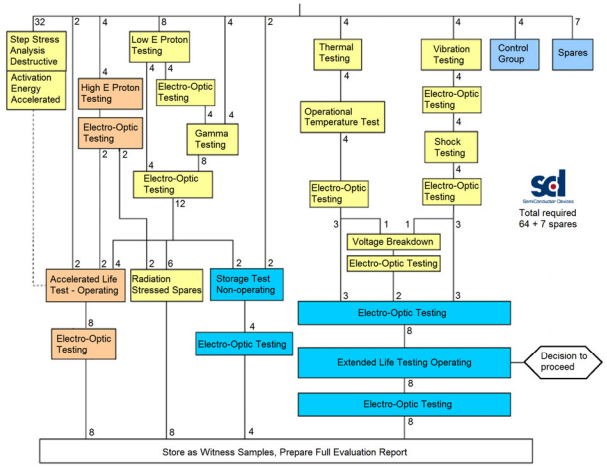
The Laser Qualification / Verification Effort

Laser Qualification
Critical Technologies Overview

Component Level

Laser-Induced Damage Threshold	=> Polarizer
Opto-electronics	=> LDA, PIN
Radiation Hardness	=> LDA, Laser rod, RTP
Contamination / Outgassing	=> Coatings



ESCC
European Space Components Coordination

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EVALUATION TEST PROGRAMME GUIDELINES

FOR

LASER DIODE MODULES

ESCC Basic Specification No. 23201

Assembly Level

Long-term Laser Operation in Vacuum

Hermetic sealing

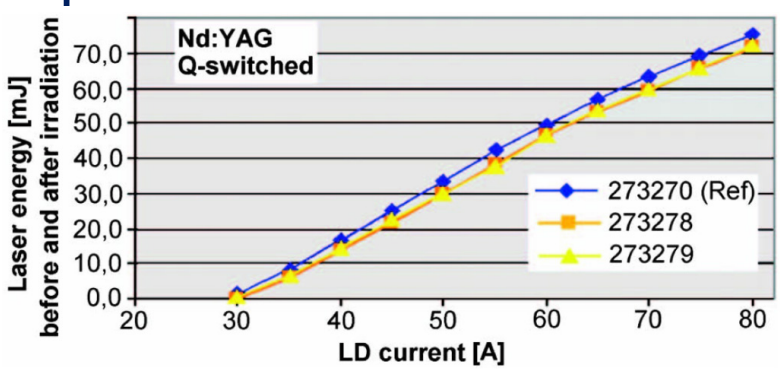
Electro-magnetic Compatibility … conducted emissions

Partial discharge

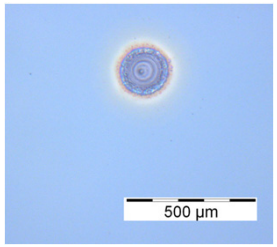
Pulse energy control

Optical alignment stability, pointing

Divergence



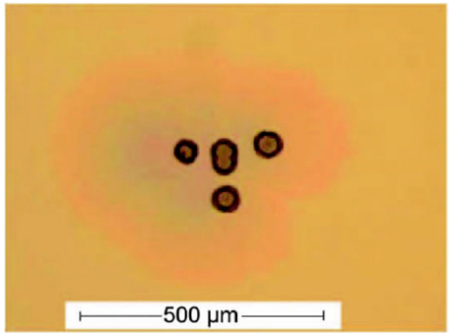
Laser Qualification Break-Down to Component Level: Test programme included > 1.500 test items



Optics: Lenses, polarizers, waveplates, mirrors, dichroics, window
Nd:YAG laser rod
Start pulse fibre set
Pump light diffuser
Variable reflection coating

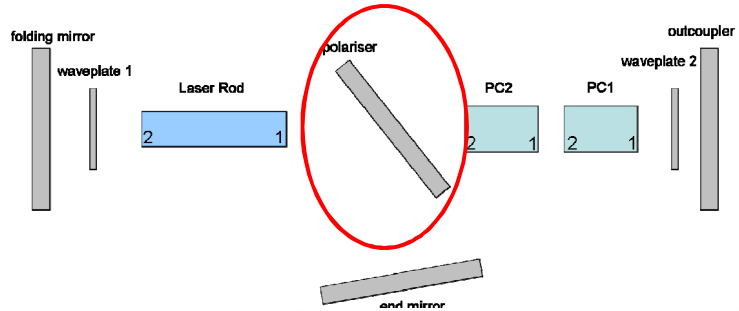
Environmental test acc. to MIL-C-48497A
Laser Induced Damage Threshold (LIDT)
Materials delta qualification
Gamma and proton irradiation
…

Optoelectronics: Laser Diode Arrays
RTP Pockels‘ cell
Photodiode

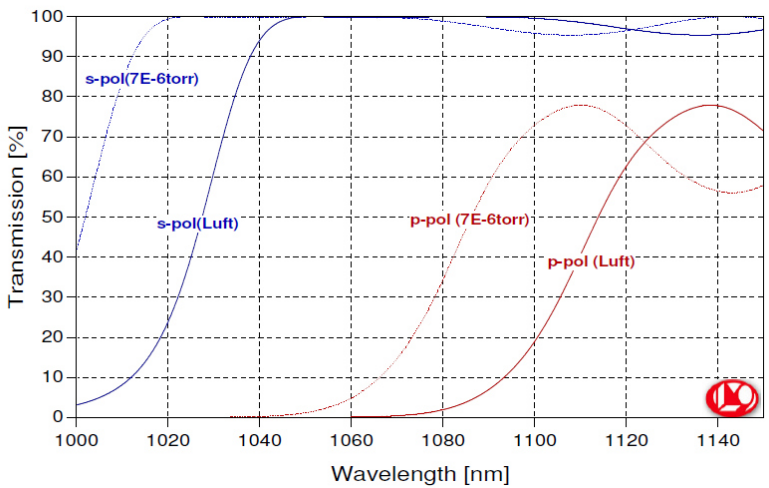


Electronics: Fast MOSFETs
HV electronic parts
Hermetic connectors

The Polarizer in the laser oscillator faces worst LIDT conditions



Optical component	Tophat pump profile	slight-peak pump profile	Zemax pump profile	expected LIDT @ 10 ns
Outcoupler	1.4 J/cm²	1.3 J/cm²	1.4 J/cm²	> 15 J/cm²
Waveplate 2	1.4 J/cm²	1.3 J/cm²	1.4 J/cm²	10 – 15 J/cm²
PC1, surface 1	1.4 J/cm²	1.3 J/cm²	1.4 J/cm²	6 – 10 J/cm²
PC1, surface 2	1.4 J/cm²	1.4 J/cm²	1.4 J/cm²	6 – 10 J/cm²
PC2, surface 1	1.4 J/cm²	1.4 J/cm²	1.4 J/cm²	6 – 10 J/cm²
PC2, surface 2	1.4 J/cm²	1.4 J/cm²	1.5 J/cm²	6 – 10 J/cm²
Polariser	2.7 J/cm²	2.6 J/cm²	2.8 J/cm²	
Laser rod, surface 1	2.7 J/cm²	2.6 J/cm²	2.8 J/cm²	10 – 15 J/cm²
Laser rod, surface 2	2.6 J/cm²	2.6 J/cm²	2.7 J/cm²	10 – 15 J/cm²
Waveplate 1	2.6 J/cm²	2.6 J/cm²	2.8 J/cm²	10 – 15 J/cm²
Folding mirror	2.6 J/cm²	2.6 J/cm²	2.8 J/cm²	> 20 J/cm²



Polarizer is located in resonator leg which is facing twice the intensity

- Nominal intensity ~2,7 J/cm²
- Qualification target value 15 J/cm²

Polarizer comes with largest layer stack – more layers, more sensitivity

- Layer stack thickness 5.8 µm

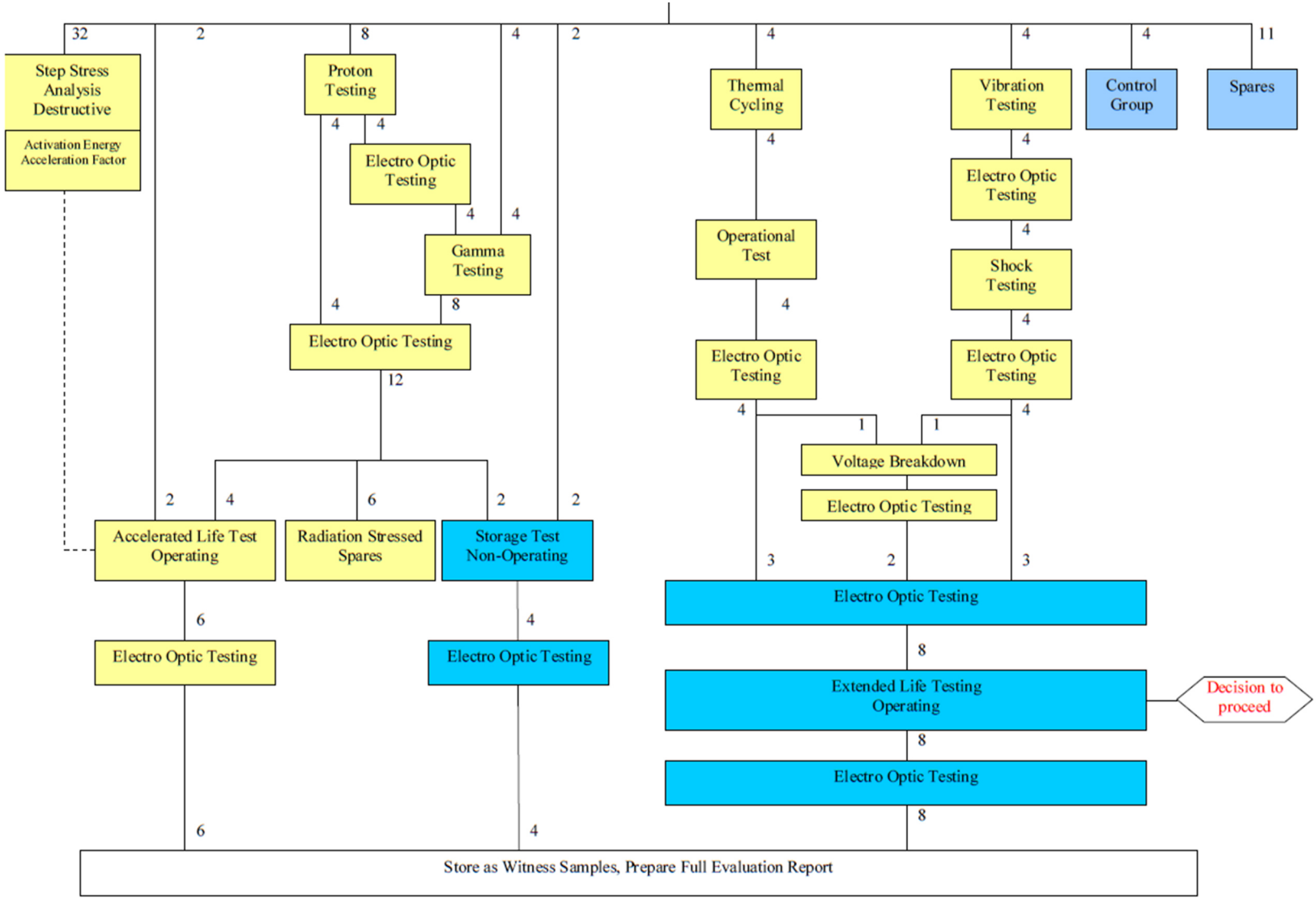
Coating options are limited for high LIDT

- Ebeam coating achieved required LIDT, but IBS did not
- other coating suppliers tried but LIDT improved only marginal
- Decision to accept ebeam coating
  - Ebeam coating density and spectra shift with humidity
  - Laser alignment performed with reduced functionality
  - 1st acceptance test with LHB provisionally sealed
  - Remove all H_2O during LHB Bake-Out

[1] C. Scurlock, Laser Risk Reduction Program, NASA GSFC
[2] C. J. Stolz, Thin Film Femtosecond Laser Damage Competition

Pump Laser Diode Arrays (LDA)

LDA Qualification



LDA Screening Test Procedure … as applicable for flight items

- Dimension and alignment check (100%)
- Visual Inspection (100%)
- Electro Optical Tests (100%)
- Thermal Cycling (100%)
- Visual Inspection (100%)
- Electro Optical Tests (100%)
- Shock Test (100G, 5 ms)
- Visual Inspection (100%)
- Electro Optical Tests (100%)
- Burn In Screening (100%)
- Extended Electro Optical Tests (100%)
- Visual Inspection (100%)

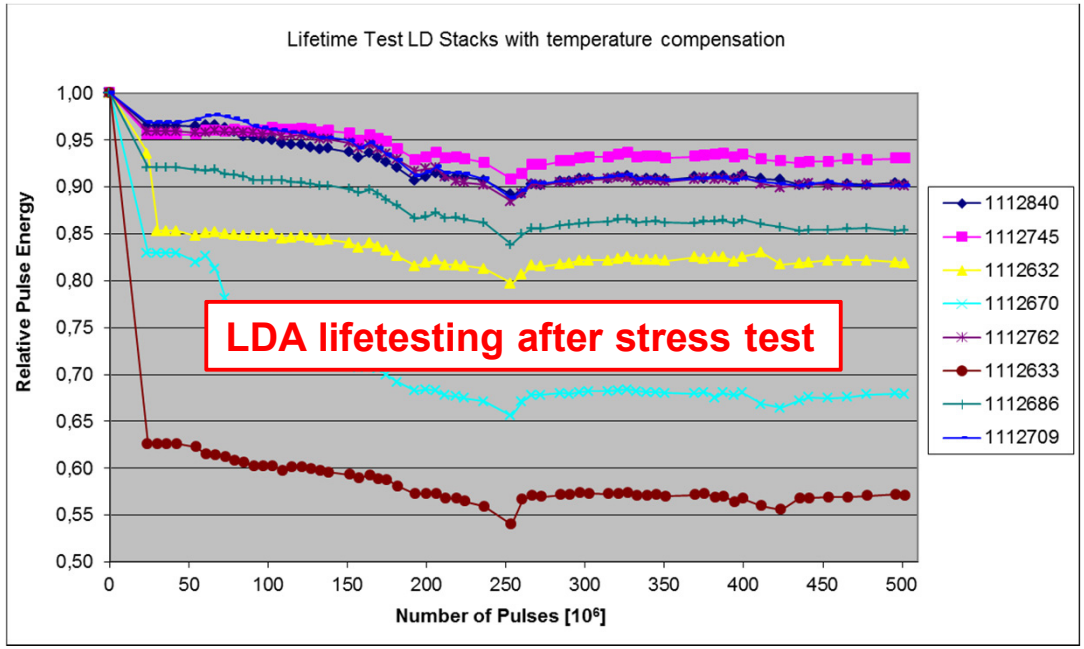
Laser Qualification
Component Level Tests

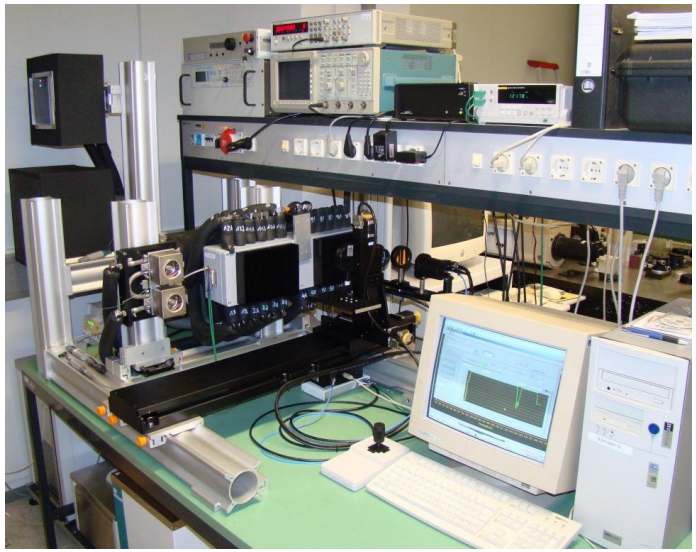
Laser-Induced Damage Threshold of coatings

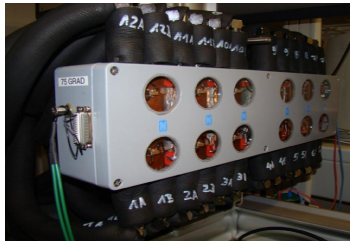
Laser Diode Arrays (LDA)

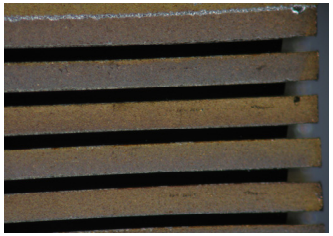
Radiation-Hardness (Laser and Q switch crystals, LDA)

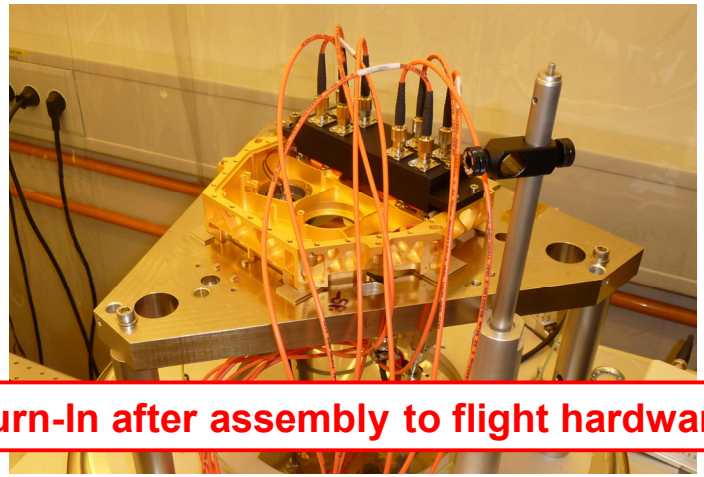
Long-term Laser Operation in Vacuum





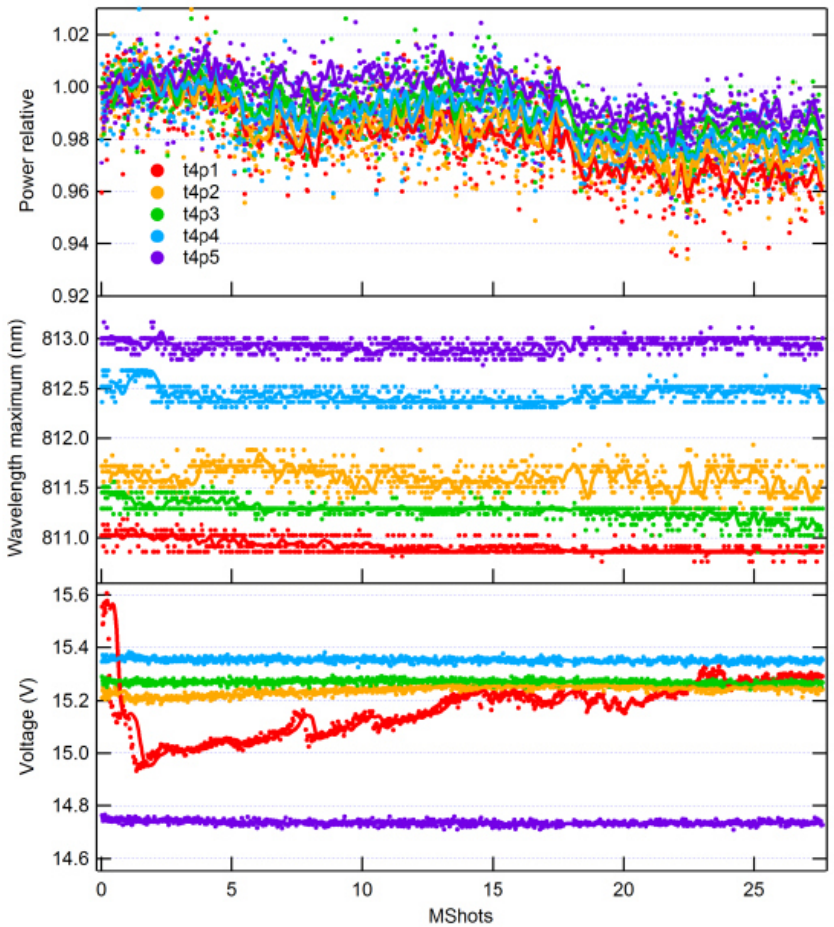


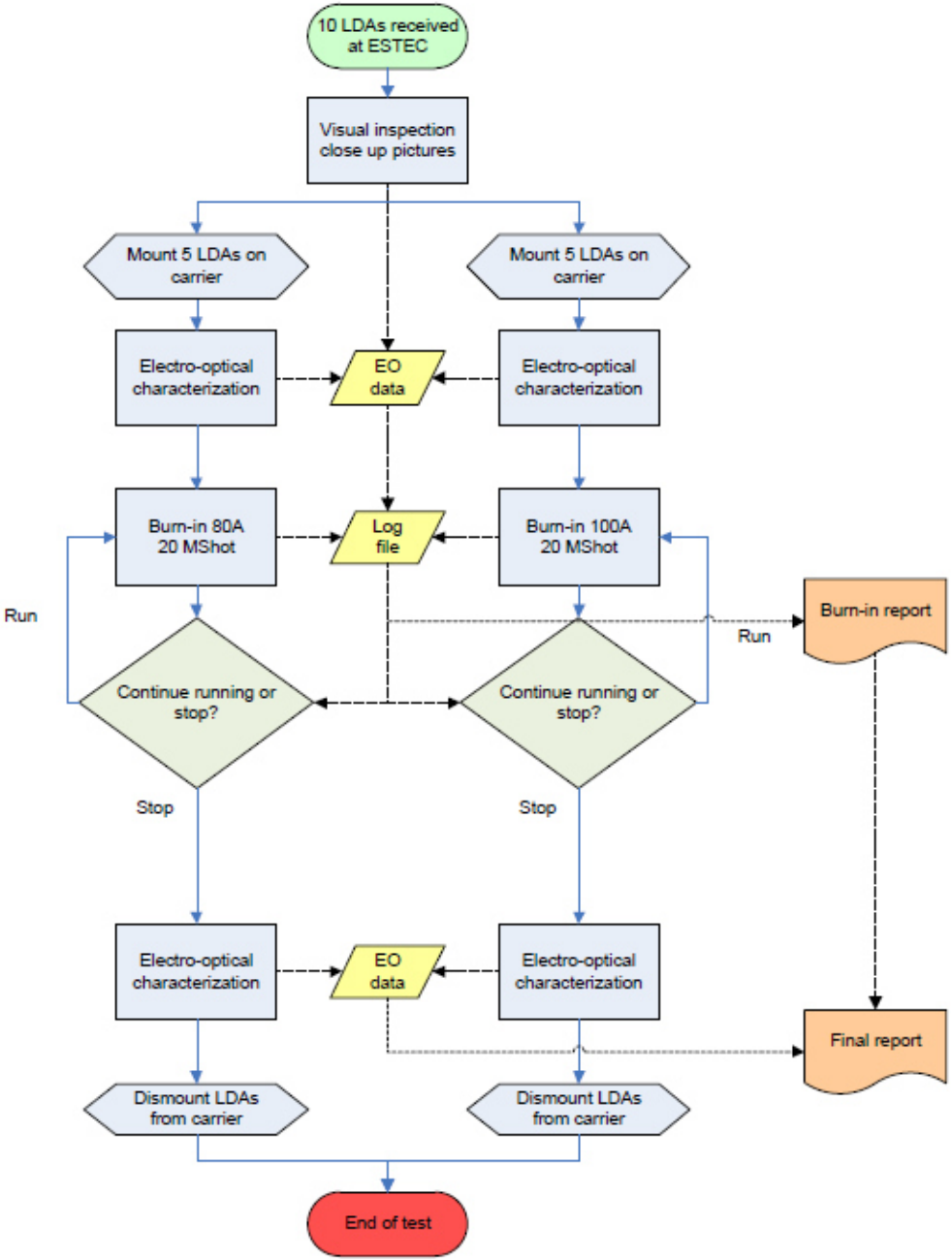




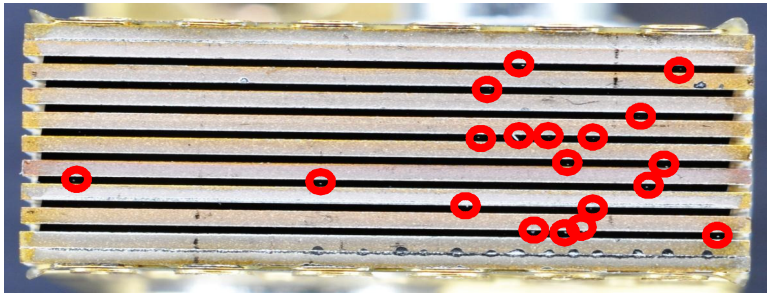
Burn-In after assembly to flight hardware

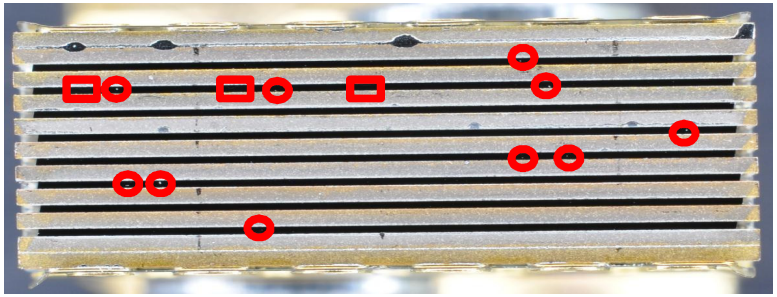
LDA Qualification Tests
ESTEC Test Program

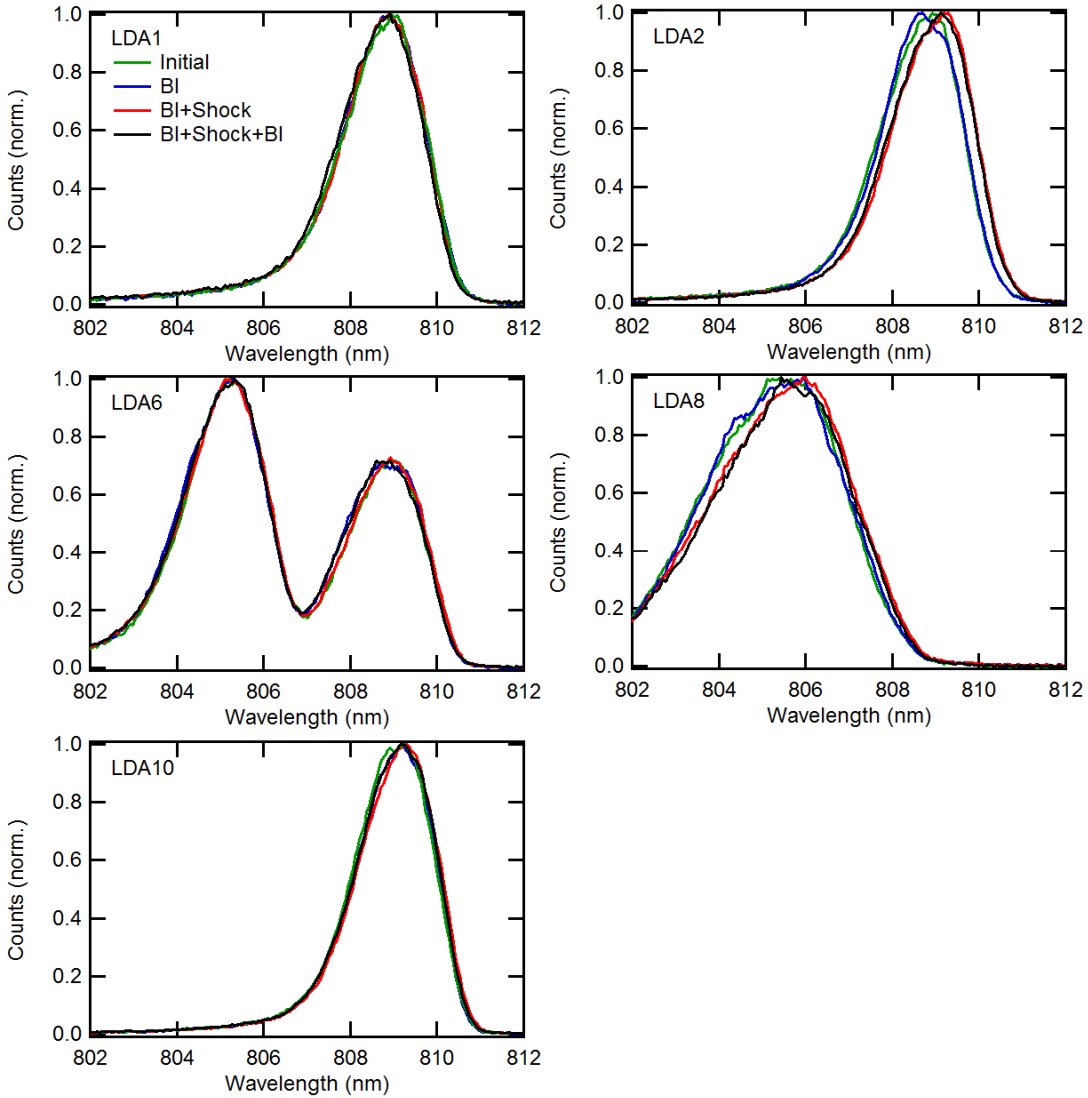




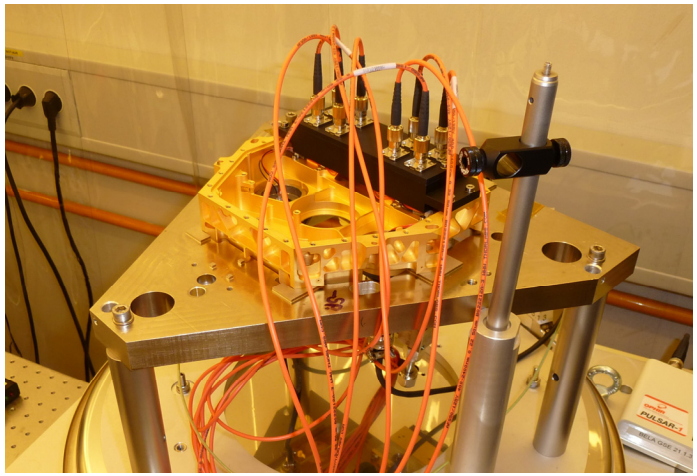
LDA Qualification Tests at ESTEC: Careful Inspection, Shock Tests, …

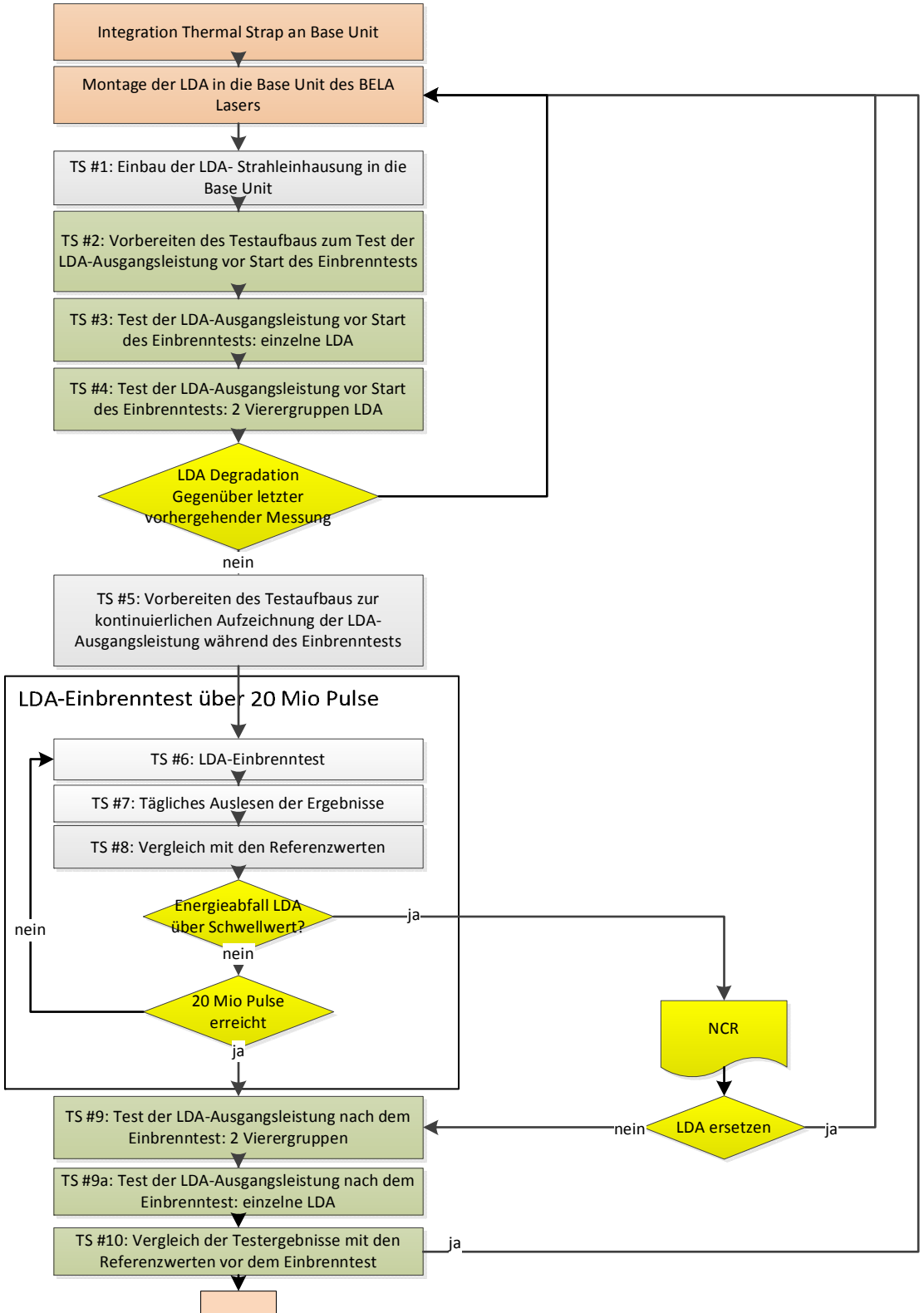




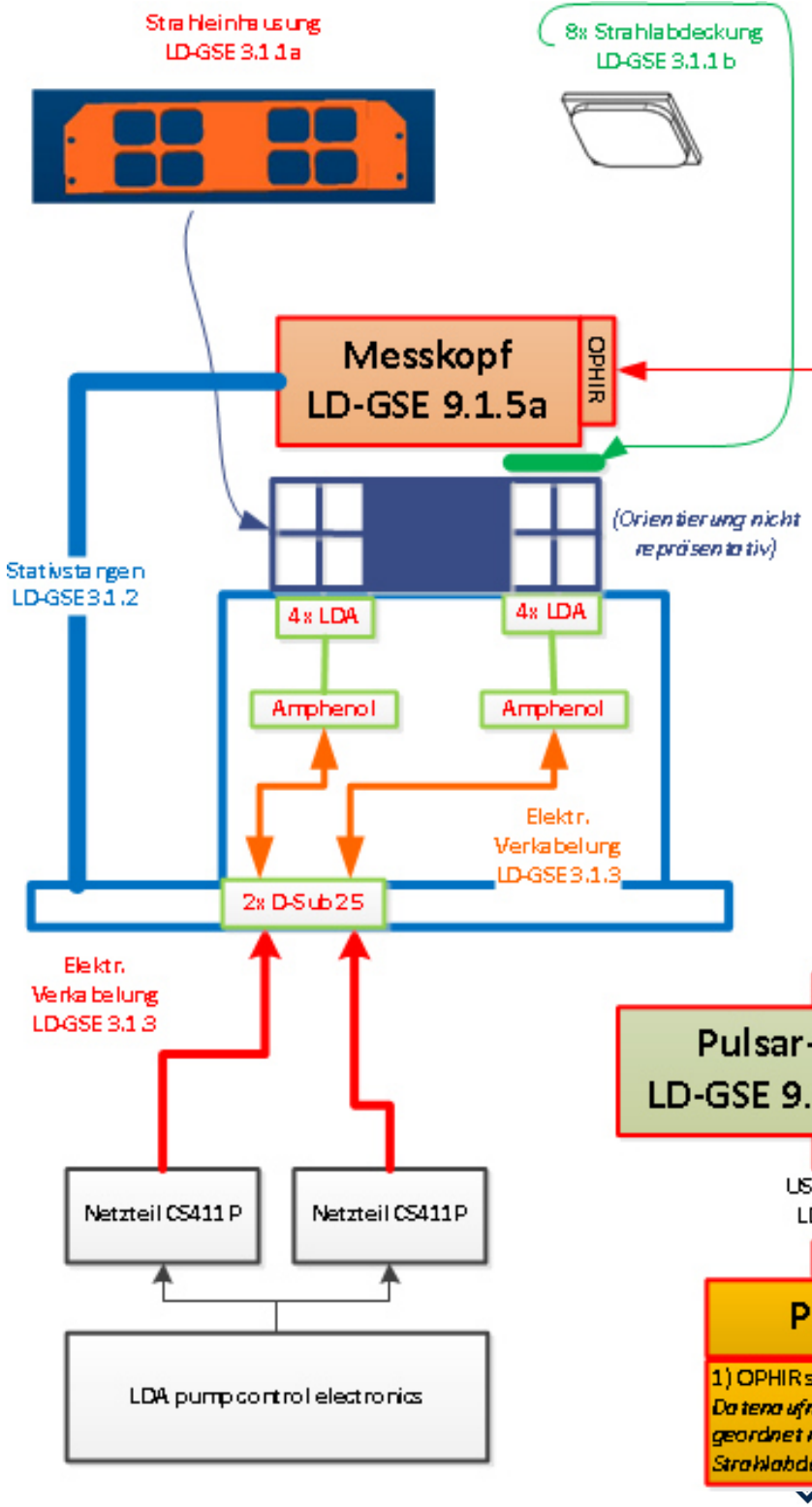


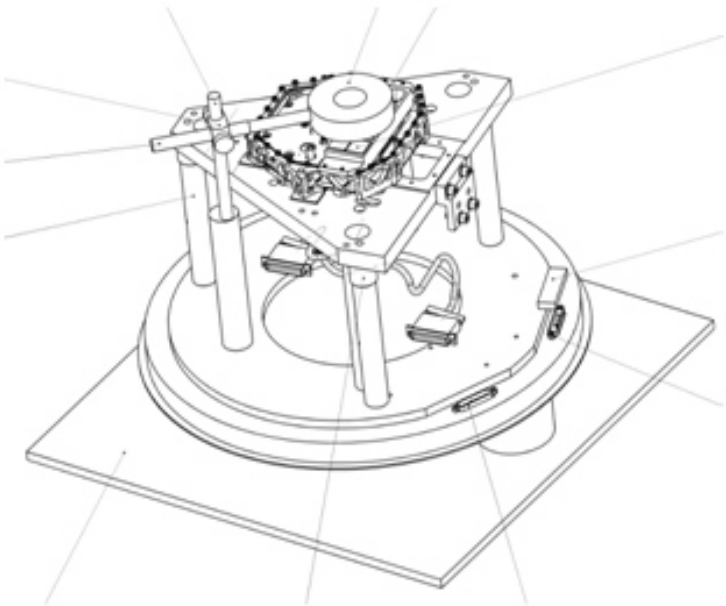
LDA Burn-In after Integration into LHB housing



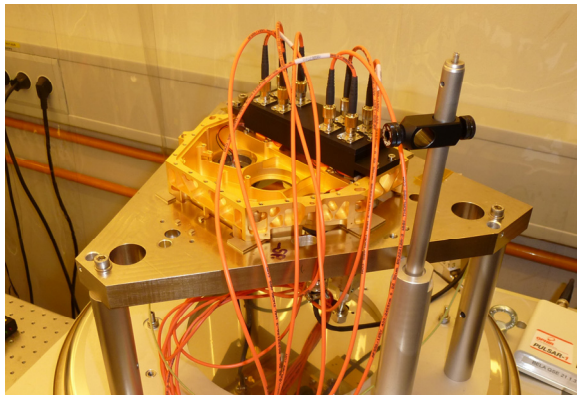


LDA Burn-In Test Config





LDA Burn-In after Integration into LHB housing ***continued***



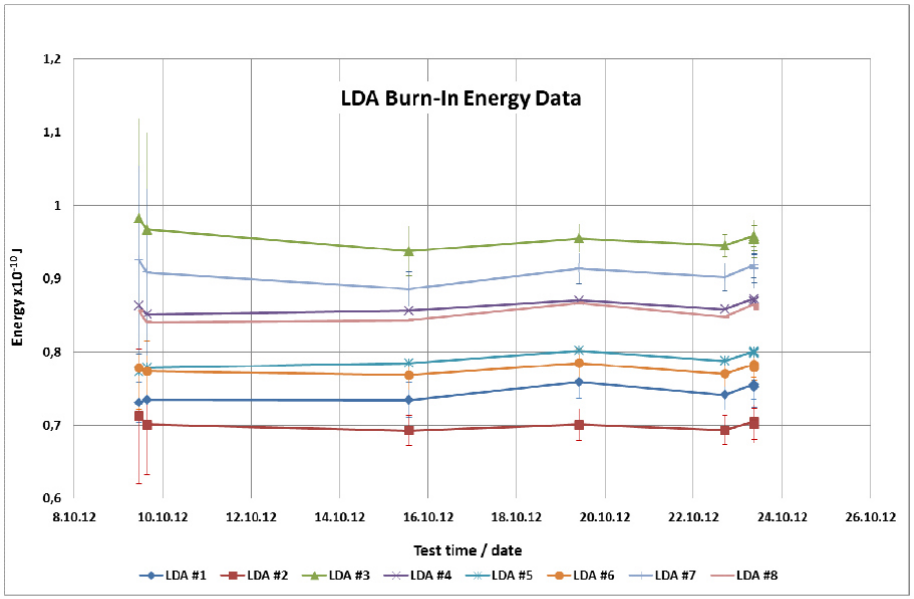
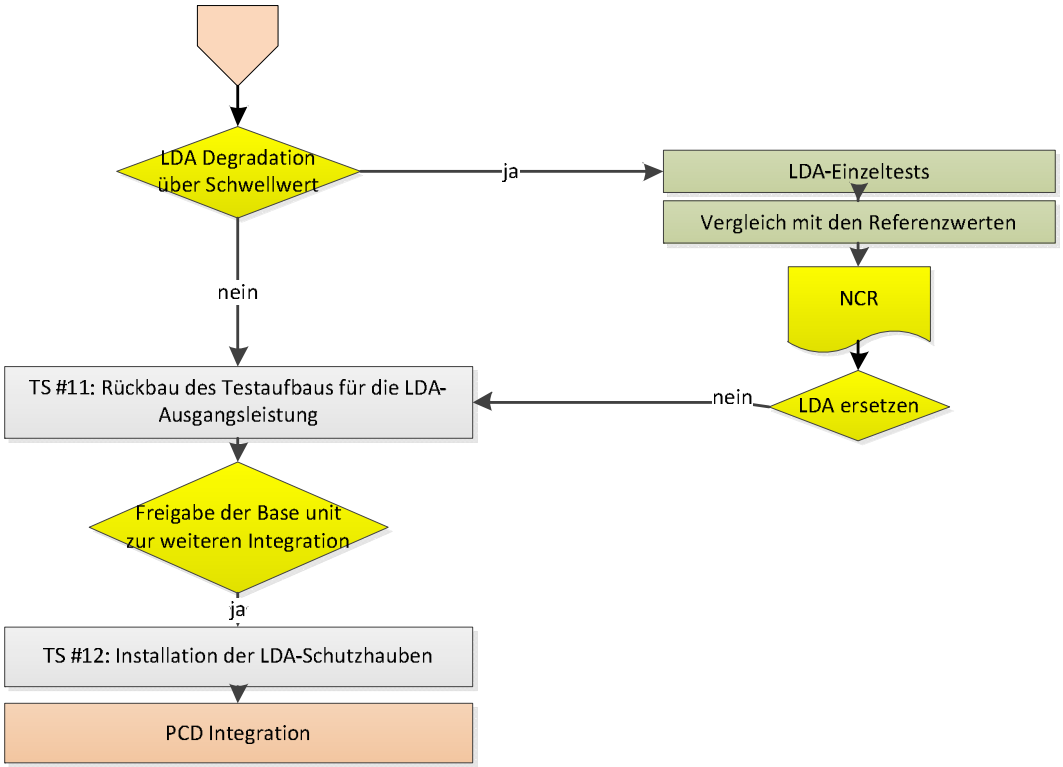
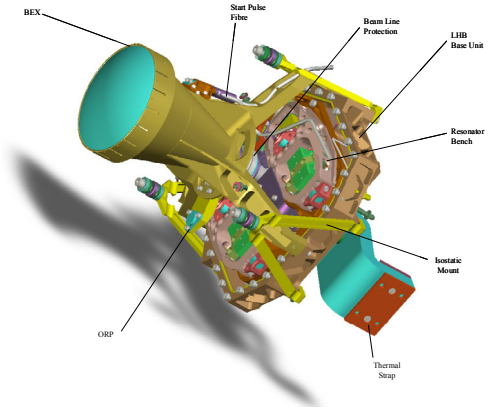


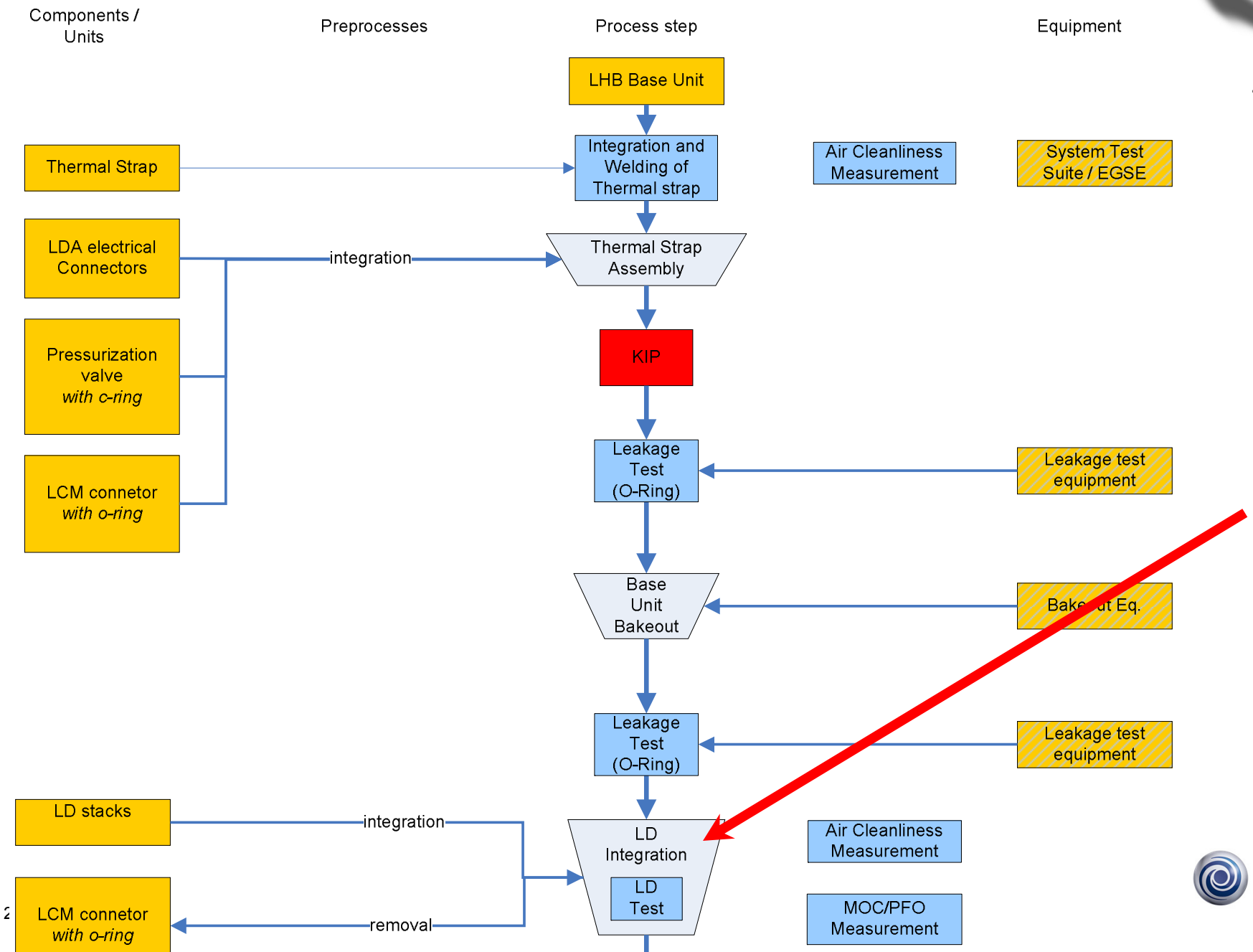
Figure 4: **Pulse Energy data (average iaw Figure 1) with standard deviations indicated as error bars**



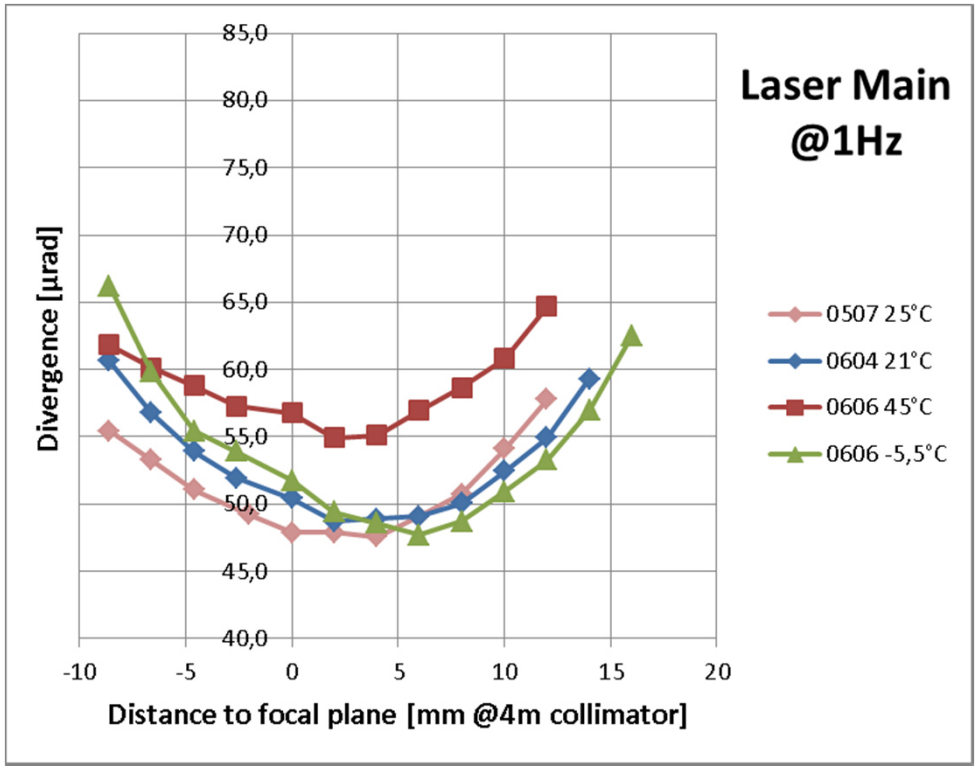
BELA Laser
Assembly, Integration and Test

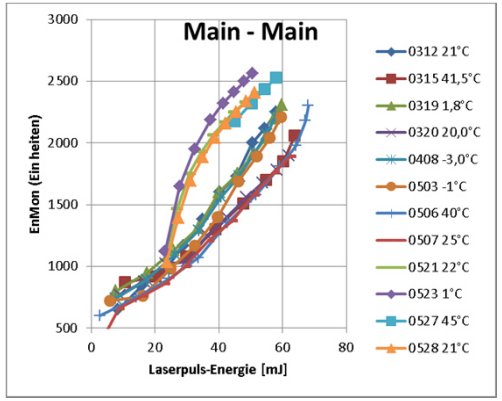
BELA Laser FM - AIV Sequence

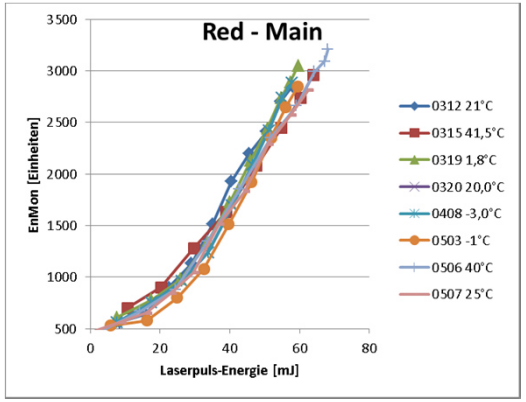


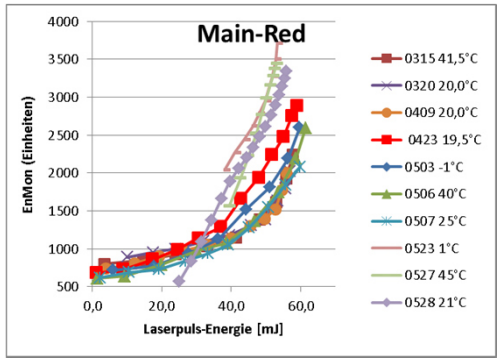


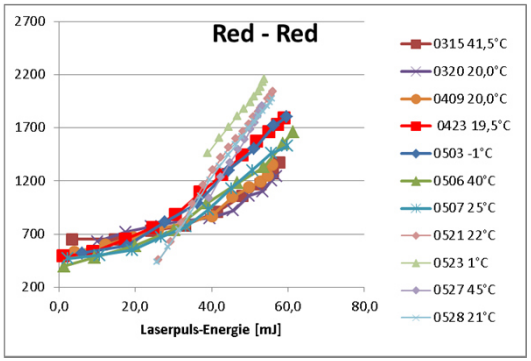
BELA Laser
Testing during Assembly & Integration Sequence









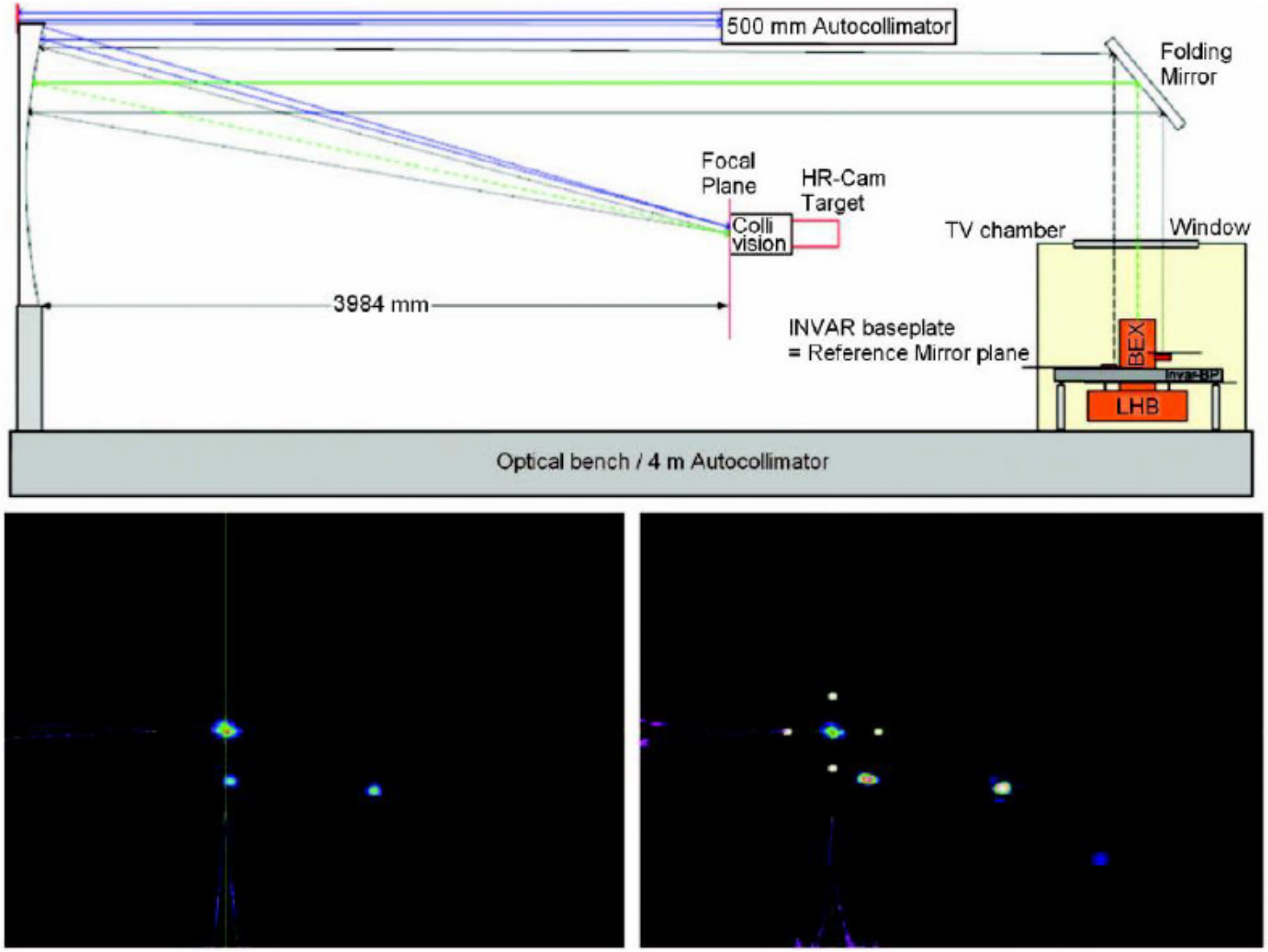


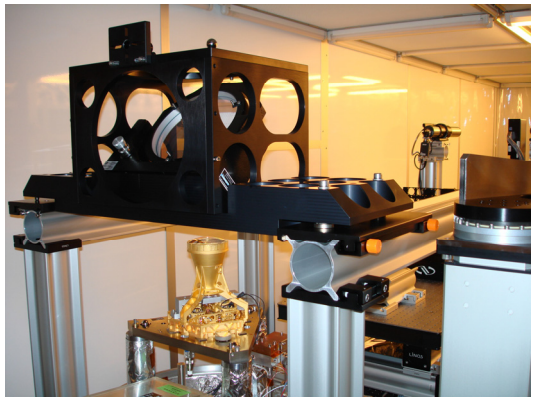
Caustics test reveals any shift in divergence

Energy Monitor data recorded for all main / red combinations

AIRBUS DEFENCE & SPACE

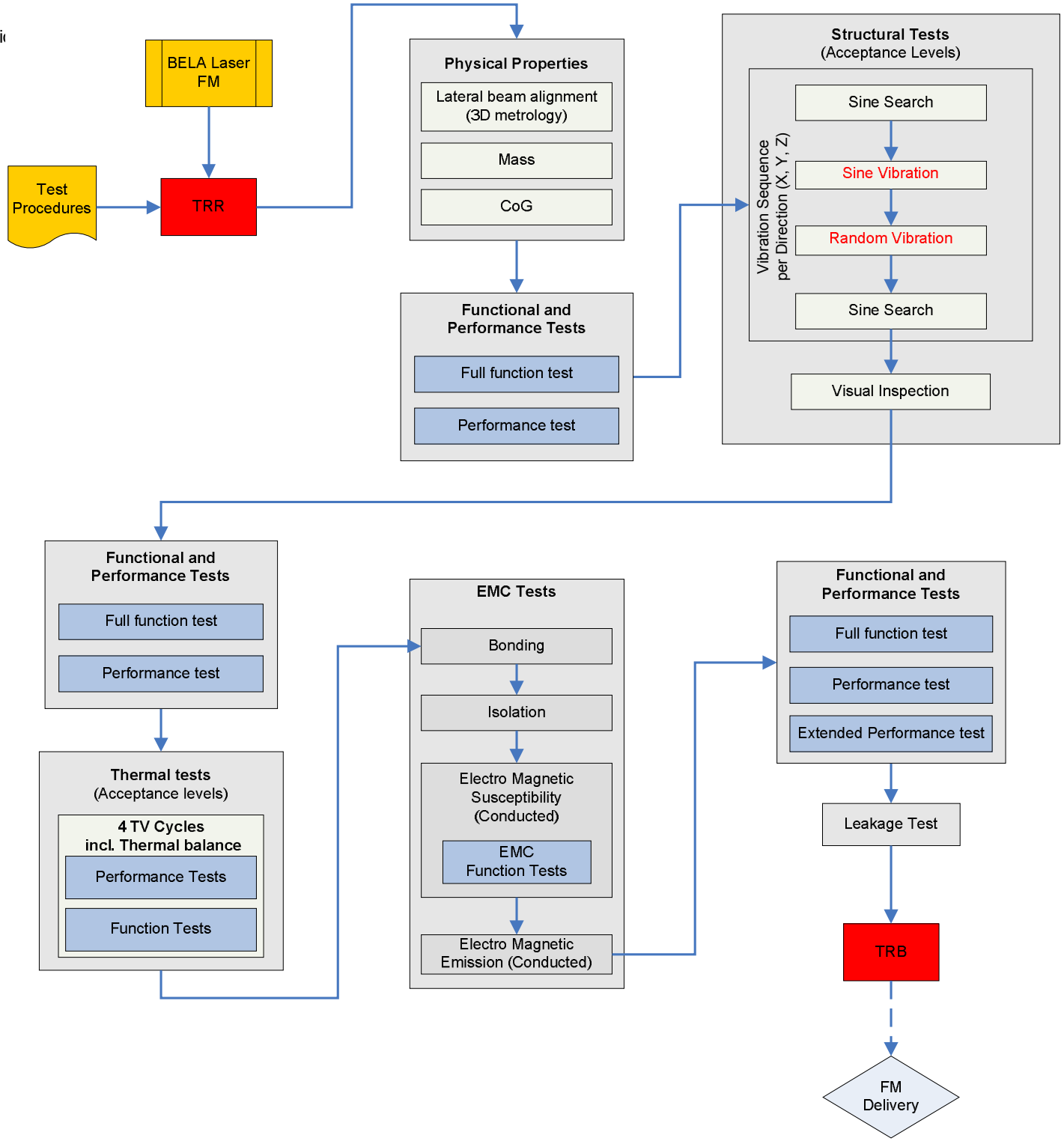
Laser Qualification: Boresight & Divergence Test Set-up

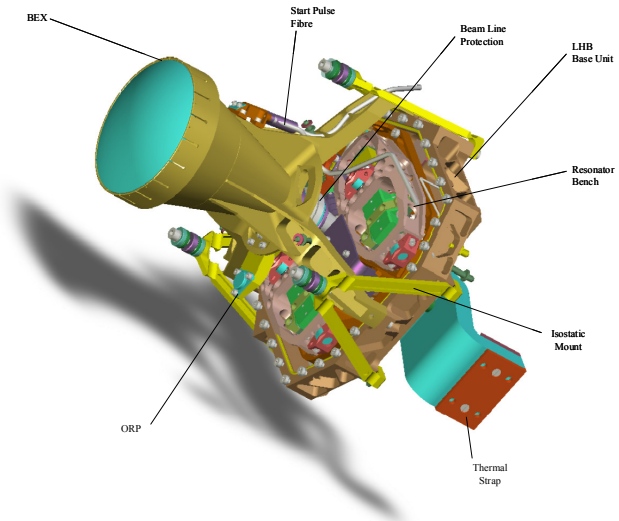




BELA Laser FM

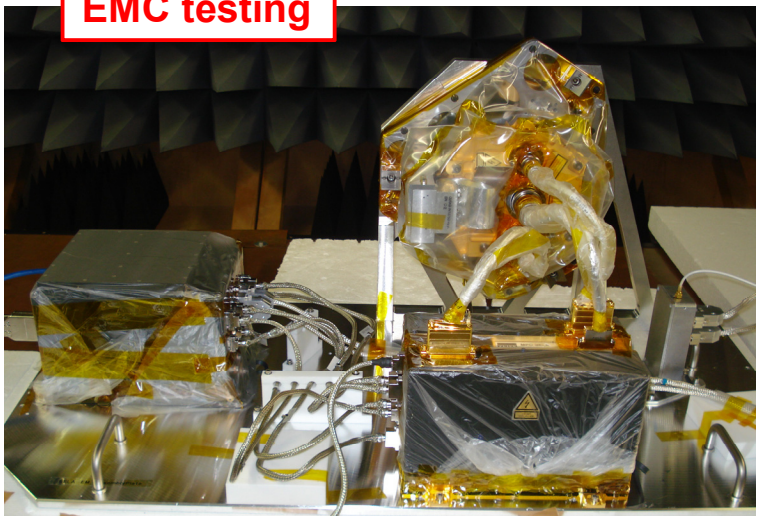
Verification Test Campaign



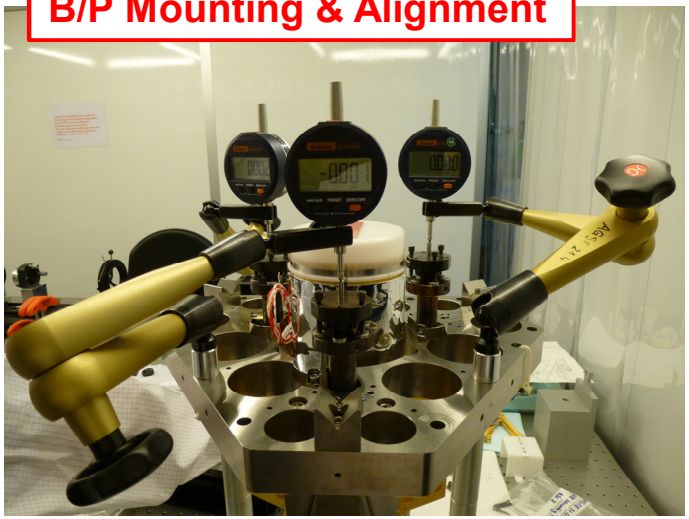


Laser Qualification, Assembly Level Tests

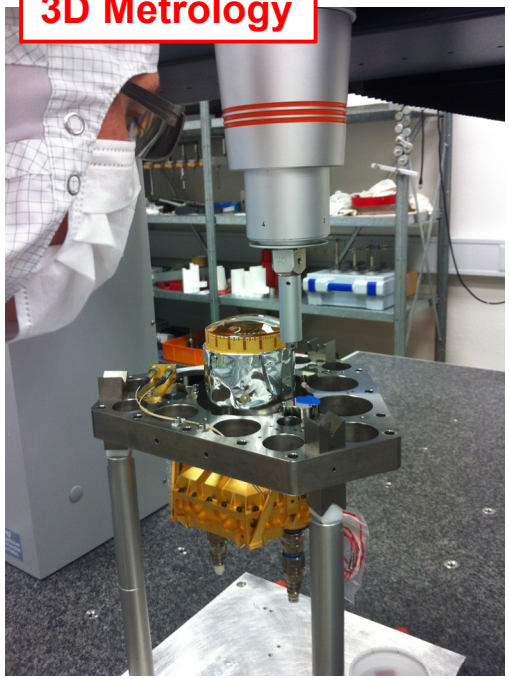
EMC testing

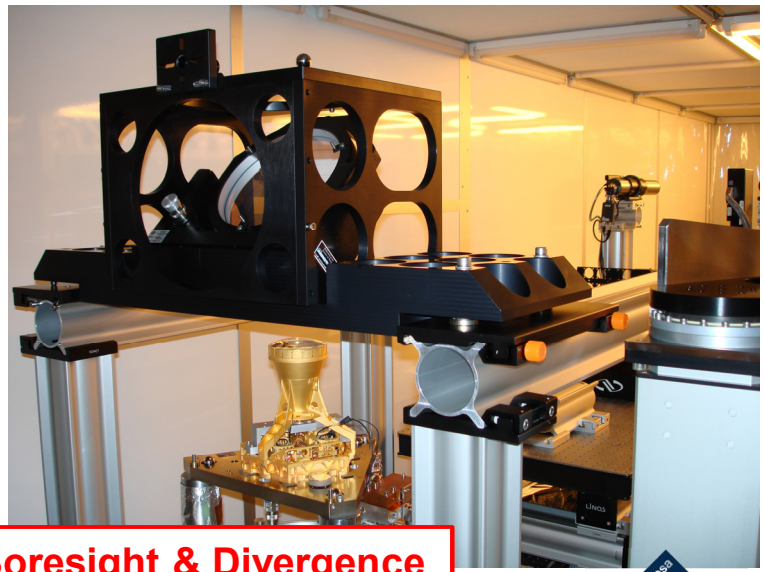


B/P Mounting & Alignment



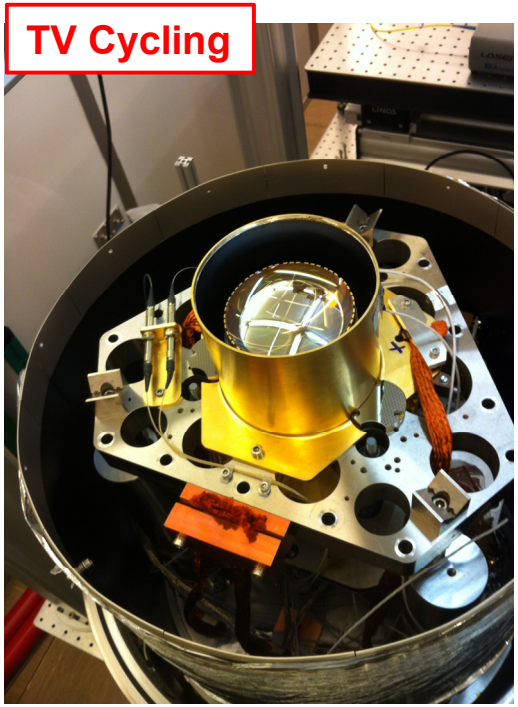
3D Metrology

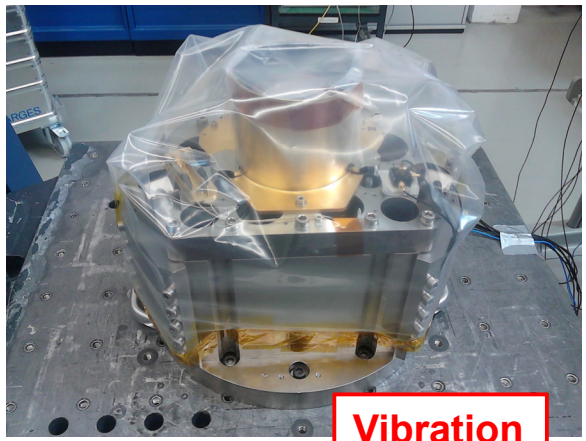




Boresight & Divergence

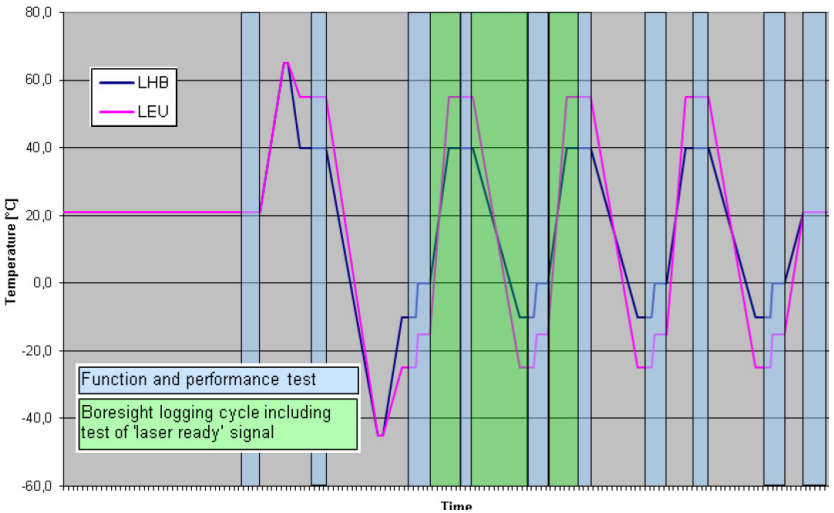
TV Cycling





Vibration

Laser Verification Tests: Boresight & Divergence

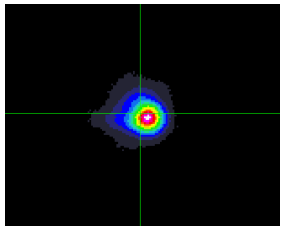


1) Boresight Mesurement (Avg 100)

	X Main [px]	Y Main [px]	X Red [px]	Y Red [px]
R1	453,0	638,0	453,0	638,0
R2	439,0	739,0	439,0	739,0
R3	446,0	739,0	446,0	739,0
Beam	463,0	340,0	477,0	387,0
ORP	-	-	-	-

2) Divergence Mesurement (Avg 100)

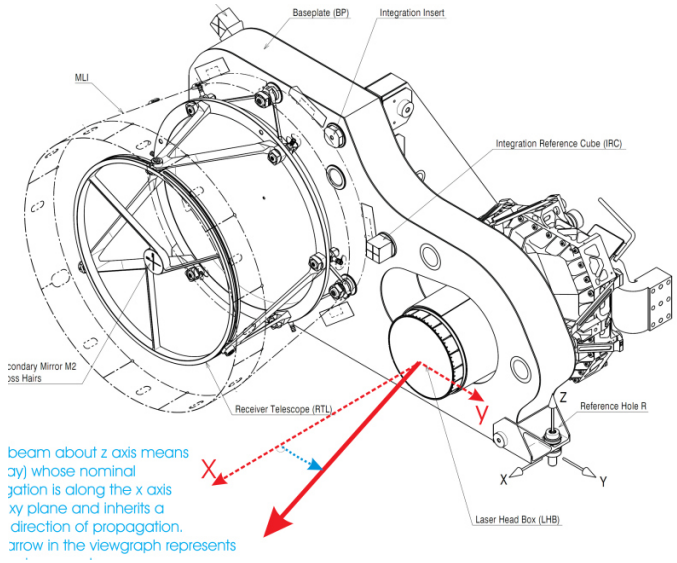
	Eff. Dia [px]	Eff. Dia [µrad]
Main	25,4	43
Red	27,8	47



Boresight Mesurement

FM

	Main			Redundant		
	LHB interface		Vector	LHB interface		Vector
	Y [µrad]	Z [µrad]		Y [µrad]	Z [µrad]	
Before acceptance Vib.	0	0	0	0	0	0
After acceptance Vib.	19	-13	23	1	-6	6
#1 Op_High	25	-19	32	13	-3	14
#1 Op_Low	33	22	40	-19	-7	20
#2 Op_High	42	-13	44	14	8	16
#2 Op_Low	24	20	31	-13	-4	14
#3 Op_High	37	-20	42	12	9	15
#3 Op_Low	26	26	36	-16	-3	16
#4 Op_High	41	-21	46	10	7	12
#4 Op_Low	22	23	32	-12	-4	13
ambient after TV	37	-5	37	9	6	11
after EMC	35	2	35	14	11	18



Laser Verification Tests – Functional Parameters

				Operation mode 10Hz			
Register	Minimum Target Value	Maximum Target Value	Date	15.07.2013	23.07.2013	20.08.2013	30.08.2013
			Name	21°C	21°C	55°C	56°C
1	4053	4061	STATUS	4061	4061	4061	406
111	0	15	REF_1	5	5	6	5
112	492	512	REF_2	510	511	509	51
113	650	1050	HV_LDD_BS	860	853	861	86
114	0	<#113 - 100	HV_LDD_AS	621	600	726	70
115	0	40	ENERGY_BS	7	7	5	8
116	50	1023	ENERGY_AS	474	506	473	50
117	570	820	TEMP_LEU_LAS1	707	708	788	78
118	570	820	TEMP_LHB_LAS1	711	711	783	77
119	570	820	TEMP_LEU_LAS2	707	710	790	78
120	570	820	TEMP_LHB_LAS2	711	705	763	77
121	460	540	ENERGY_AS_C	470	507	498	48
122	570	820	TEMP_LEU_LAS1_C	718	719	800	79
123	570	820	TEMP_LHB_LAS1_C	711	717	779	76
124	570	820	TEMP_LEU_LAS2_C	717	719	800	79
125	570	820	TEMP_LHB_LAS2_C	715	714	780	77
141	4095	4095	BIT	4095	4095	4095	409

El.-magn. Compatibility - Key drivers

Parameter	Value	To consider
LDA drive current	100 A	Shifting ground, magnetic fields
PCD switching time	10 ns	Spikes during signal acquisition
High voltages	3 kV	Electrical break-down

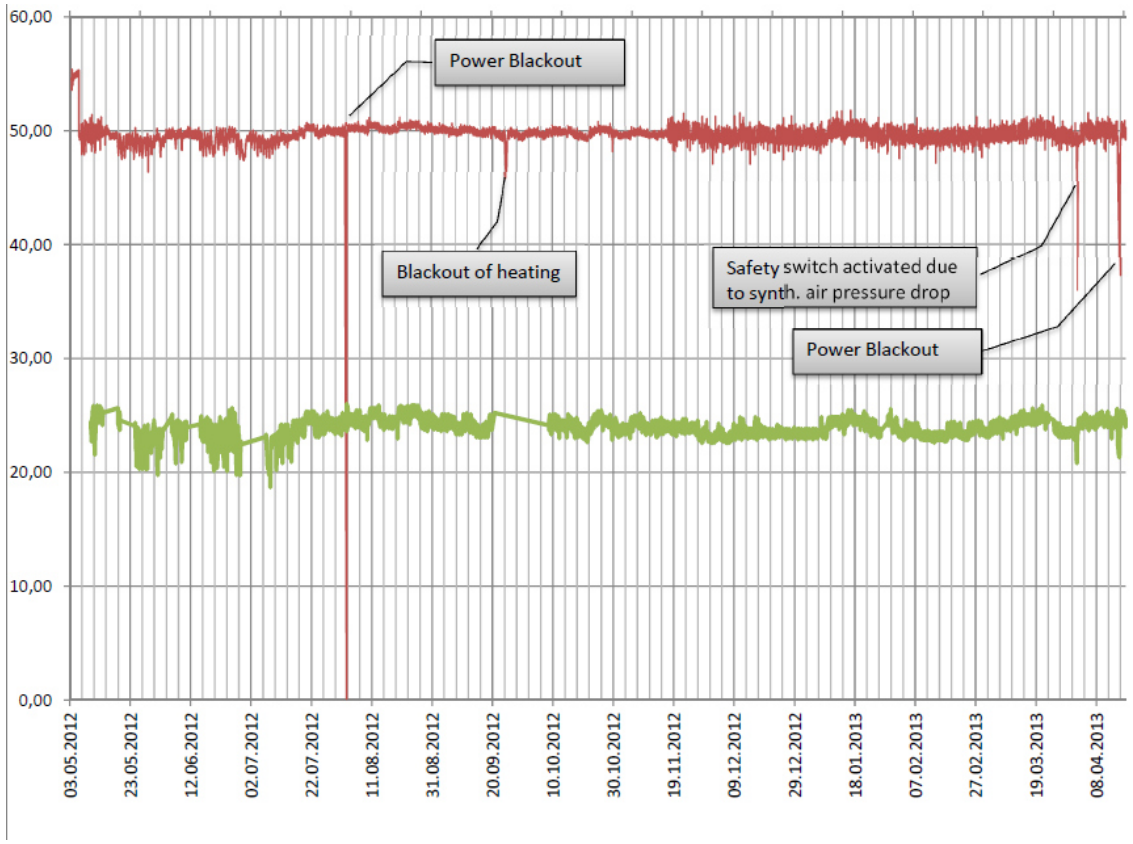
1. LDA drive current
   - „Laser system“ is broken down to LEU as a unit and LHB as a rather minor assembly
   - Laser diode driver (LDD) is situated in LEU – far from „Laser head“ (LHB)
   - Strong electrical current runs long way through payload
   - For flight hardware, joint EMC testing of the whole transmitter was performed

2. PCD switching time
   - PCD is situated close to Q switch in LHB compartment
   - PCD spikes affect energy monitor signal
   - PCD power is provided through LDD which is located in LEU
   - Laser system‘s EMI filter is located in LEU

3. High voltages for Q switching
   - Distances of several millimeters needed for safe electrical insulation
   - Many items involved in switching chain (MOSFET cascade)
   - Test without conformal coating
   - Detailed partial discharge tests

Laser Verification Tests - Life Model Test Results

Laser Pulse Energy Lifetime testing



AIRBUS DEFENCE & SPACE

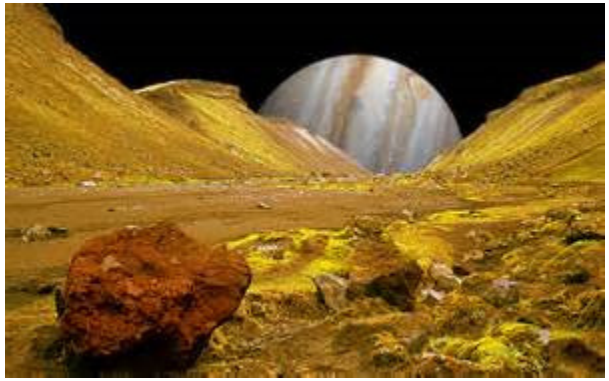
BELA Conclusions

The qualified BELA Laser is based on the reliable and industrialized laser range finders manufactured by Airbus DS Optronics.

A number of significant learnings have been made during development and verification, in particular with the qualification model.

Qualification test records have established the manufacturers confidence that all critical design areas have been addressed successfully.

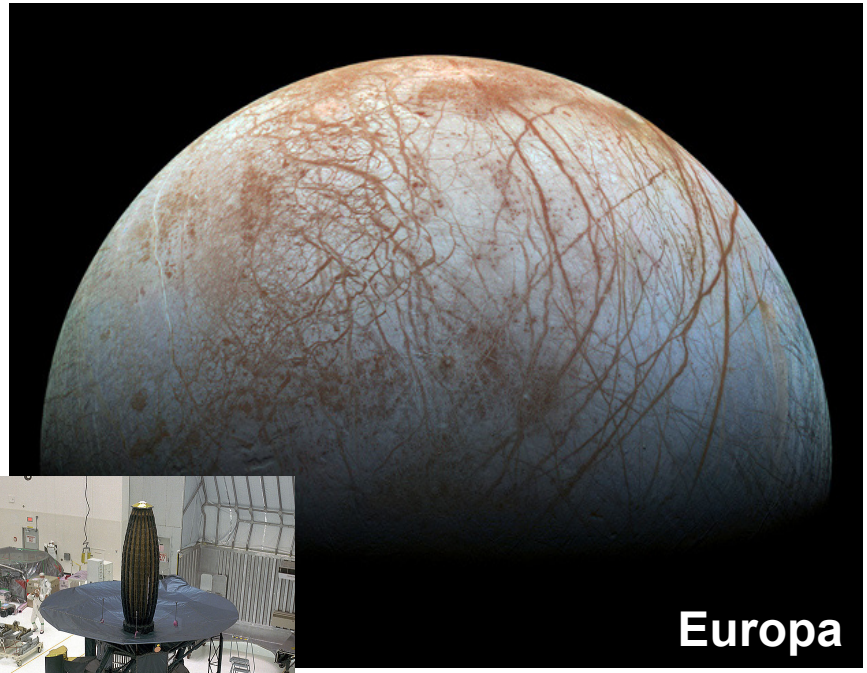
Adoption of an unstable resonator design proved successful and extendable to other high-power applications.

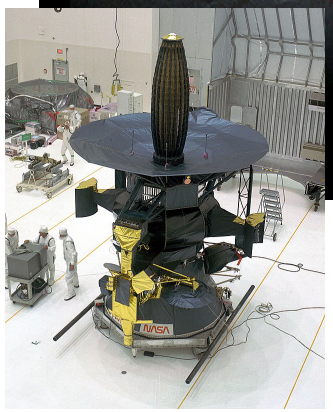


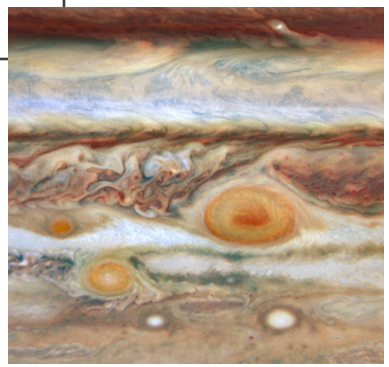
ESA's JUICE Mission - The Ganymede Laser Altimeter

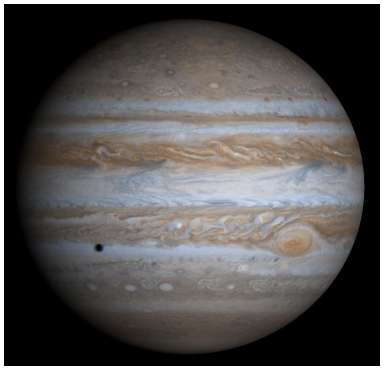
Mission Description

Key mission drivers and technology challenges	Radiation Power budget Mass budget
Responsibilities	ESA: manufacturing, launch, operations of the spacecraft and data archiving PI Teams: science payload provision, operations, and data analysis.



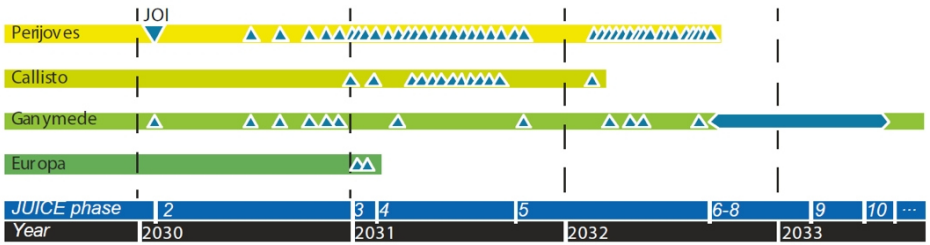


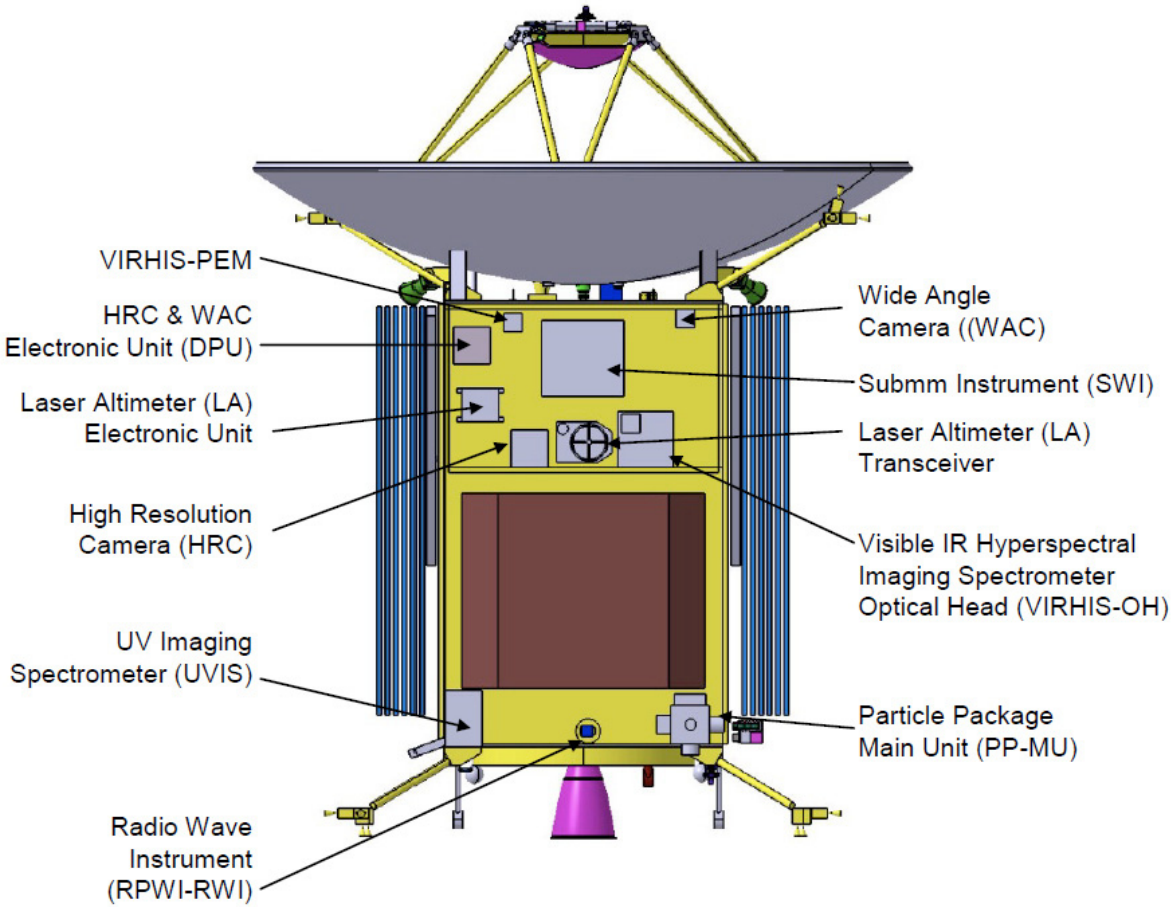




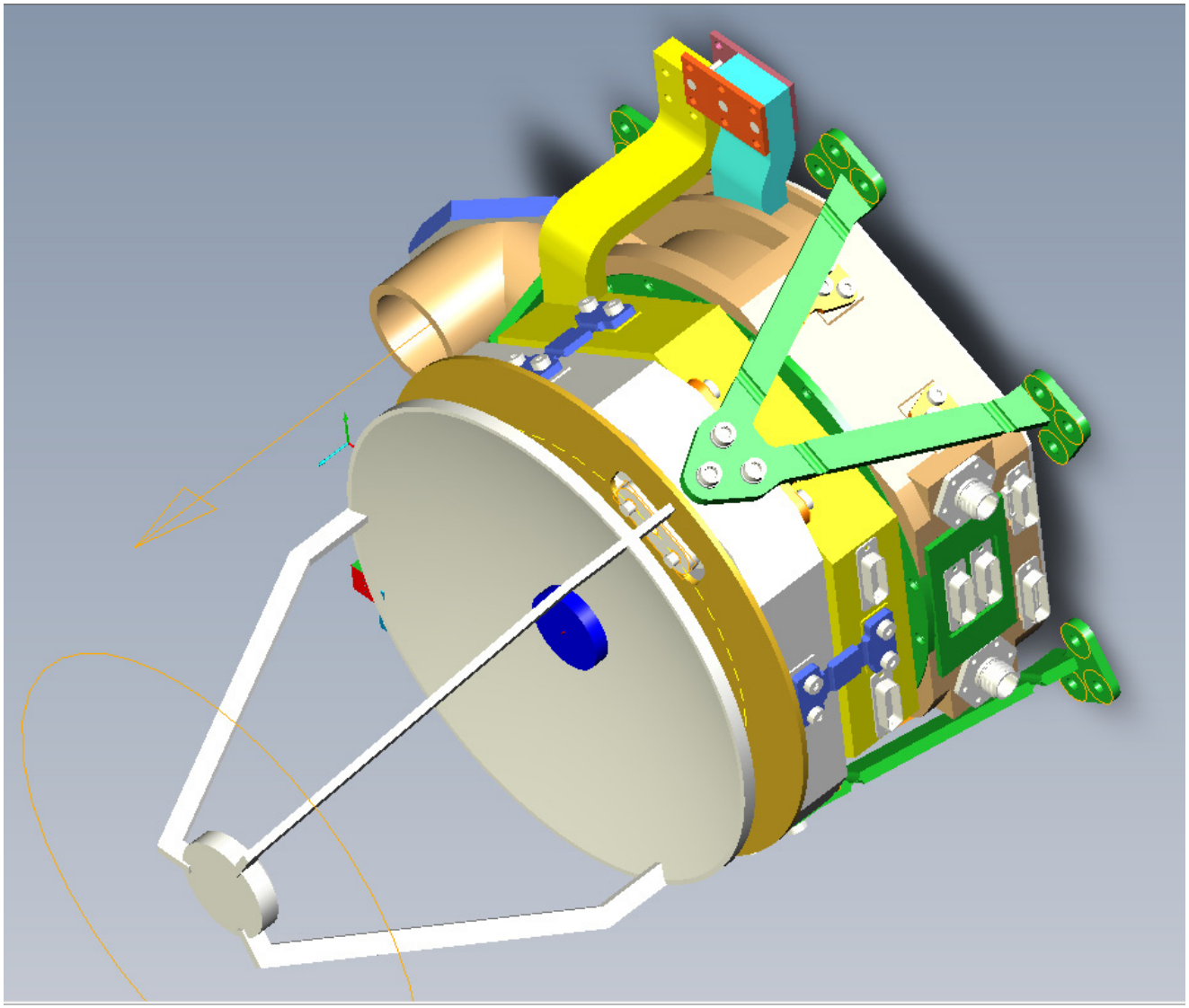
Der Satellit „Jupiter Icy Moons Explorer" (JUICE)

Short name	Instrument Name
JANUS	Jovis, Amorum ac Natorum Undique Scrutator, camera system
MAJIS	Moons and Jupiter Imaging Spectrometer
UVS	UV Imaging Spectrograph
SWI	Sub-millimetre Wave Instrument
GALA	Ganymede Laser Altimeter
RIME	Radar for Icy Moons Exploration
J-MAG	Magnetometer for JUICE
PEP	Particle Environment Package
RPWI	Radio & Plasma Wave Investigation
3GM	Gravity & Geophysics of Jupiter and Galilean Moons
PRIDE	Planetary Radio Interferometer & Doppler Experiment





The GALA transmitter unit is currently under development in Oberkochen



Vielen Dank für Ihre Aufmerksamkeit.