Ground-based, Scanning Water Vapor DIAL Reference Systems

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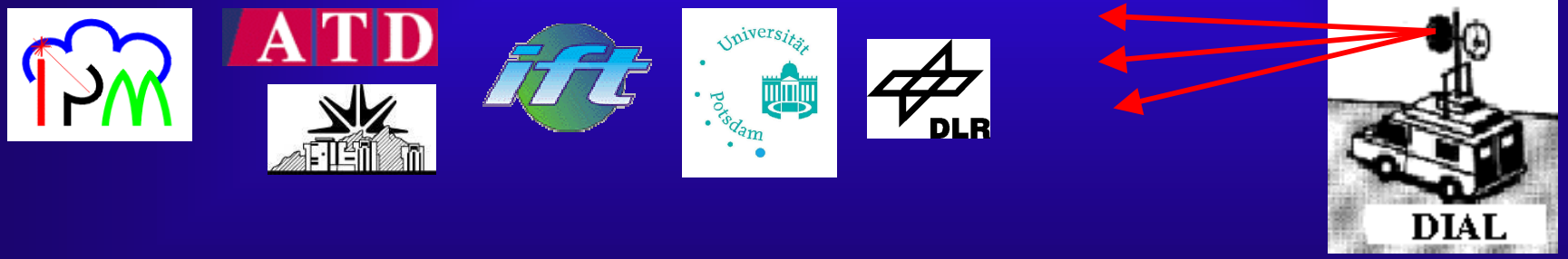
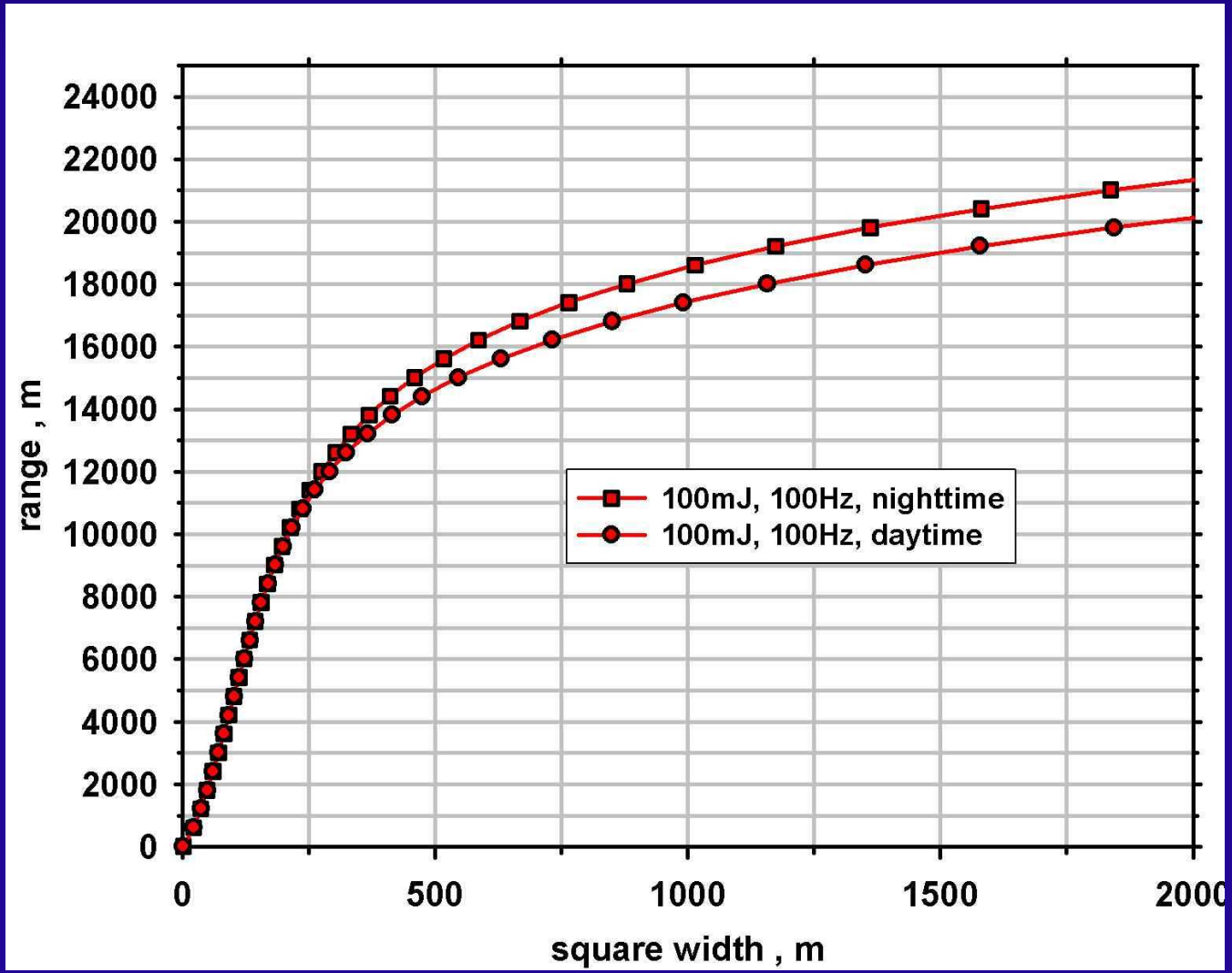


1. Motivation

- Large gaps in our knowledge of the global water vapor distribution is a major hindrance for progress in atmospheric sciences
- Water vapor DIAL is a key technology which has the potential to revolutionize our knowledge of atmospheric processes
- Simultaneously significant advances in weather and climate research can be expected

Expected performance of scanning water vapor DIAL



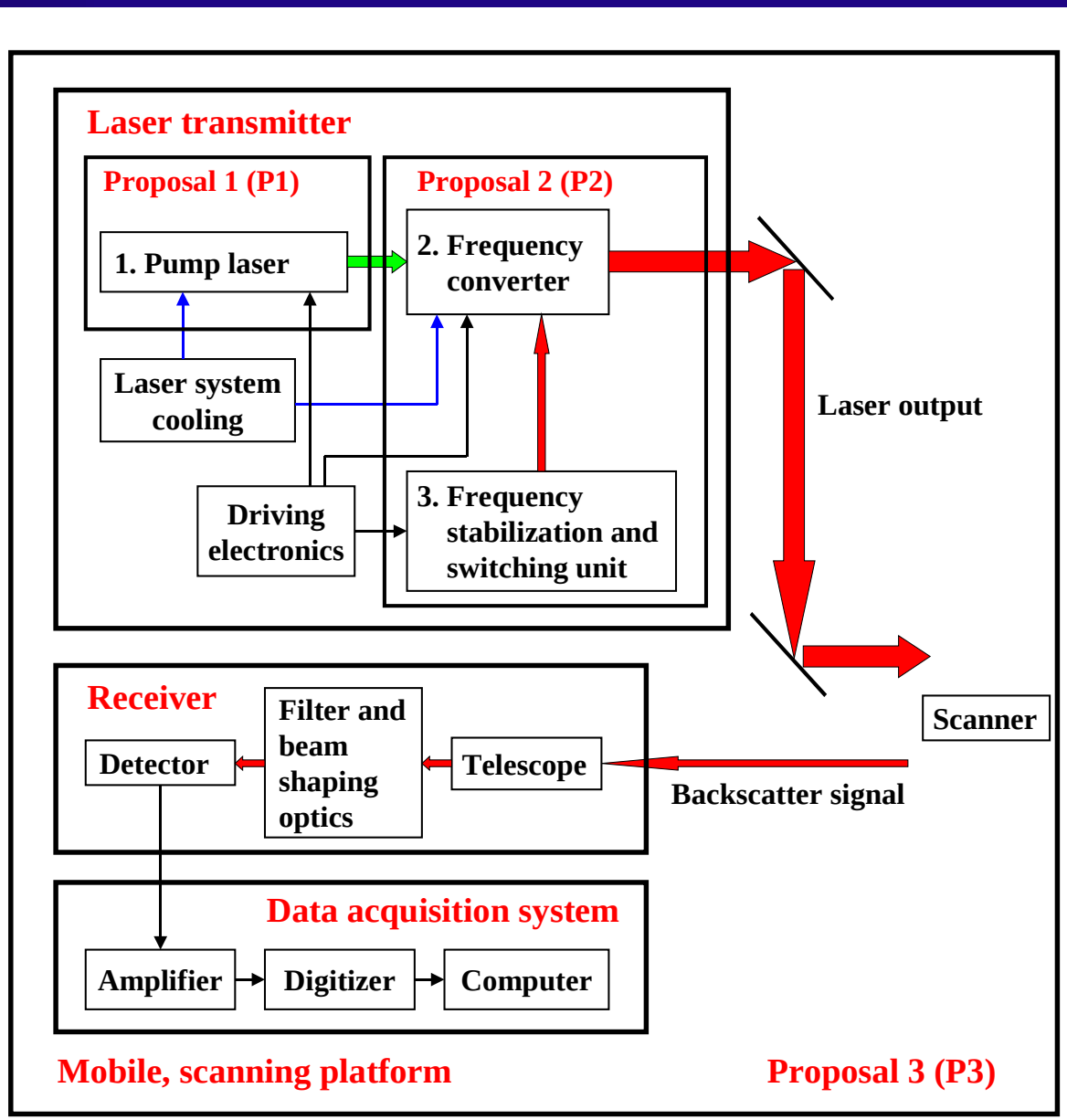
1 min round-trip time, <5% noise error

(Wulfmeyer and Walther 2001)

2. DFG Project goal and design

- **Development of a water vapor lidar reference system based on a high-power laser transmitter using the DIAL technique**
  - **P1: High-power pump laser, 400 W (UP)**
  - **P2: Ti:Sapphire frequency converter, 20 W (UHOH, DLR)**
  - **P3: Mobile platform with scanner (IfT)**
- **Key features:**
  - **mobile**
  - **operational**
  - **3-d scanning**
  - **simultaneously high resolution, accuracy and range**
  - **demonstrator for airborne and space borne systems**

Relation between the projects



Boundary conditions considered for space borne DIAL:

- 1% overall eff.
- 10% pump laser eff.
- 50% doubler
- 20% frequ. conv.

Currently no demonstrator

P1: High-power pump laser

Diode laser pumped laser system:
- **400 W average power, scalable**
- **10-100 ns pulse duration**
- **Rep. rate 100-1000 Hz**
- **$M^2 < 1.5$**
- **Single-frequency operation by injection seeding**
- **High wall-plug efficiency**

Frequency quadrupling 266 nm:

- **Ozone DIAL**

- **Aerosol lidar**

Frequency tripling 355 nm:

- **Ozone DIAL**
- **Aerosol lidar**
- **Temperature Raman lidar**
- **Water vapor Raman lidar**
- **HSRL (EARTHCARE reference system)**
- **Incoherent Doppler lidar (ADM Reference system)**

Frequency doubling 532 nm:

- **Aerosol lidar**

- **Water vapor DIAL by means of frequency conversion to 800-950 nm (WALES reference system)**

Fundamental 1064 nm:

- **Aerosol lidar**

Using frequency conversion with OPO or Cr^{4+}:YAG to > 1400 nm:

- **Eye-safe aerosol lidar**

- **Coherent Doppler lidar**

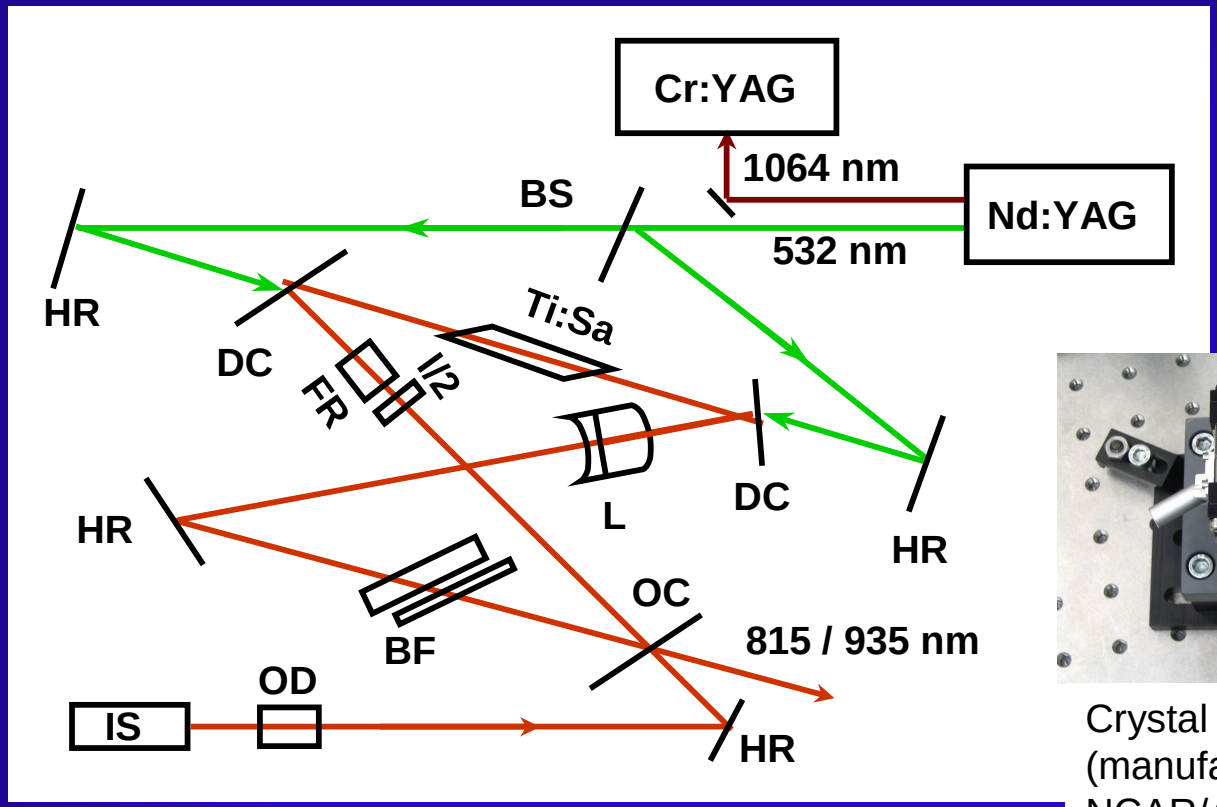
- **DIAL**

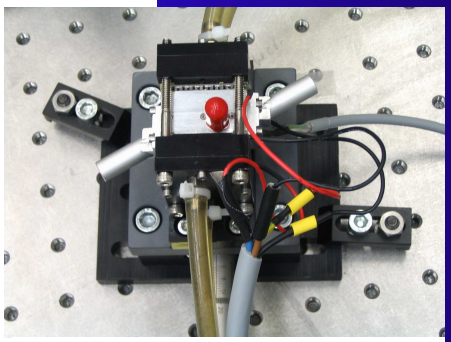
Goals of P1:

Development of a pump laser with the following specs:

1. **Full diode laser pumped**
2. **Efficiency: > 10 % overall wall-plug (incl. cooling, etc.)**
3. **Average power: > 400 W**
4. **Repetition rate: 100-1000 Hz (lower rep. rates preferred)**
5. **Pulse duration: 10-100 ns**
6. **Beam quality: $M^2 < 1.5$**
7. **Frequency stability: optionally injection seeding**
8. **Potential of scalability**
9. **Operational**
10. **Frequency doubling with > 50 % efficiency**

P2: High-power Ti:Sapphire laser

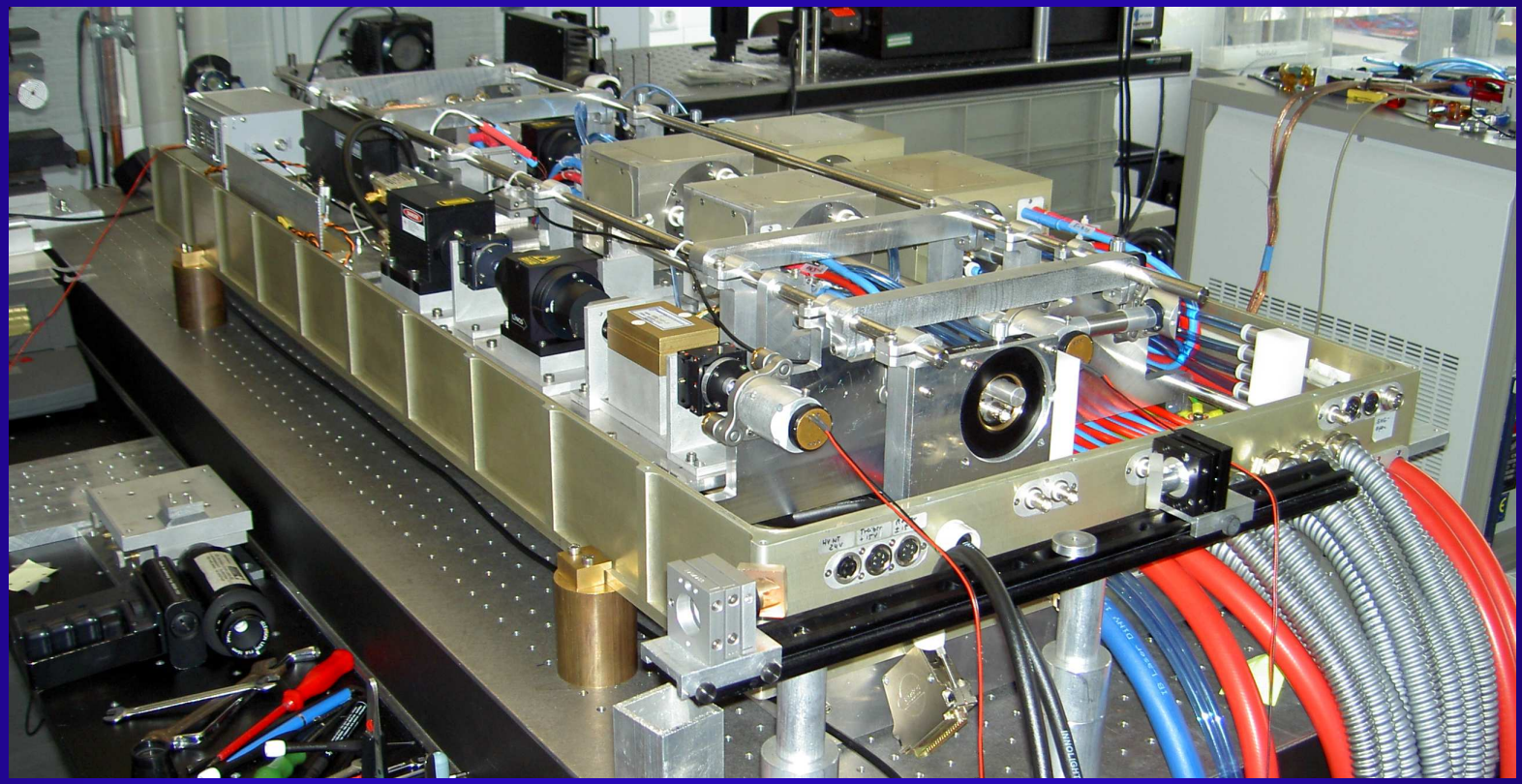




Crystal chiller (manufactured at NCAR/ATD).

Envisioned set up: Single dynamically stable, unidirectional ring resonator

P2: UHOH pump laser



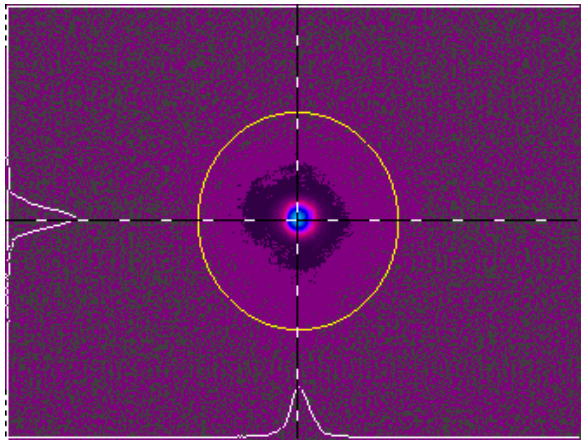
IB-Laser High-power Pump Laser System:
67 W @ 1064 nm (250 Hz), M^2 = 1.5, final goal: 100 W

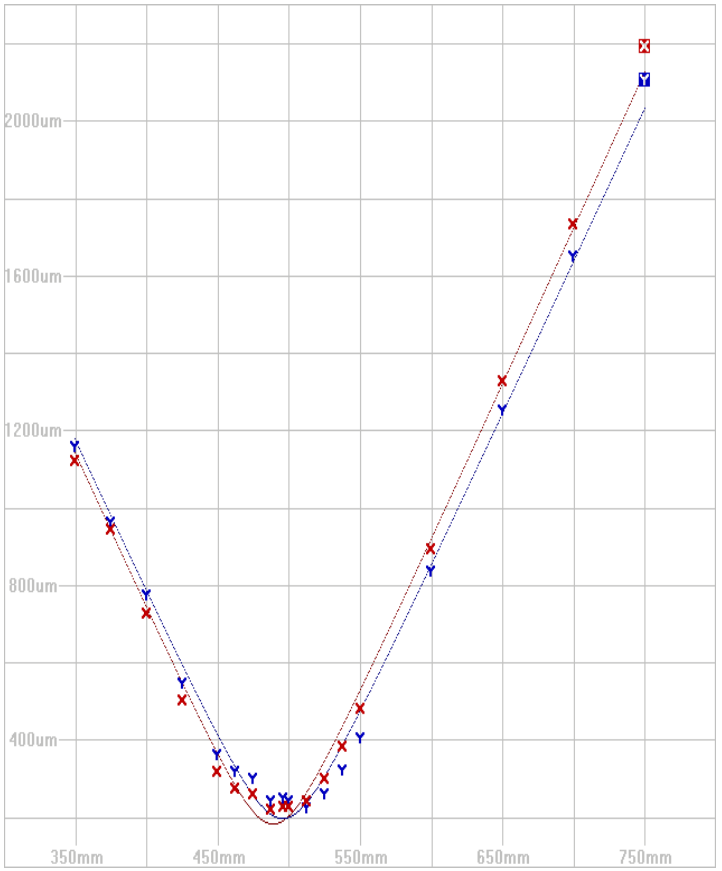
25 W @ 532 nm (250 Hz), M^2 = 2, final goal: 50 W

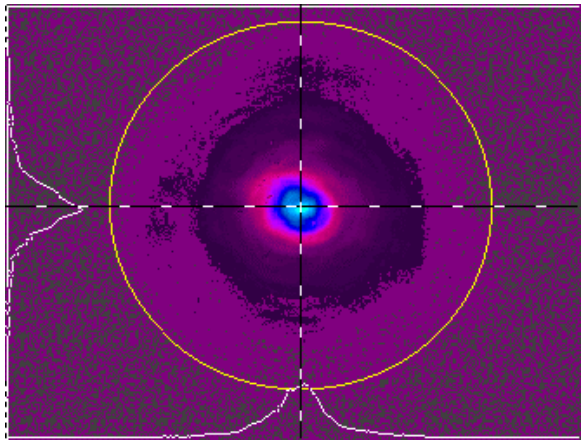
Frame1

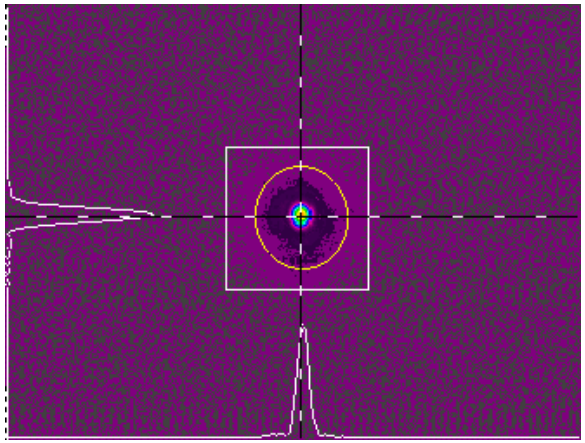
M^2-Messung bei 532 nm und 26 W @ 250Hz

Frame 18



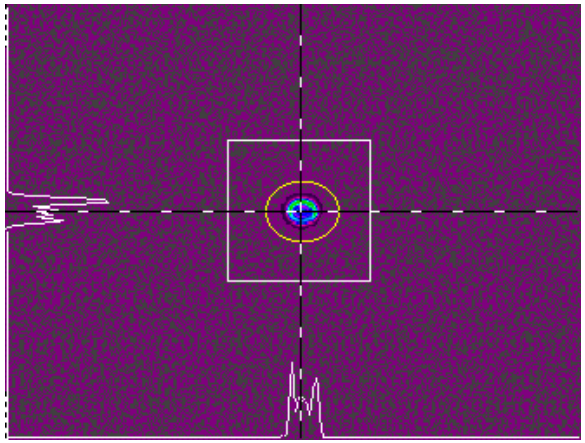






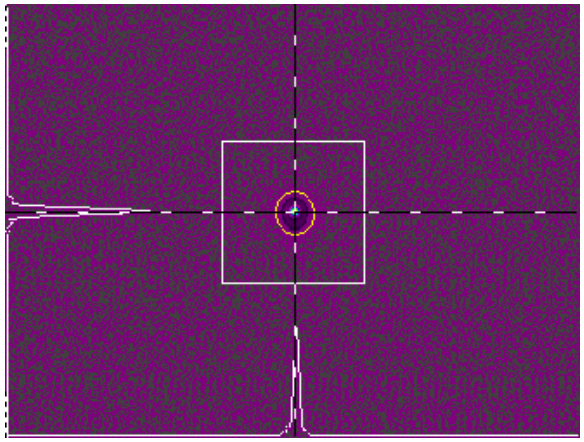
Frame 8

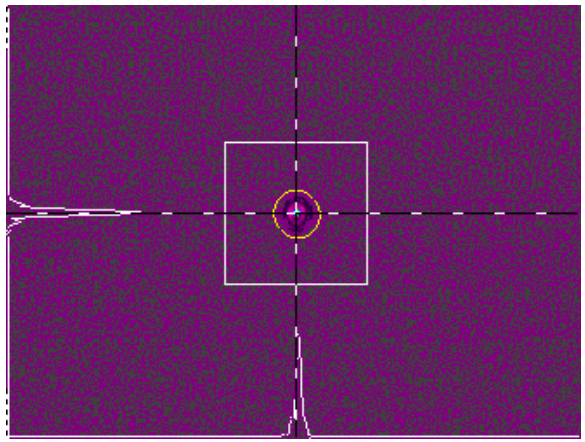
Frame 10



Frame 4

Frame 13





M^2_X = 2,20
M^2_y = 2,33
Astigm.= 0,33
Asymm.=1,04

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Goals of P2:

Development of a Ti:Sapphire laser with the following specs:

1. **Pumped by laser developed in task 1**
2. **Wavelength: 810-820 nm**
3. **Conversion efficiency > 20 % (laser pump wavelength)**
4. **Pulse duration: 10-100 ns**
5. **Beam quality: $M^2 < 2$**
6. **Frequency stability: 60 MHz**
7. **Spectral Bandwidth: 120 MHz**
8. **Spectral purity: > 99.95 %**
9. **Alternating dual frequency operation for DIAL measurements (frequency separation 10 < 100 GHz)**
10. **Operational**
11. **Compact design for application on mobile platform**

Two DIAL transmitter are under development, one system will be incorporated in DFG system, the other one will be delivered to NCAR/ATD.

Simultaneously, an eye-safe DIAL transmitter development is ongoing based on Cr^{4+}:YAG. Performance simulations are promising.

P3: Mobile, scanning platform

Goals of P3:

Development of a water vapor DIAL system:

1. **Operational (automatized)**
2. **Mobile**
3. **Scanning**
4. **Coated for 800-1600 nm**
5. **Telescope diameter: 1 m**
6. **State-of-the-art daylight background suppression**
7. **Low noise receiver for near-infrared region**
8. **Design optimized for eye-safe operation**
9. **Software for data analysis including error analysis**

Strong collaboration with NCAR/ATD

Status and goals

- Two DIAL system developments going on in Germany and US
- DFG funding: €2M
- UHOH/NCAR system funding: internal, 1.2M€
- Strong collaboration and coordination
- First test measurements planned in Spring 2005 at UHOH:
  - transmitter from UHOH
  - large receiver from NCAR/ATD
  - validation using NCAR reference radiosondes
- First field operation:

  DFG Research Project QPF, Summer 2007, with two systems