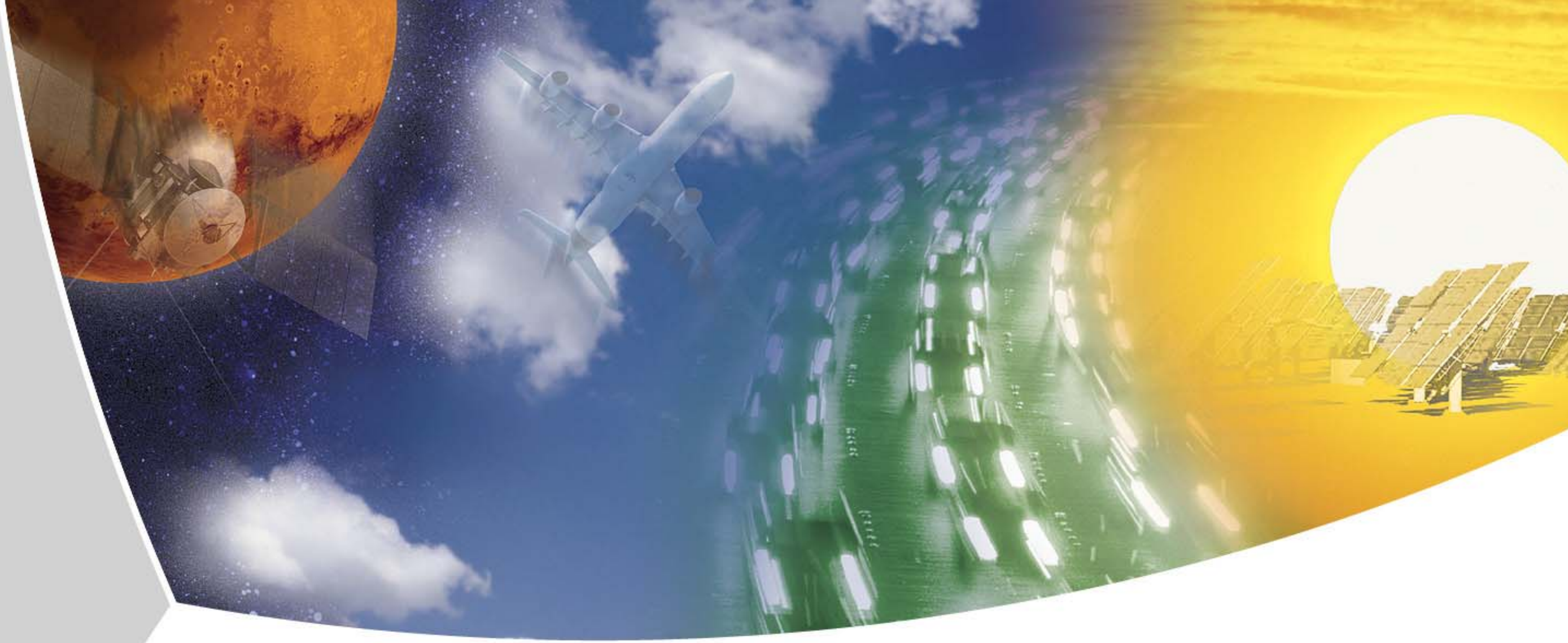


Wales Airborne Demonstrator

Martin Wirth, Andreas Fix, Gerhard Ehret

DLR, Institut für Physik der Atmosphäre

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

One-day meeting ESA-DLR on Technology Activities for Spaceborne DIAL Instruments , ESTEC, Noordwijk, 18.11.2005

DLR WALES: Motivation of the Project

- **Airborne Demonstrator for Water Vapour DIAL in Space**
- **4 Wavelengths Lidar in the 935nm H_2O-Band**
- **State-of-the-art System for Atmospheric Research**
- **Satellite Validation**

Falcon

HALO

Design Goals

Design Goals

- *Technologically equivalent* to proposed space system (4-wavelength setup in 935 nm H_2O-Band)
- Compact, robust, (quasi-) autonomous
- Modular, extendable
- Also State of the Art for airborne application (not *only* a WALES-Demonstrator)

Co-operation : DLR Stuttgart, DLR Berlin, DLR Oberpfaffenhofen

Project head: Martin Wirth

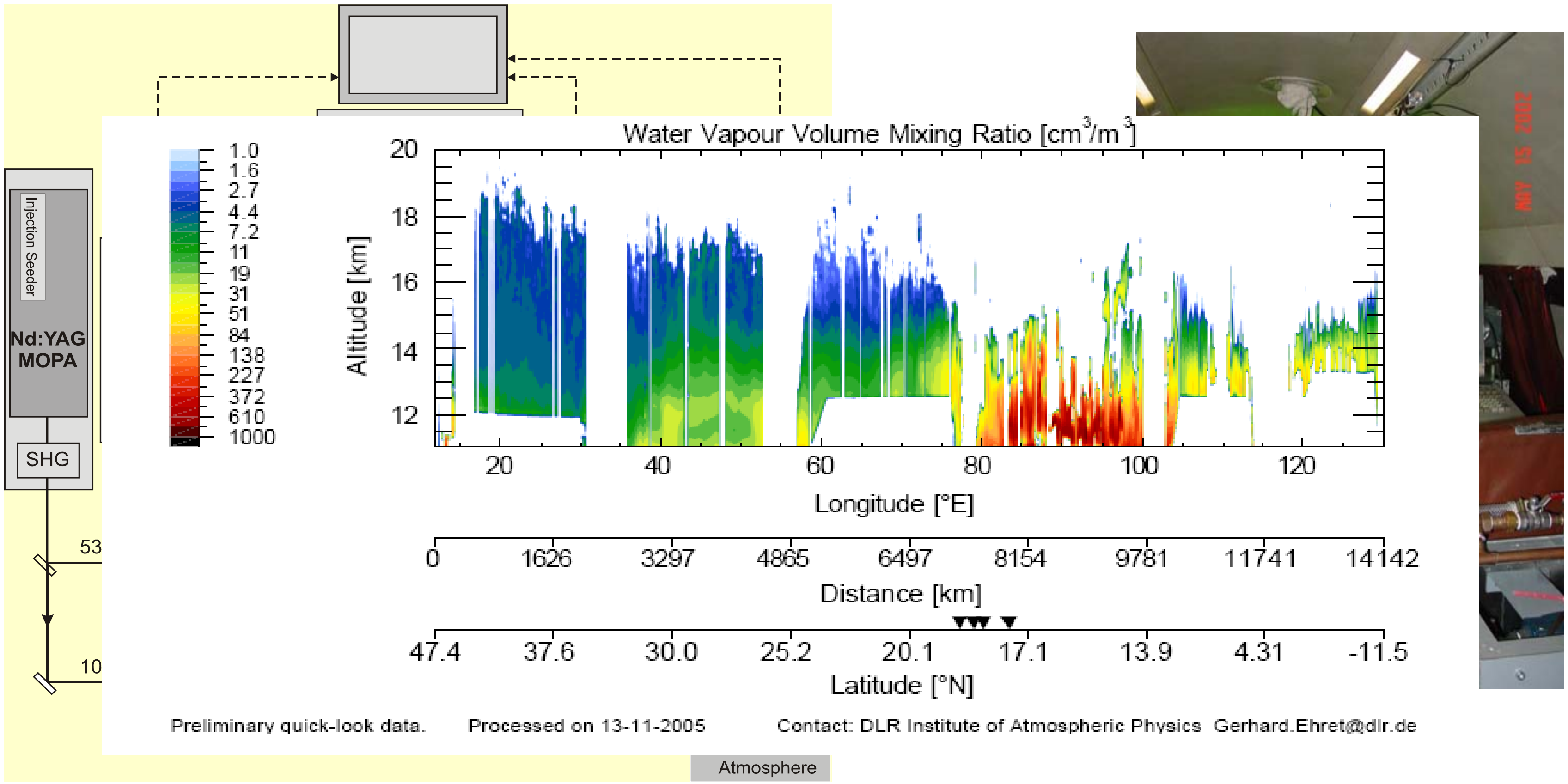
Special Requirements for Airborne Deployment

- Temperature changes in the range of 10-15 °C/h
- Rapid pressure changes of 0,3 bar
- Vibrations, mechanical stress induced by bending platform
- Crash proof up to 18 g
- Has to fit into a volume of 100 x 110 x 90 cm (without telecope)
- Maximum total weight of less than 400 kg
- Limited cooling power (< 2 kW)
- Small exit aperture (8 cm central window) for 4 outgoing beams
- System warm-up for full performance less than 1/2 h
- Resistant to high humidity and insects (tropical campaigns)
- Has to be (dis-)assembled easily

⇒ Critical elements: Hermetically sealed and integrated

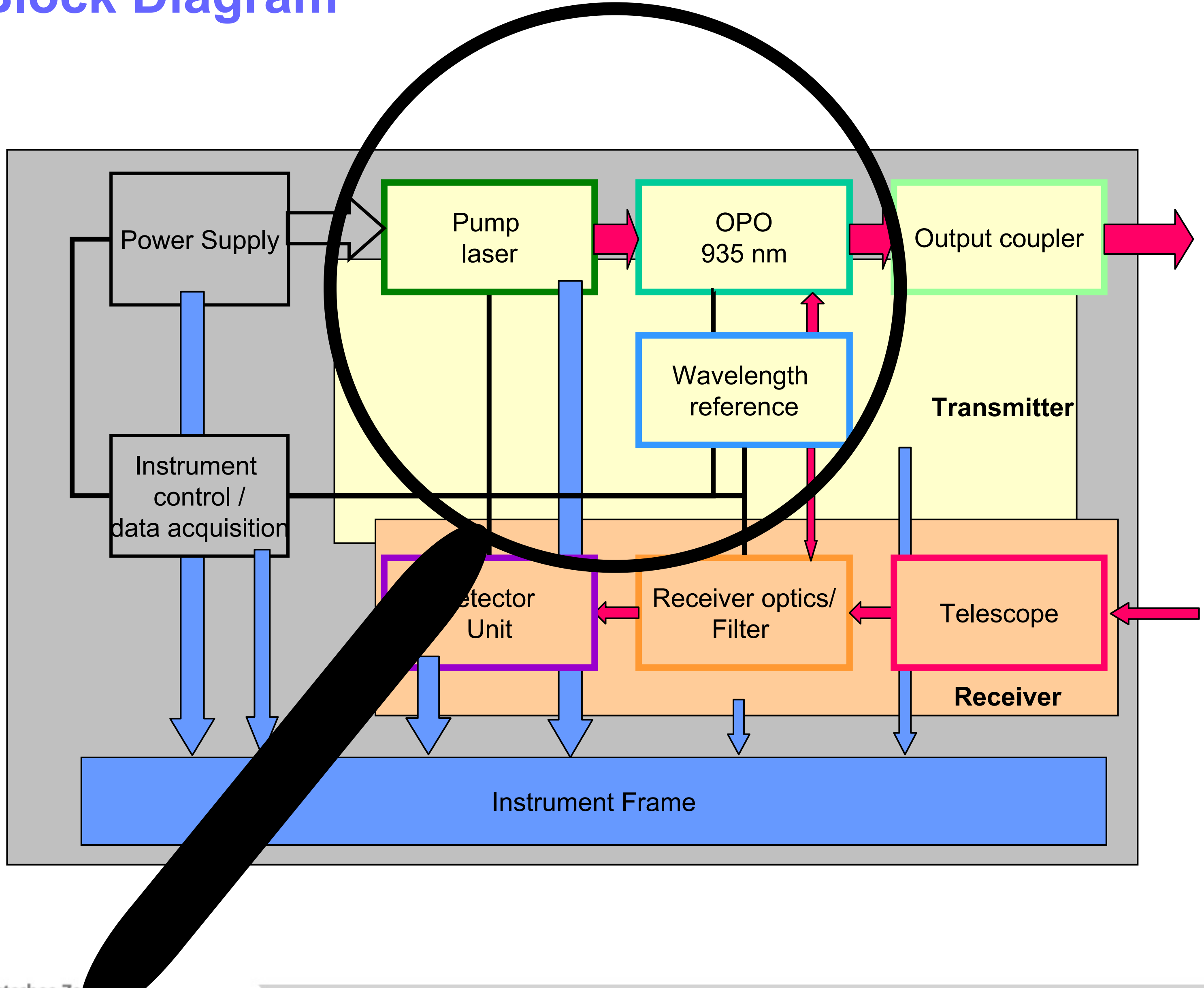
⇒ Only components with small space and power consumption can be used

Heritage: DLR Airborne H2O DIAL



G. Poberaj et al., Appl. Phys. B, 2002

Block Diagram



Airborne Multi-Wavelength H2O DIAL:

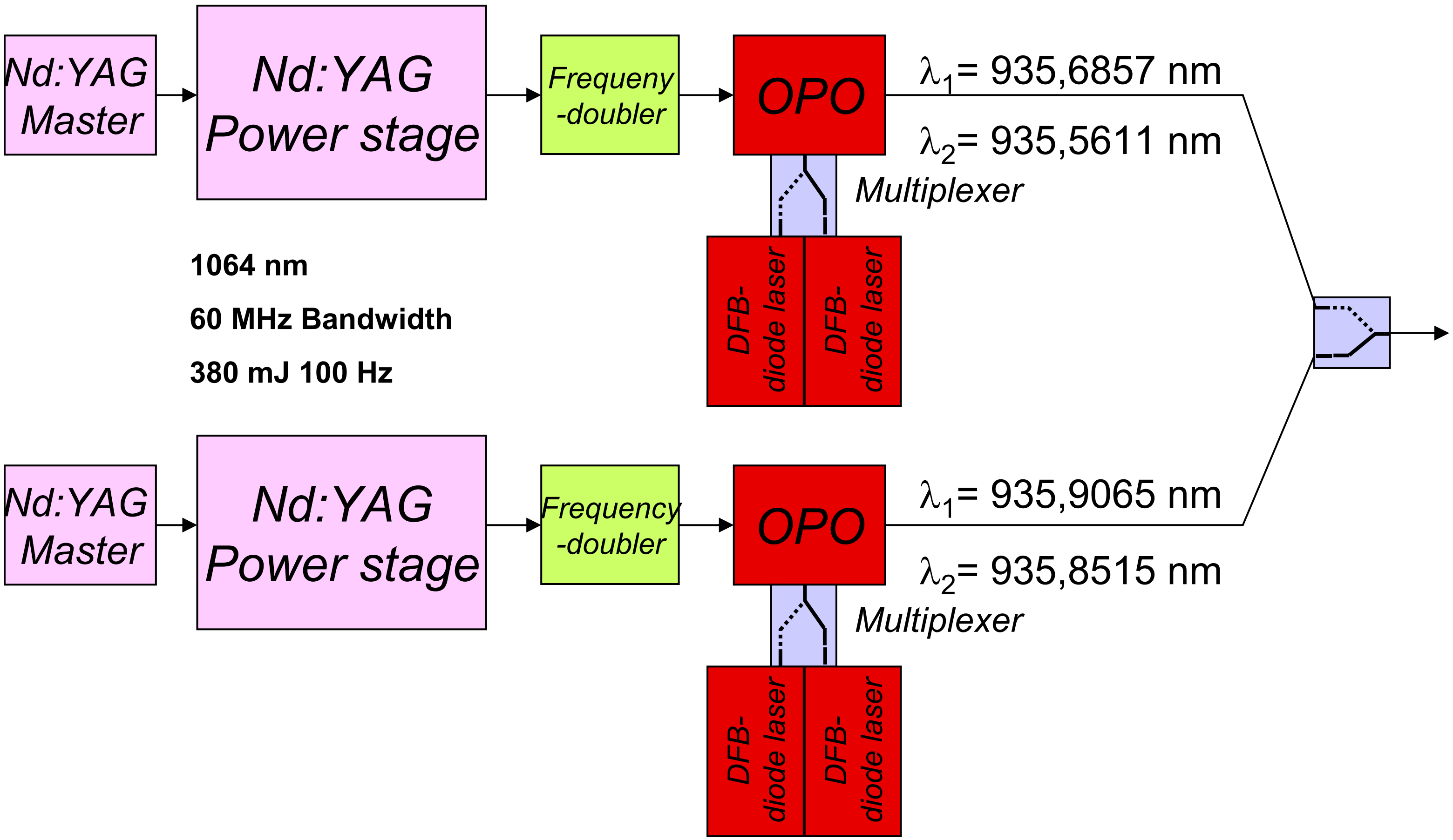
Transmitter Specifications

	Threshold Requirement	Optimistic Estimate (from 2003)	Current State
Output Power			
Laser Output @ 1064nm	250 mJ	400 mJ	
Laser Output @ 532nm	130 mJ	220 mJ	
OPO Output @ 935nm	25 mJ	40 mJ	
Repetition rate (all 4 pulses)	50 Hz	50 Hz	
Spatial Beam Quality			
OPO Beam Diameter (2nd M)	6 mm	4 mm	
OPO Beam Divergence	< 2 mrad	< 1 mrad	
Beam Quality M^2	< 6	< 3	
Boresight Stability	<±50µrad	<±30µrad	
Spectral Beam Quality			
Pulse Linewidth	< 250 MHz	<150 MHz	
Frequency Stability	< 50MHz	<35MHz	
Spectral Purity	>99.7%	>99.9%	

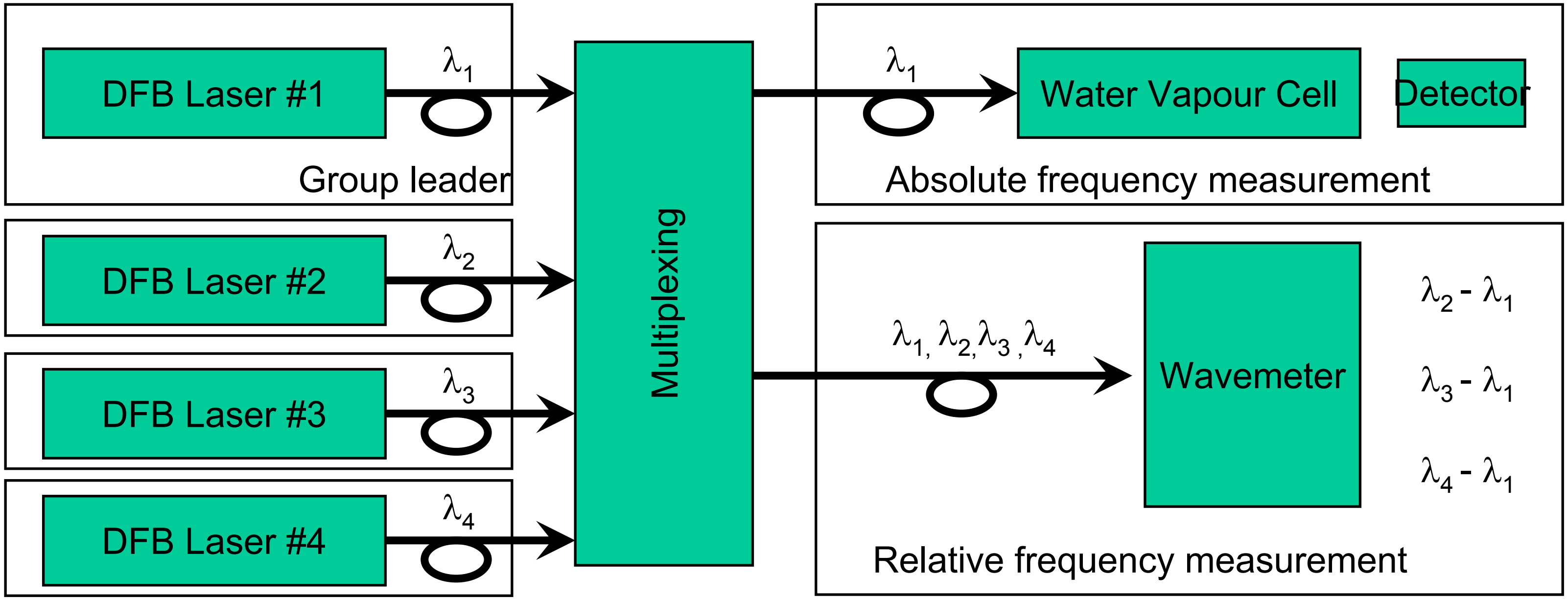
Airborne Multi-Wavelength $H2O$ DIAL:
Receiver Specifications

Parameter	Unit	Anticipated
Receiver Telescope Optic (circular) Aperture	m	0.48
Spectral Filter Width	nm	0.7
Spectral Filter Transmission	-	0.7
Telescope Transmission	-	0.90
Receiver Field of View	mrad	1.2
APD Effective NEP	fW/√Hz	3.5
APD Quantum Efficiency		0.85
APD Fano Factor (at gain 100)		3.5

Transmitter Concept (2x2 = 4)

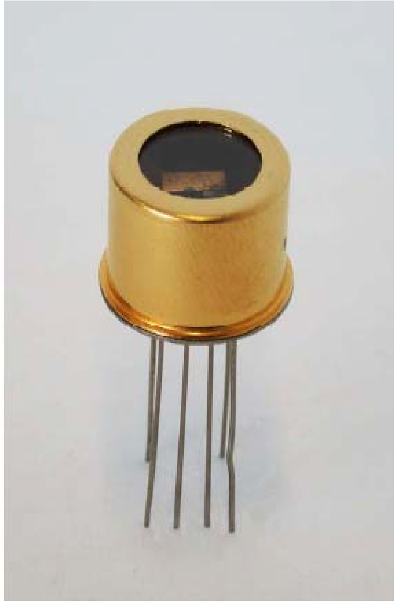


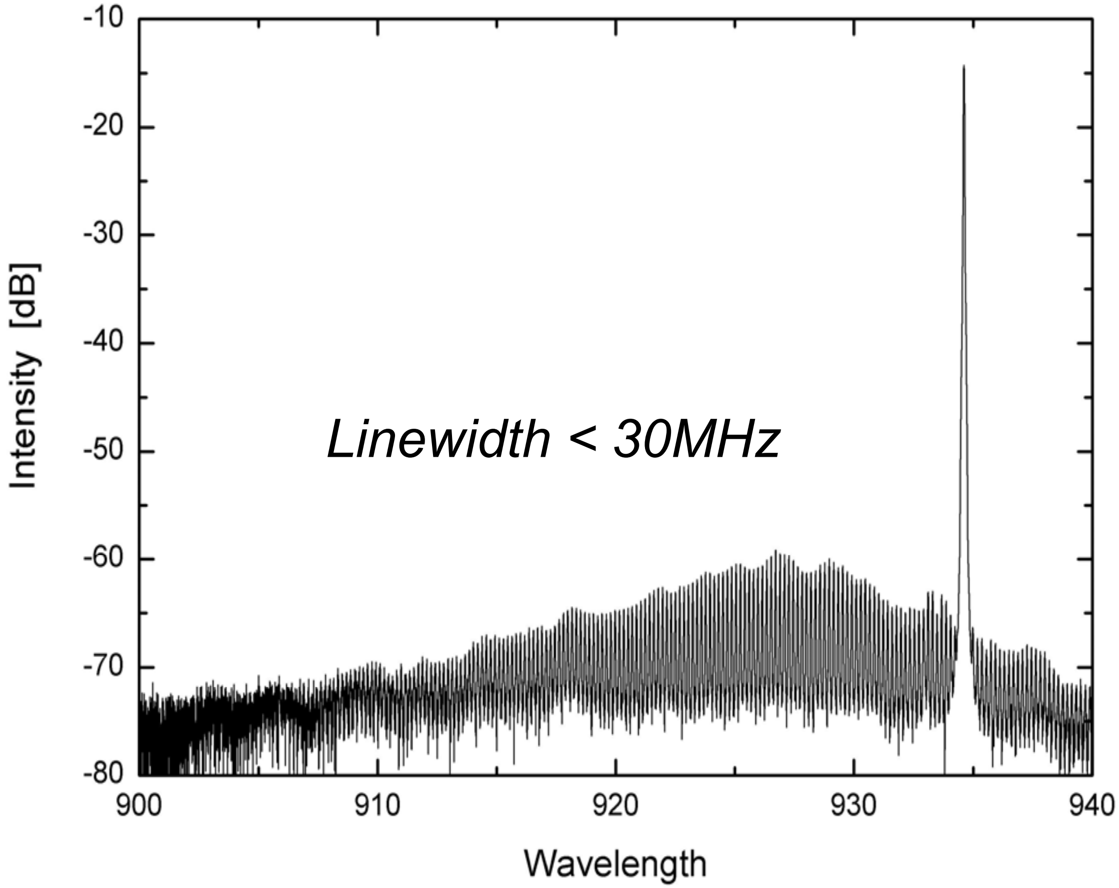
Seedlaser: Wavelength Stabilisation Concept



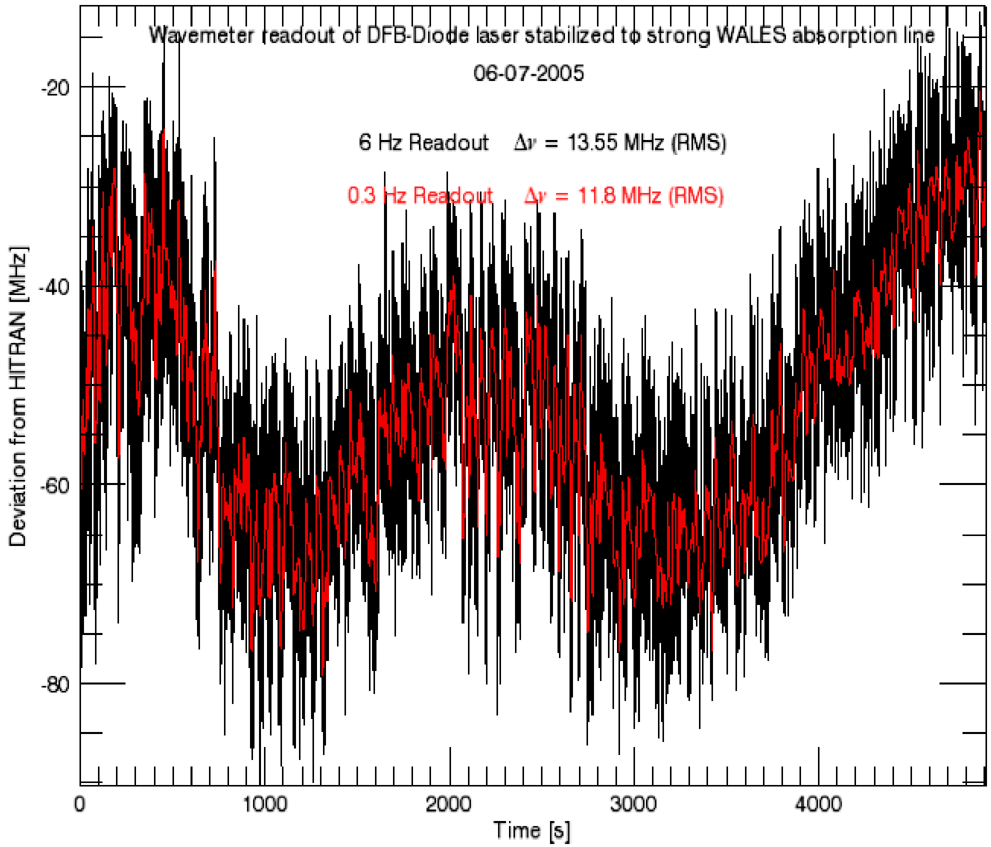
- **Stabilisation of the highest absorption wavelength to a water vapour reference cell**
  Advantages: Absolute Calibration of the wavelength with the highest accuracy requirements, needs only a relatively short multipass cell
- **Relative stabilisation of the other wavelengths using a commercial wavemeter**
  Advantages: easy to use, approved components, unambiguous frequency determination

DFB Laser Performance: Side-mode suppression





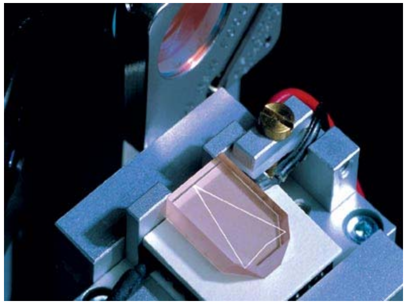
DFB Laser Performance: Stability



WALES specification is 60 MHz RMS !

Pump Laser: Monolithic Master Laser

Mephisto-Q: pulsed, inherently single frequency



Energy: ~15-50 µJ
Pulse length : 3-15 ns
Stability: 1 MHz/min
Passively Q-switched

Advantages

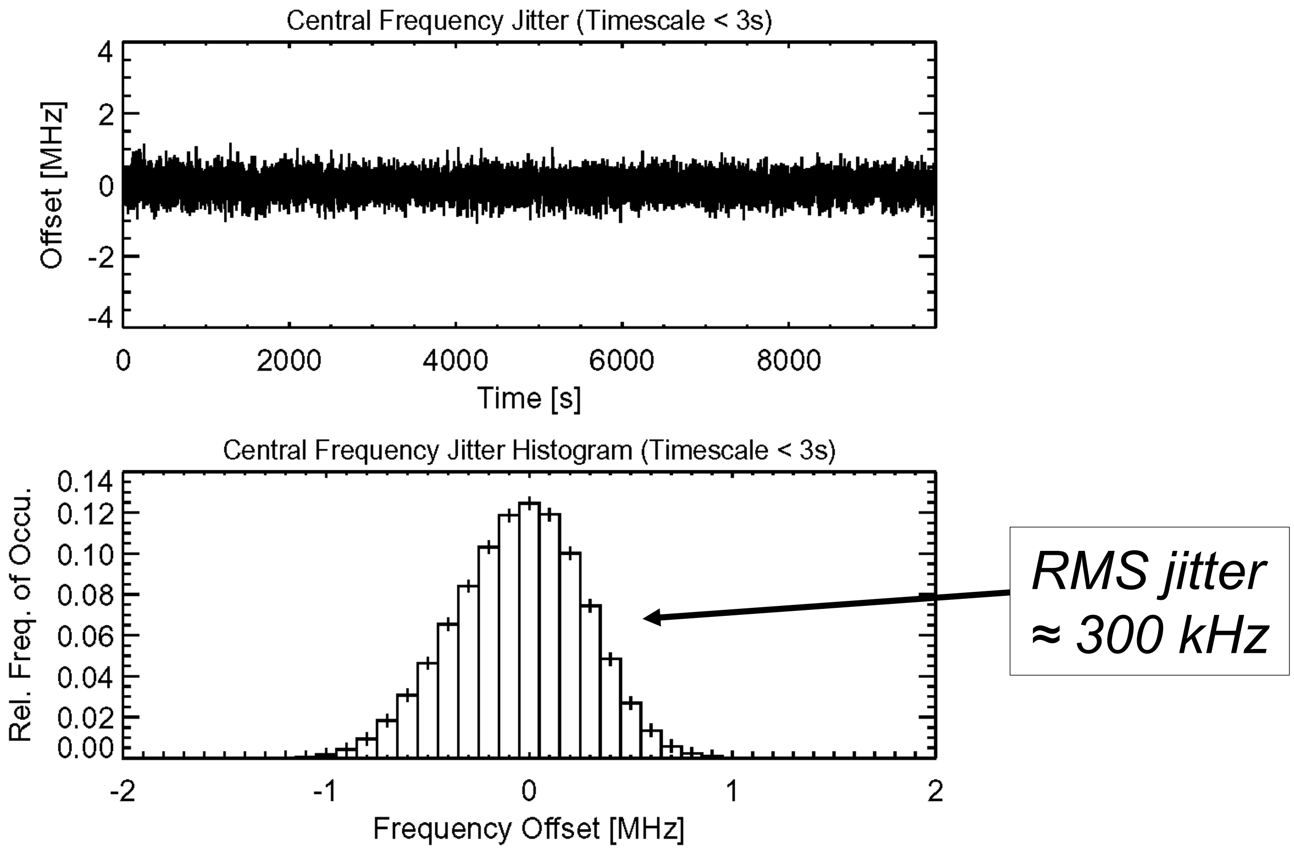
- Very low sensitivity to vibrations
- No problems with thermal gradients (whole laser is temperature stabilized to mK)
- No active resonator stabilization necessary
- No suppression for amplified seed radiation necessary
- Very simple double pulse possible (master runs at 4 kHz)
- Large longitudinal mode separation (approx. 6 GHz): good for spectral purity
- No electro-optical q-switch: no lifetime problems with crystals and HV-electronics

Possible Disadvantages

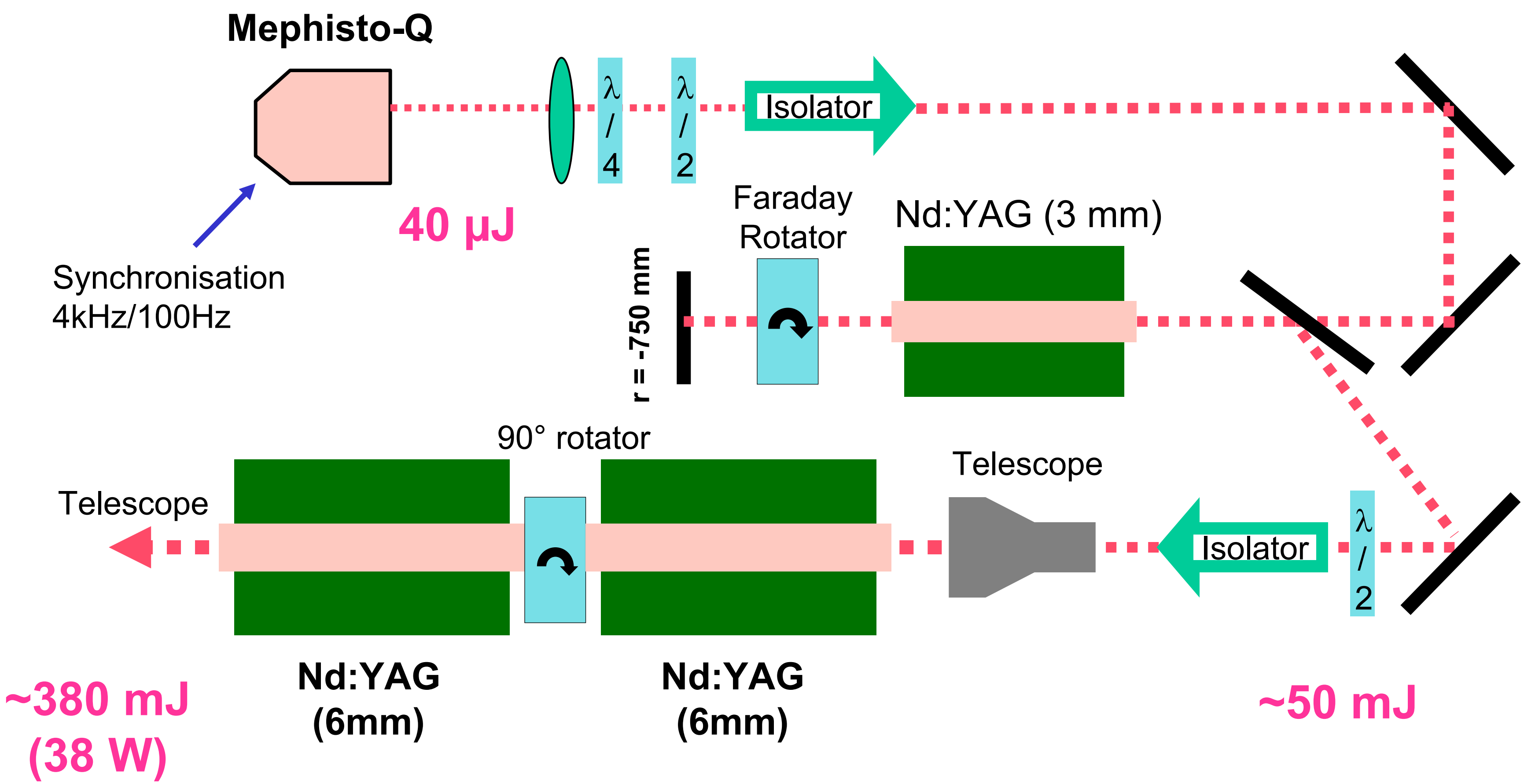
- Has to be synchronized to power stage by a phase locked loop (jitter ≈ 1 µs)
- Unusual temporal pulse shape (slow ascent, fast descent)

Mephisto-Q: Frequency Stability

- *Measured by heterodyne technique*



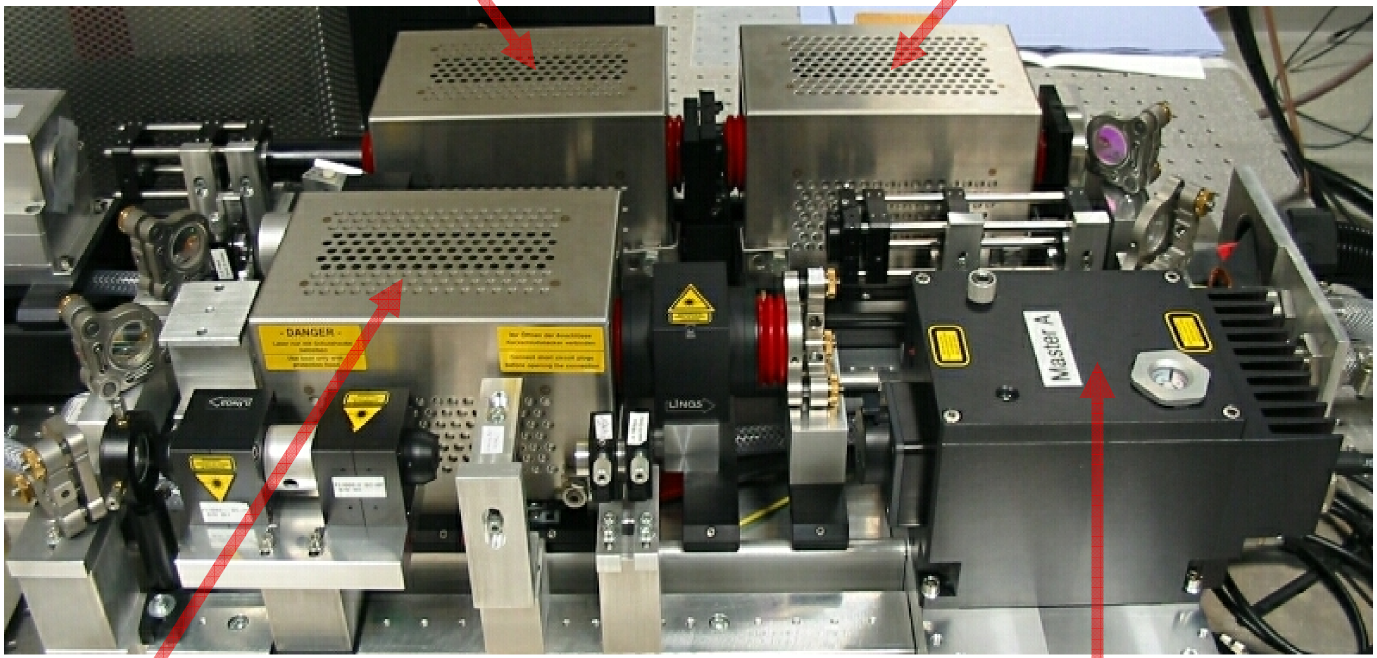
Pump laser: Laboratory Breadboard Schematics



Pump Laser: Laboratory Breadboard Realisation

2. Main Amplifier

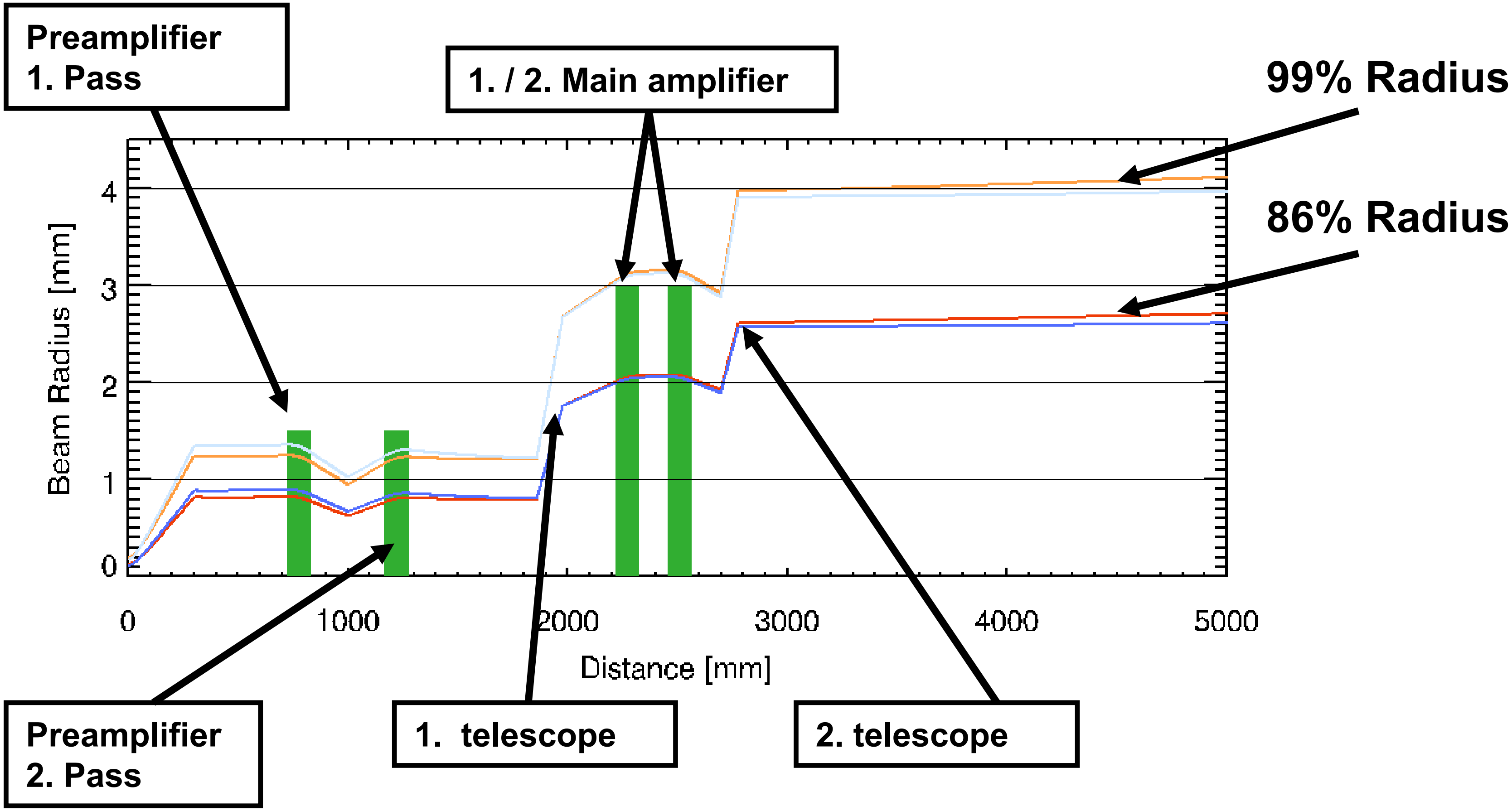
1. Main Amplifier



Preamplifier

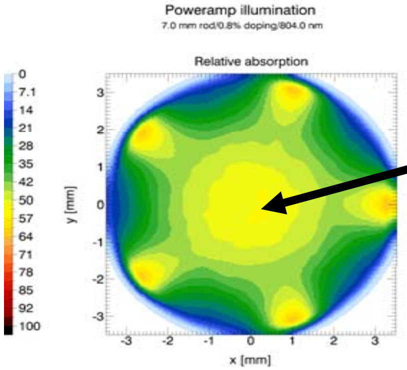
Monolithic master oscillator in pressure tight housing

Pump Laser:
Simulation of beam propagation and thermal lensing



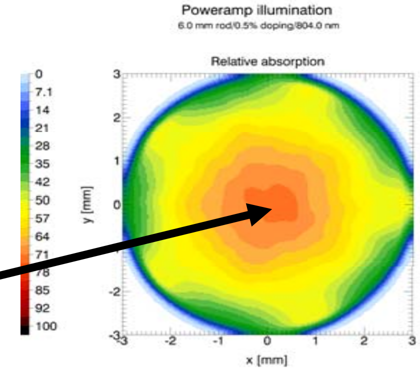
Pump Laser:

Optimisation of Rod Diameter and Doping

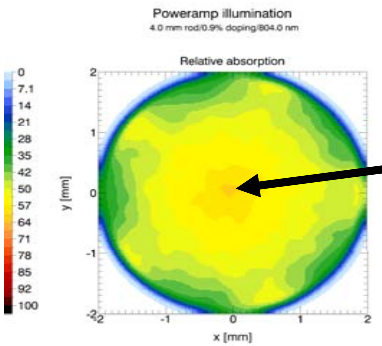


Main Amplifier

7 mm /0.8% Nd
(Rofin-Sinar-Standard)
replaced by
6 mm / 0.5% Nd

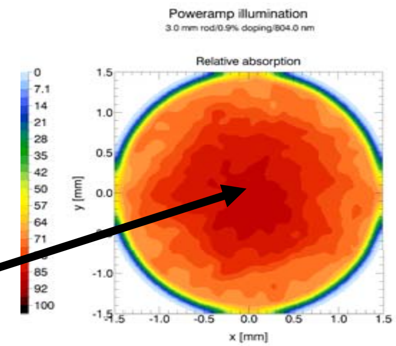


⇒ Significantly more homogenous inversion distribution over a large temperature range



Preampifier

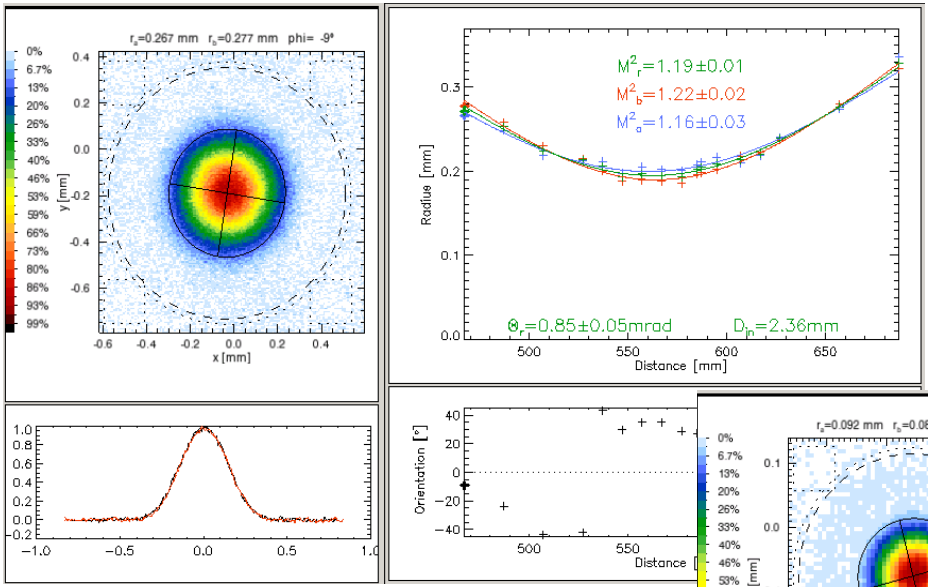
4 mm /0.9% Nd
(Rofin-Sinar-Standard)
replaced by
3 mm / 0.9% Nd



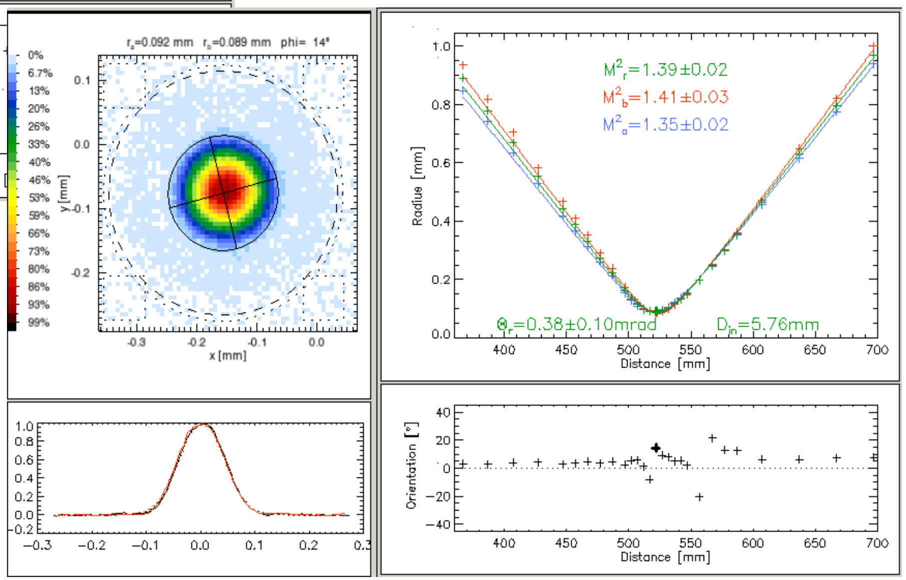
⇒ Pulse energy raised from 35 mJ to 50 mJ accompanied by a reduction in pump energy by 35%

Pump Laser: Beam Quality of the Breadboard

Preamplifier:
M^2 = 1.2 @ 50 mJ/100 Hz

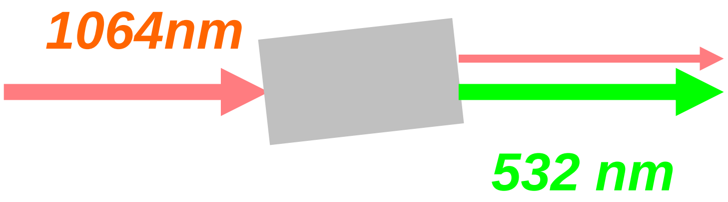


Mainamplifier:
M^2 = 1.4 @ 380 mJ/100 Hz

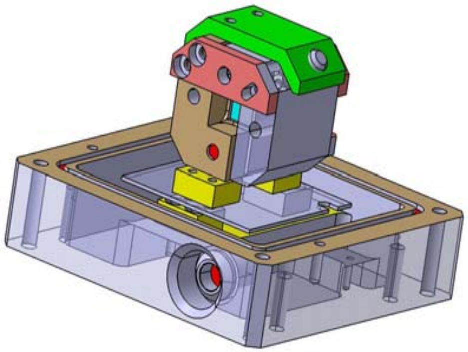


Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

Pump Laser: Second Harmonic Generation

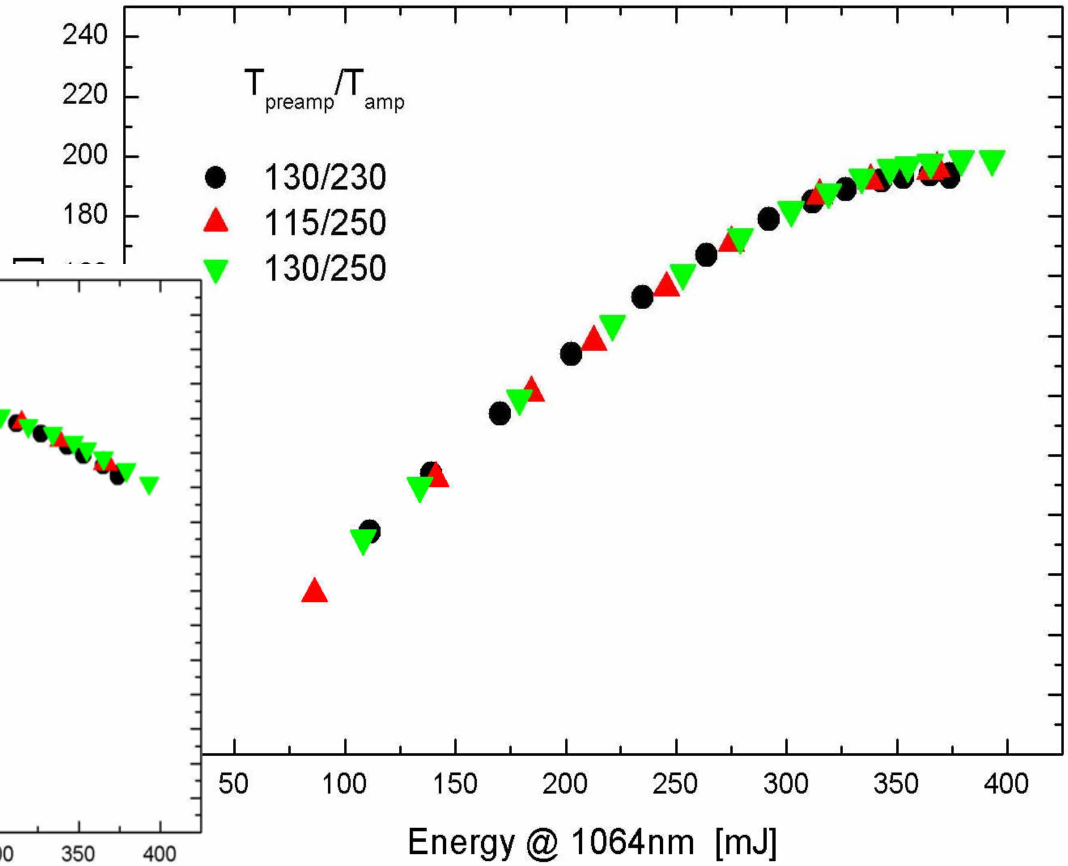


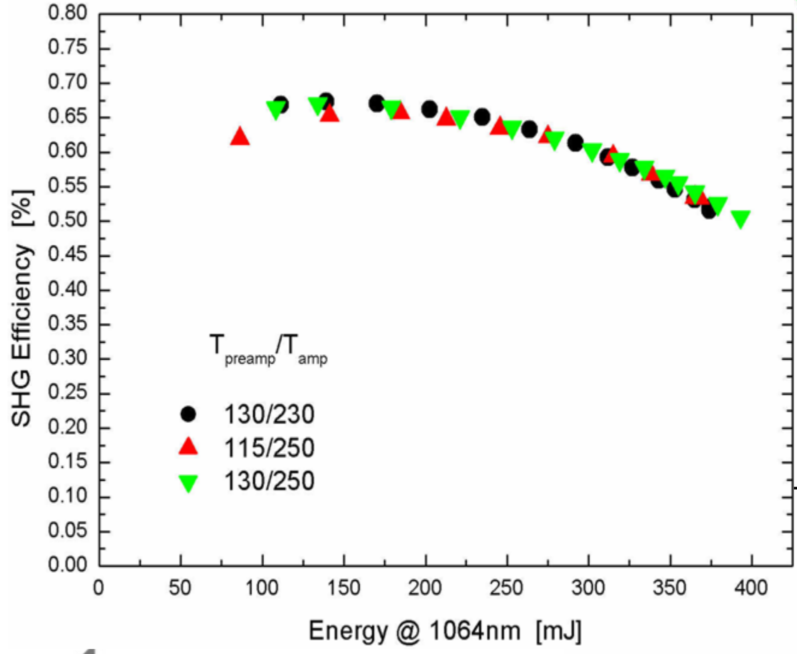
- Comparative test of different SHG-Cristals
- Different materials:
  - LBO, Typ 1, NCPM, 150°C
  - KTP, Typ 2, CPM, RT
  - KTP, Typ 2, CPM, 80°C
- Different suppliers
- Development of a crystal oven



Pump Laser: Second Harmonic Generation

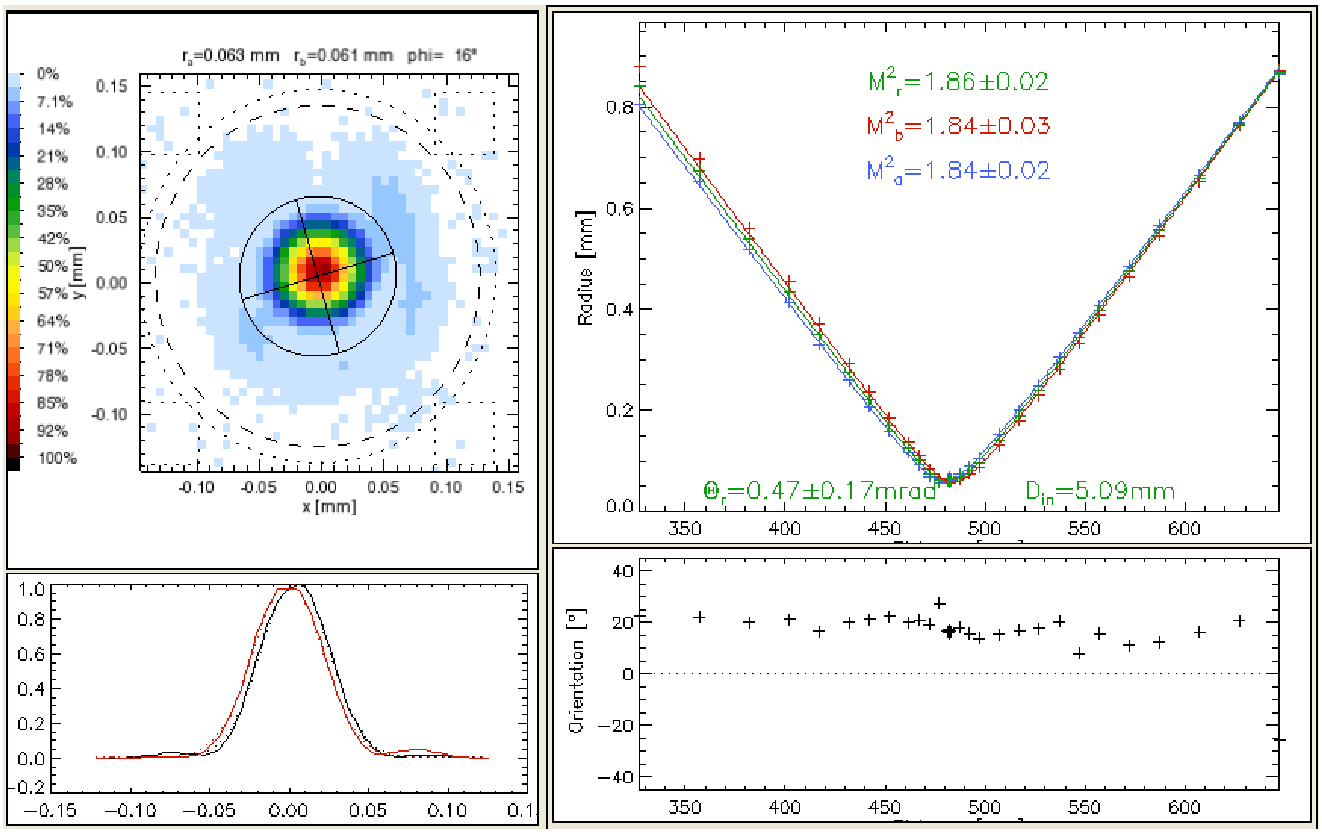
- **10 mm KTP at 80°C**
- η > **50%**
- η_{MAX} > **65%**





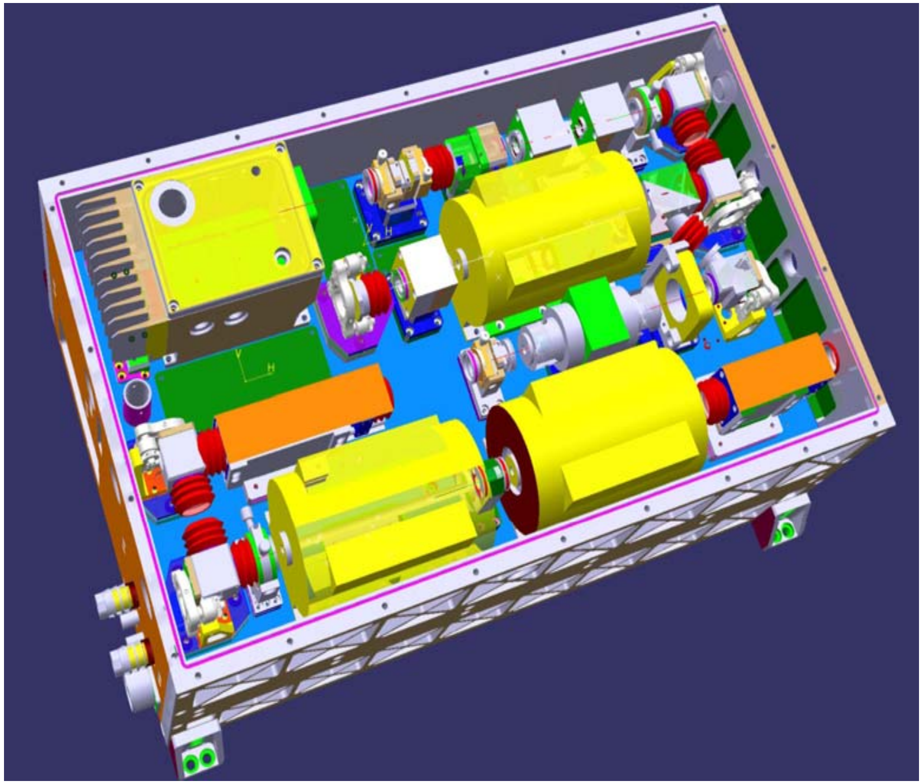
Pump Laser: Beam Quality at 532nm

$M^2 = 1.8$



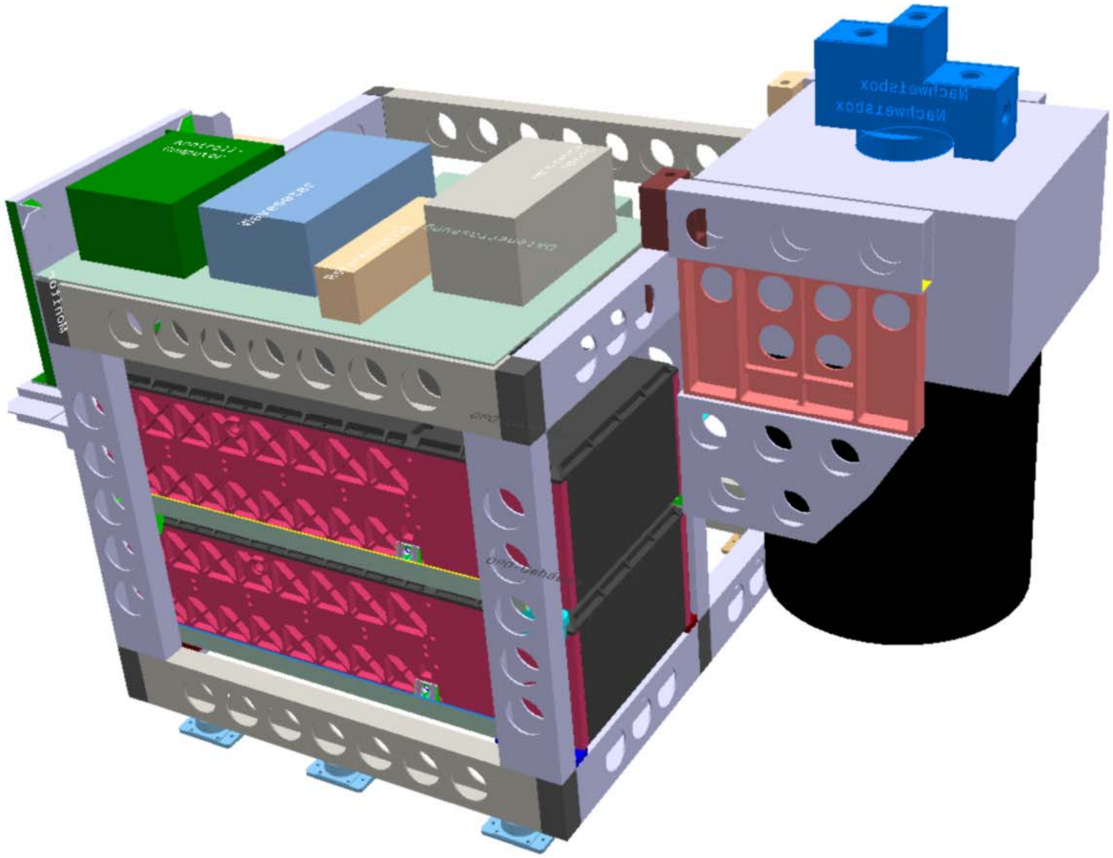
Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

Pump Laser: Flight Module is currently manufactured



- *Dimensions: 700 mm x 412 mm x 257 mm including all electronics*
- *Wall-plug Efficiency (1064nm): 5.1% / 750 W power consumption*

Airborne Multi-Wavelength H_2O DIAL:
Aircraft Rack with all Components



Time Schedule

Q4/2005	All critical transmitter components built and test in a laboratory setup
Q2/2006	Integration of all sub systems in the lab and first atmospheric measurements (*out of the window*)
Q3/2006	Assembly of the complete system within aircraft frame and ground testing
Q4/2006	First test flight
Q3/2007	Full aircraft certification and first airborne campaign