The BELA - The first European Planetary Laser *Altimeter:*

- Conceptional Design and Technical Status -

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LOC

Introduction

- Institute of Planetary Research
- Bepi-Colombo and BELA – Science Goals

Technical Concept and Work Sharing

- Overview
- The Laser
- Optics
- Electronics

Outlook, next activities

DLR-Institute of Planetary Research, Berlin

Planetary Science & Sensor Design, Test & Calibration

Head: Prof. Tilman Spohn

Planetary Geology: Ralf Jaumann

Planetary Sensor Systems: Harald Michaelis

HRSC – High Resolution Stereo Camera

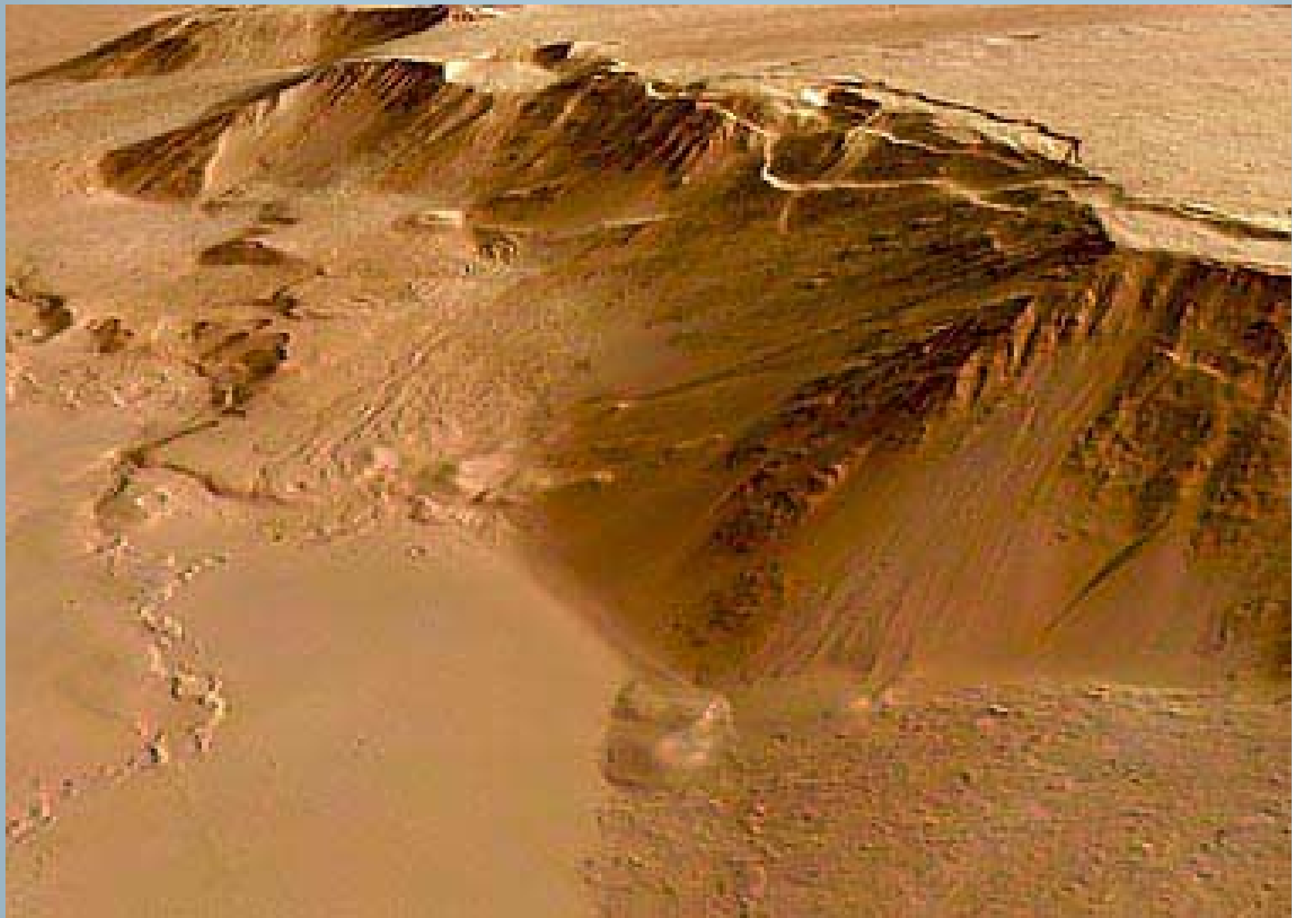
HRSC:
Focal length
175 mm

SRC:
Focal length
975 mm

Simultaneous image taking in

- High resolution: Nadir-Sensor, 10 m/Pixel from a height of 250 km
- Stereo: 4 Sensors, 10-20 m/Pixel from a height of 250 km
- Colour: 4 Sensors, red, green, blue, near infrared
- Maximum resolution: 2,3 m/Pixel from a height of 250 km
- Output-data rate: 25 Mbit/Sec., Online-compression
- Mass: 19,6 kg

Mars Express = First European Mission to Mars



2. Bepi- Colombo and BELA

Bepi- Colombo

=

First European Mission to Planet Mercury

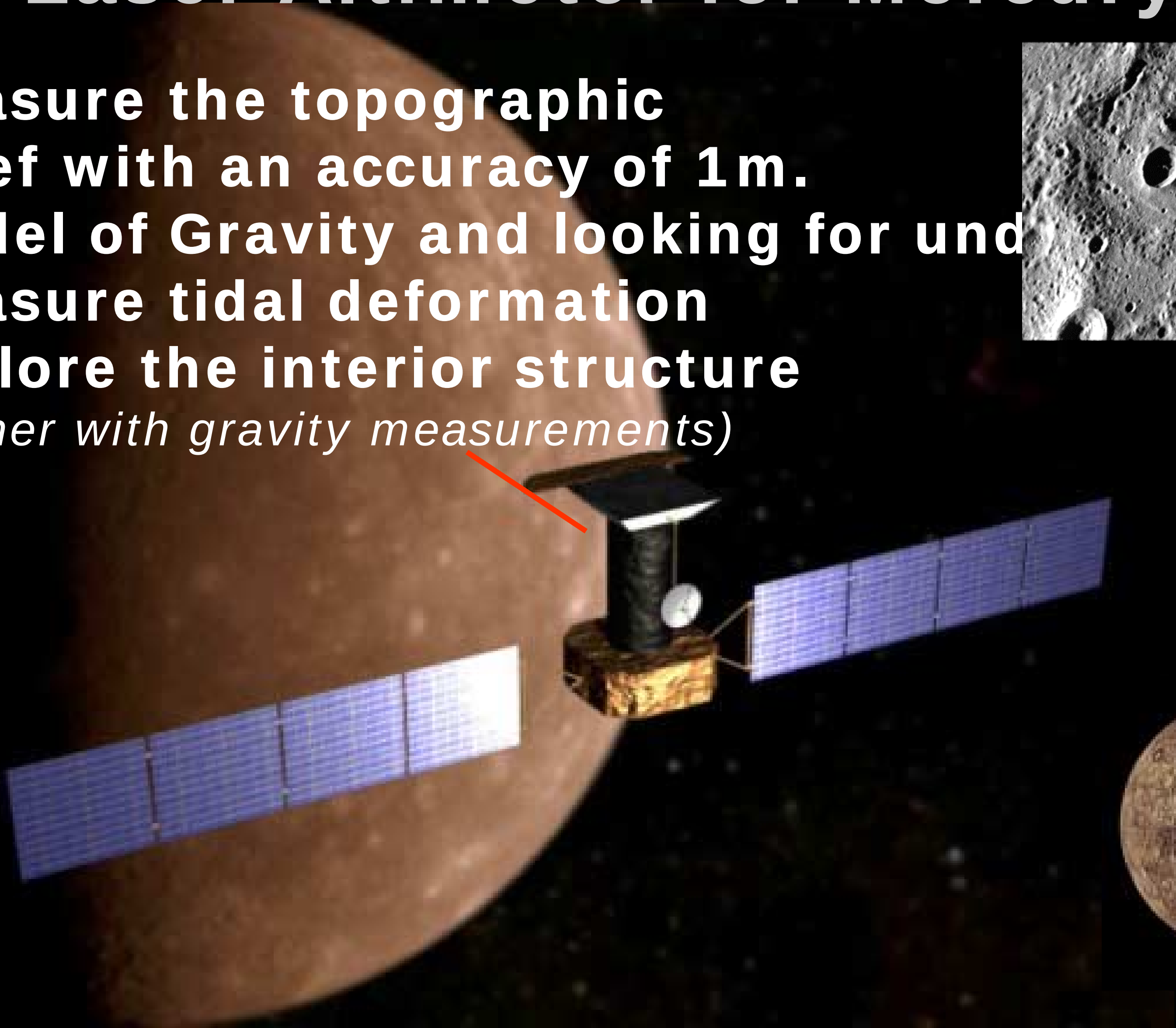
2. Bepi- Colombo and BELA

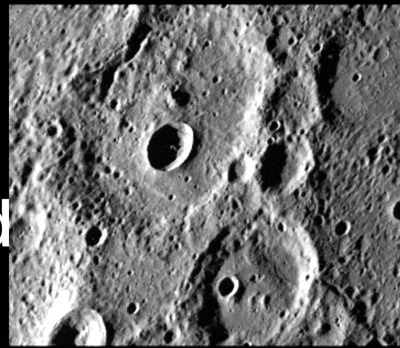
- **Origin and evolution of Mercury as a planet close to its parent star**
- **Mercury figure, interior, structure and composition**
- **Interior dynamics, origin of the magnetic field**
  - ***Launch 8/2013***
  - ***6 years travel***
  - ***2 years operation in orbit around Mercury***
  - ***Polar orbit: 400km/1500km***
  - ***Orbit period: 2.32hrs (ground velocity 2.2-3km/s)***

BELA
A Laser Altimeter for Mercury

- Measure the topographic relief with an accuracy of 1m.
- Model of Gravity and looking for und
- Measure tidal deformation
- Explore the interior structure

(together with gravity measurements)

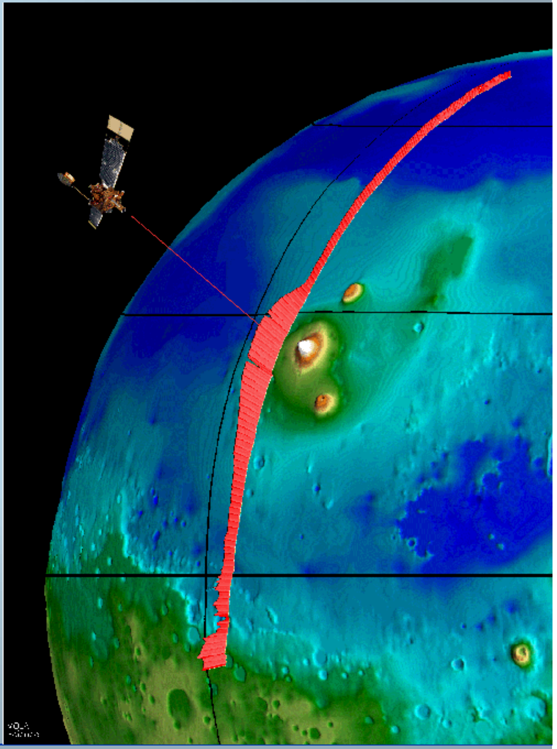




BELA – A Laser Altimeter for Bepi Colombo

Instrument Key Requirements

- Global topographic mapping with height accuracy of 1m wrt. COM (goal)
- Surface spacing 300m (shot to shot)
- High detection probability (>70%) up to 1000km
- Laser footprint <100m



BELA – The Bepi Colombo Laser Altimeter

Design Driver:

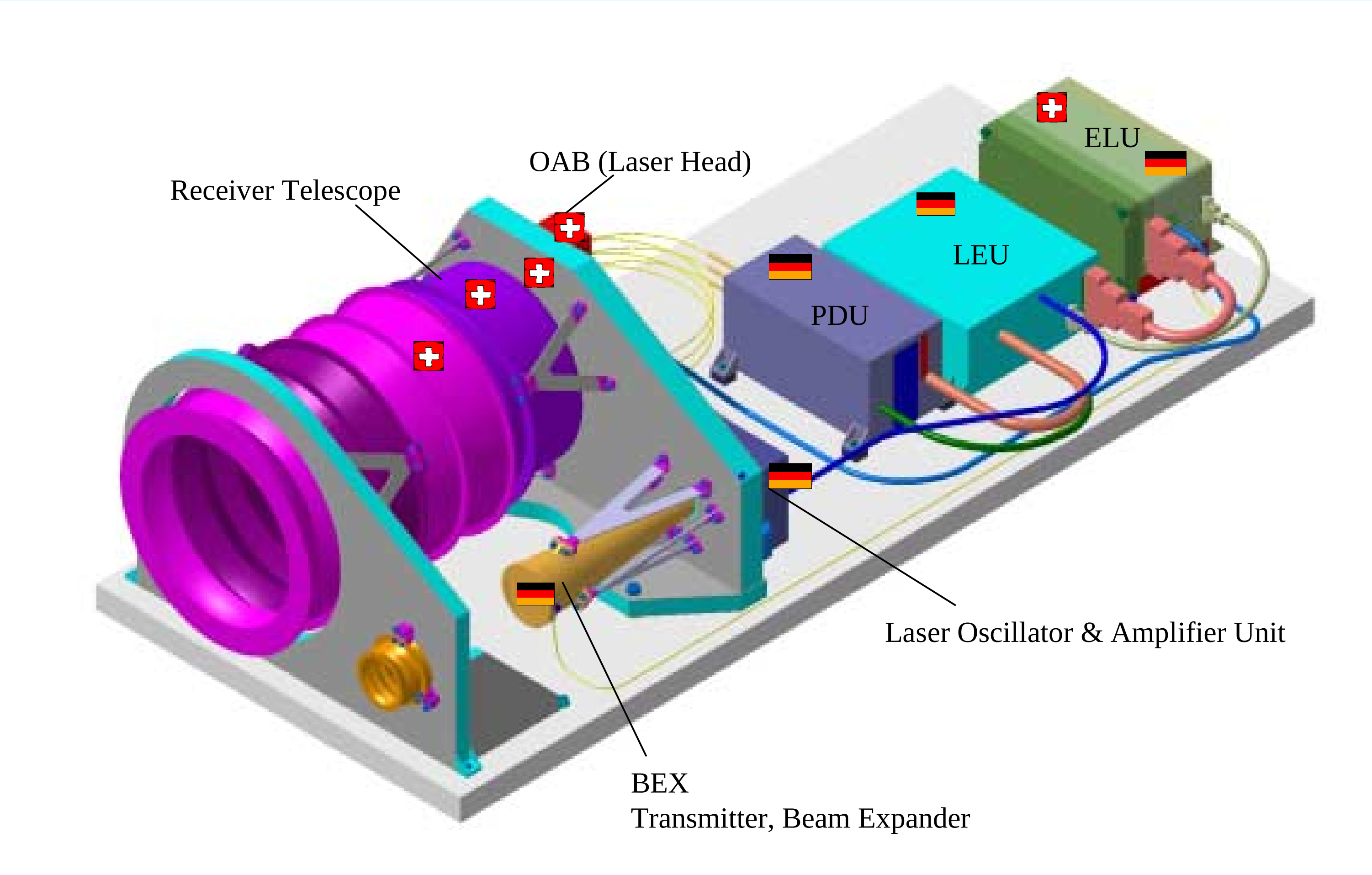
- High thermals and solar flux,
- Alignment stability
- cosmic radiation levels,
- low resources (mass)

BELA – The Bepi Colombo Laser Altimeter

Main Characteristics:

- 20-25cm lightweight telescope (1kg) with large baffle for thermal protection
- Backend optics with 1nm filter /FWHM) and >80% transmission
- High sensitive (low noise) APD detector
- 50mJ, 3ns diode pumped Nd:YAG laser, 10Hz nominal repetition rate
- 50mm (20x) Beam Expander with ~50m footprint @1000km
- Common EBox (called ELU) with receiver-, START-electronics and LEON-3 processor, power converter, Thermal controller
- 12kg, 33W (nominal)

1. BELA – Main Components



BELA Technical Status (I)

- Instrument Performance Modeling (PFD)
- Modeling of Thermal Environment and Control
- Prototype of BELA laser was designed and fabricated in Germany (MPS/DLR/German Industry)
- Beam Expander Telescope (prototype) designed, fabrication is in process
- START pulse electronics (with 1GHz pulse digitization) was designed and fabricated by DLR (prototype)
- Prototype of Receiver baffle fabricated and in test
- Receiver Telescope (ENT) and APD-detectors (customized- Perkin-Elmer) procured
- Build of a Demonstrator is in process (satellite ranging/transponder experiment)

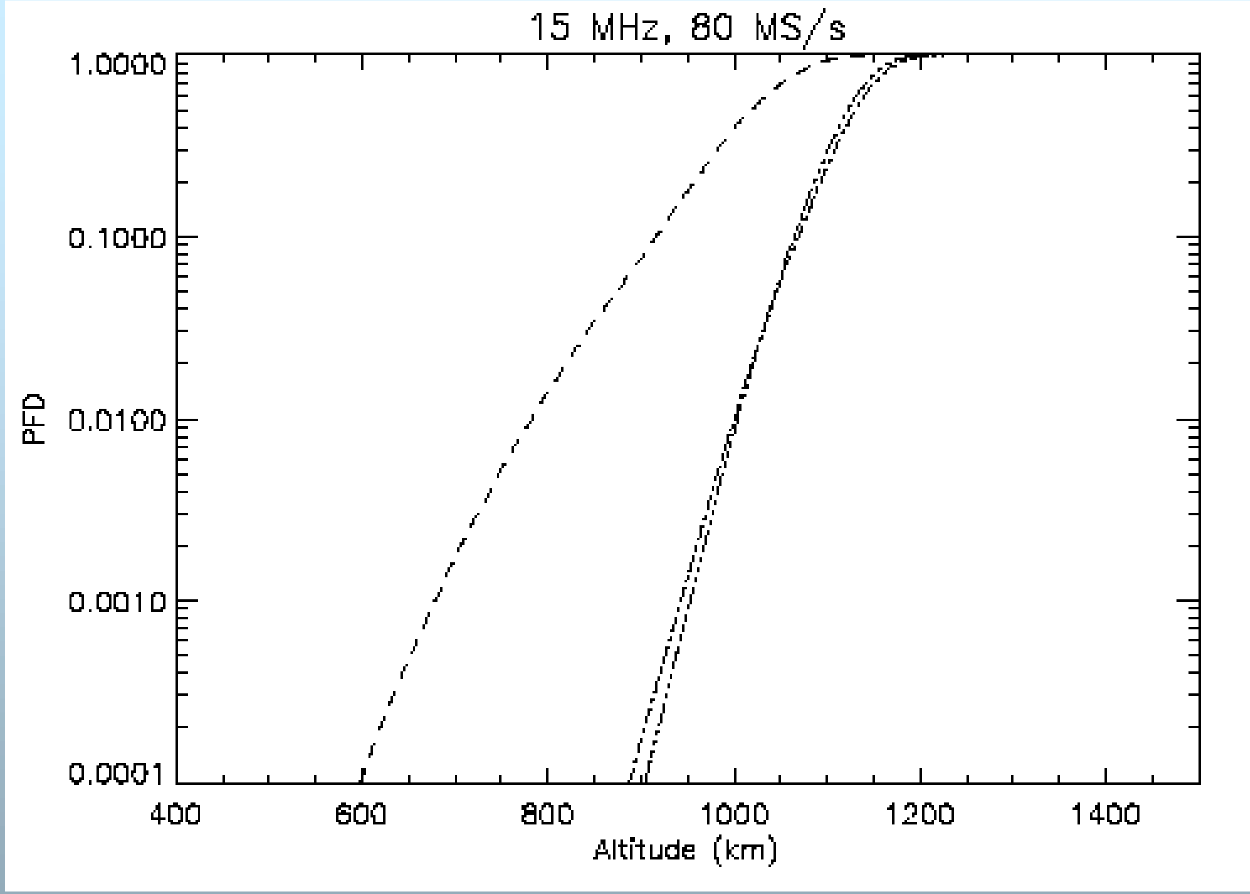
DLR

BELA

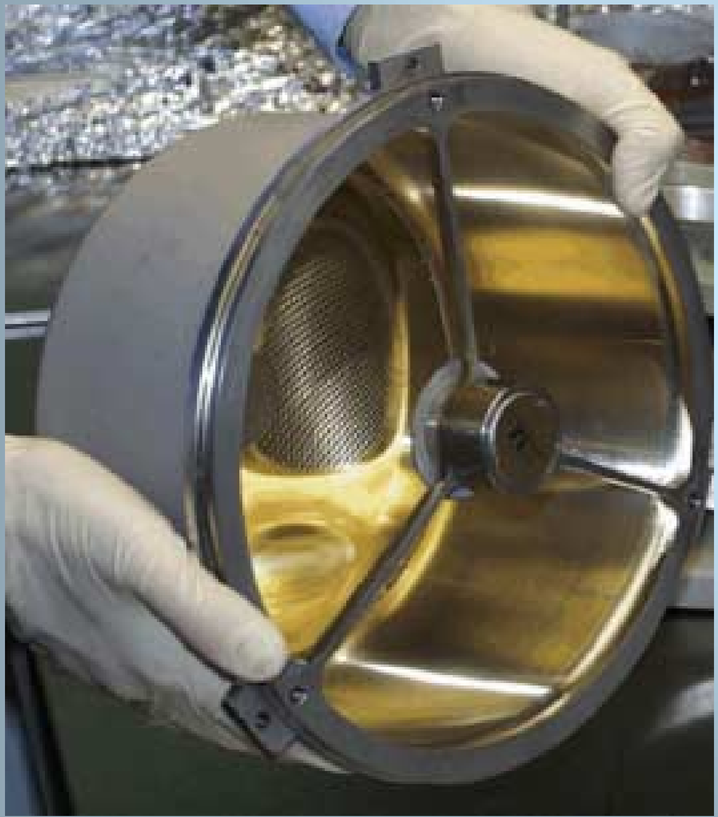
- **Instrument Modeling Parameters**

Parameter	Symbol	BELA
S/C		
Destination		Mercury
Altitude	H	400-1500 km
Pointing uncertainty	$\delta\varphi$	25µrad
Laser transmitter		
Pulse energy	E_r	50 mJ[a]
Pulse width	δ_0	3.4 ns[b]
Wavelength	λ_T	1064 nm
$1/e^2$ beam divergence	θ_T	25 µrad[c]
Repetition rate	ν_T	10 Hz
Collimator efficiency	ϵ_T	0.80
Receiver optics		
Arperture radius	r_R	125 mm
Focal length	f_R	1250 mm
Field of view	θ_{FOV}	200 µrad[c]
Optical efficiency	ϵ_{RO}	0.70[d]
Filter transmission	ϵ_{RF}	0.80
Filter bandpass	δ_{RF}	0.42 nm[b]
Detector		
Quantum efficiency	ϵ_{QE}	0.38
Gain	M	150
Excess noise index	χ	0.25
Surface dark current	I_{DS}	20 nA[a]
Bulk dark current	I_{DB}	50 pA[a]
Electronics		
TIA Bandwidth	B_0	20 MHz
ADC sample period	T_R	12.5 ns
Noise floor	δI_{NF}	1.0 pA $Hz^{-1/2}$

PFD (Probability of false detection) as function of height



BELA Technical Status (I): Receiver Telescope



- Electroformed nickel telescope
- 200 mm clear aperture
- 0.3 mm thickness
- athermal design
- no thermal protection filter
- gold coated

BELA Technical Status (I): FE- Optics with filter

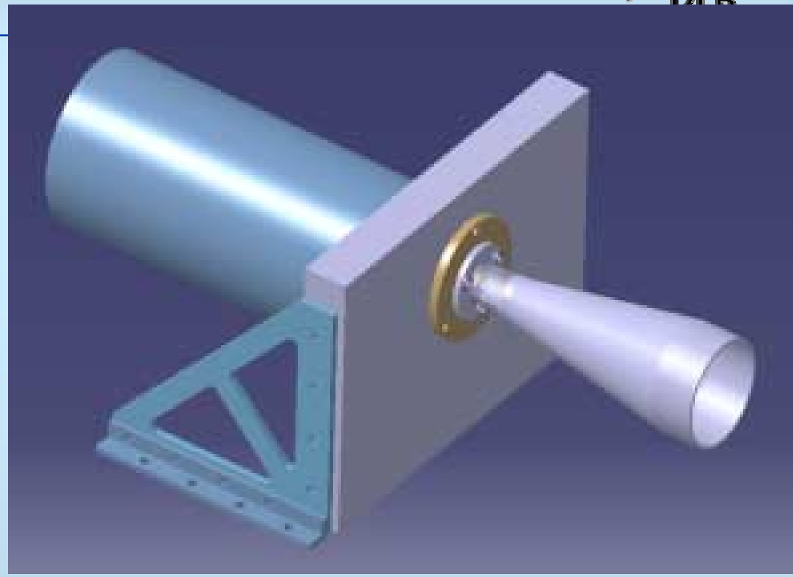
- Breadboard back end optics
- 1:1 re-imaging
- very small and light weight
- includes 1064 nm / 1 nm bandwidth filter

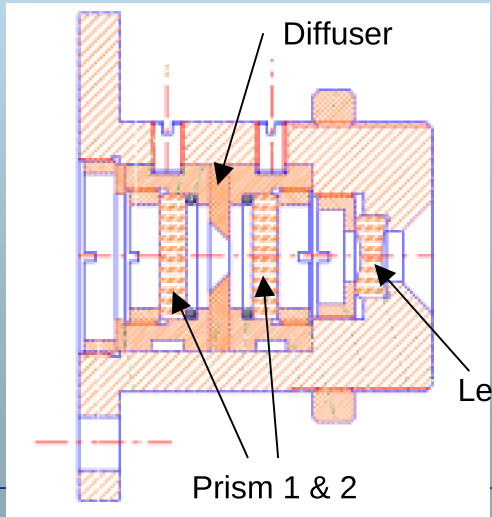
BELA Technical Status (I): Baffle

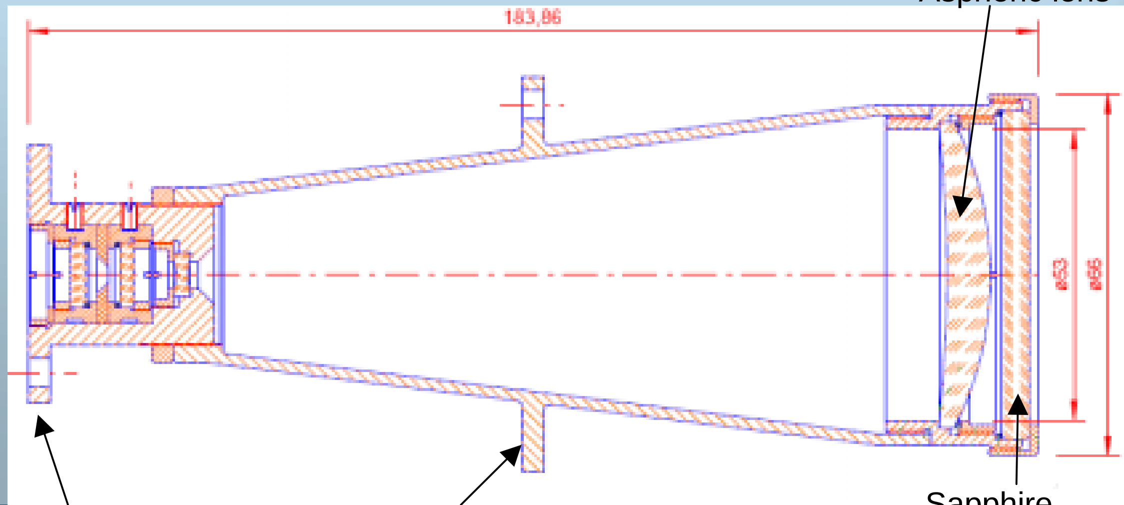
The instrument uses a reflective baffle with a geometry proposed in 1994 by Stavroudis. Outer vane surfaces are ellipsoids, inner vane contours are hyperbolas. This geometry ensures that rays entering the baffle are reflected back through the aperture after 1 or 2 (average 1.4) reflections. The breadboard baffle was manufactured by Universität Bern. Single vanes are diamond-turned from Aluminum, and coated in order to maximize overall energy reflection in both visible and planetary solar/IR flux. Vanes are mounted to each other by screws. Inner diameter: 200 mm. Total length 290 mm. Mass 716 g.

2. Optical prototype of the Beam Expander

- Design completed (M=20)
- Aspheric lens
- 2 wedge prism
- Fabrication is in process







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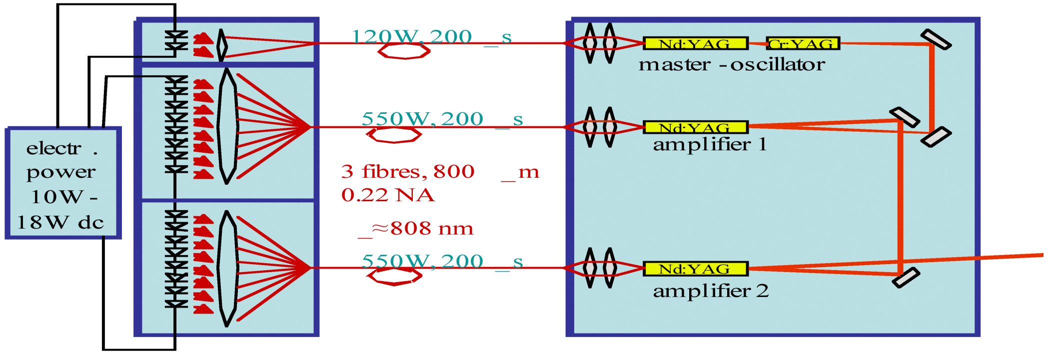
BELA- Laser – Block Diagram

MPS

vH&S LZH EADS DILAS Diodenlaser GmbH for MPS



3 Pump Modules — Oscillator-Amplifier-Box

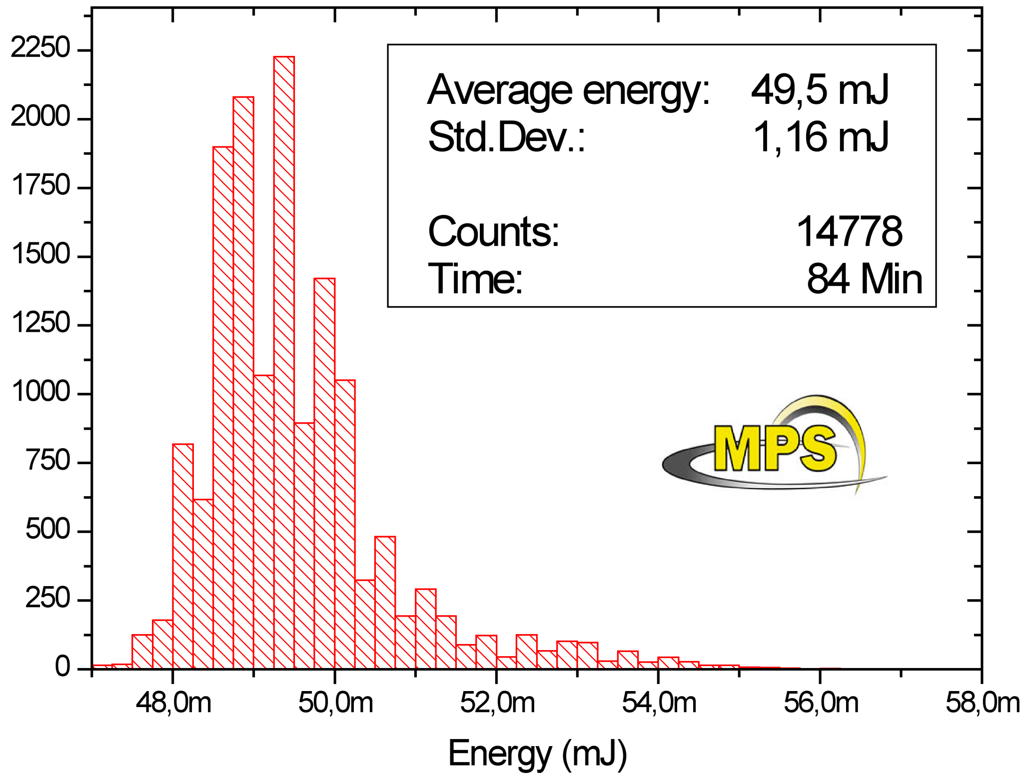
The BELA instrument requirement is to have 3 fibre coupled pump sources (called modules); two of them shall deliver 550W ex fibre each for amplifier pumping while the third has to deliver 120W ex fibre for oscillator pumping.
The diodes for oscillator pumping shall be available in could redundancy, which means that two bars will be operated and two other bars can be used alternatively (not sketched).

BELA- Laser (PM)

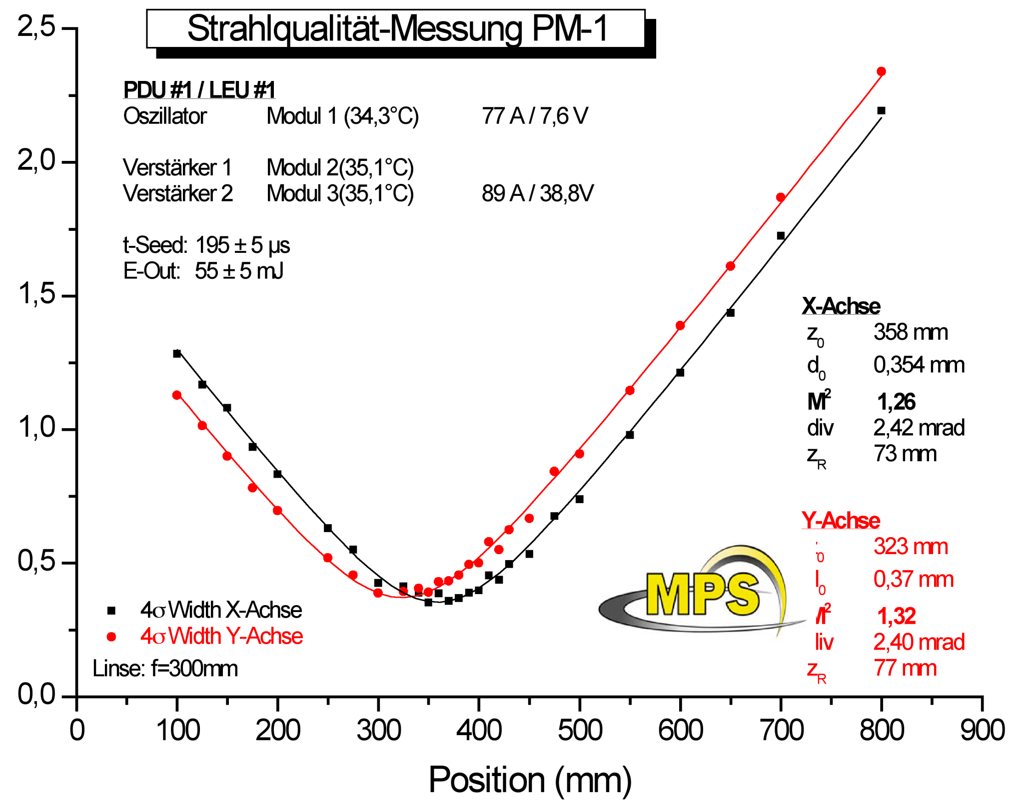
- PDB (Pump Diode Box
- OAB (Laser Head)
- LEU (Control Electr.)

Energy Measurement

Pulse Energy Distribution

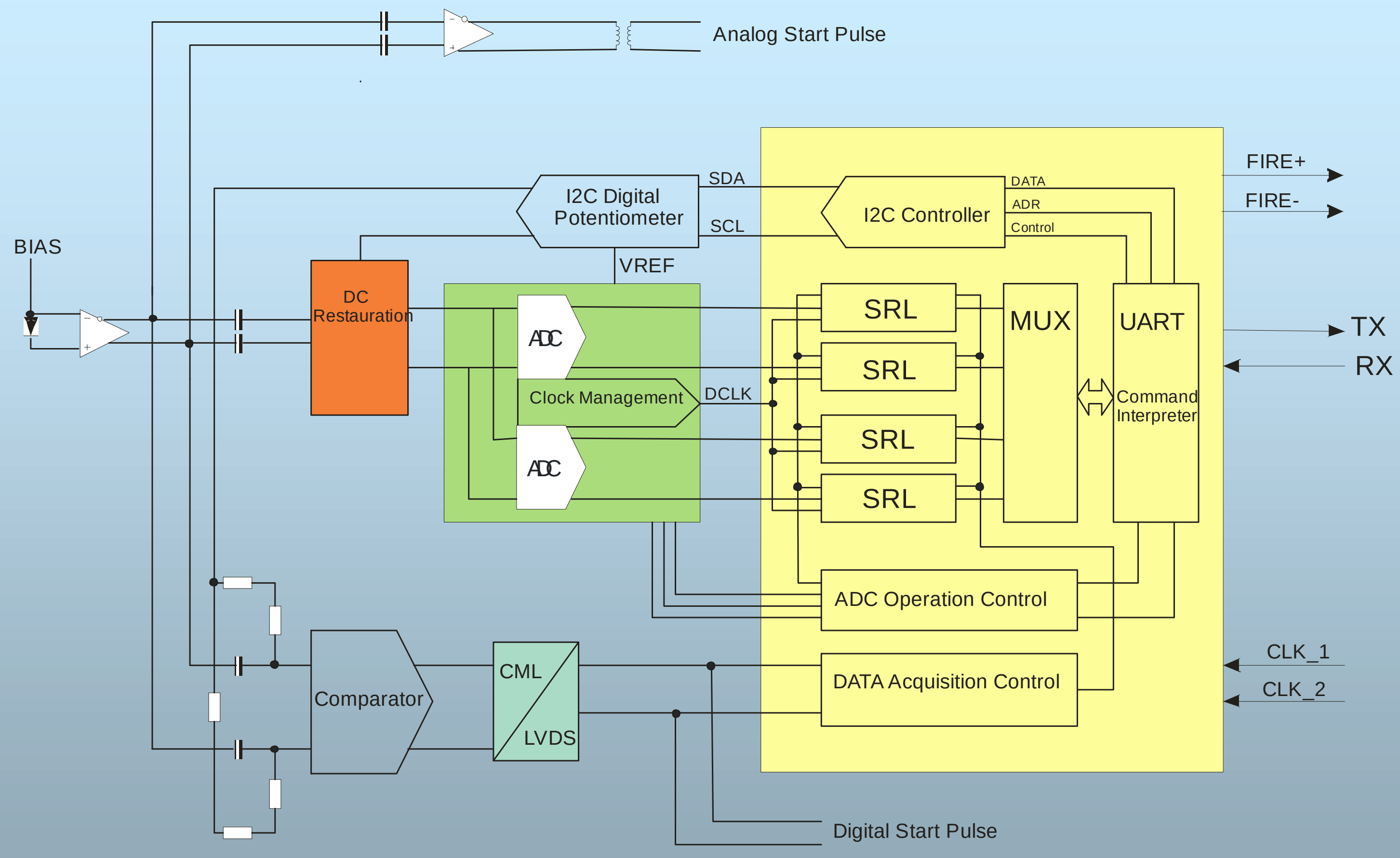


Beam Quality

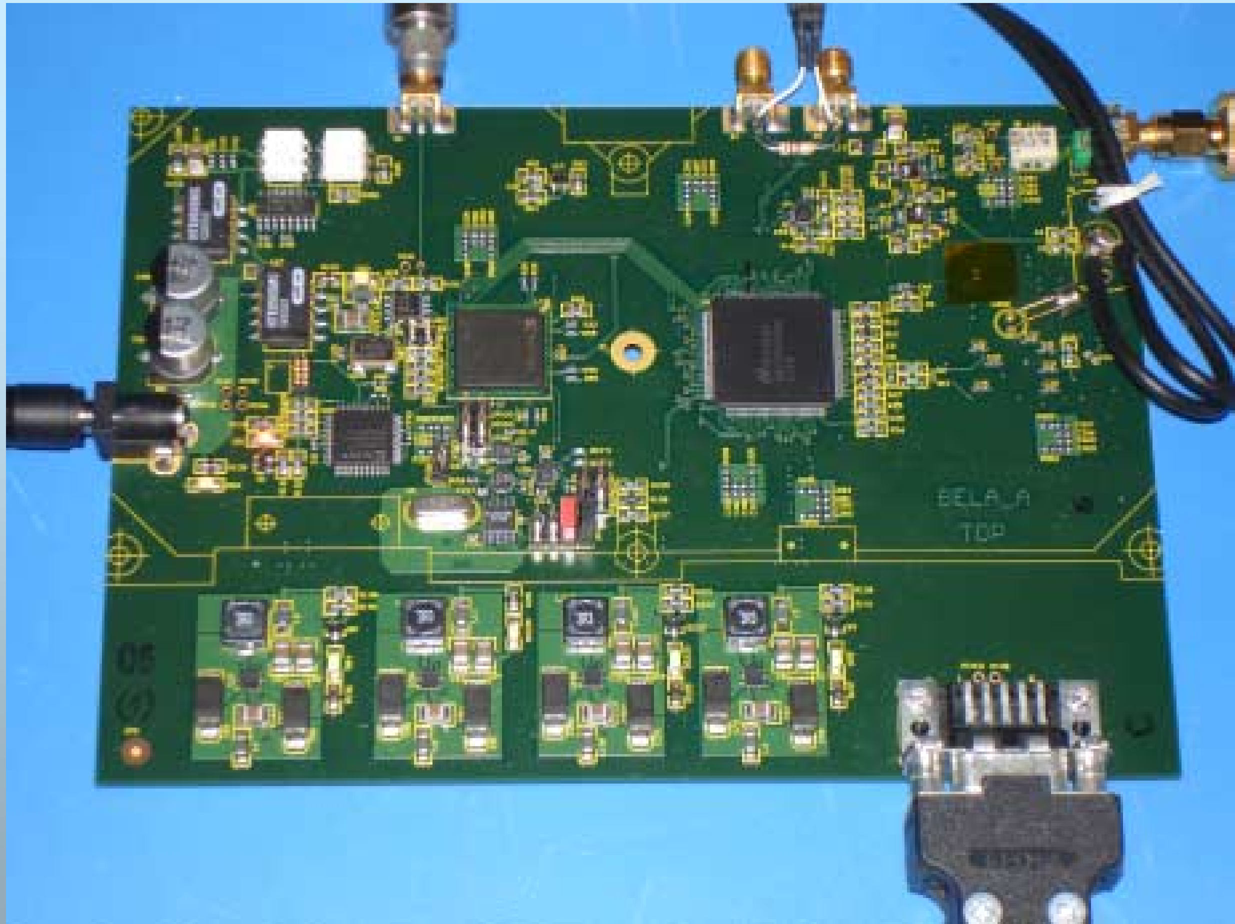


M^2- measurement

1. START Pulse Electronics - Block Diagram



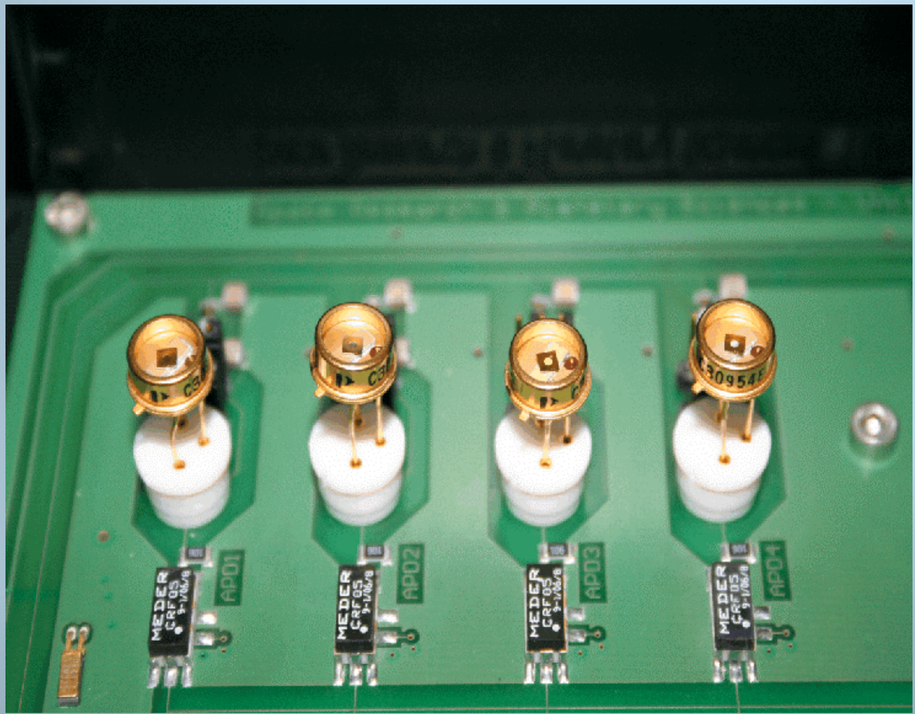
2. START Pulse Electronics: PCB with High Speed Digitization



BELA Technical Status (II)

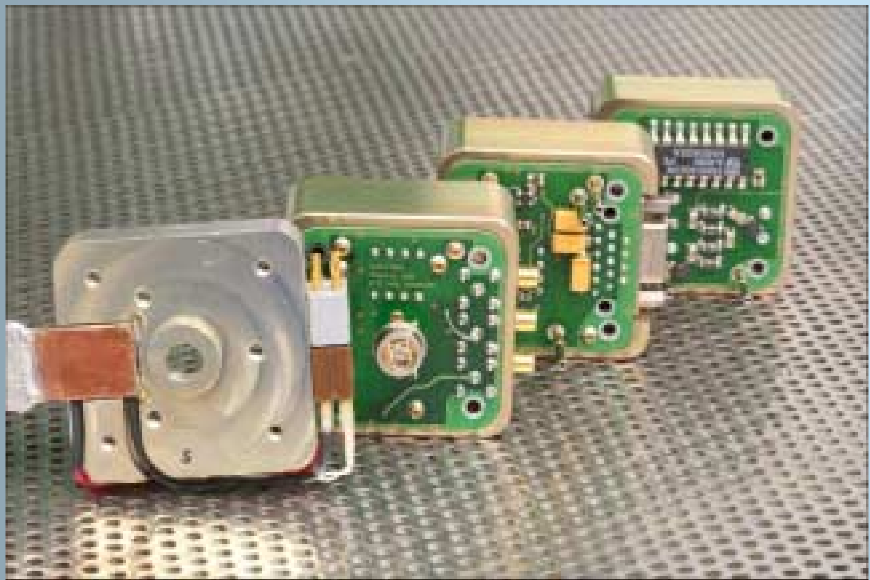
Receiver (UBE):

- Procurement and test (in process) of customized APD detectors



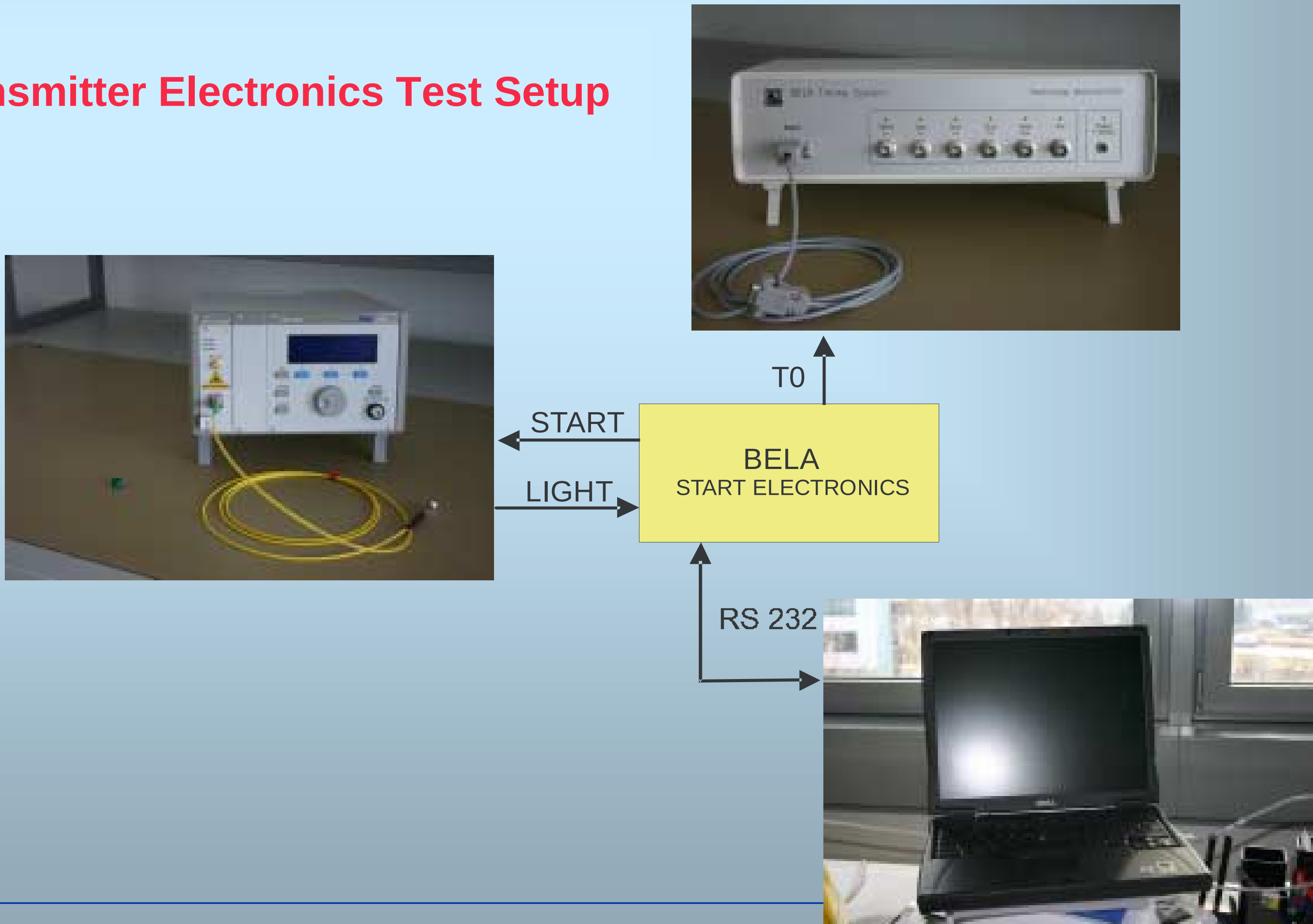
BELA Technical Status (II)

Receiver (UBE):



- Breadboard focal plane assembly, with
- Perkin-Elmer avalanche photo diode
- Peltier cooler for detector
- Thermal braid to remove heat from warm side of Peltier
- DC/DC converters

Transmitter Electronics Test Setup



3. Outlook, Focus area of coming months

- **Laser Tests**
- **Detector (APD) Tests**
- **Thermal modelling, Thermal design & control concept**
- **Definition mechanical interface and alignment concept**
- **Design of Receiver Electronics**
- **Demonstrator/Transponder Integration and Test (together with U. Schreiber/LRS-Wettzel, Germany)**

Reserve

Functional Principle of the HRSC-Camera

Stereoscanner
- 9 line sensors
- each with 5184 Pixel

Super Resolution Channel
- 1 matrix sensor
- 1024x1024 Pixel