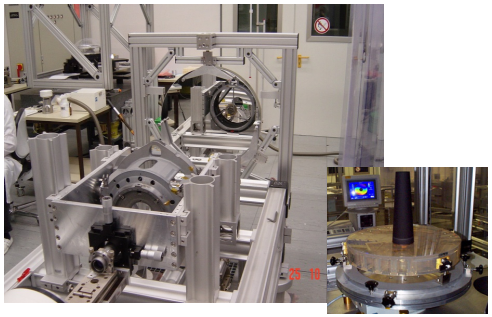




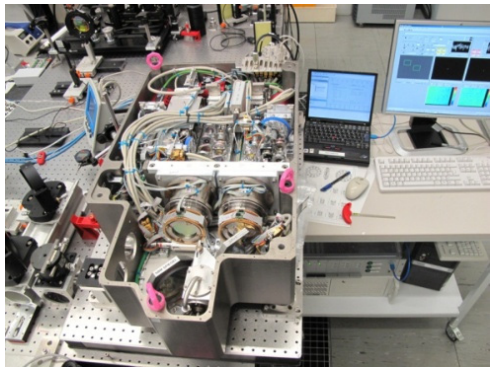


Optical Metrology

Custom Optical Assemblies



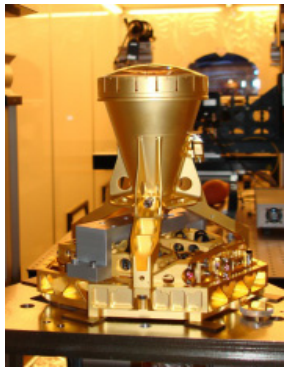
- **Test equipment for optical payloads**
- **Optical metrology and precision actuators**



Optical Communication

Laser ranging & Laser communication

- **Laser communication**
- **Laser altimetry**
- **LIDAR**



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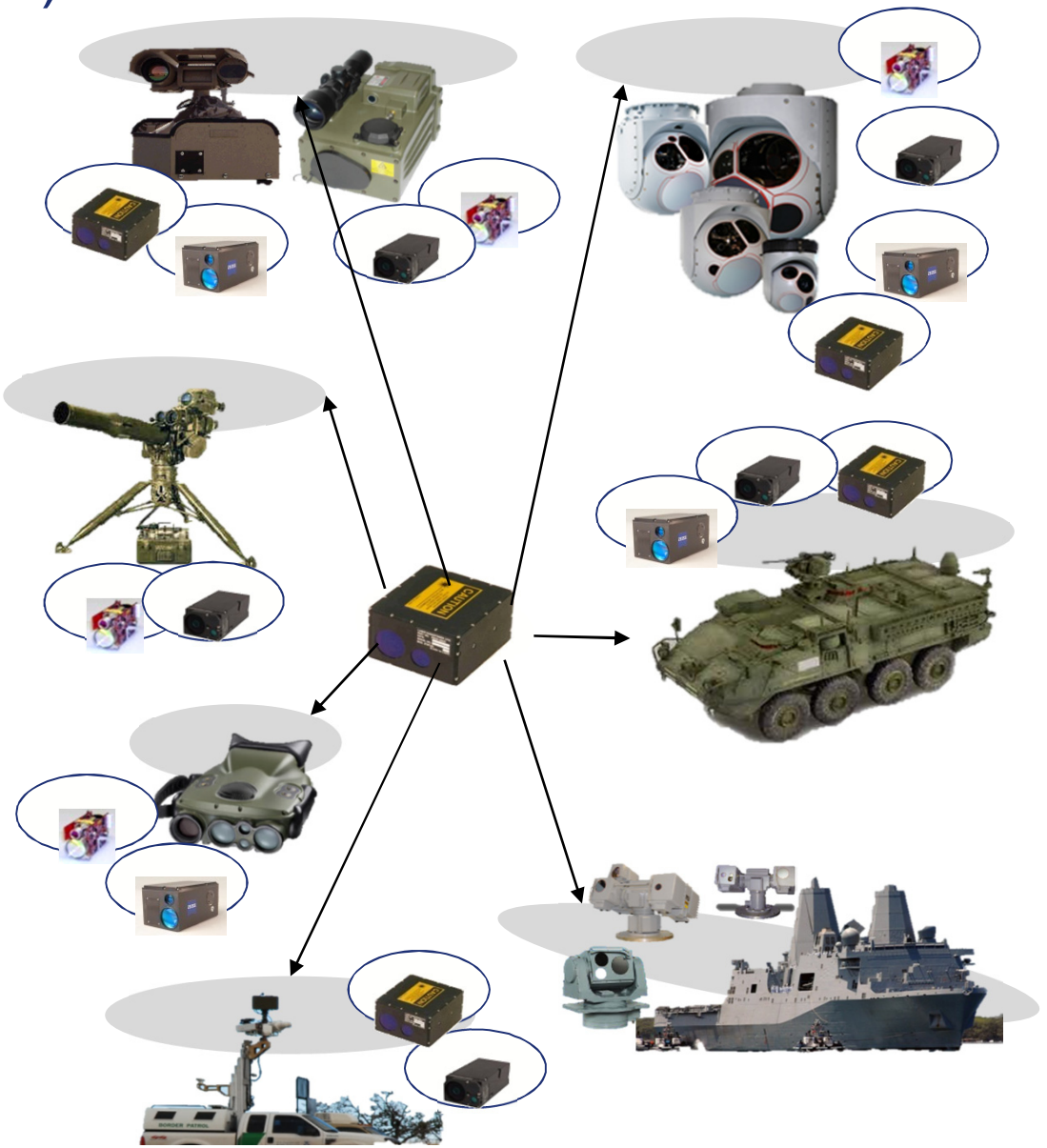
Heritage - Laser Rangefinders (LRF) and Designators

Products:

- LP16, LP17D, LP18D & LP19D Eyesafe laser range finders series: multiple application, compact, light weight, affordable.
- Mini Designator Rangefinder Series MD-NES, MDR-NES, MDR-ES: compact, effective, tested & verified.
- Global sales of LRF's in large numbers to many clients.



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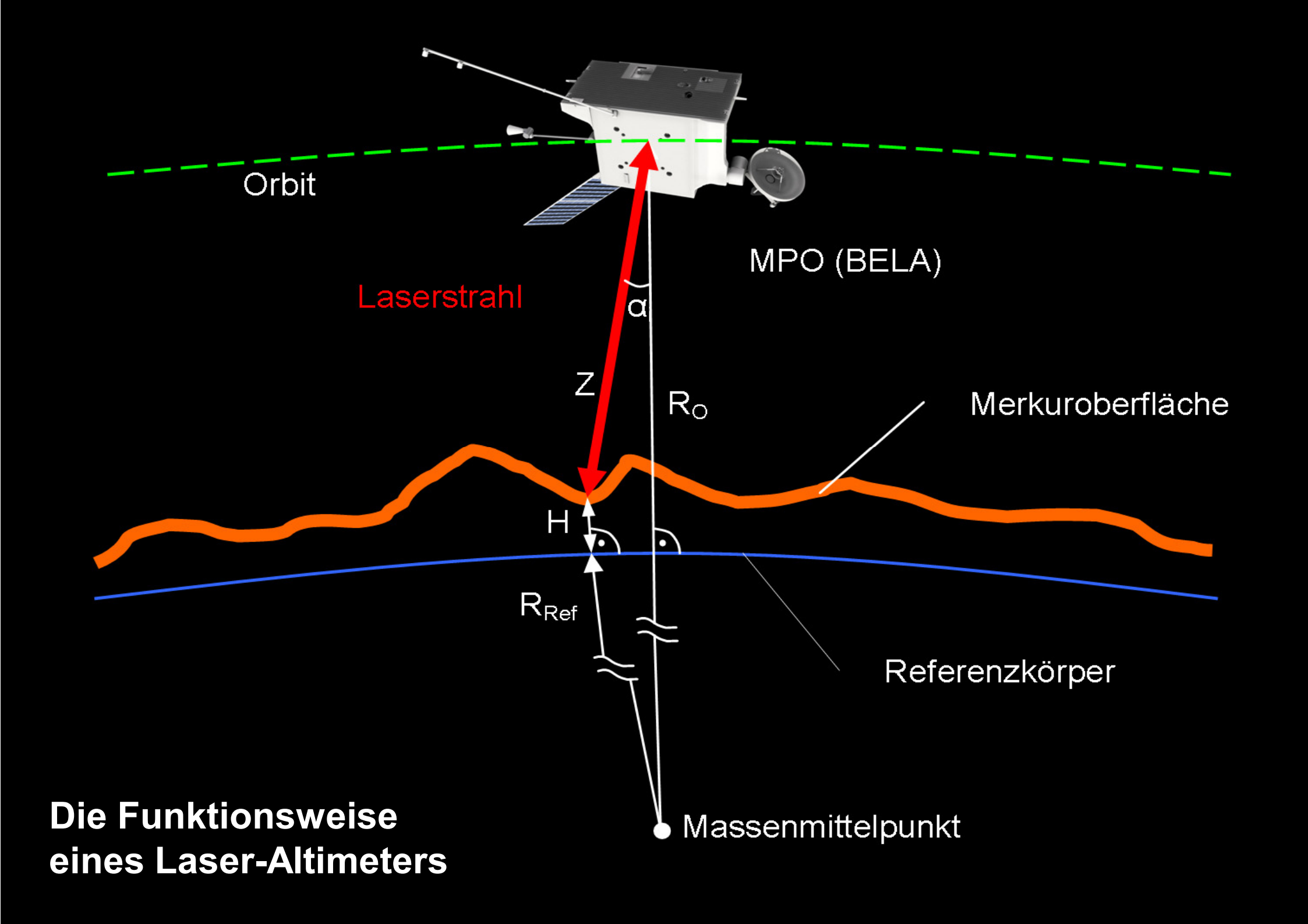
Laser Altimetry – A Short Introduction



Die Funktionsweise eines Laser-Altimeters

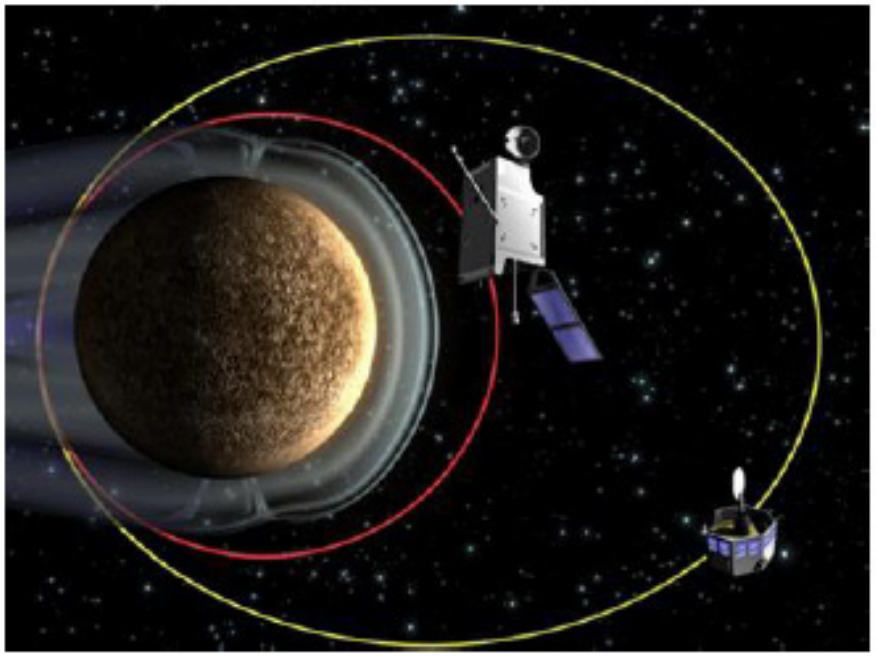
ESA‘s BepiColombo Mission - Science Objectives

- Surface morphology and geology
- Albedo measurements
- Tidal deformations of the surface

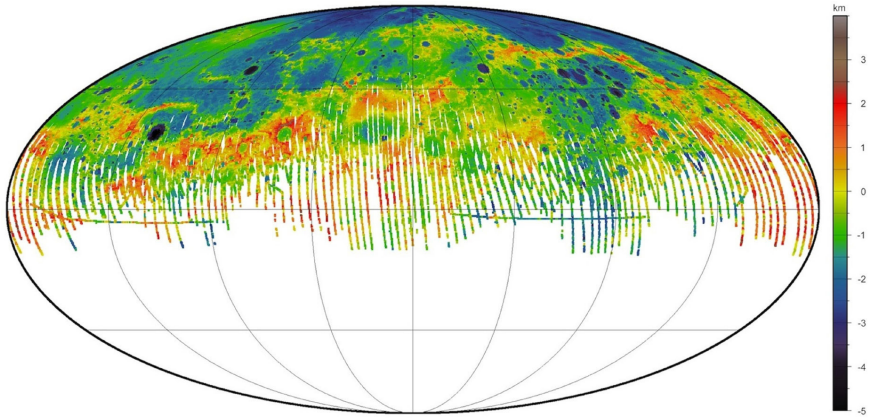
- Geodesy => Digital Terrain Model
- Planetary figure and gravity field determination
- Interior structure exploration

NASA Predecessor Mission „Messenger“ including laser altimeter „MLA“

cf. http://tharsis.gsfc.nasa.gov/



Orbits of the BepiColombo MPO and MMO space-craft around Mercury

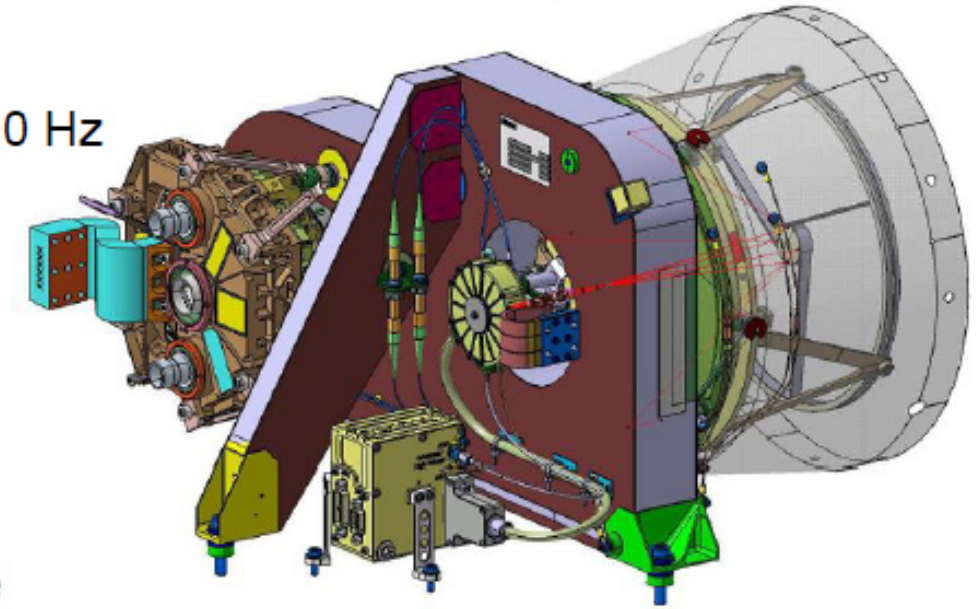


MLA measurement coverage of Mercury, as of 13 September 2012.
SPIE Newsroom. DOI: 10.1117/2.1201210.004489

The BepiColombo Laser Altimeter BELA

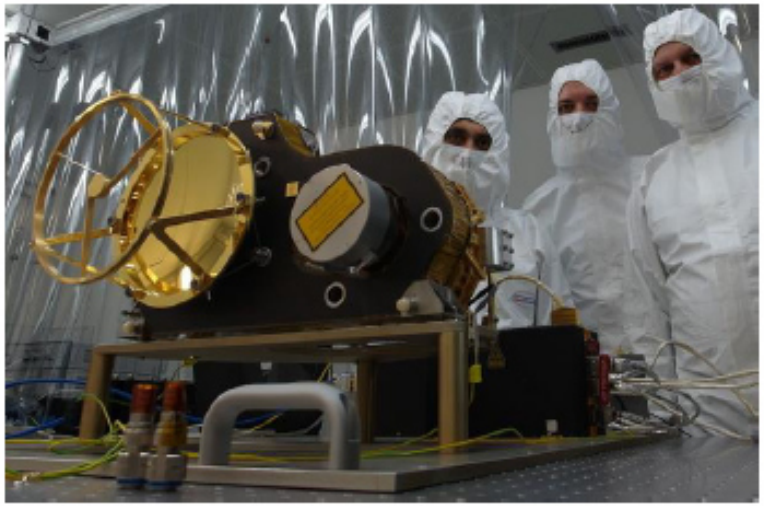
Transmitter TX

- diode-pumped Nd:YAG, 50 mJ, 5 ns, 10 Hz
- Straylight Protection Unit
- Transmitter Baffle Unit
- Electronics Unit



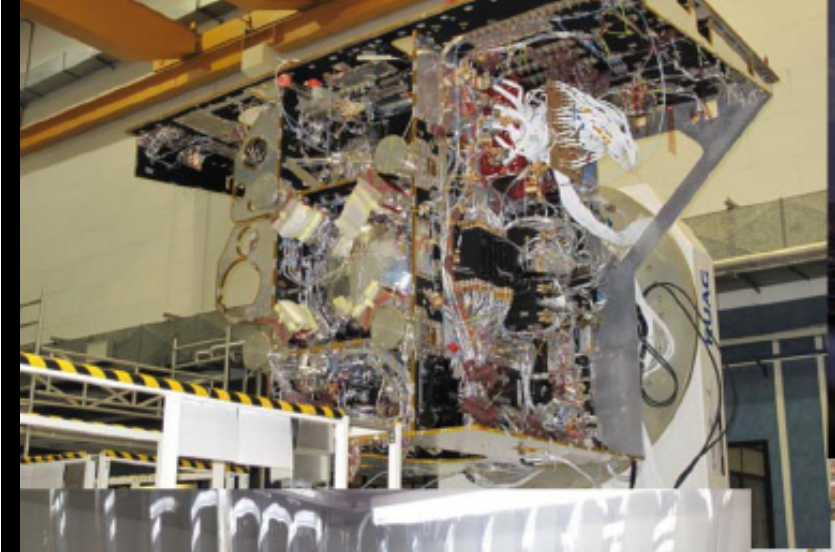
Receiver RX

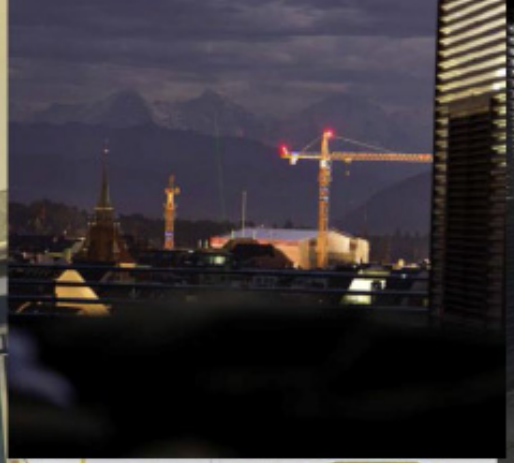
- Cassegrain telescope, Be, 22 cm dia.
- Perkin Elmer Si Avalanche Photodiode
- 80 Msample/s rangefinder
- Stavroudis Baffle Unit

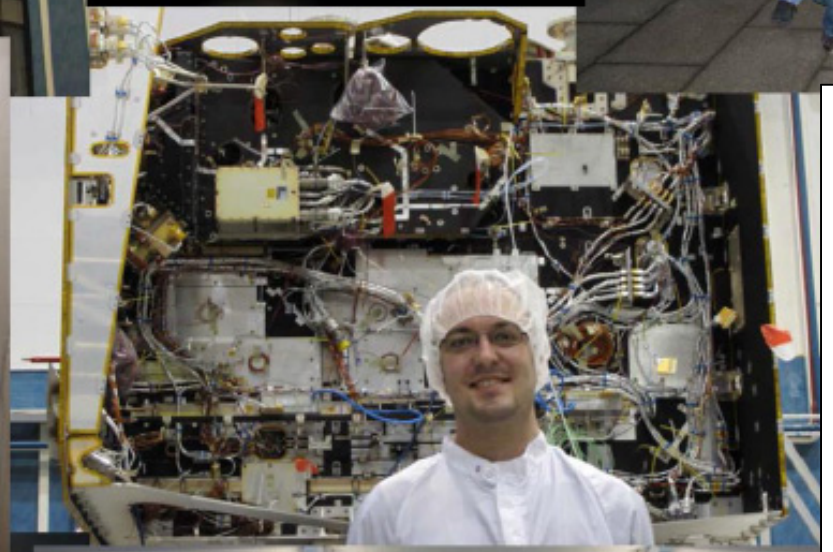


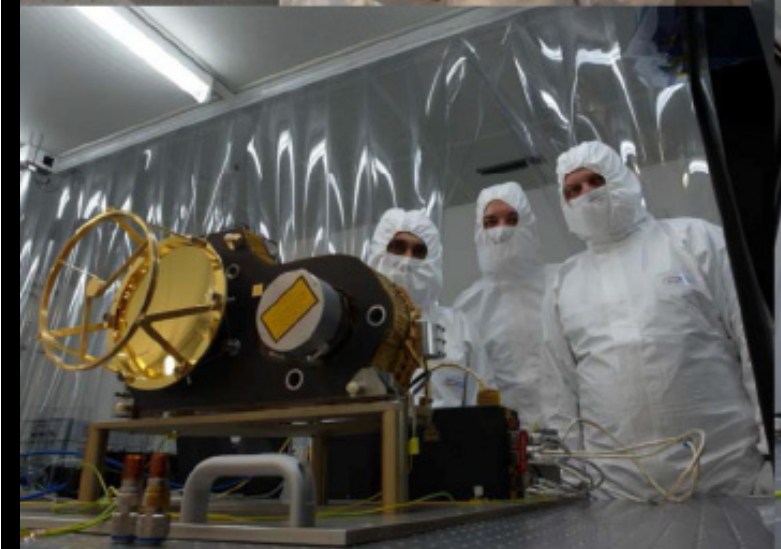
Team

- CoPI Nicolas Thomas, University of Bern
- CoPI Tilman Spohn, DLR-PF Berlin
- MPS Göttingen, IAA Granada









BepiColombo

BELA

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MPS

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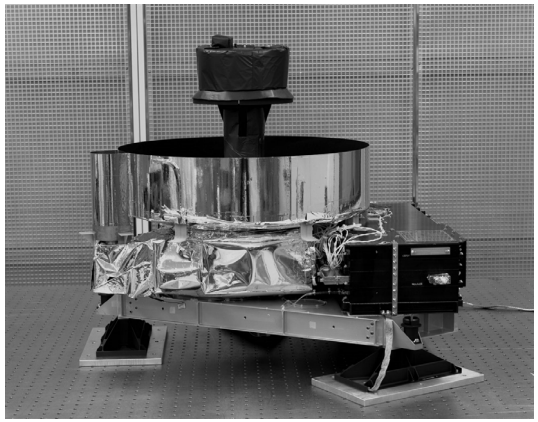
UNIVERSITÄT
BERN

DLR

Satellite missions including Laser Altimeters - An Overview

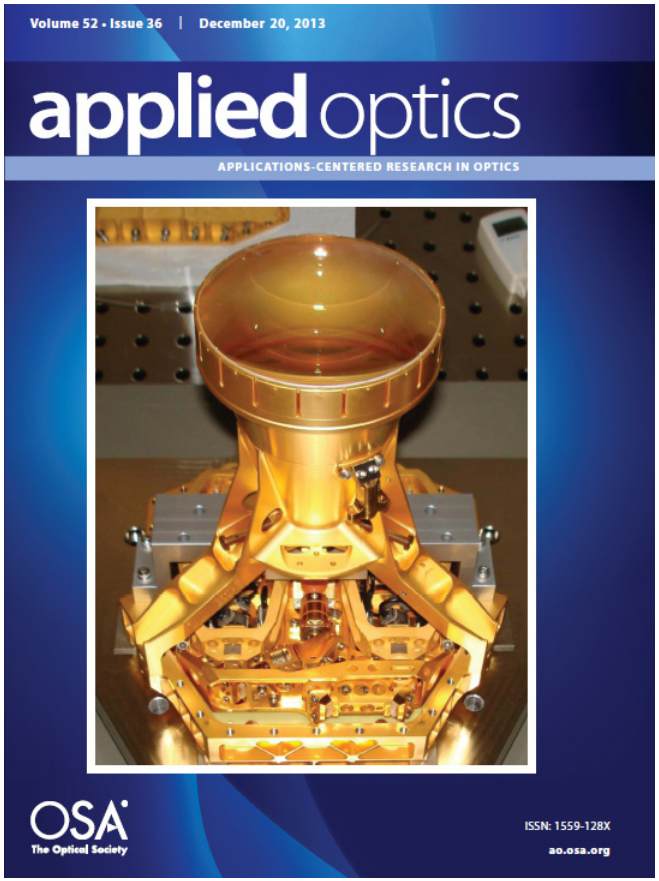


Acronym	Instrument Name	Mission	Destination	Operator	Launch
MOLA	Mars Observer Laser Altimeter	MGS	Mars	NASA	1996
GLAS	Geoscience Laser Altimeter System	ICESat	Earth	NASA	2003
	Hayabusa LIDAR	Hayabusa (Muses-C)	Asteroid	JAXA	2003
MLA	Messenger Laser Altimeter	Messenger	Mercury	NASA	2004
LOLA	Lunar Observer Laser Altimeter	LRO	Moon	NASA	2009
	Hayabusa 2 LIDAR	Hayabusa 2	Asteroid	JAXA	2014
BELA	BepiColombo Laser Altimeter	BepiColombo	Mercury	ESA	(2016)
ATLAS	Advanced Topographic Laser Altimeter System	ICESat 2	Earth	NASA	(2016)
GALA	Ganymede Laser Altimeter	JUICE	Jupiter System	ESA	(2022)


esa
esa
esa
esa
APCO

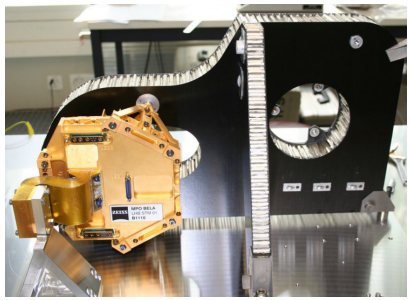
BepiColombo Laser Altimeter (BELA) – Laser Design

BELA Laser Transmitter is based on a Space-qualified diode-laser pumped Nd:YAG Laser

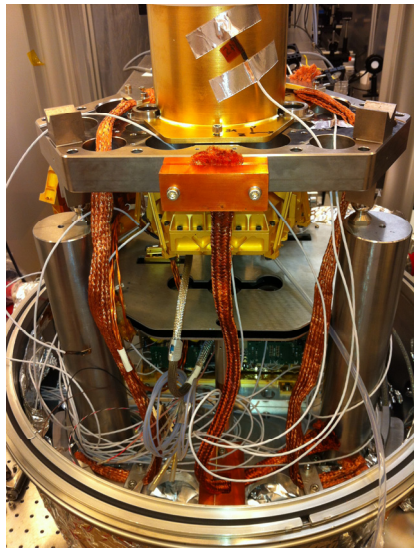


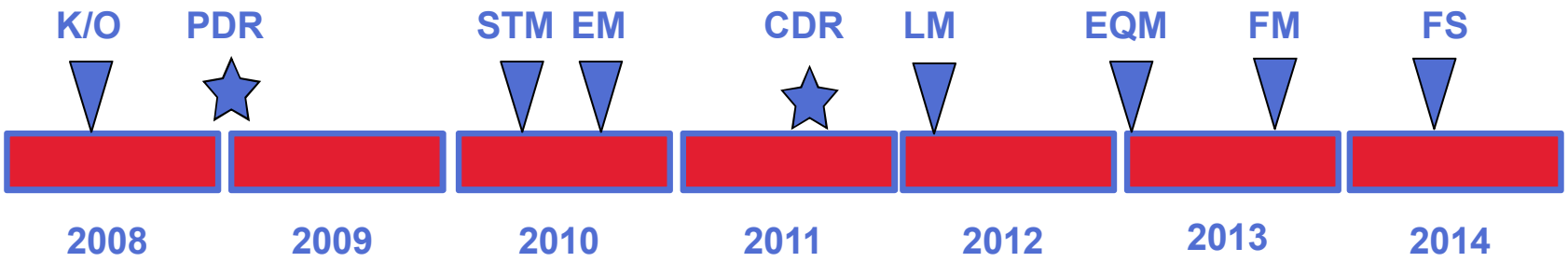
- Wavelength 1064.5 ± 0.25 nm
- Pulse energy 40-50 mJ
- Life time 300 Mshots
- Pulse width 5 ns ± 1 ns
- Repetition rate 1 … 10 Hz
- Beam divergence 40 … 60 µrad
- Pointing stability < 50 µrad
- Beam quality ≈ 2.7
- Cold-redundant

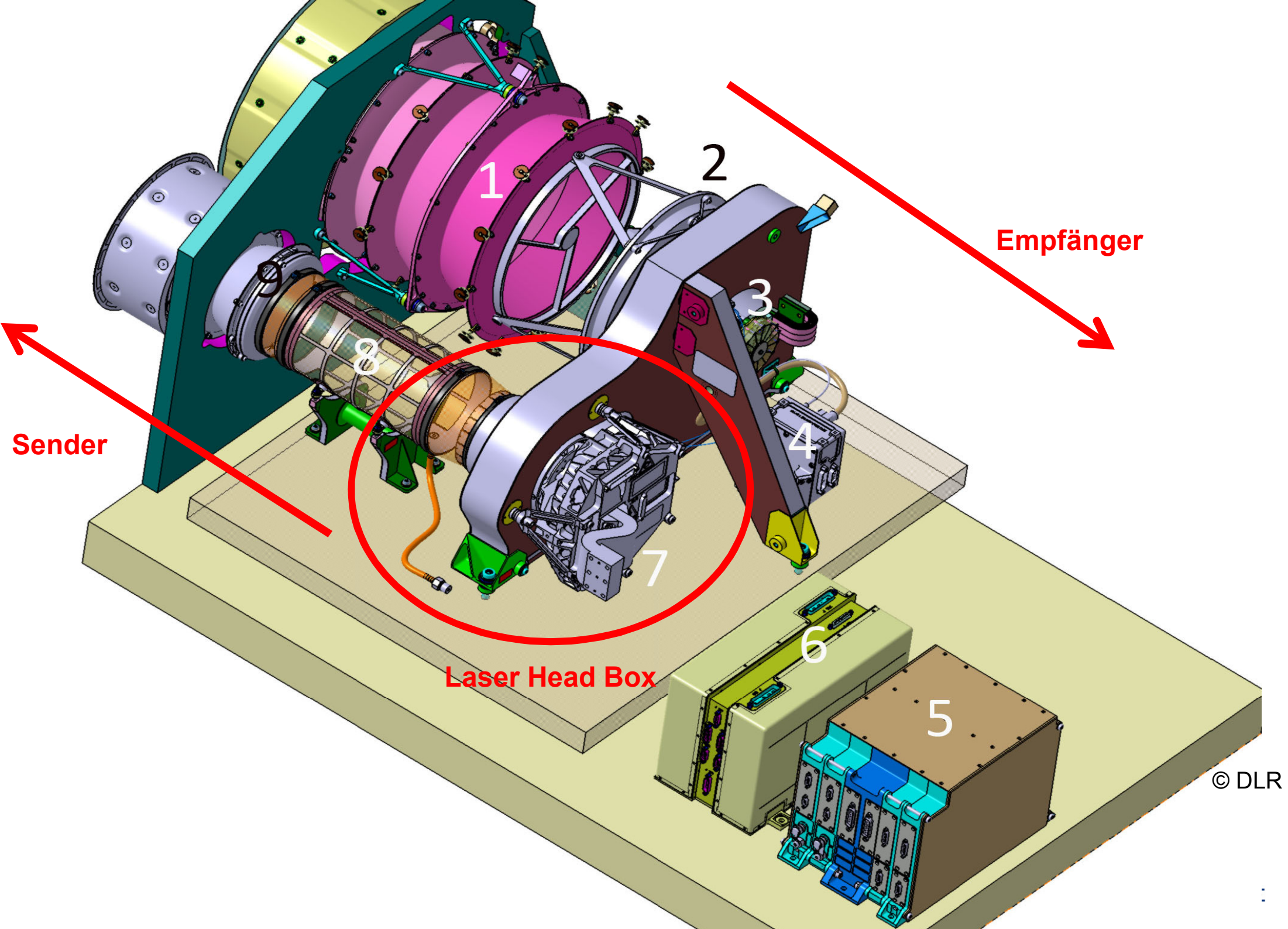
BELA Laser Qualification - Timelines

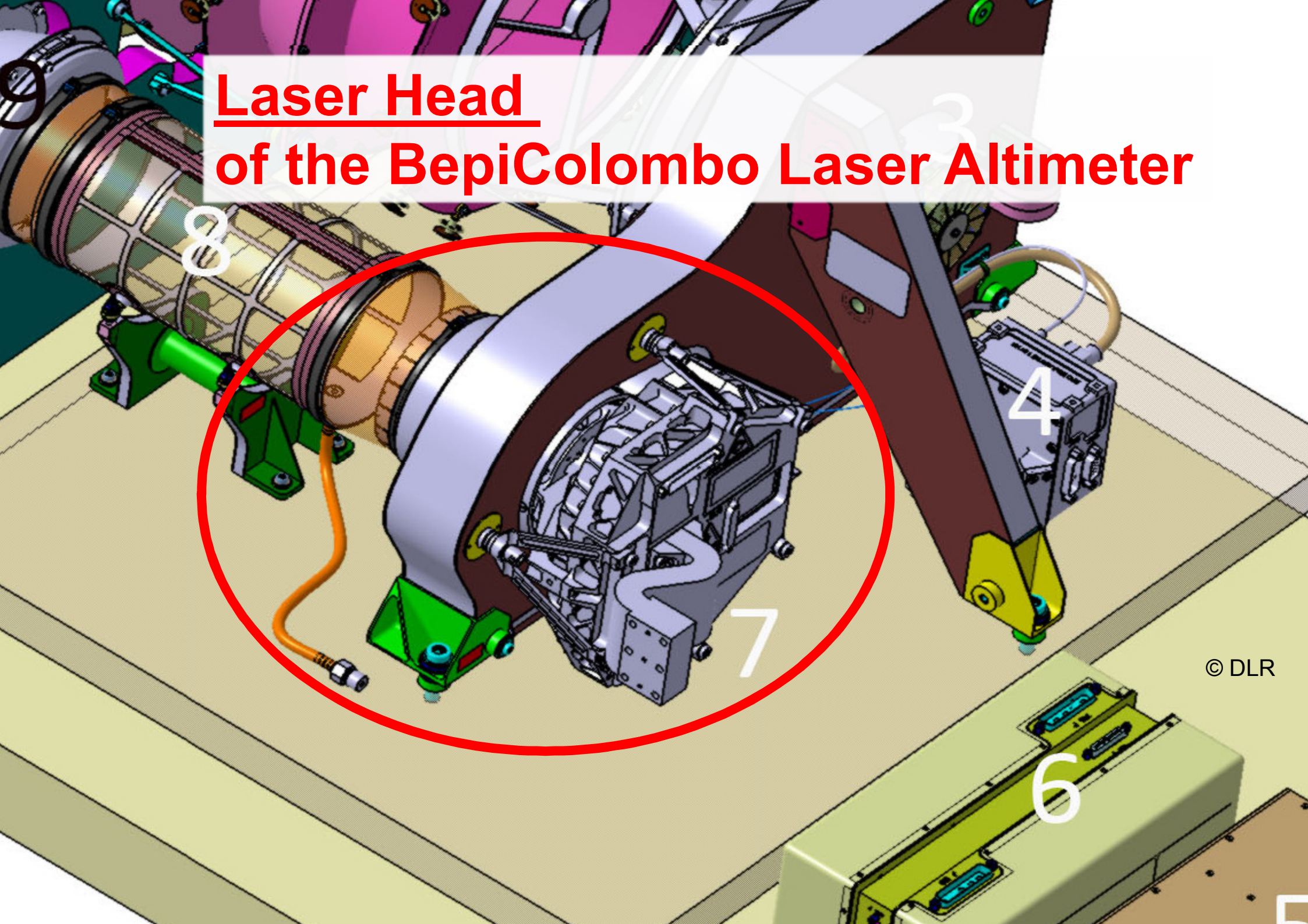


Hardware Model	Delivery date
Structure Thermal Model	21.04.2010
Electrical Model	11.08.2010
Life Model *(assembly completed)*	28.02.2012
Engineering Qualification Model	31.01.2013
Flight Model	30.10.2013
Flight Spare Model	29.07.2014








Laser Head
of the BepiColombo Laser Altimeter
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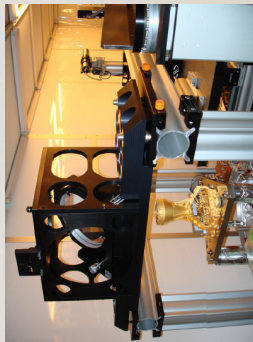
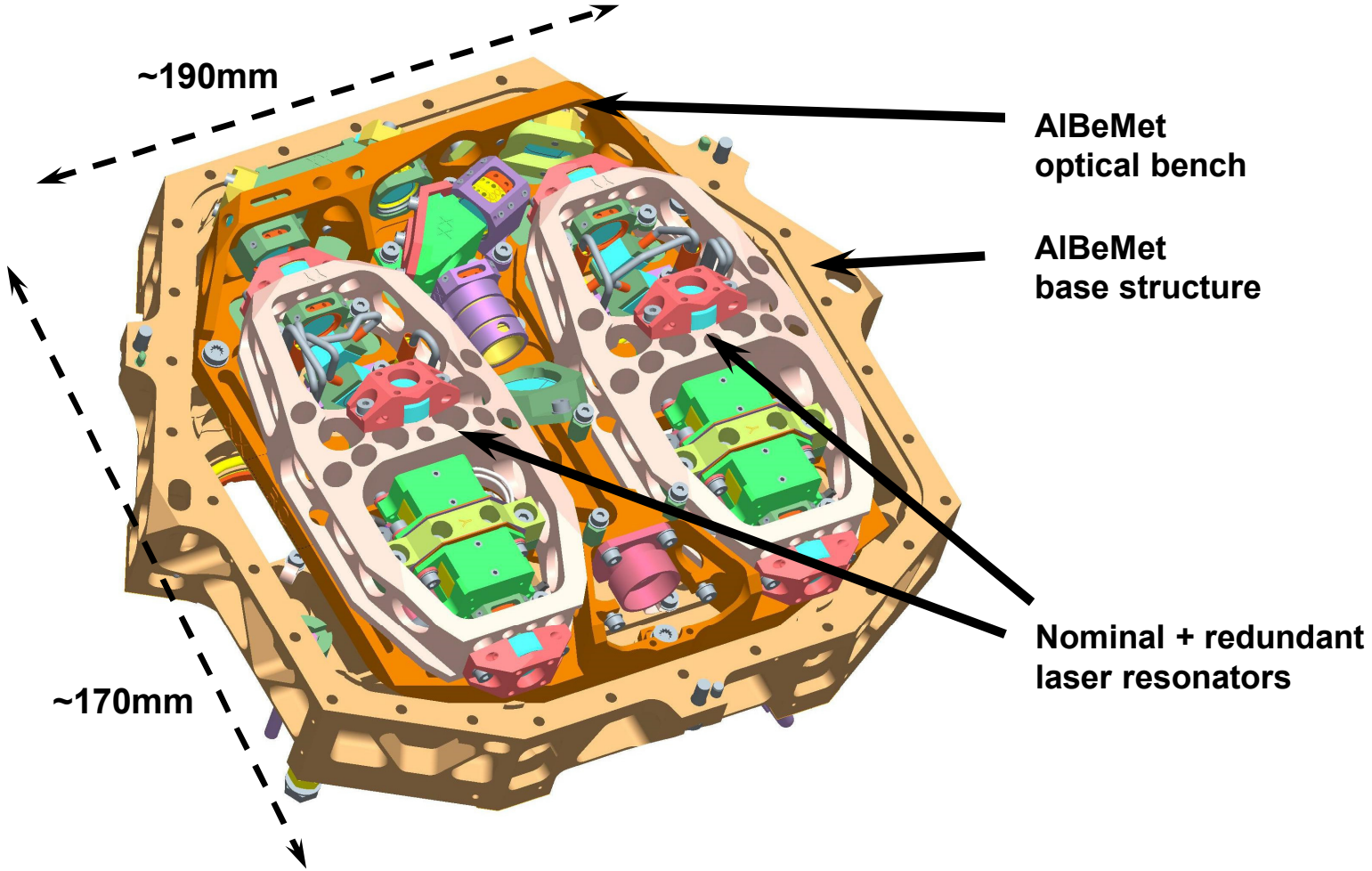
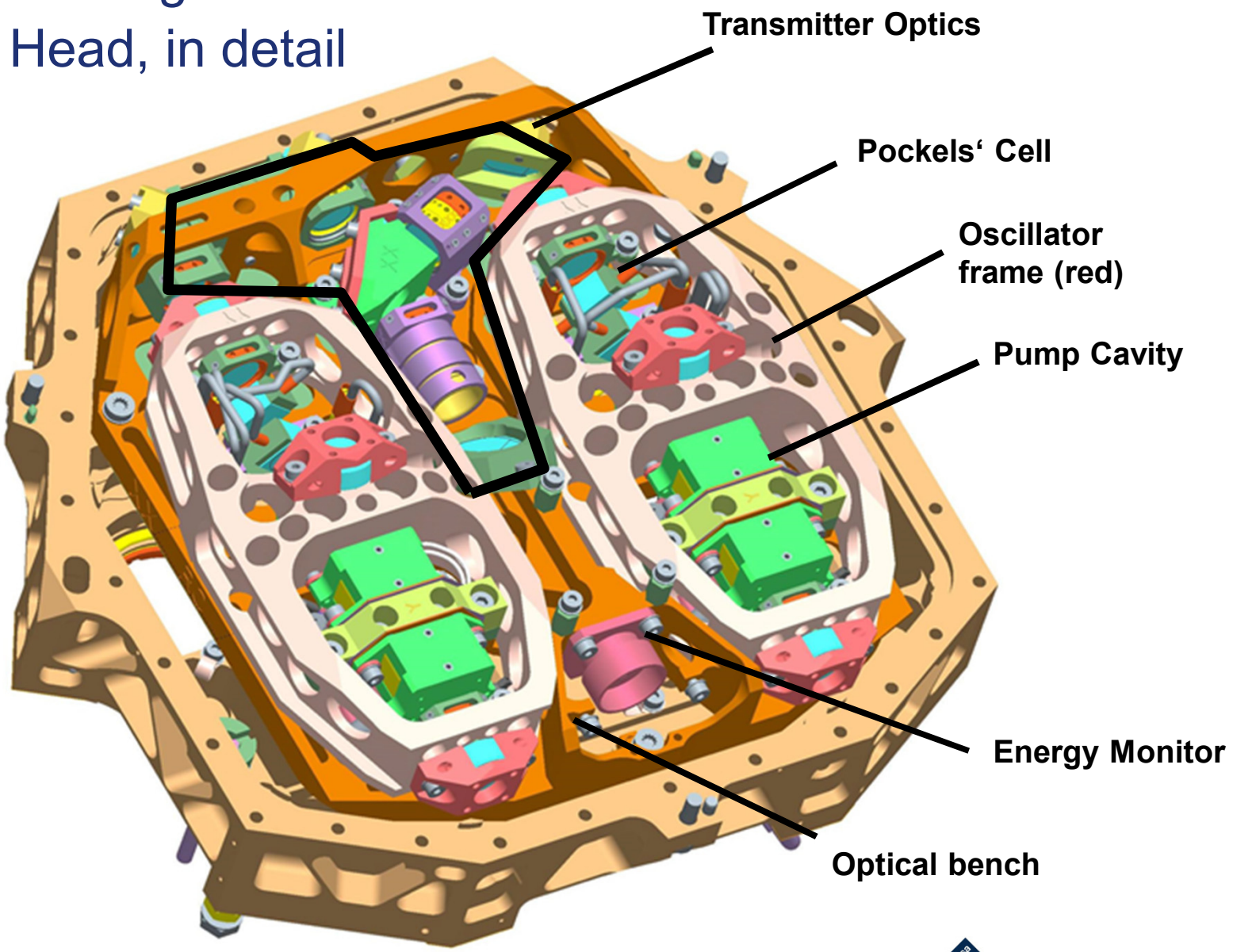


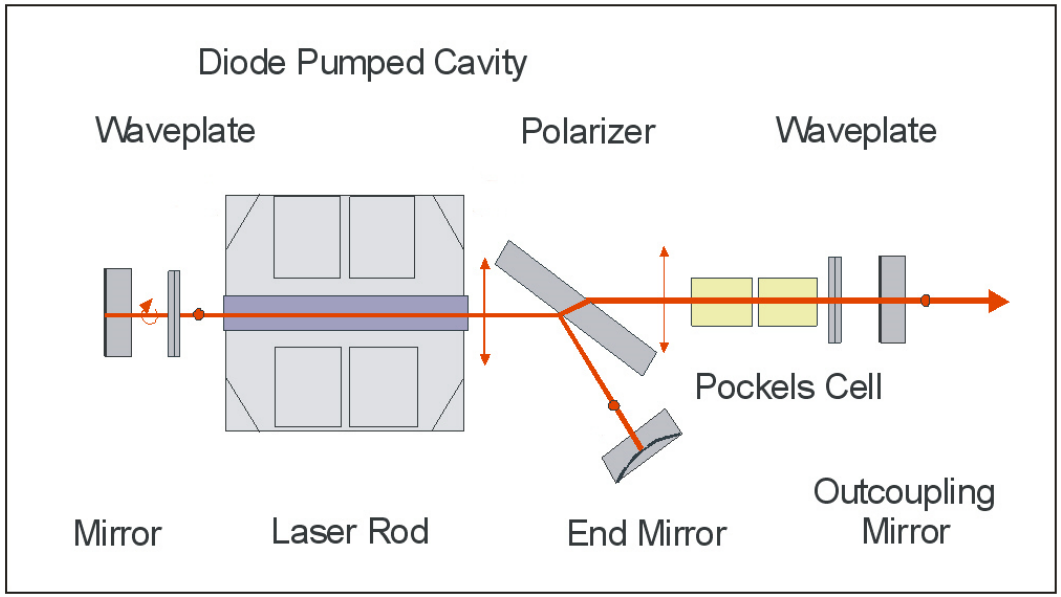
BELA Laser Design
The Laser Head (Cover removed)

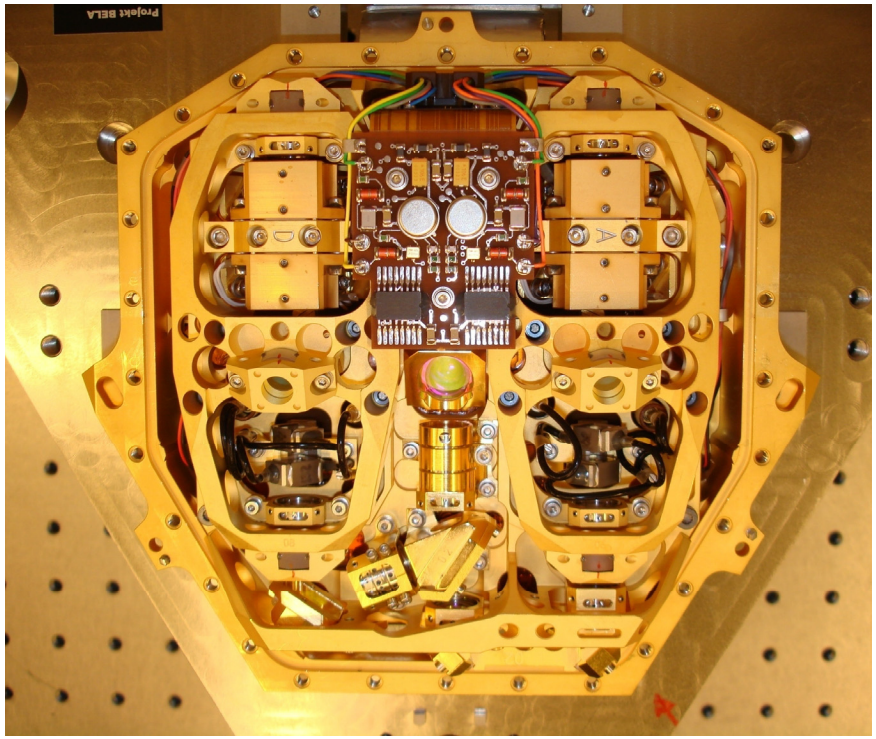


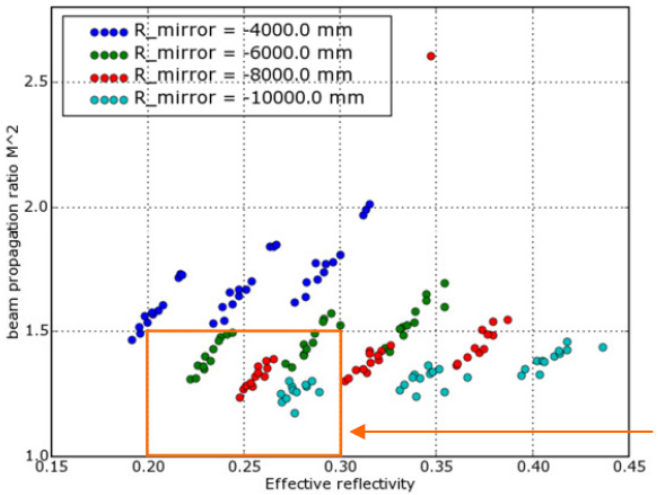
BELA Laser Design
The Laser Head, in detail

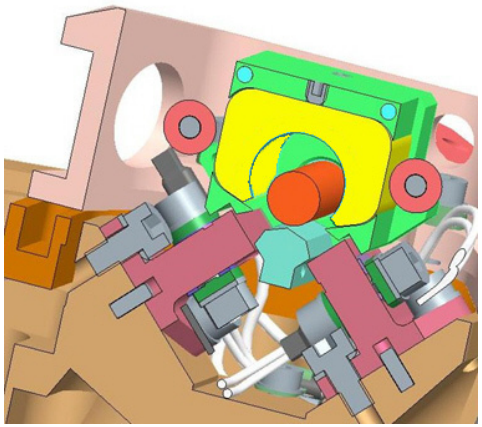


The Optical Design of the Laser Head

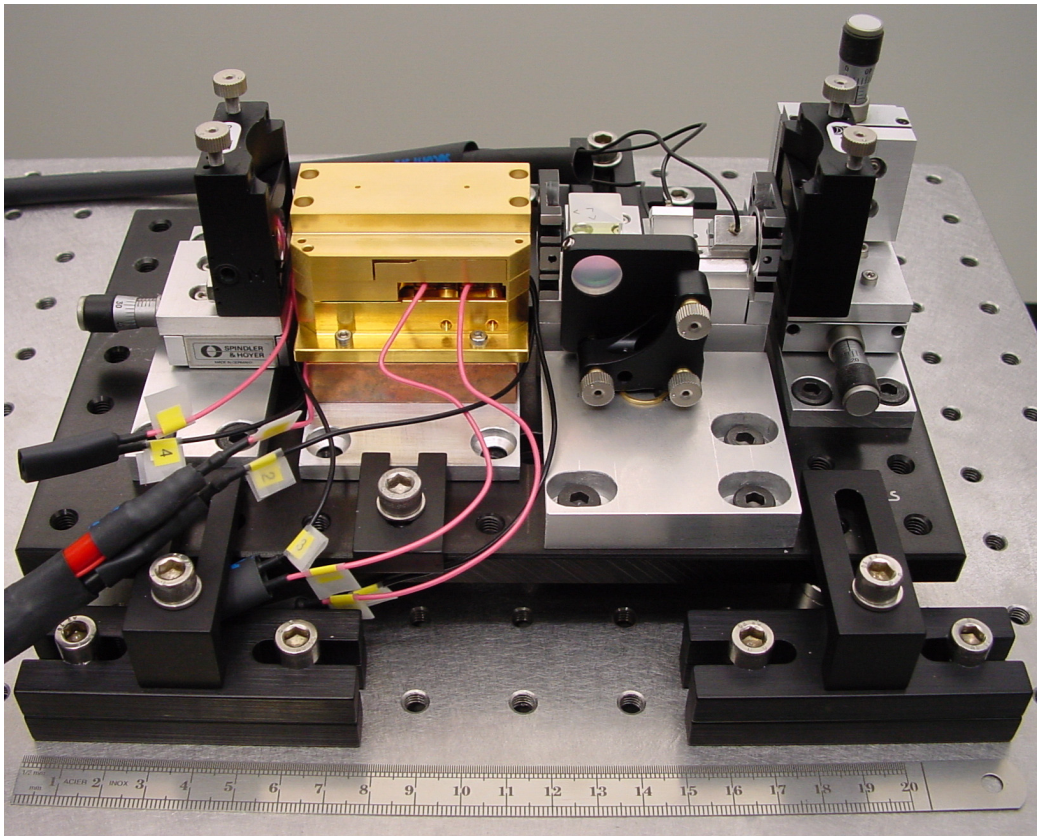


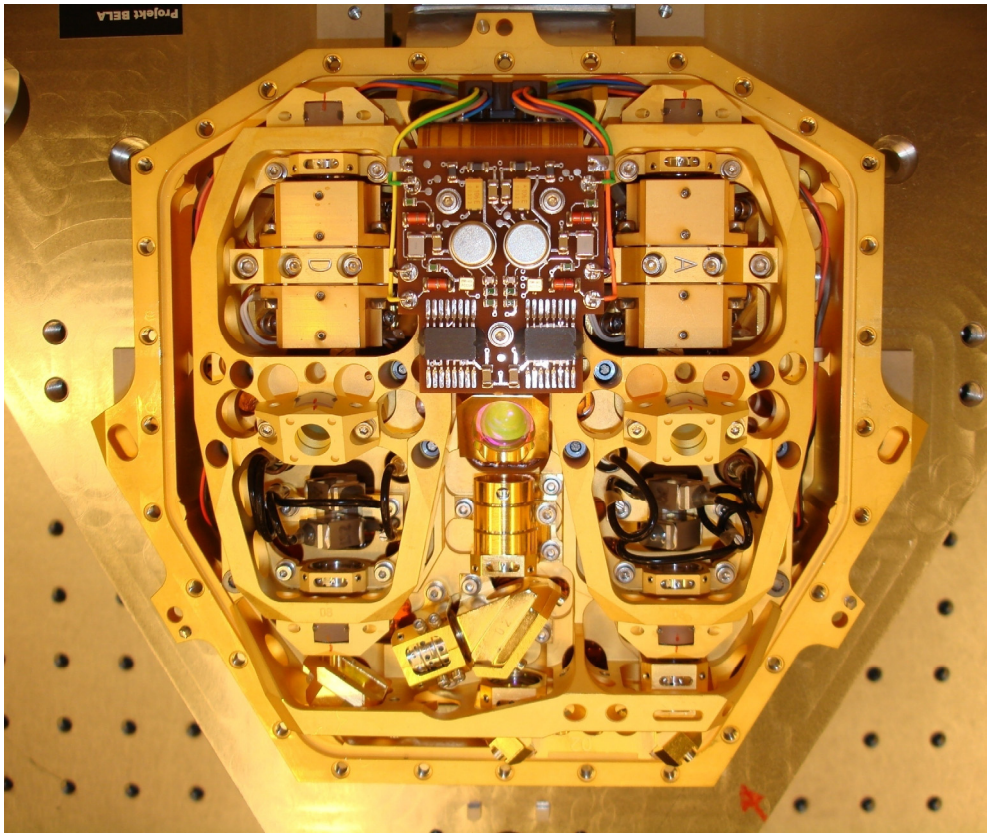




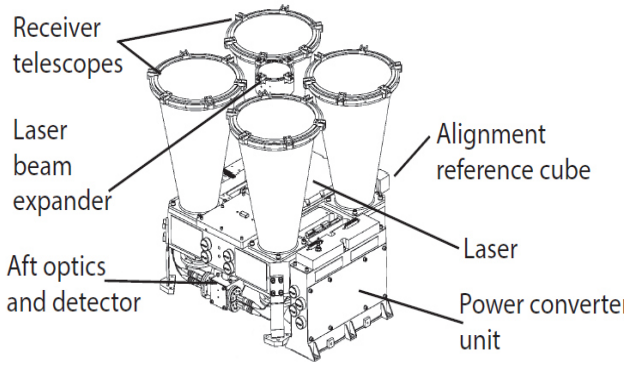


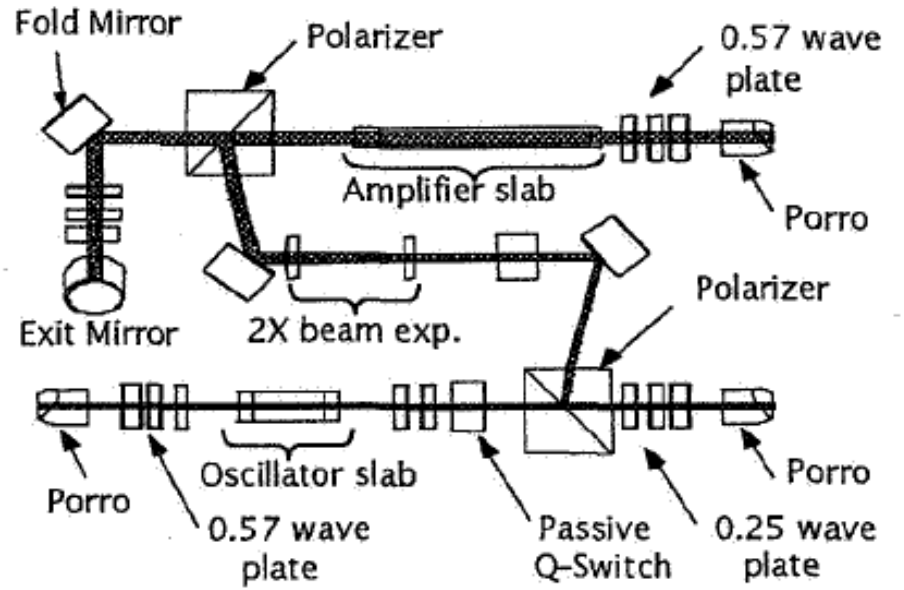
The BELA Laser Resonator Design Concept was proven during a precursor „Microlaser“ study





For Comparison: The Messenger Laser Altimeter (MLA)

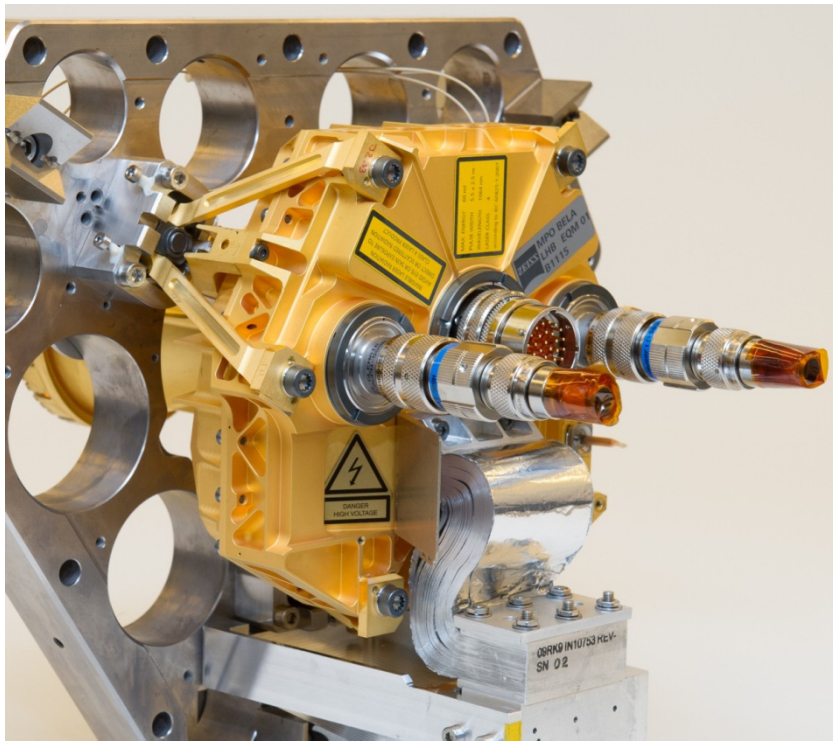




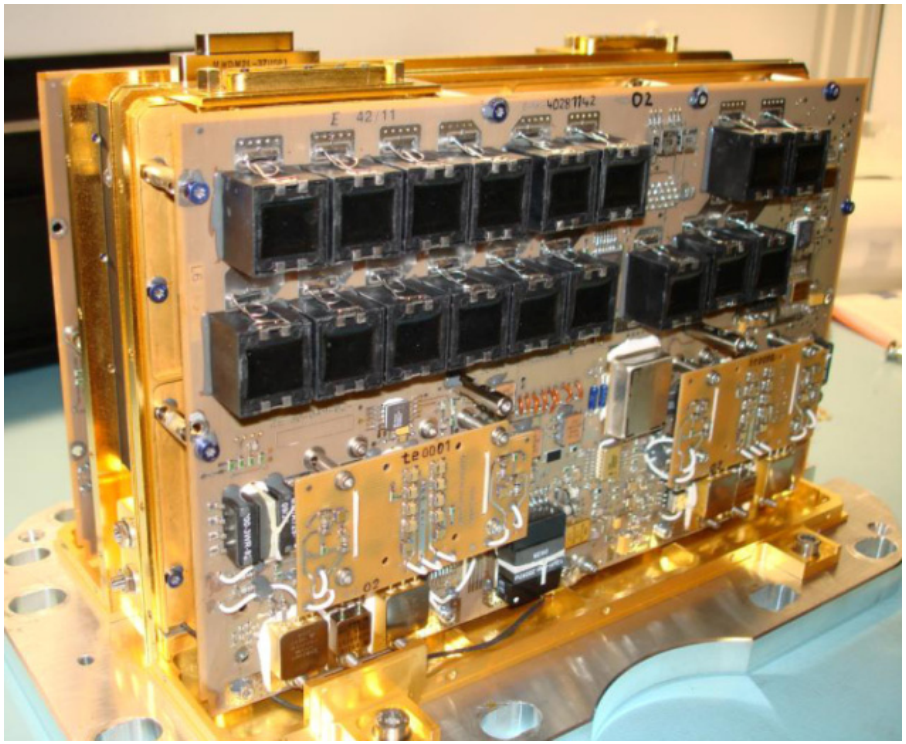
Laser pulse energy	20 mJ
Pulse repetition rate	8 Hz
Pulse width	6 ns FWHM
Wavelength	1064.30 ± 0.05 nm
Beam divergence	80 μrad
	full angle at e^{-1} points
receiver aperture	11.5 cm diameter, x4
Receiver field of view	400 μrad
Receiver Optics Transmission	77%
(including bandpass filter)	
Receiver optical bandwidth	0.7 nm FWHM
Detector active area	0.7 mm diameter
Detector responsivity	300 kV/W
Detector electrical bandwidth	140 MHz
Preamp noise equivalent power	40 $fW/\sqrt{Hz}$
Receiver matched filter bandwidth	8, 63, 283 ns FWHM
	for Channels 1, 2, and 3
Receiver timing accuracy	$<$ 1 ns standard deviation
Data rate	2.4 $kbits/s$
Operation duty cycle	15 to 45 minutes
	per 12 or 8 hour orbit
Weight	7.4 kg
Size	30 (W) $\times$ 34(L) $\times$ 29(H)
Power	23 W operating
	12 W standby
	8 W keep-alive

[1] X. Sun et. al., Calibration of the Mercury Laser Altimeter, subm. IEEE, 2013
[2] D. J. Krebs et. al., Appl. Opt. 44 (9), 1715, 2005

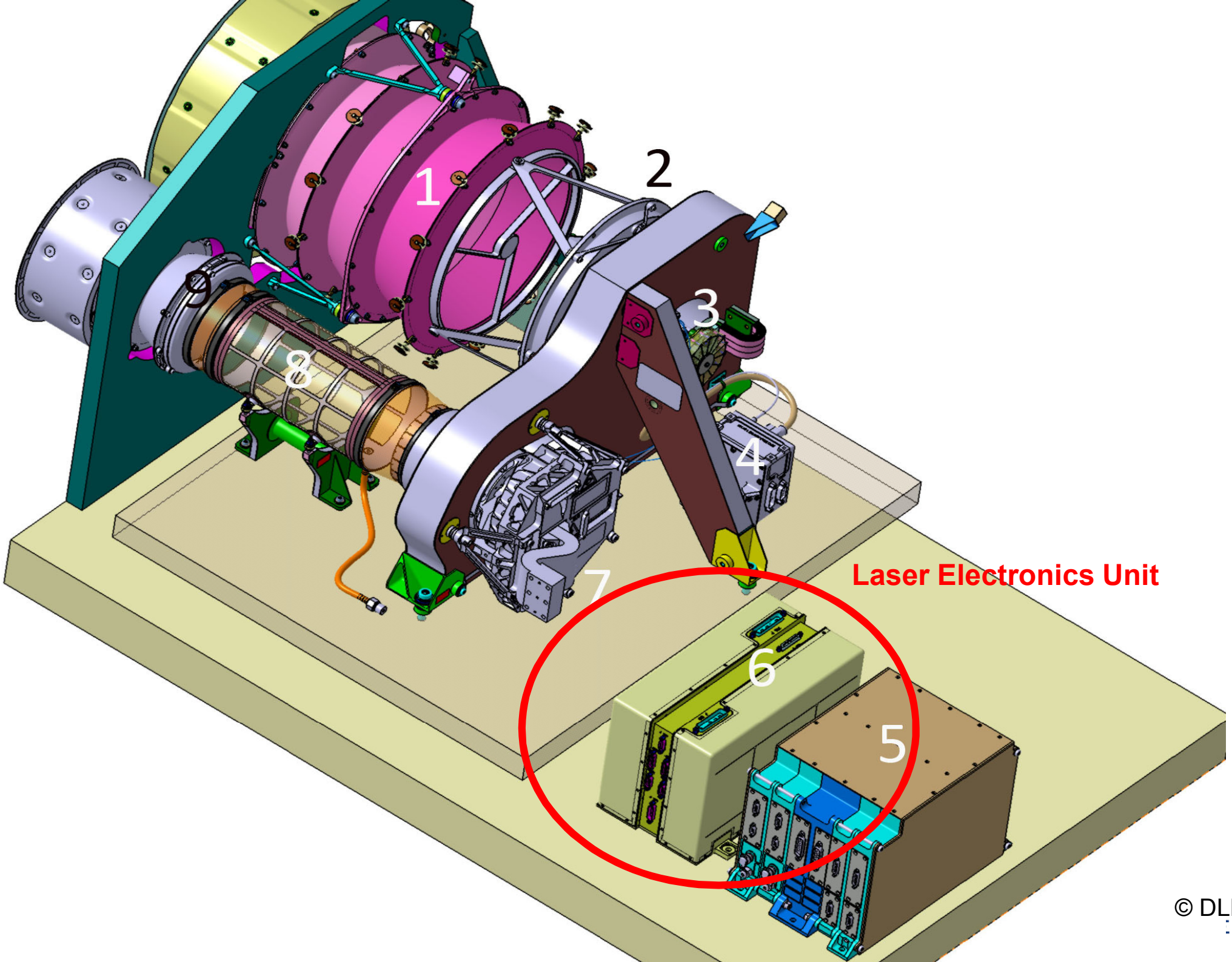
BELA Laser Design
Overview

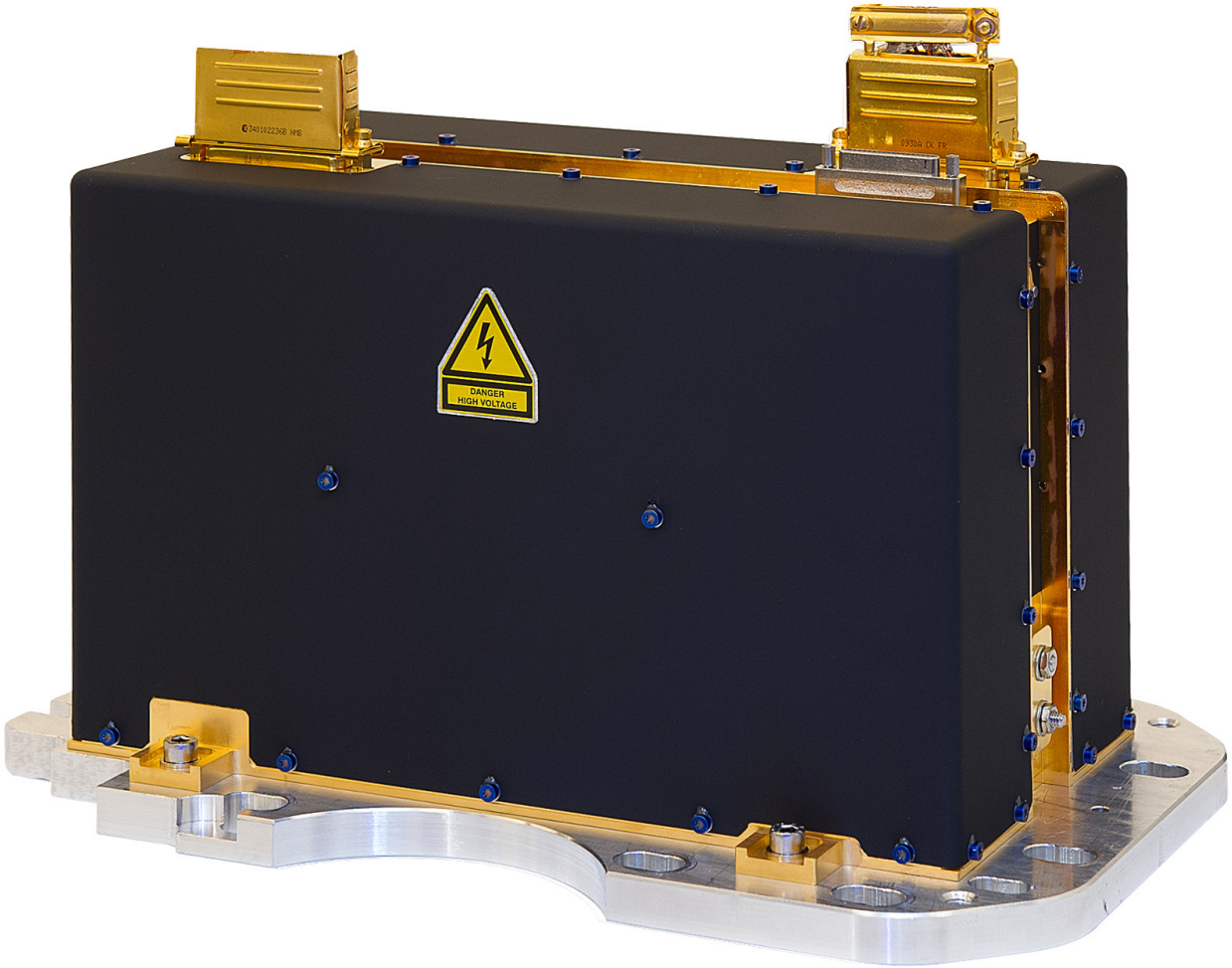


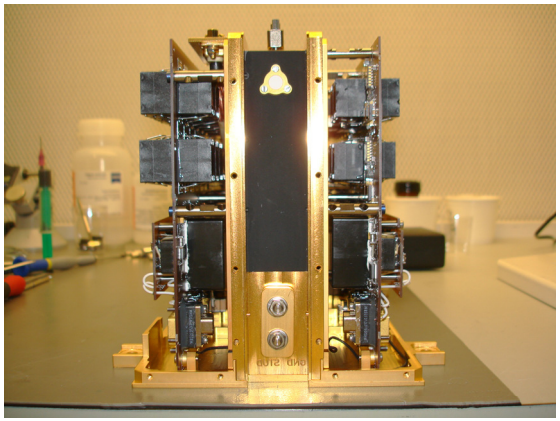
Laser Head (LHB)

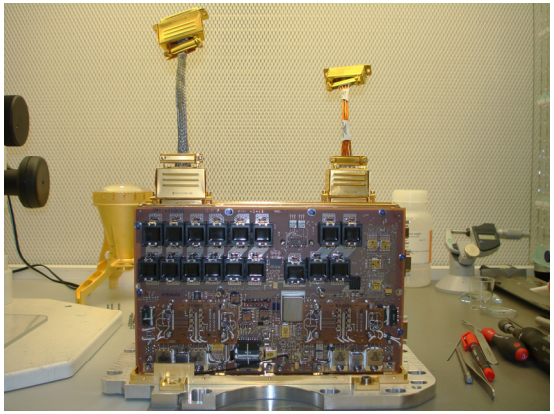


Laser Electronics (LEU)
(Cover removed)




DANGER
HIGH VOLTAGE





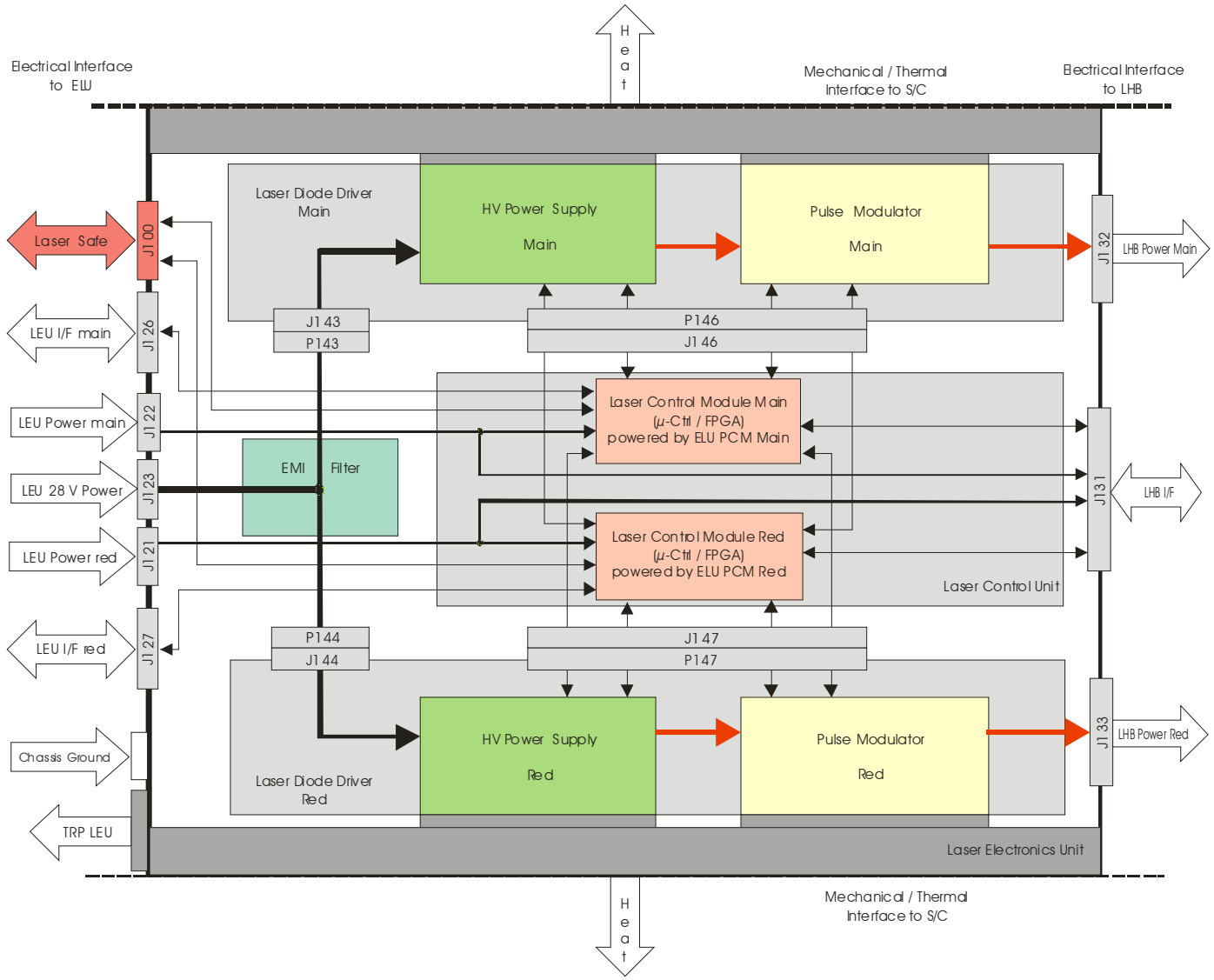
The Laser Electronics (LEU)

Comprising:

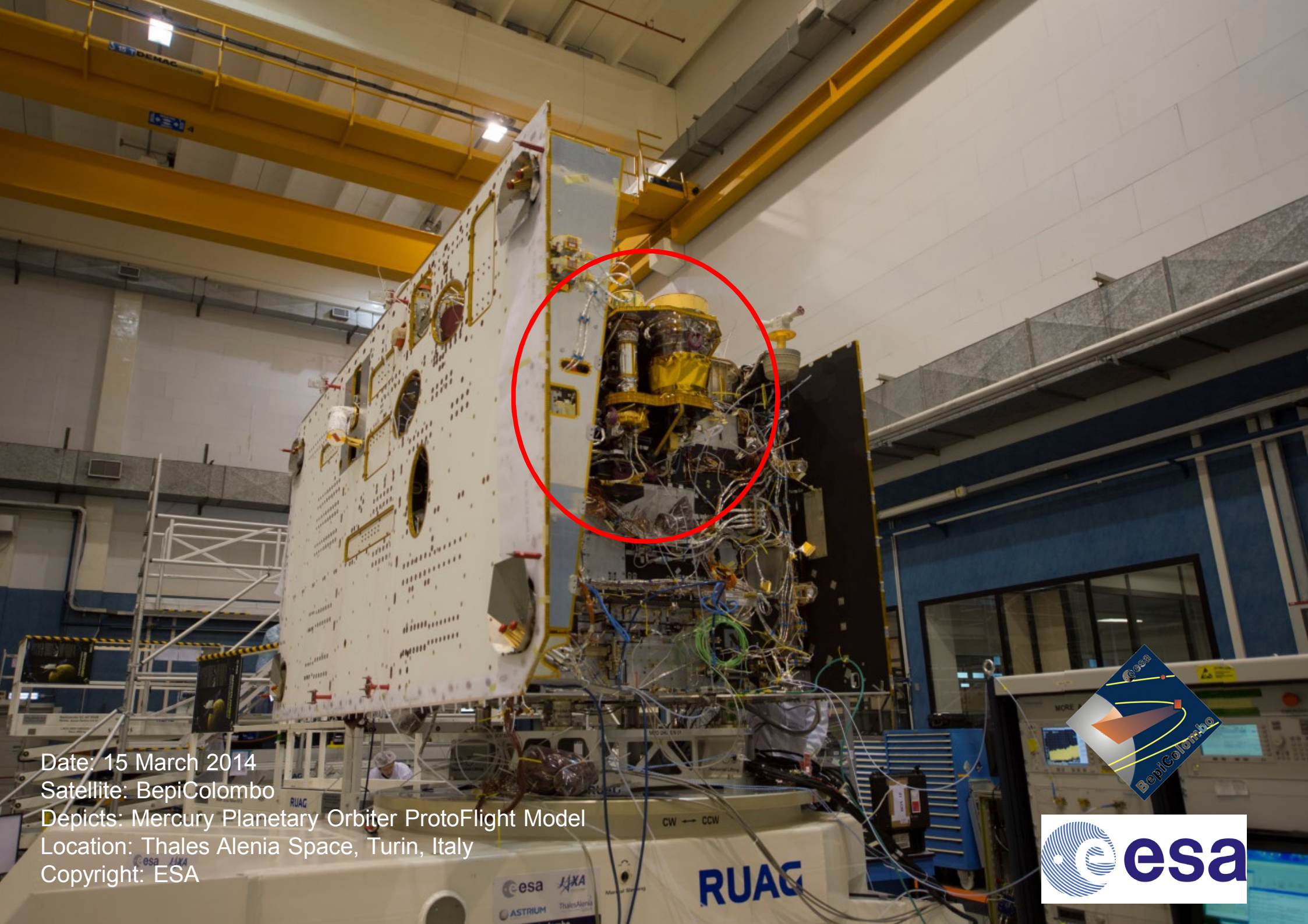
Laser Control Module

Laser Diode Driver

EMI Filter



Pockels' Cell Driver
Energy Monitor
Temperature Sensor
} LHB



Date: 15 March 2014
Satellite: BepiColombo
Depicts: Mercury Planetary Orbiter ProtoFlight Model
Location: Thales Alenia Space, Turin, Italy