Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Institut für Meteorologie und Klimaforschung, Bereich Atmosphärische Umweltforschung (IMK-IFU), Garmisch-Partenkirchen

A High-power Differential-absorption Lidar for Free-tropospheric Sounding of Water Vapour

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Lidar Methods:

Lidar sounding offers the advantages of both high temporal and vertical resolution, ideal for tropospheric studies

Methods: Raman lidar, differential-absorption lidar (DIAL)

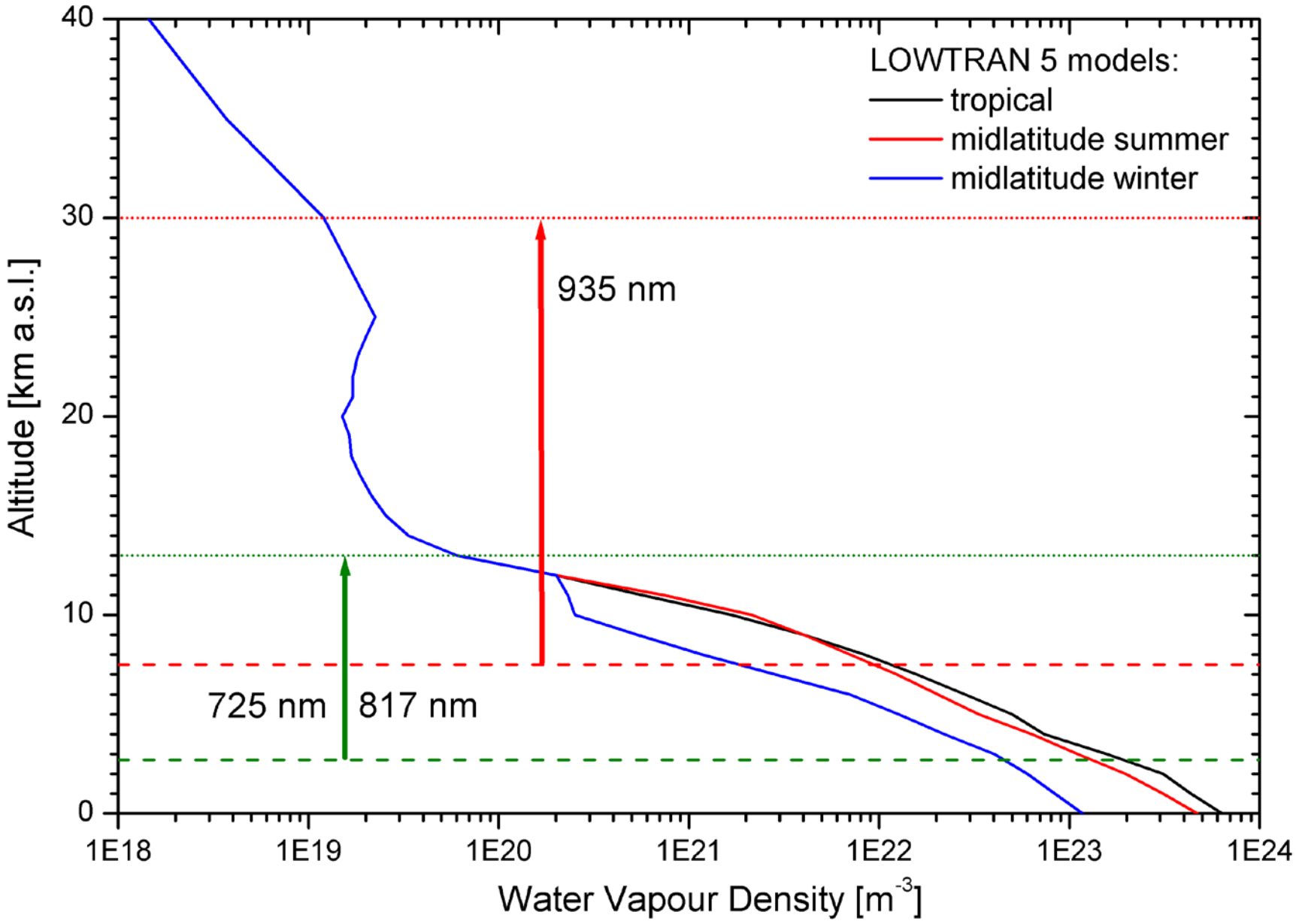
Raman lidar is usually preferred due to its capability of automatic operation.

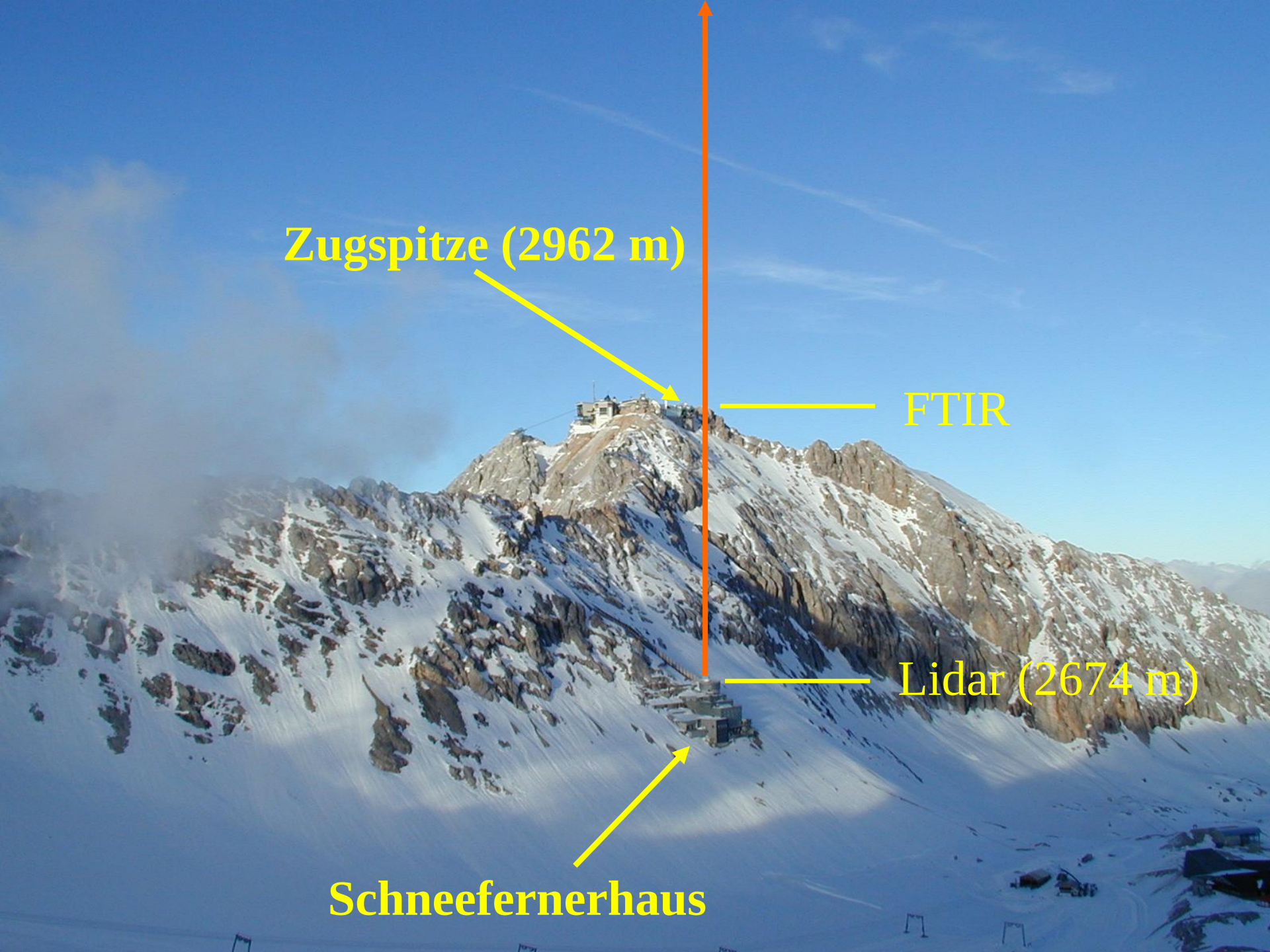
DIAL is substantially better during daytime if the laser pulse energy and the size of the receiver are made comparably large.

Goal:

Development of a DIAL with the system specifications of a Raman lidars: order-of-magnitude increase of the pulse energy with respect to dye lasers.

Operating Range of DIAL Measurements




Zugspitze (2962 m)
FTIR
Lidar (2674 m)
Schneefernerhaus

Advantages of the High-altitude Site:

– Mostly outside the moist atmospheric boundary layer

– outside the fog layer in autumn and winter

– earlier beginning of measurements also in summer

History of Narrow-band Tunable Pulsed Lasers

Dye Lasers:

1975: Wallenstein, Hänsch: **E = 0.5 mJ**, Δt = 10 ns, Δν = 85 MHz (460 nm)

1976: Blit, Ganiel, Treves: **E = 50 mJ**, Δt = 0.5 ms, Δν = 30 MHz (585 nm)

1987: Cromwell, Trickl, Kung, Lee: **E = 130 mJ**, Δt = 12 ns*, Δν = 43* MHz (563 nm)

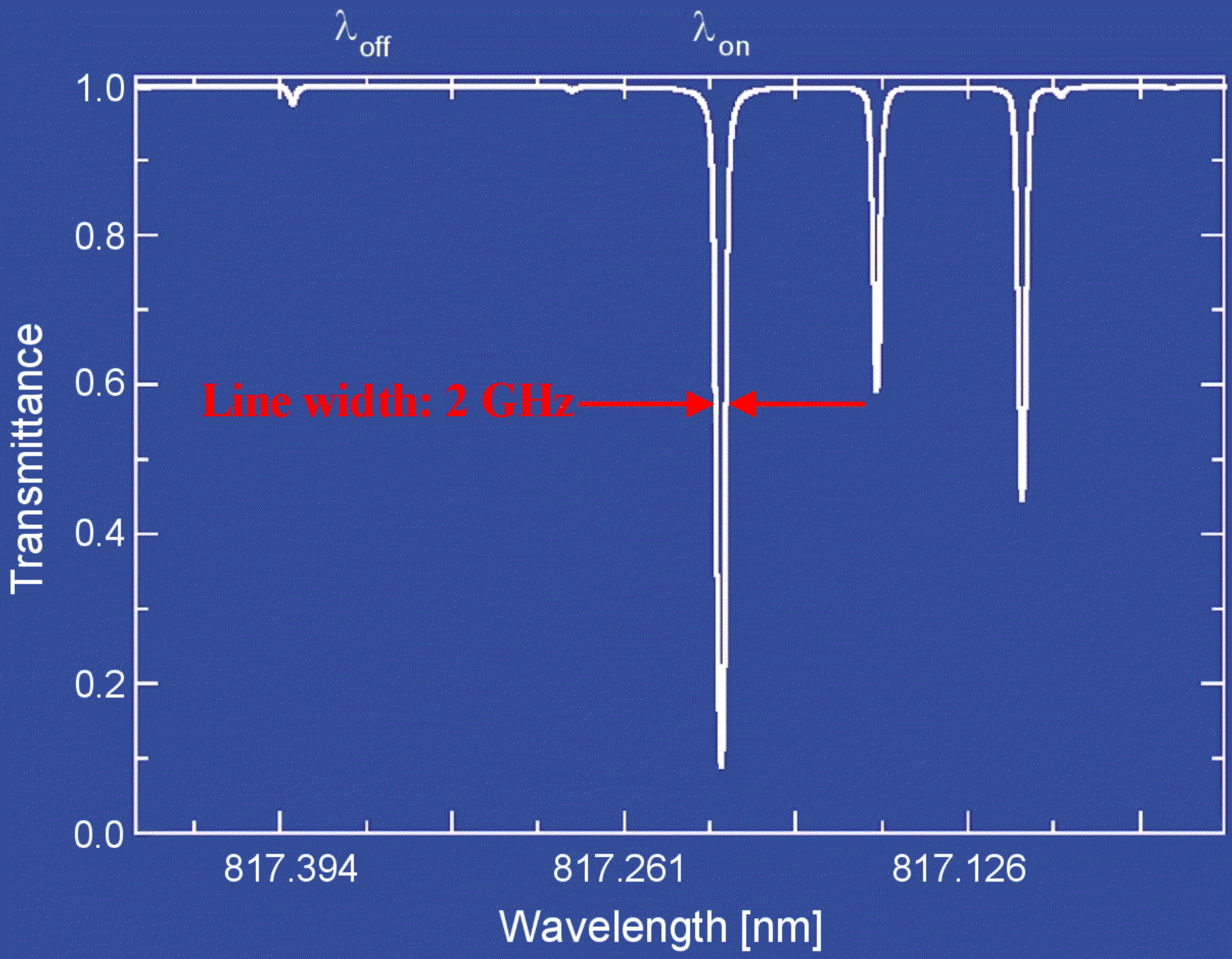
*M. Vrakking

1997: Eikema, Ubachs, Vassen, Hogervorst: E = **220 mJ**, Δt = 6.5 ns, Δν = 90 MHz (585 nm)

Solid-state Lasers:

1996: Grützmacher, Steiger: **265 mJ** (729 nm)

Vogelmann, Trickl: E = 700 mJ ?, Δν = 100 MHz (Δt = 5 ns, 800 nm)


λoff
λon
1.0
0.8
0.6
0.4
0.2
0.0
Transmittance
Line width: 2 GHz
817.394
817.261
817.126
Wavelength [nm]

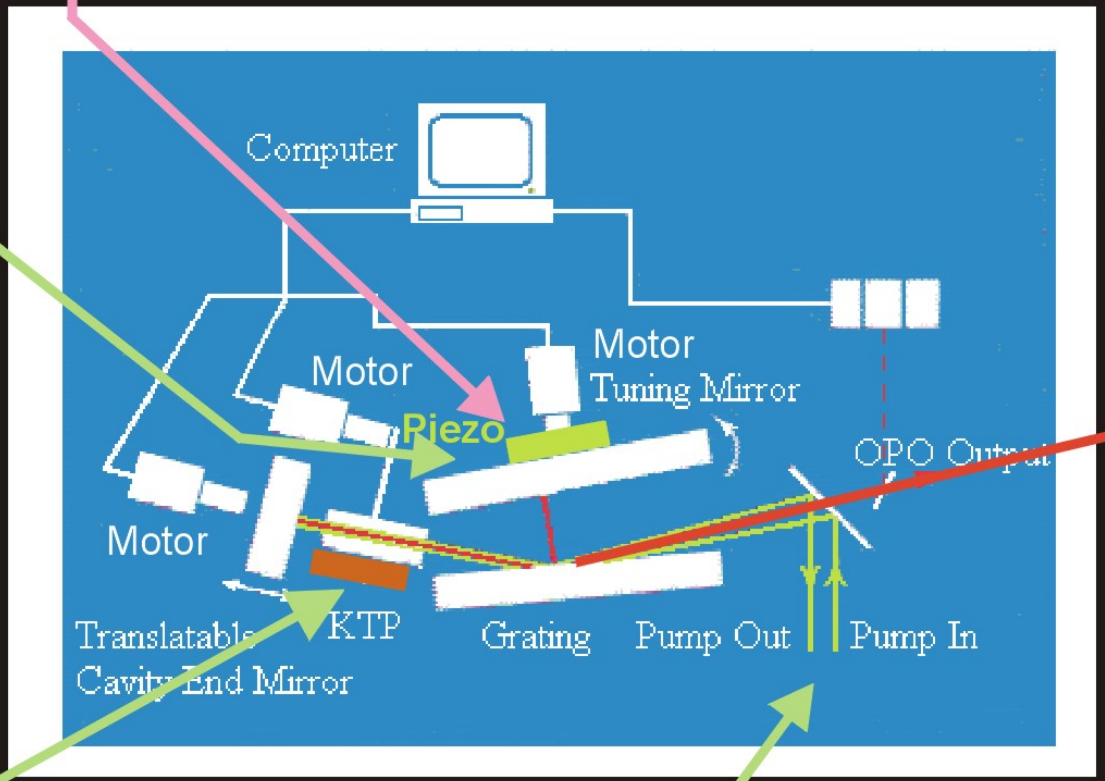
Upgrading the Mirage Littman OPO

Wavelength control

PC

LM007

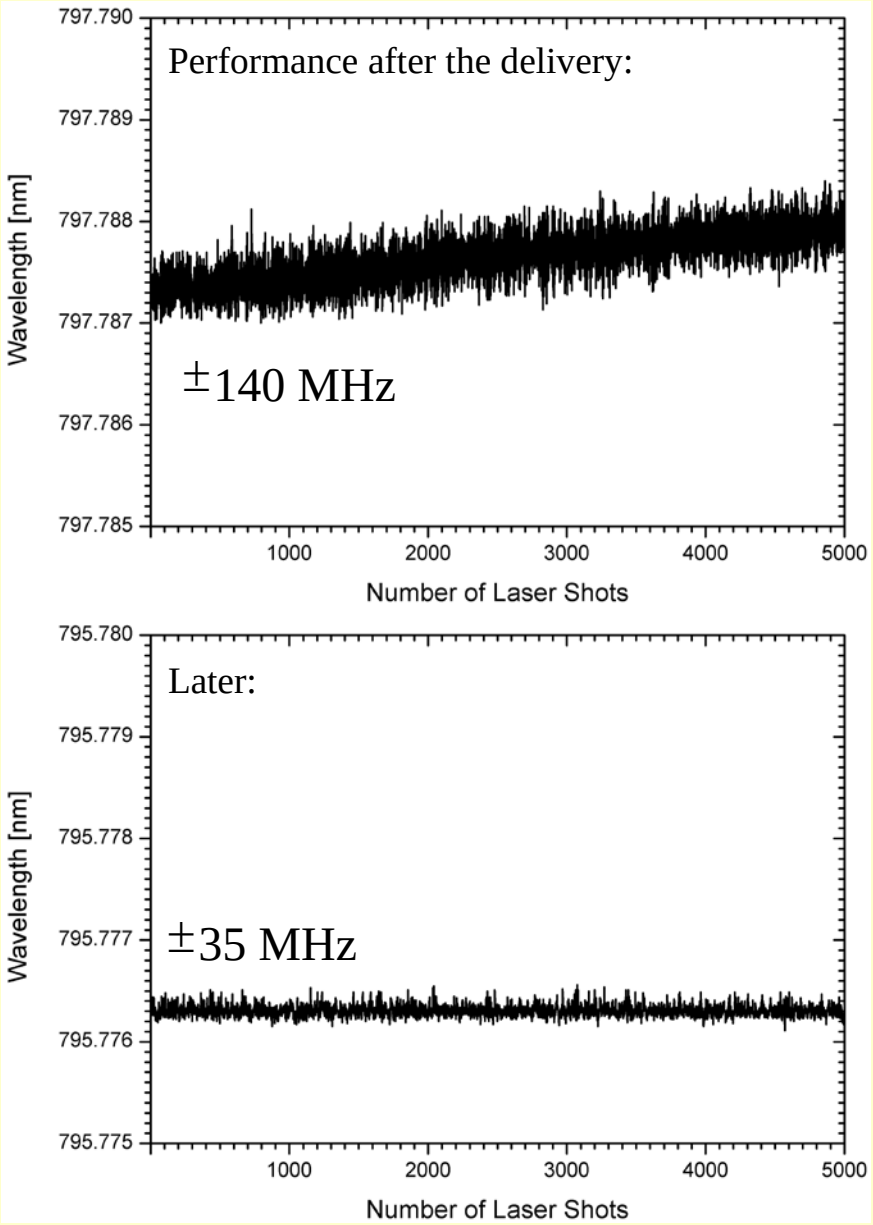
Fine tuning

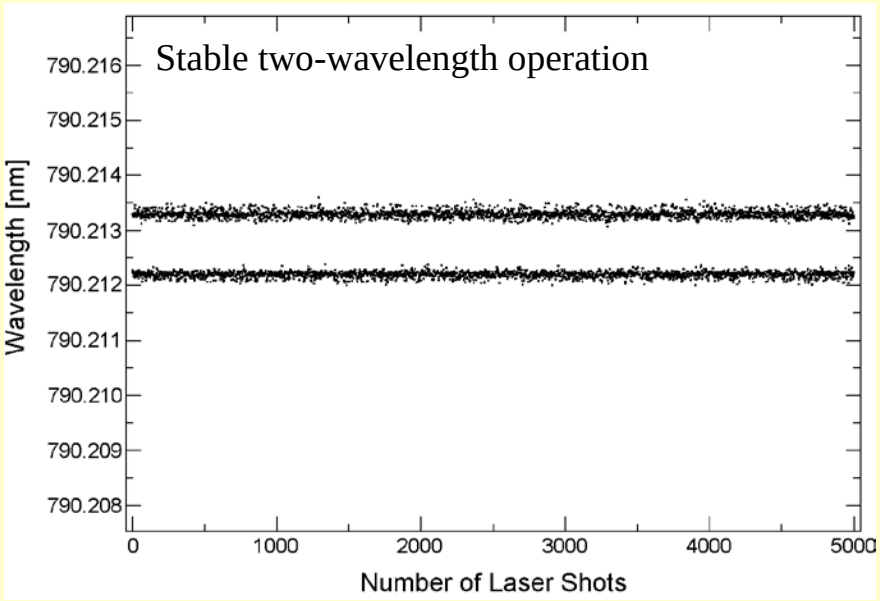


Crystal heating

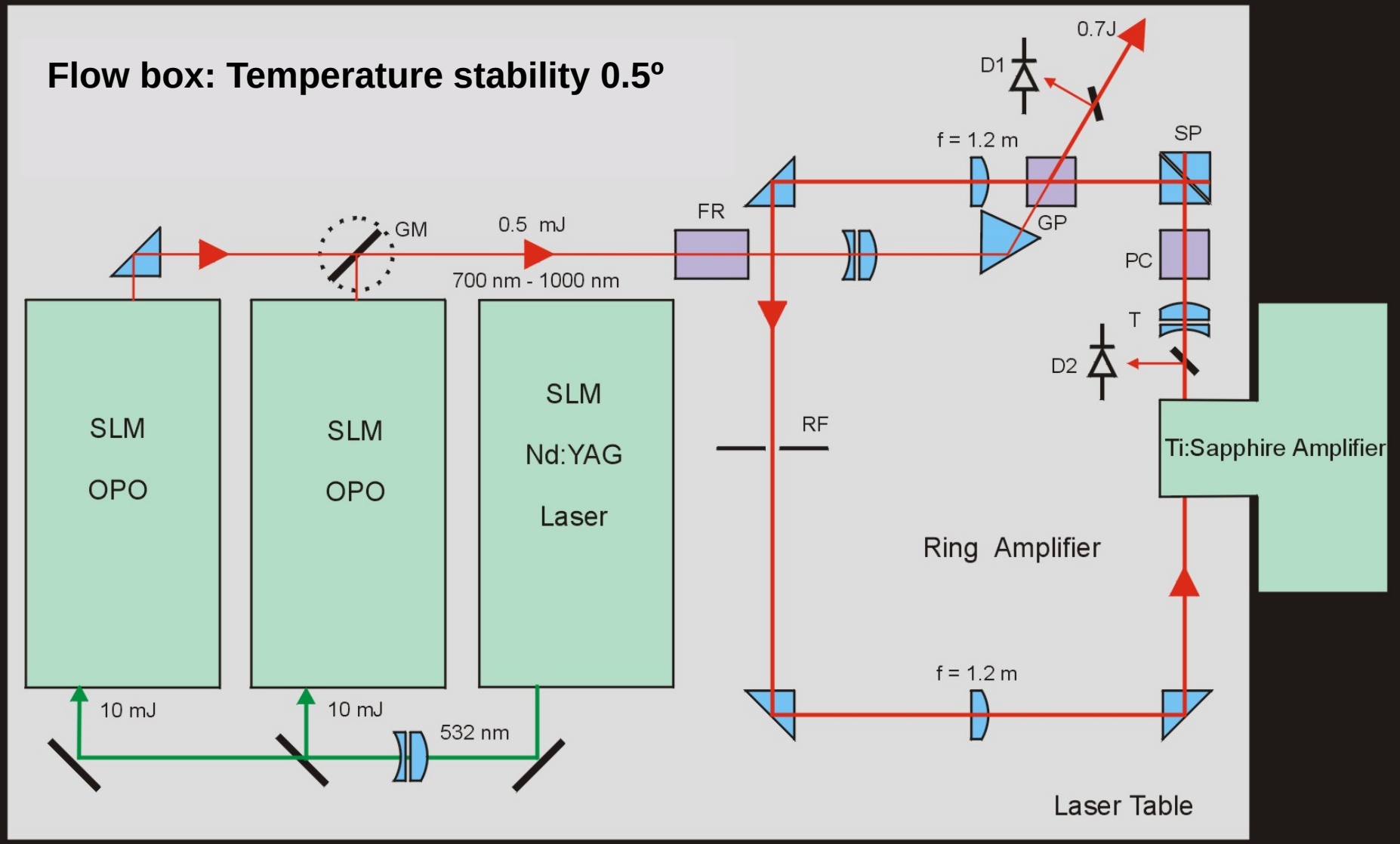
Elliptical pump beam

Results of the Improvements



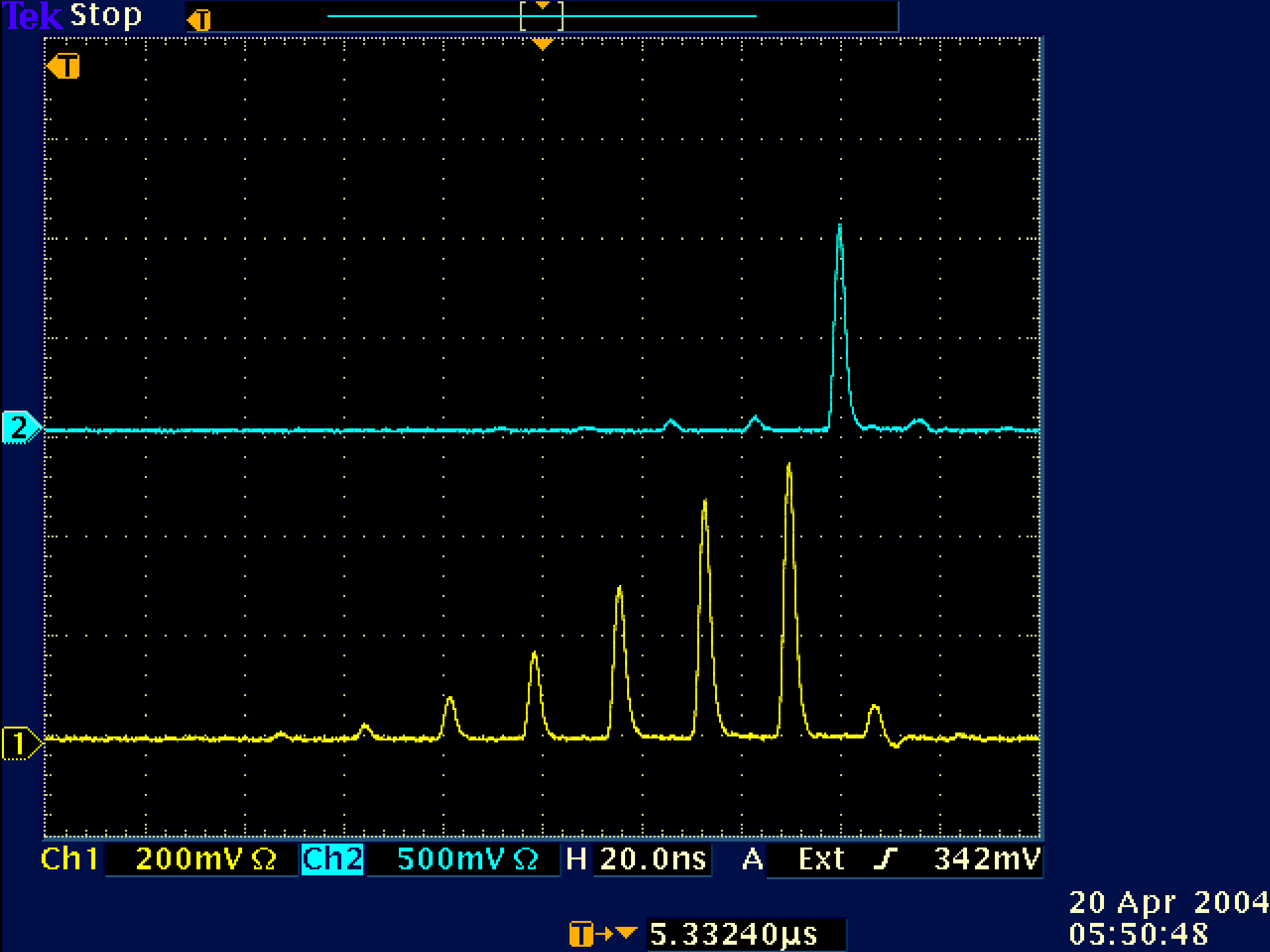


- Very rare mode hops
- Transversally stable beam, pointing fluctuations ≤ 50 μrad
- Low intensity fluctuations
- Laser threshold lowered from 16 mJ to 6-8 mJ
- Near transform-limited pulses ($\Delta\nu$ = 130 MHz, transform limit for 4 ns: 110 MHz)

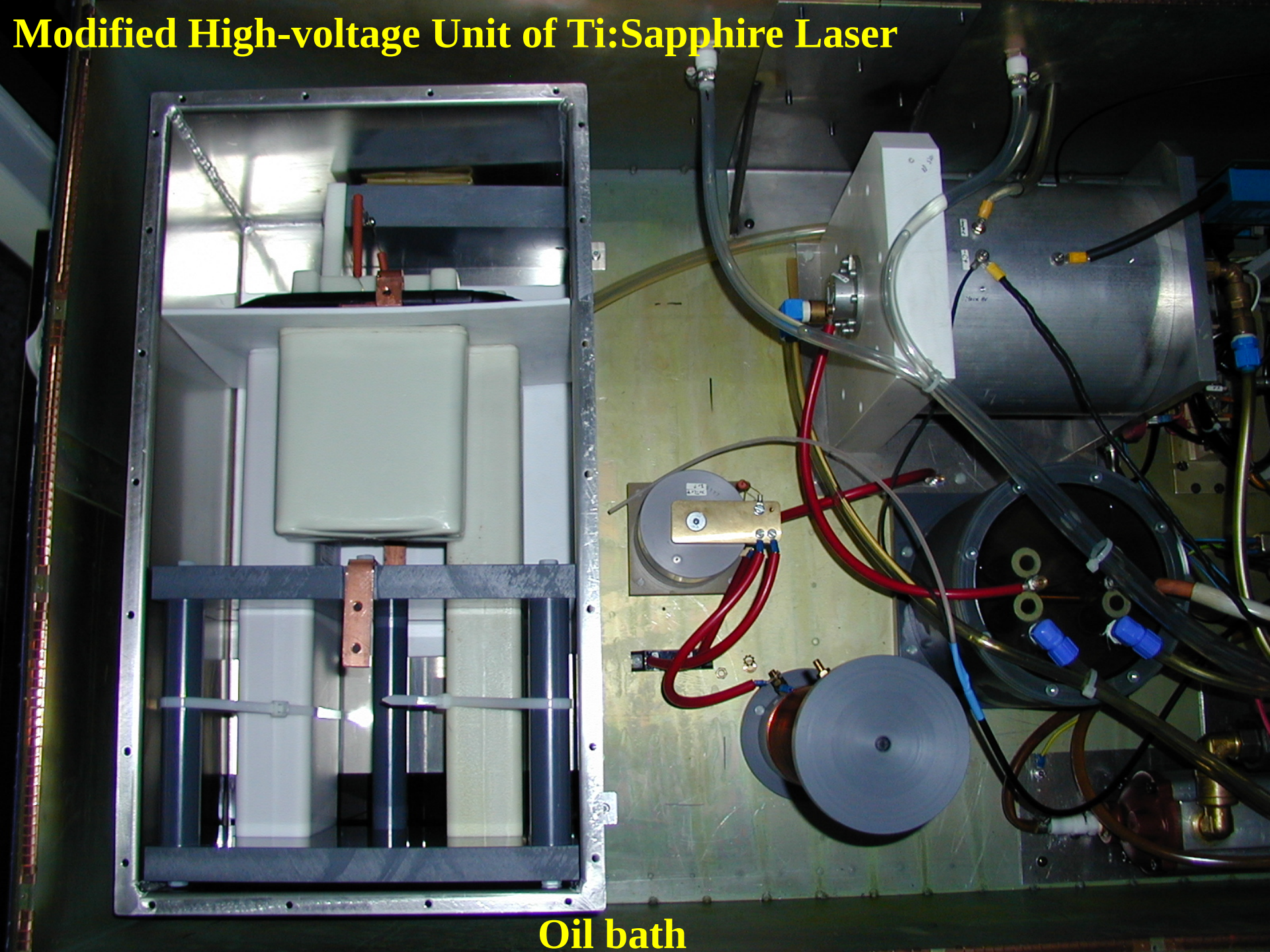

Flow box: Temperature stability 0.5º
0.7J
D1
f = 1.2 m
SP
GM
0.5 mJ
FR
GP
700 nm - 1000 nm
PC
T
D2
SLM
OPO
SLM
OPO
SLM
Nd:YAG
Laser
RF
Ti:Sapphire Amplifier
Ring Amplifier
f = 1.2 m
10 mJ
10 mJ
532 nm
Laser Table

The Move: April 10-12, 2003

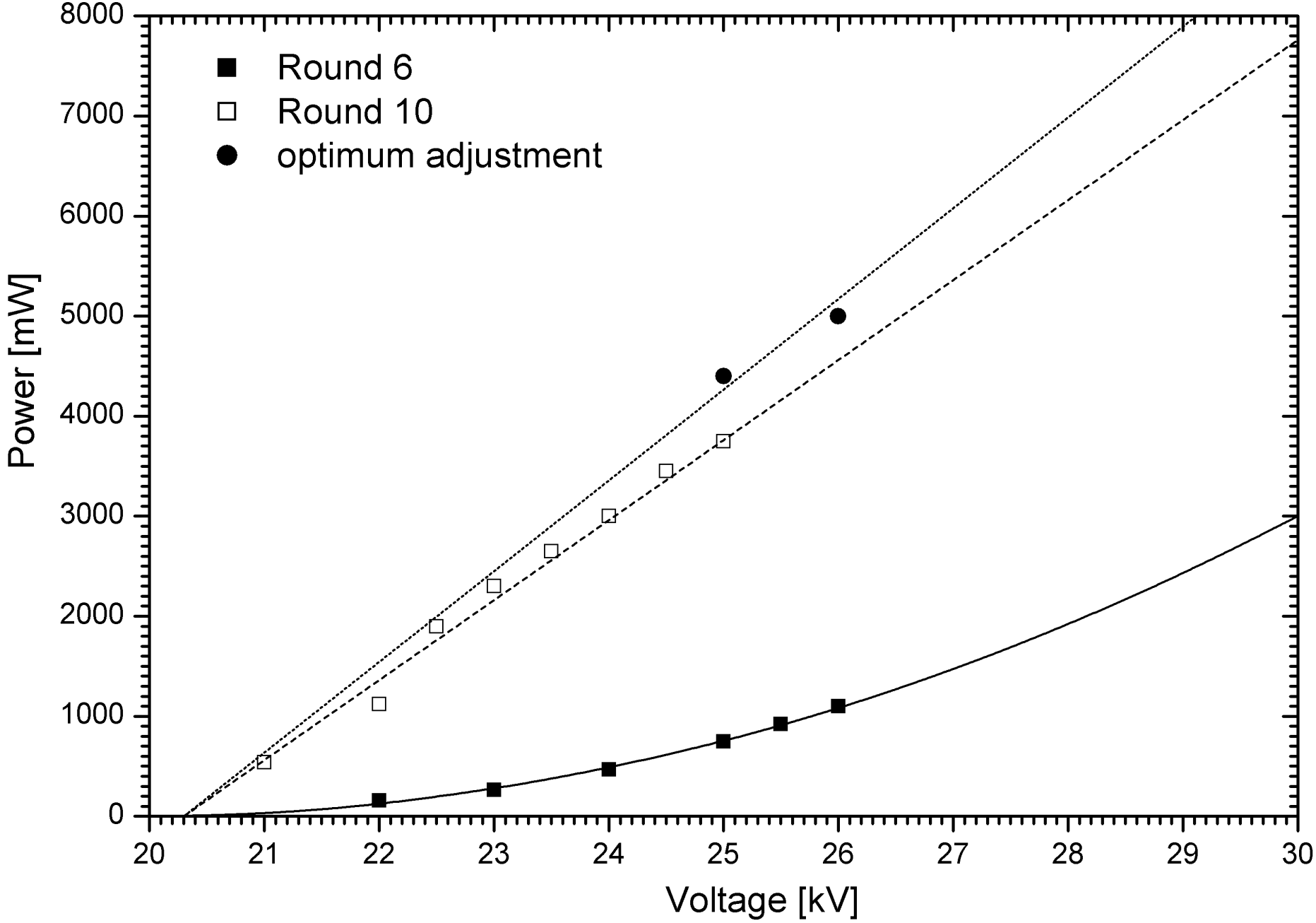
–24º C at the summit!!!!


Tek Stop
Ch1 200mV Ω
Ch2 500mV Ω
H 20.0ns
A Ext 342mV
5.33240µs
20 Apr 2004
05:50:48

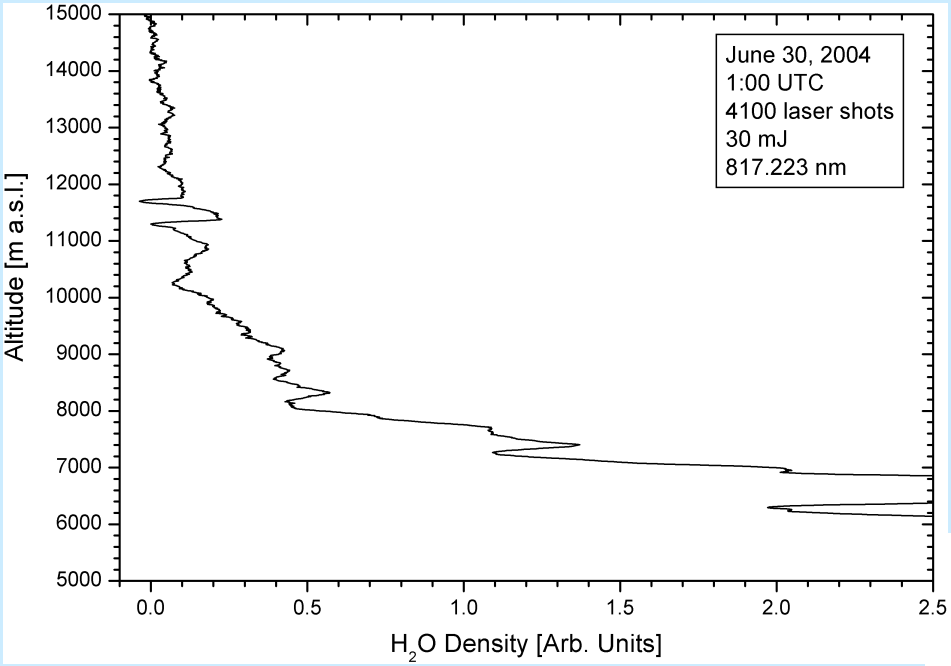
Modified High-voltage Unit of Ti:Sapphire Laser

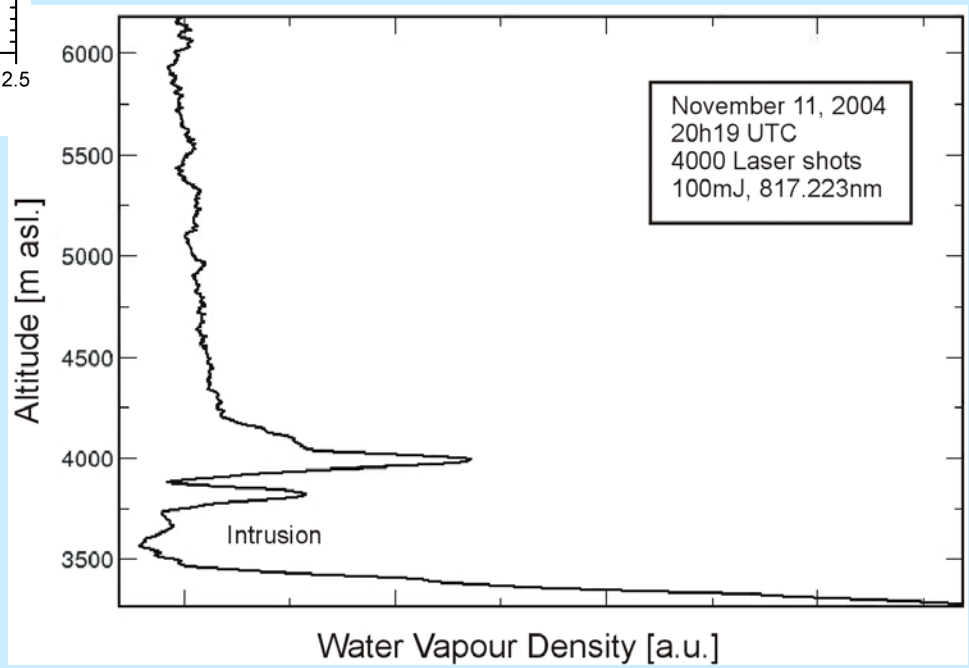


Oil bath


Round 6
Round 10
optimum adjustment
Power [mW]
Voltage [kV]
0
1000
2000
3000
4000
5000
6000
7000
8000
20
21
22
23
24
25
26
27
28
29
30

2004: First Lidar Measurements

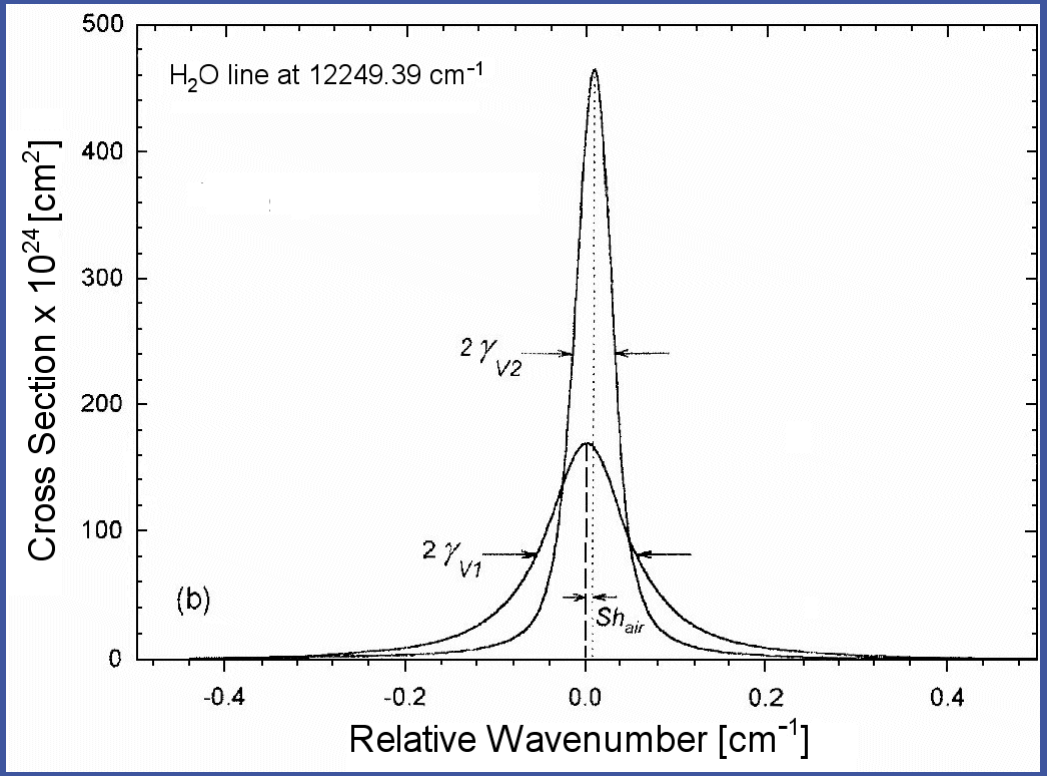


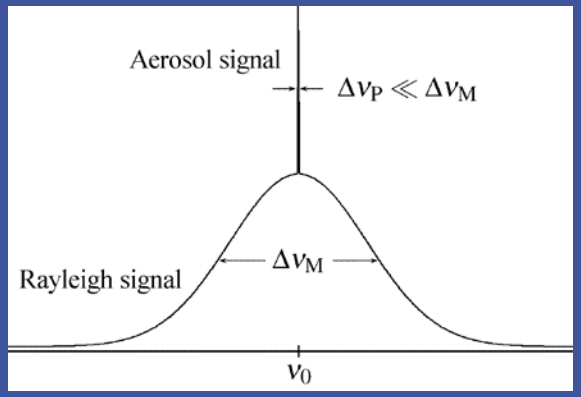


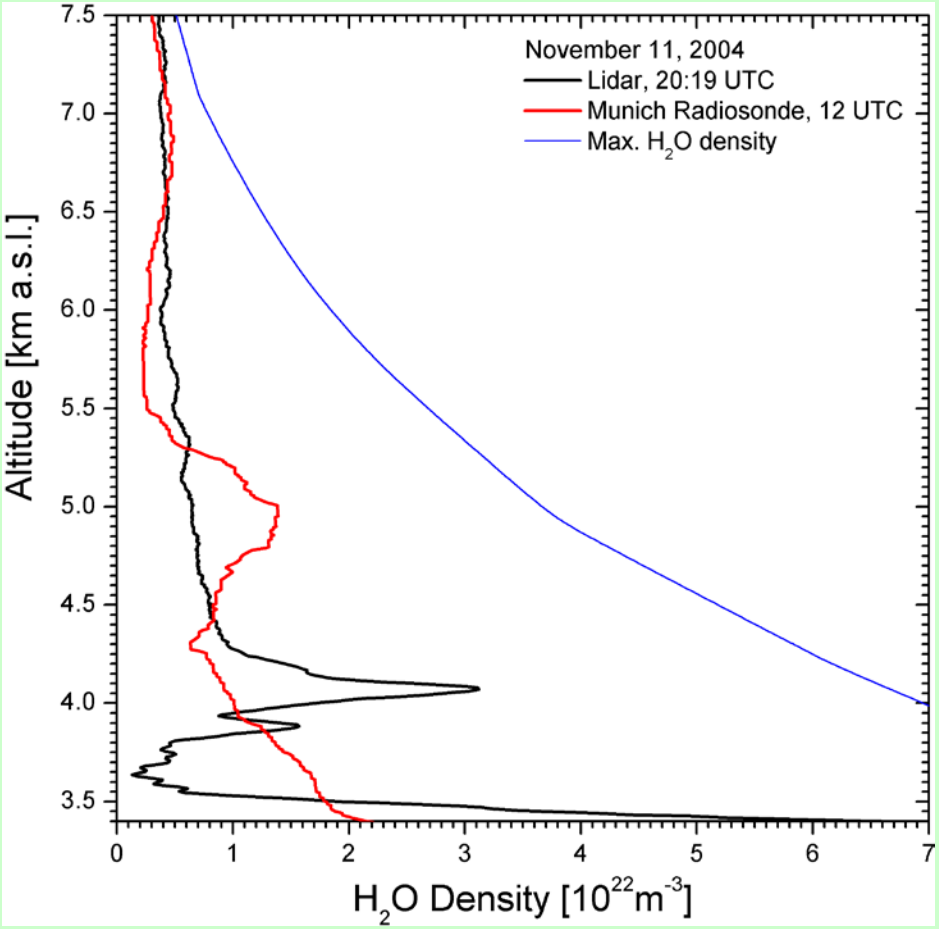
Influence of the Line Shapes

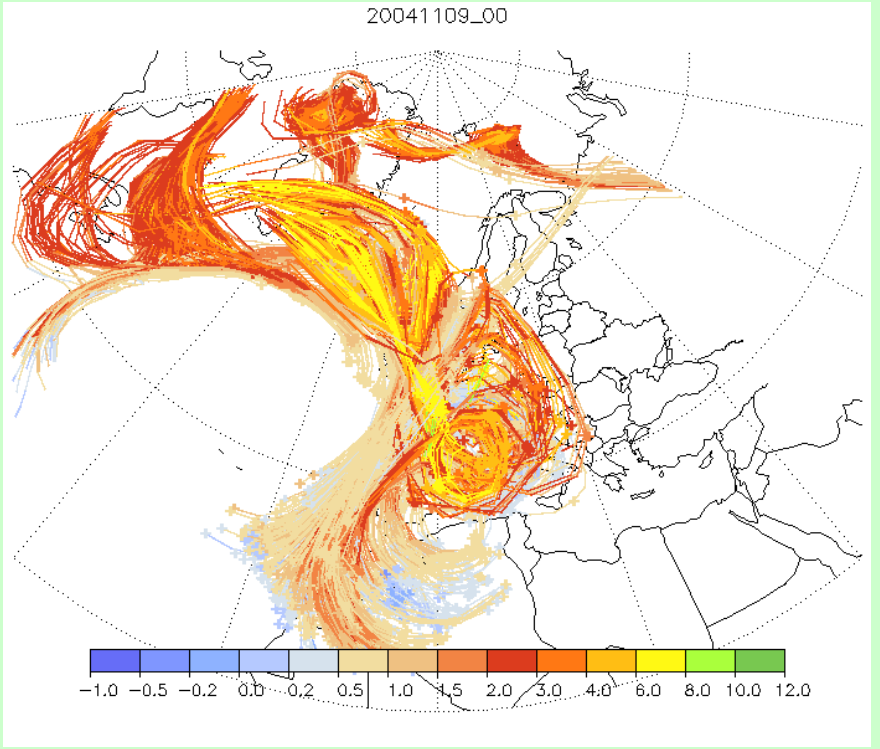
For a narrow-band laser not only the shape of the molecular absorption line as a function of the altitude needs to be taken into account:

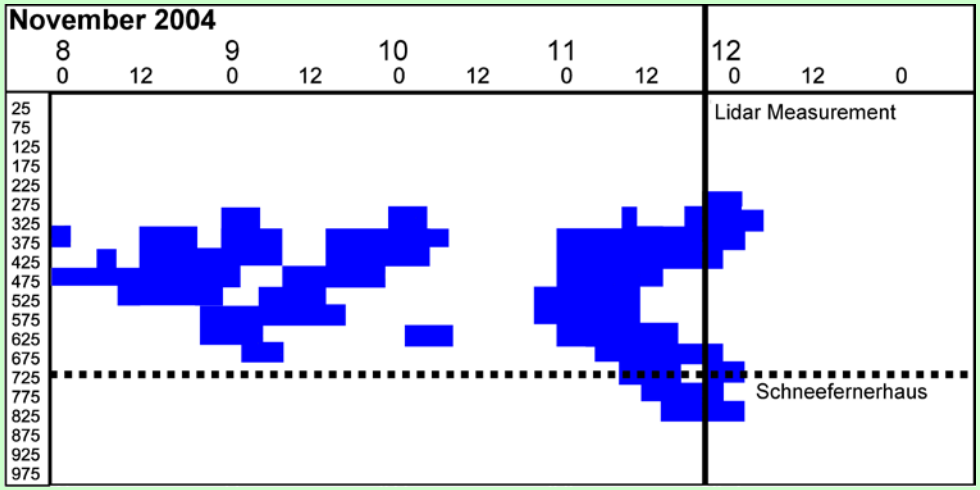
The backscattered light has a complex shape also depending on the altitude.

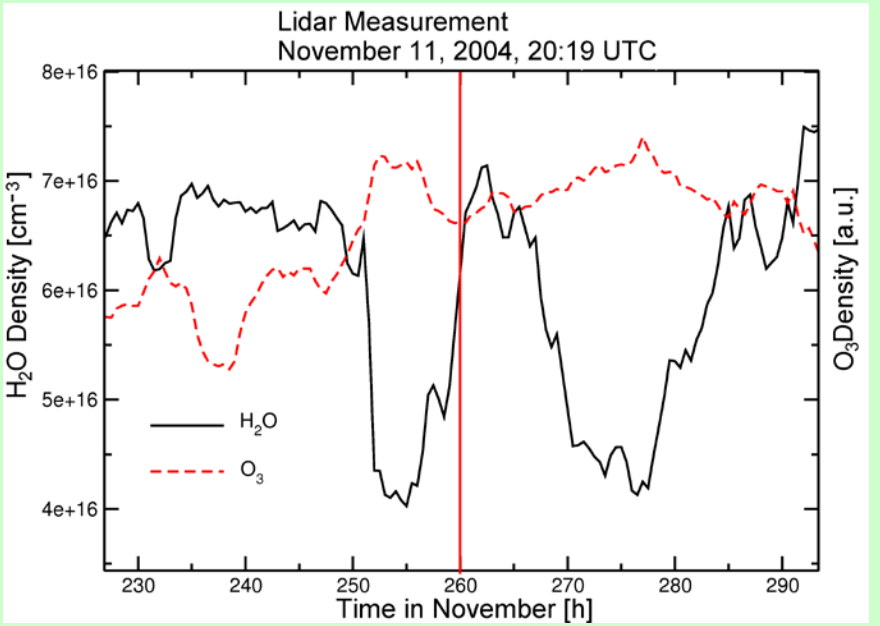




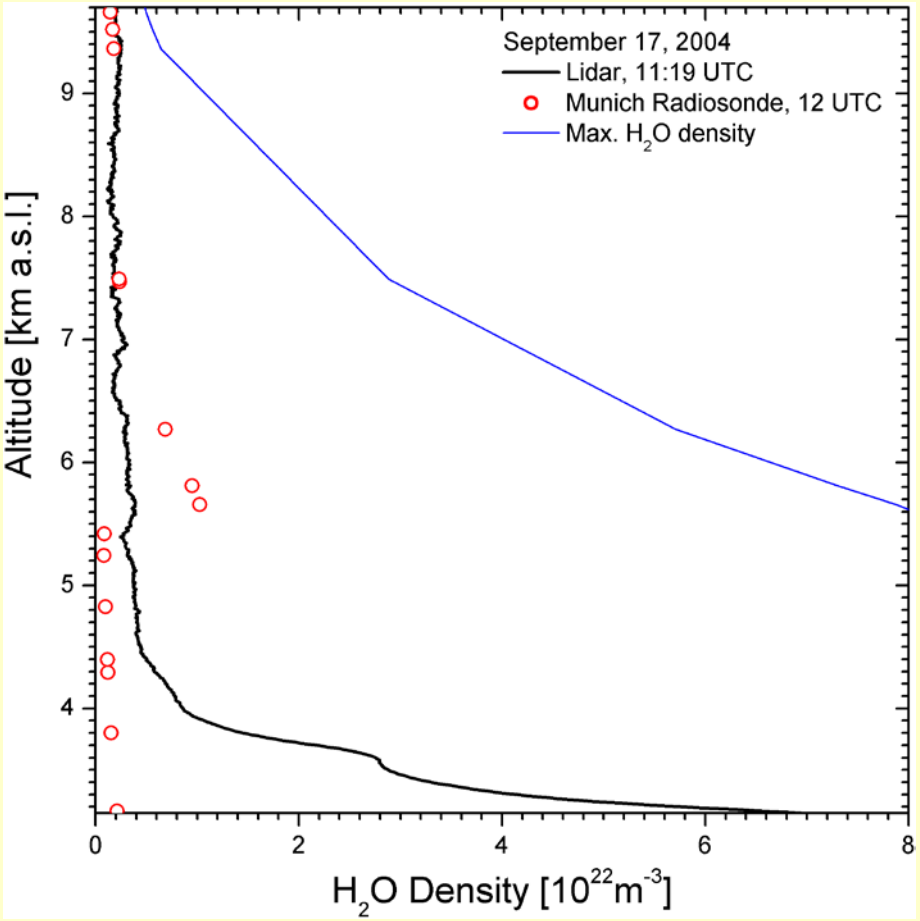

November 11, 2004
Lidar, 20:19 UTC
Munich Radiosonde, 12 UTC
Max. H2O density
Altitude [km a.s.l.]
H2O Density [10^22 m^-3]


20041109_00
−1.0 −0.5 −0.2 0.0 0.2 0.5 1.0 1.5 2.0 3.0 4.0 6.0 8.0 10.0 12.0

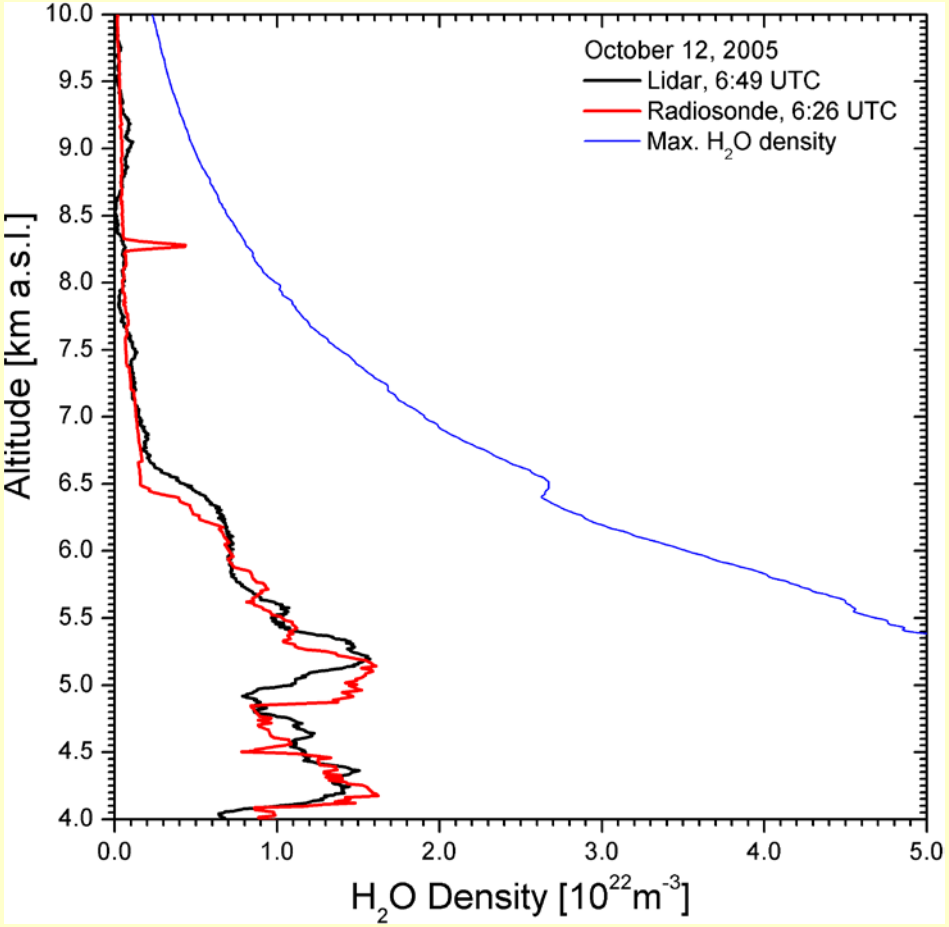

November 2004
Lidar Measurement
Schneefernerhaus


Lidar Measurement
November 11, 2004, 20:19 UTC
H2O Density [cm^-3]
O3 Density [a.u.]
H2O
O3
Time in November [h]

Daytime measurement under very dry conditions



Validation by intercomparison by radiosondes lauched at Garmisch-Partenkirchen (LMU)




A sometimes dangerous site!

Thank you!