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Automated Raman Lidar for Day and Night Operational Observation of Tropospheric Water Vapor for Meteorological Applications

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Overview

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- Motivation
- Raman lidar basics
- Instrument design
- Results
- Conclusion

Motivation

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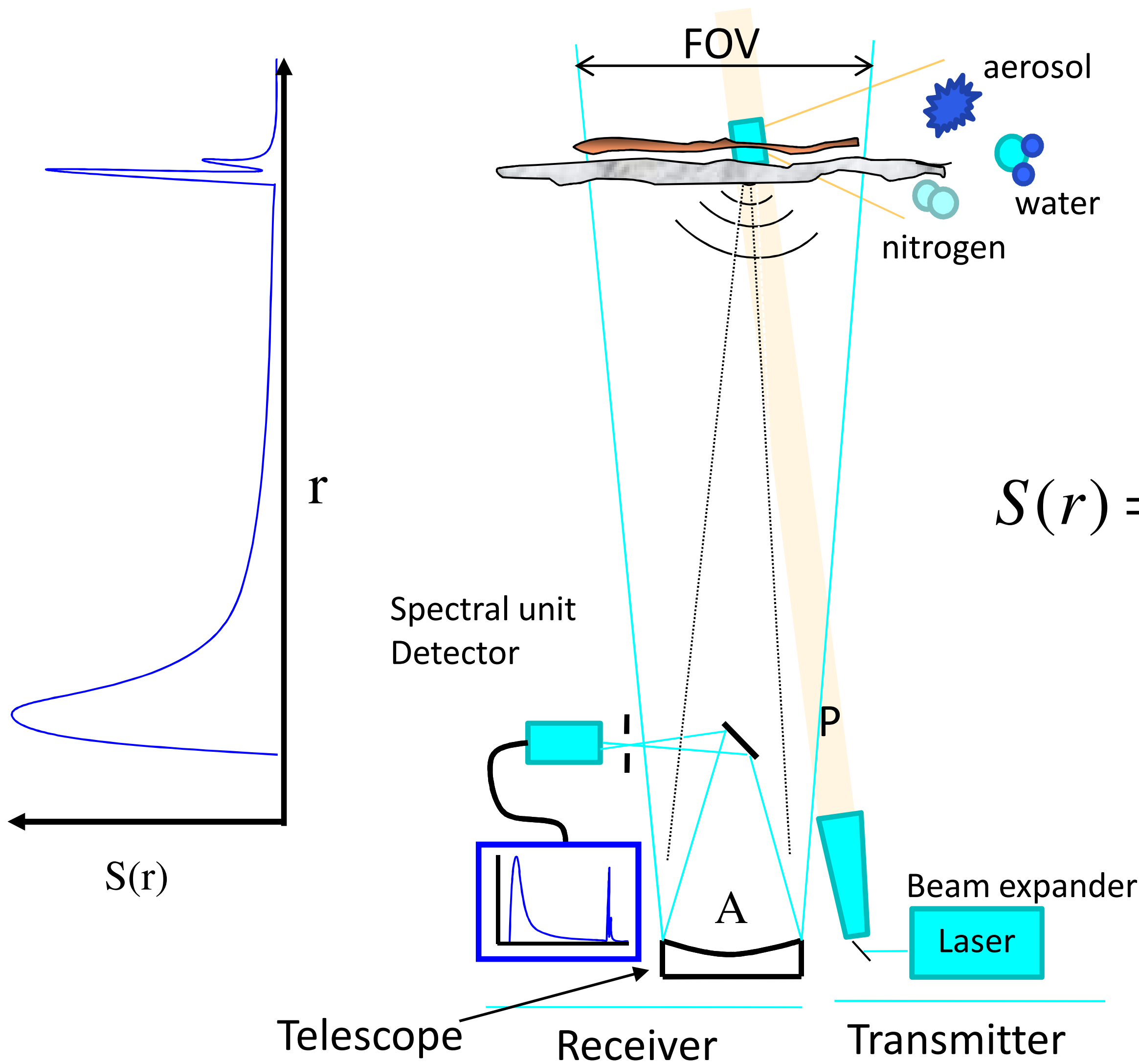
- Need of continuous high spatial and temporal resolution water vapor vertical profiles for the operational numerical weather forecast models (NWFM)
- Continuous data base for climatology studies
- Verification and calibration of GPS water vapor measurements

Lidar basics



$$S(r) = P\varepsilon \frac{A}{r^2} \beta(r) T(r)$$

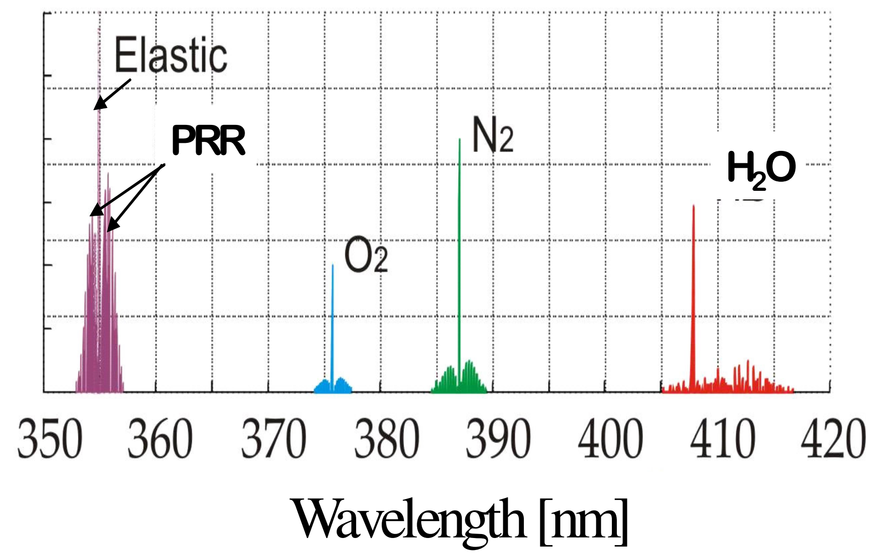
Raman lidar and daytime operation

$$S_x = P_L \varepsilon_x \frac{A}{r^2} N_x(r)\sigma_x T_x(r) + P_{sbx}$$

$$\sigma_x \approx \lambda^{-4}$$

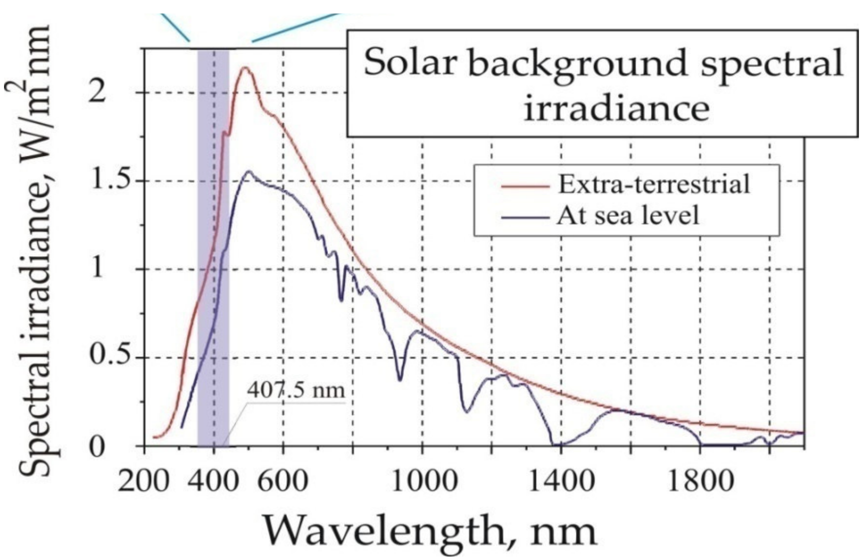
$$w(r) = g\frac{m_H}{m_N} = k\frac{S'_H}{S'_N}c(r)$$

$$P_{sbx} = R^{sky} A\ \Omega^2 \Delta\lambda_x$$



Reducing the sky background

$\Omega^2 \Delta\lambda_R \downarrow$ NFOV-NB



Lidar specifications

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Water vapor mixing ratio

Detection limit 0.02 g/kg

Statistical error < 10 %

Height range / resolution

Daytime 150-5'000 m / 30-600 m

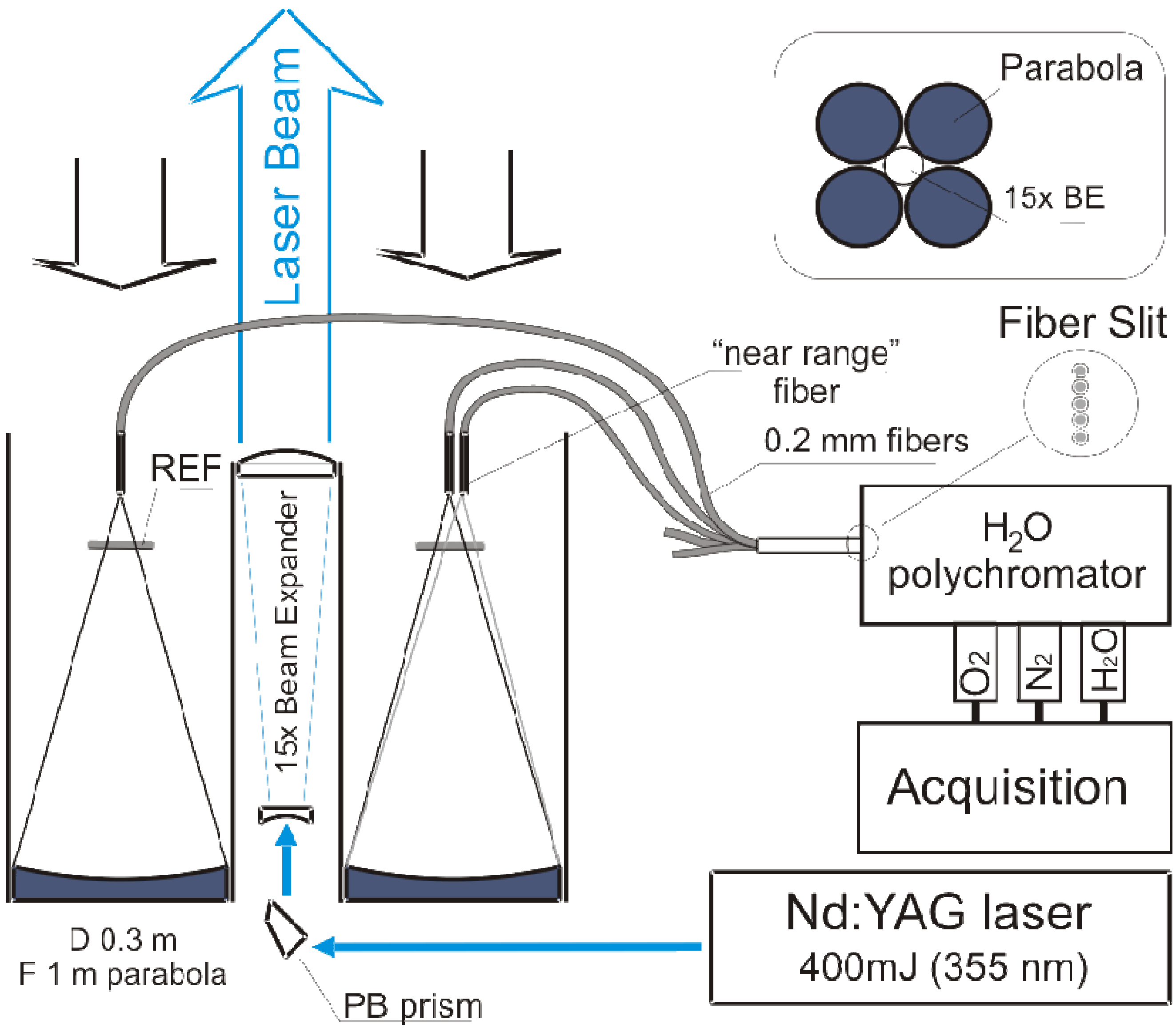
Night time 150 – 7'000 m / 30-600 m

Acquisition time 15-30 min

Additional requirements

- Unattended, continuous operation, minimal maintenance
- Long term stability, data consistency >20 years (climatology)
- High reliability > 85% technical availability
- Eye safety

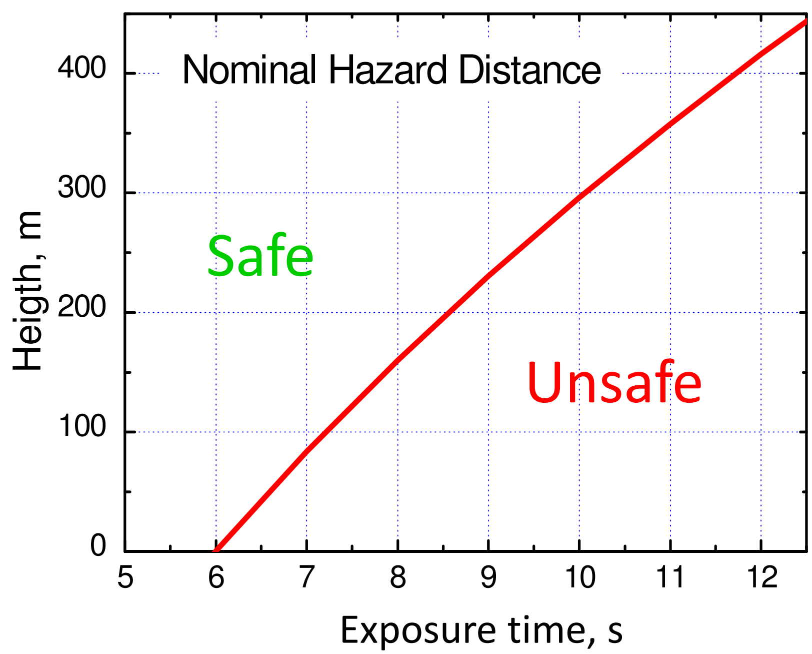
Optical scheme



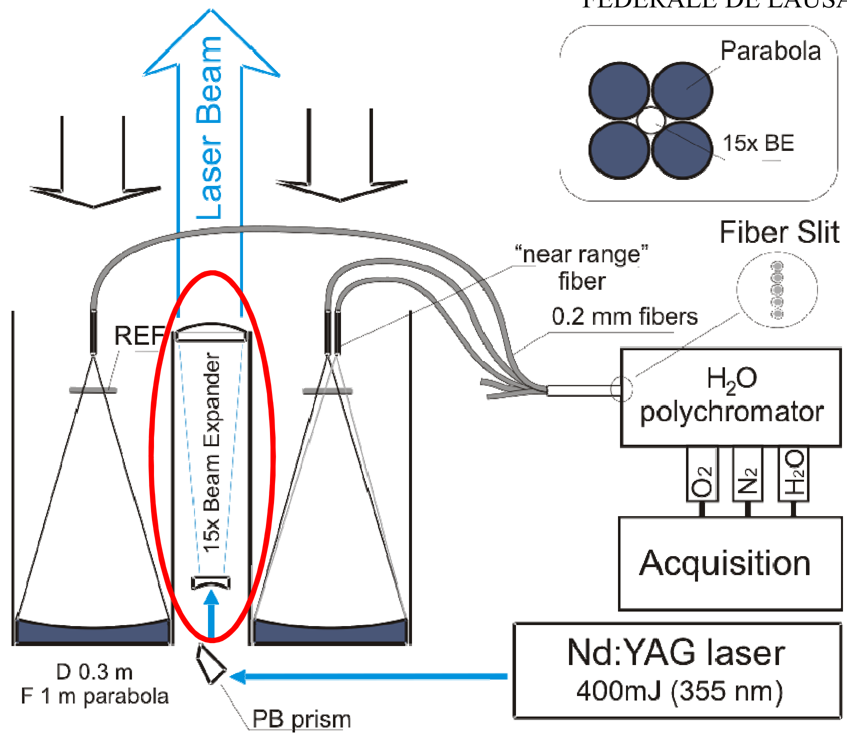
Transmitter

High energy/pulse
Eye safety
Low beam divergence for NFOV

Nominal hazard distance from the lidar
in case of intrabeam viewing



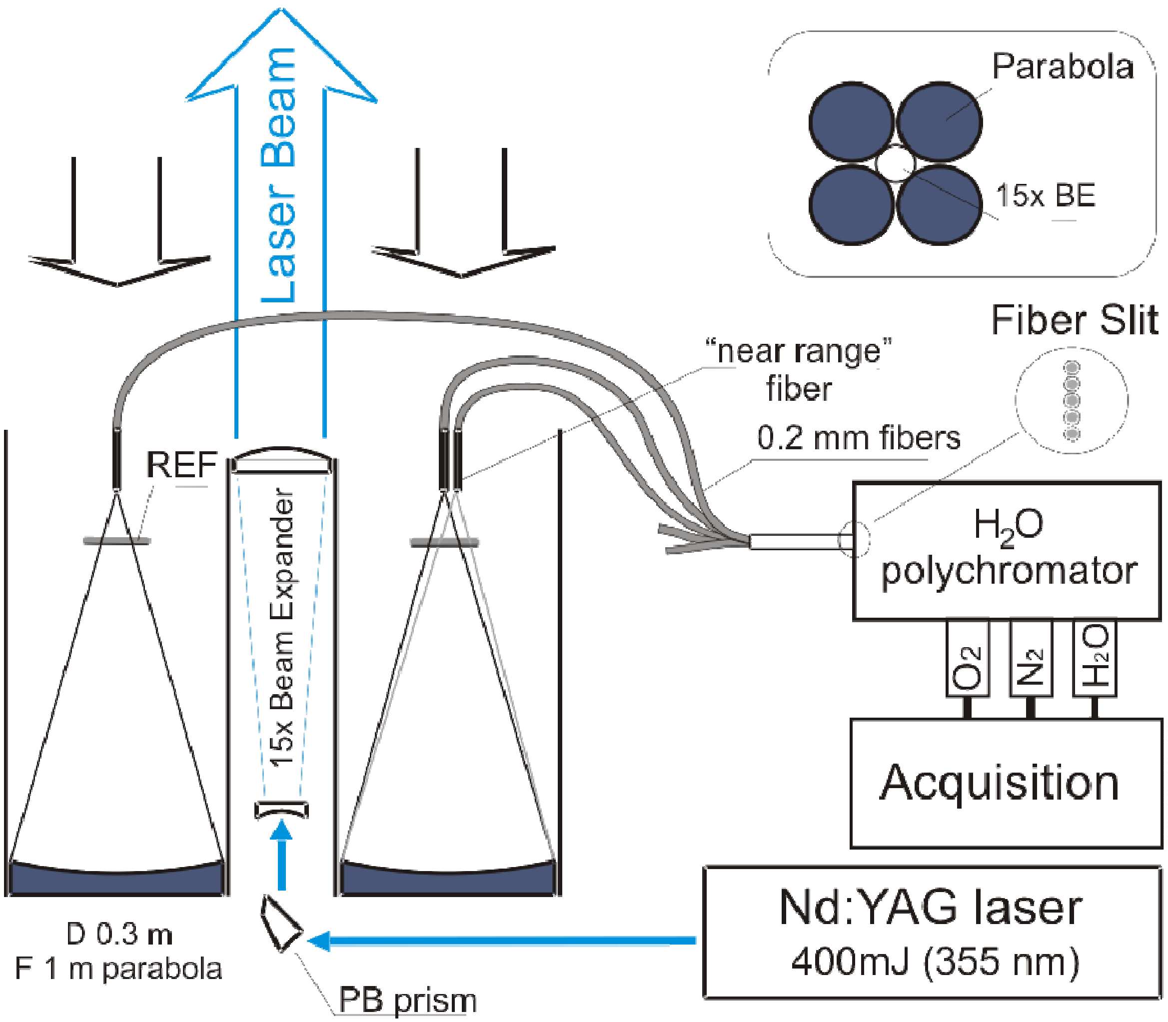
Θ = 70 µrad, D = 140 mm

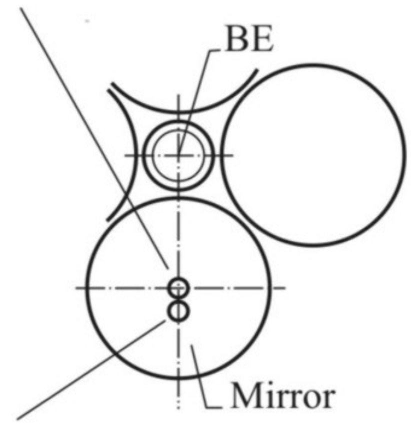


Laser
Nd :YAG, 400 mJ @ 355 nm, 30 Hz

IEC 60825-1, "Safety of laser products"

Lidar scheme -telescope





Four 30 cm, 1 m FL parabolic mirrors
0.2mm fibers
FOV 0.2 mrad

HR coating (99.8)

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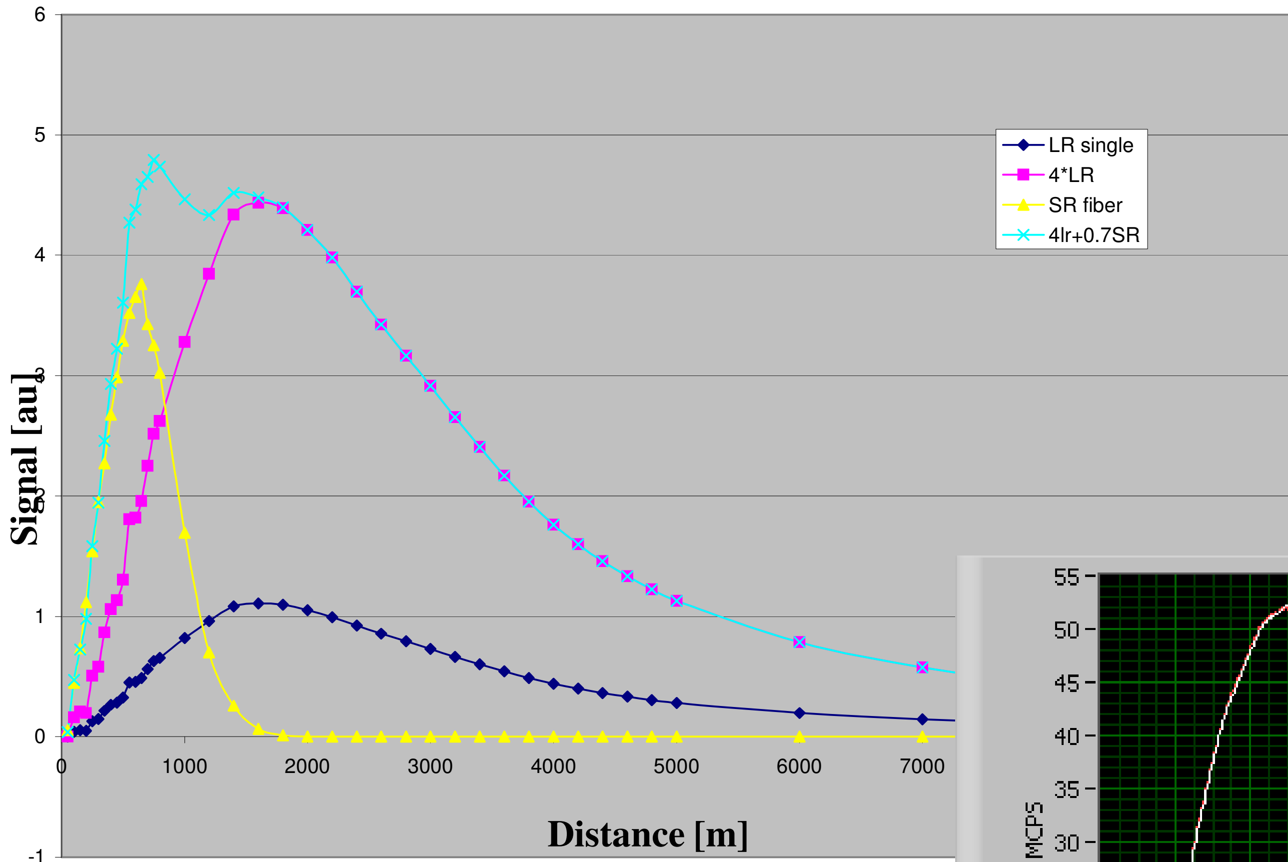
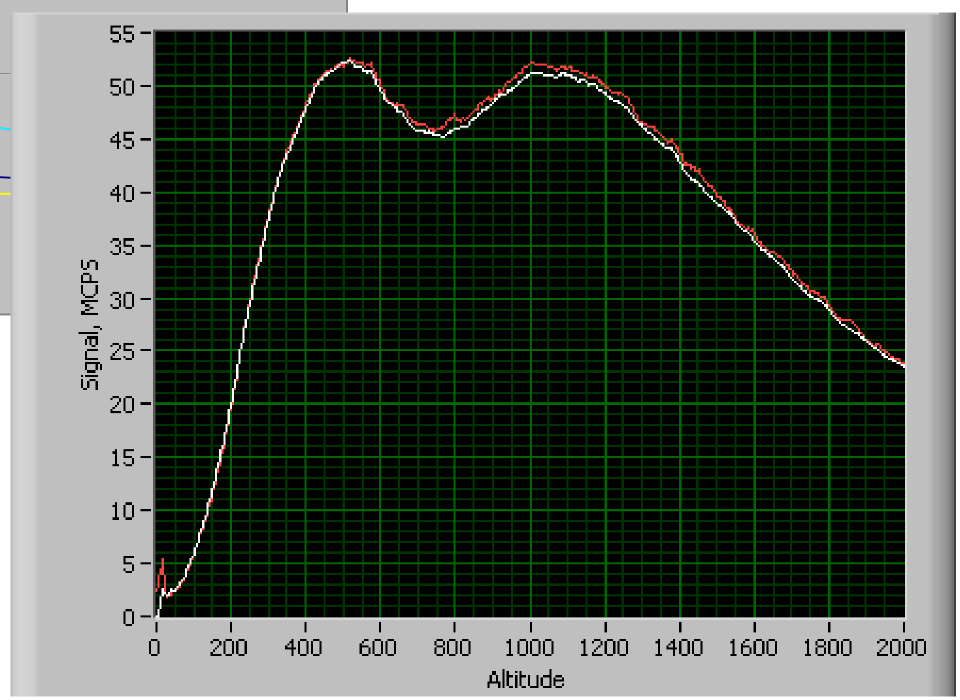
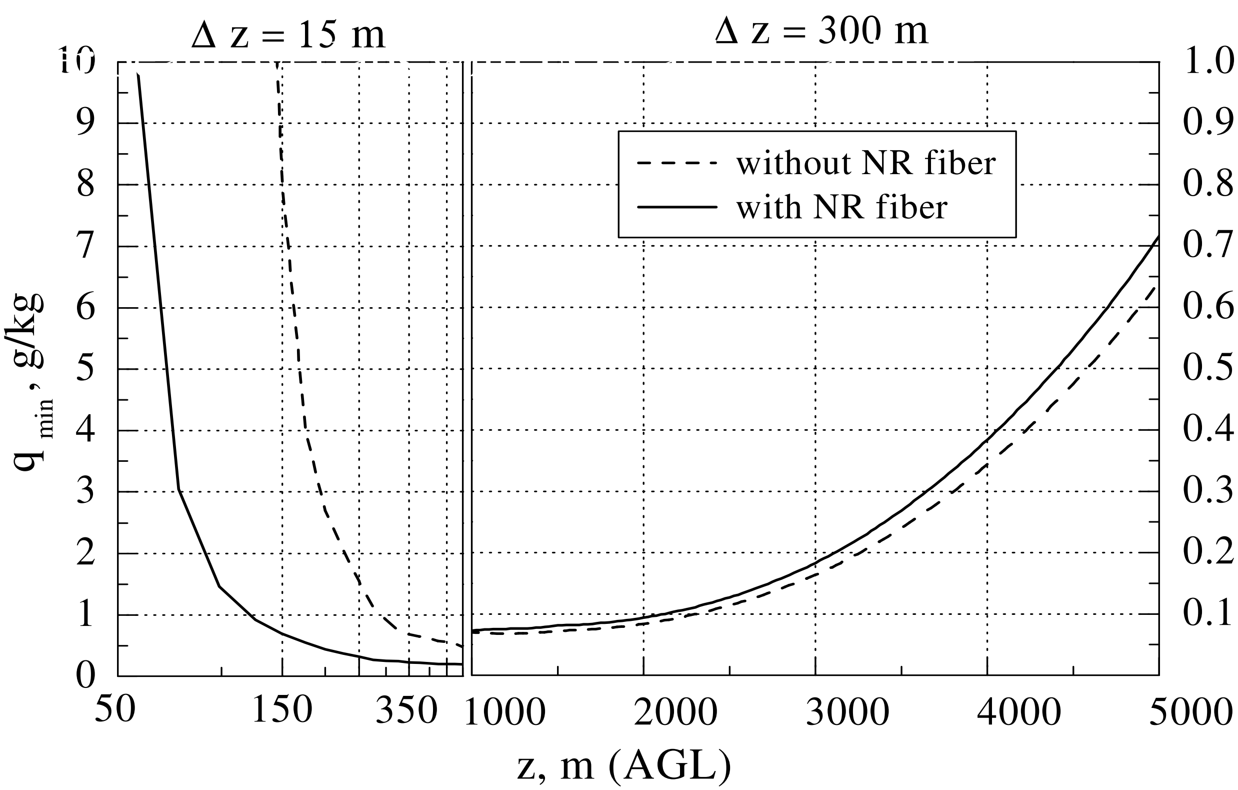
Lidar signals





Receiver telescopes



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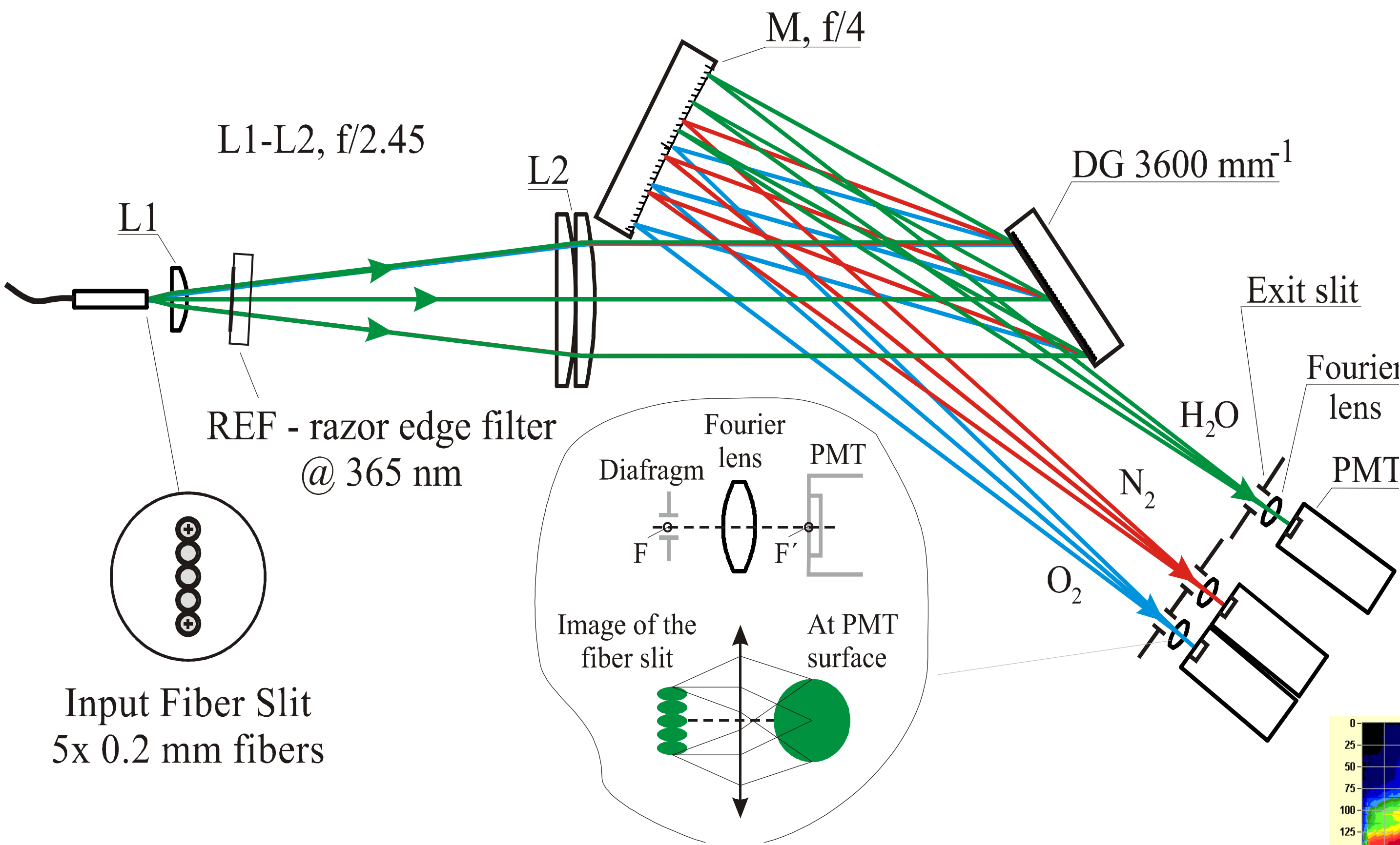
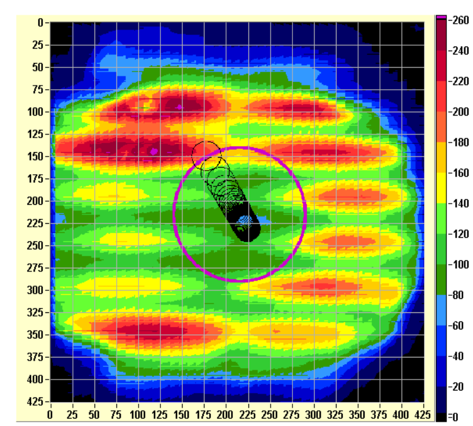
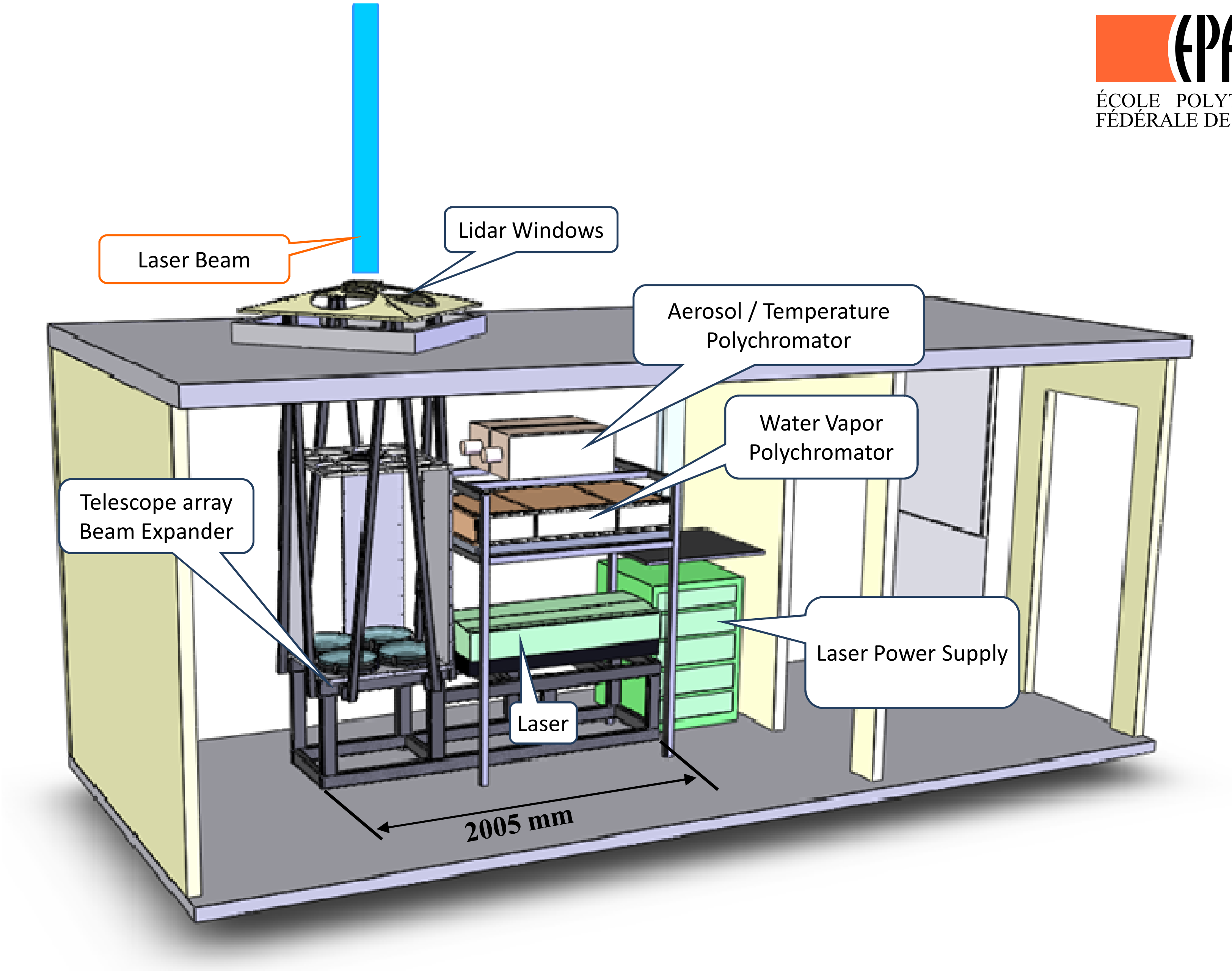
Polychromator scheme





0.3 nm bandwidth 38% transmission



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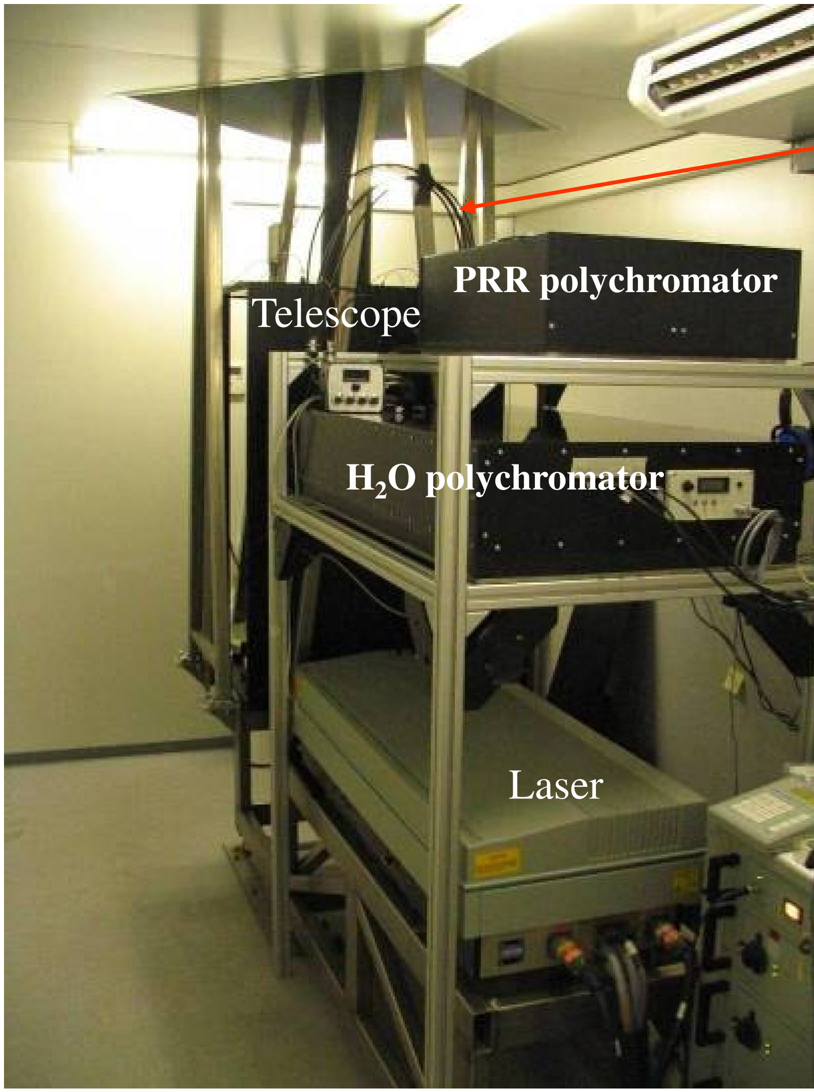
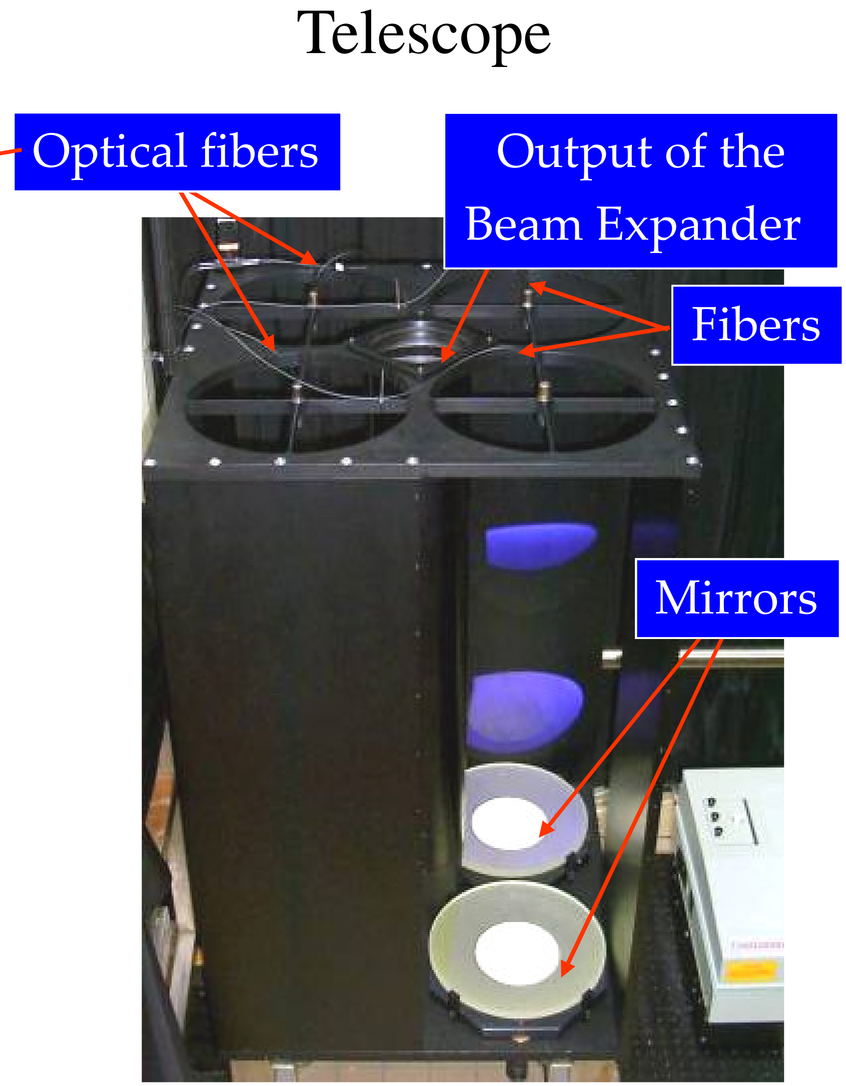
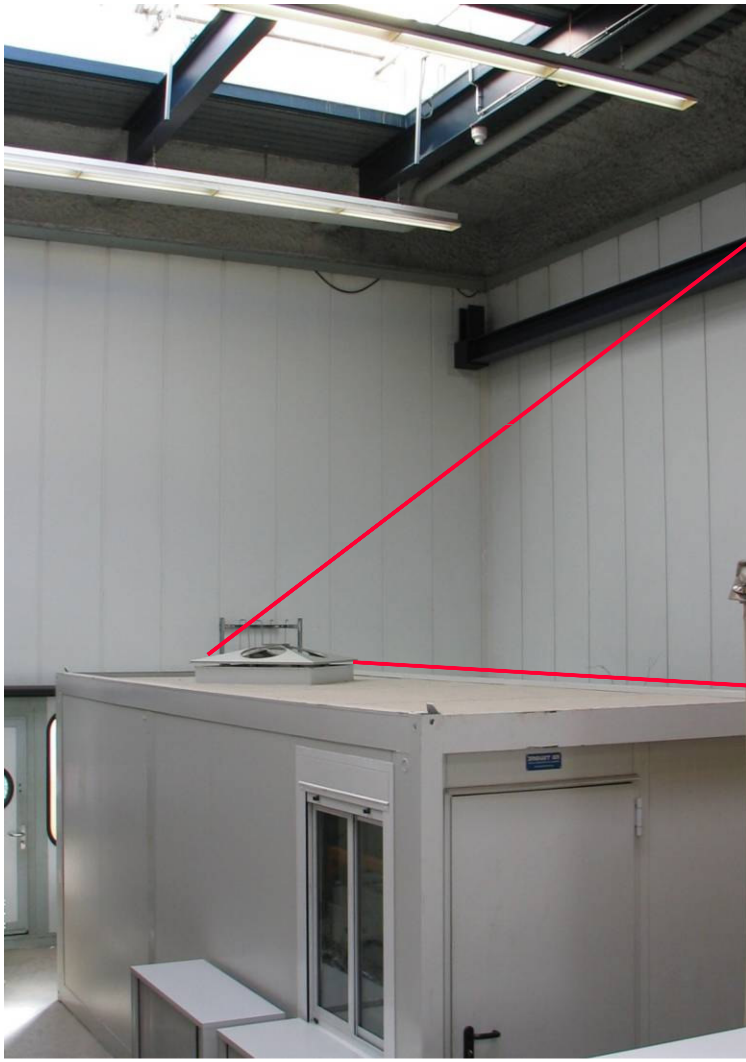
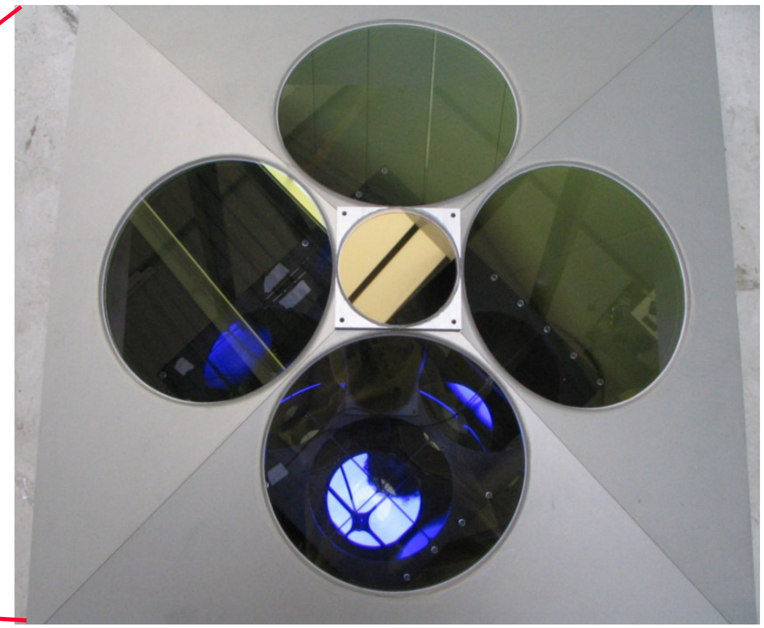
Inside view


PRR polychromator
Telescope
H_2O polychromator
Laser


Telescope
Optical fibers
Output of the Beam Expander
Fibers
Mirrors

Outside view

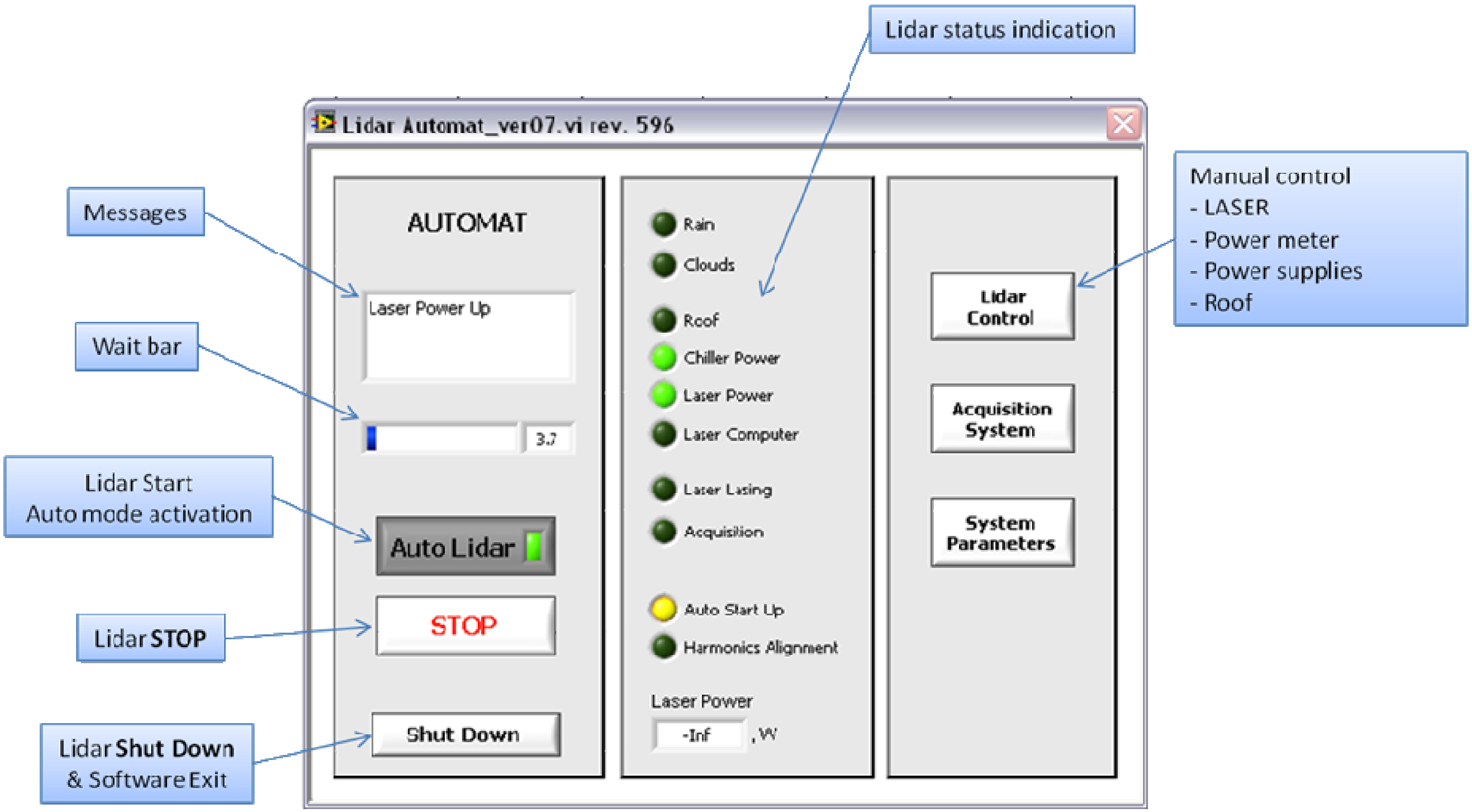




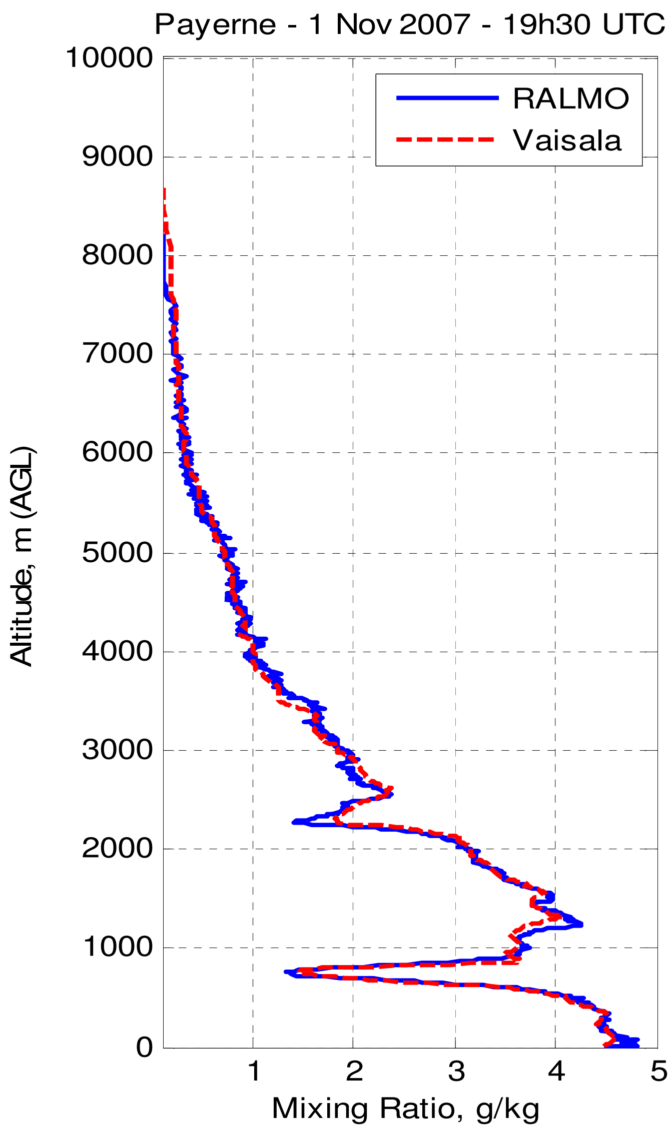
Automation

LA - Lidar Automat (LabView)

ADT - Automated Data Treatment (Matlab)

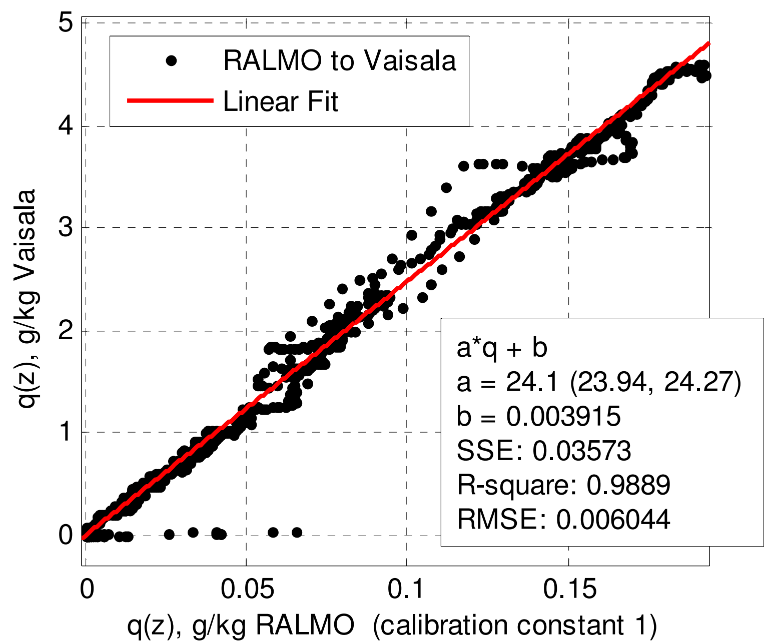


Calibration

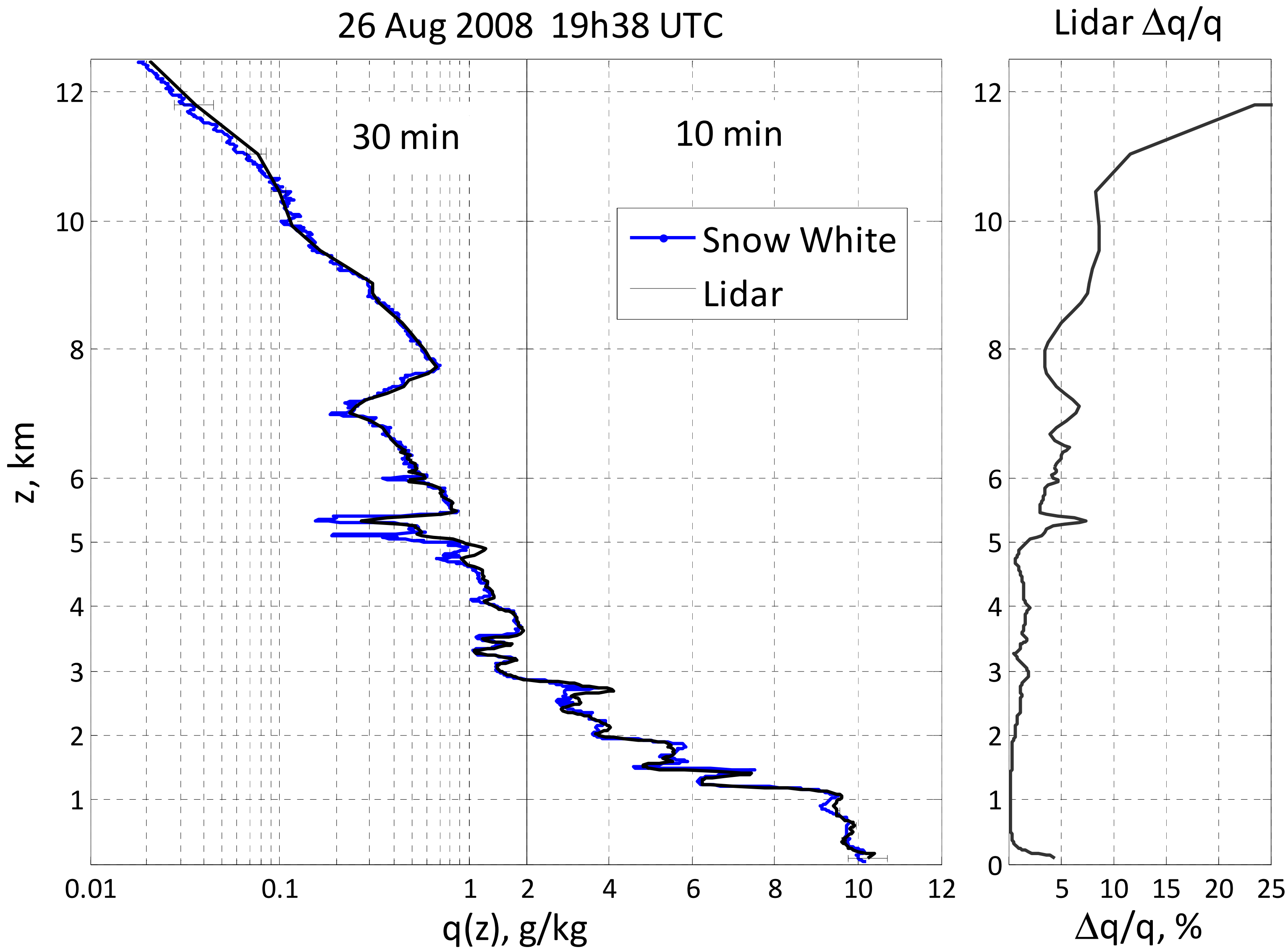


RALMO
Time and range resolution
15 min and

Vaisala$_i$ = ***a*** * RALMO$_i$ + ***b***



Intercomparison night time



Intercomparison day time

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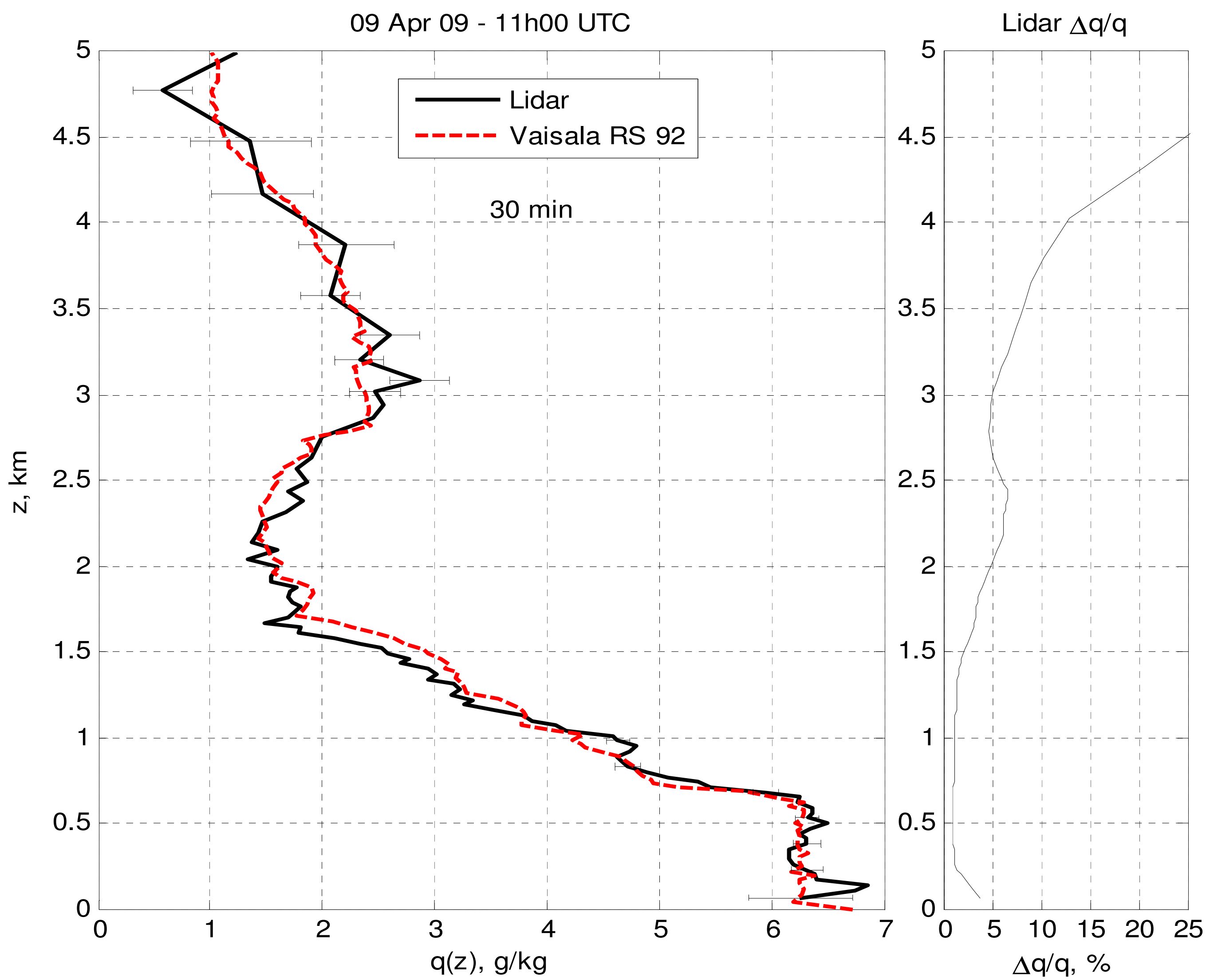
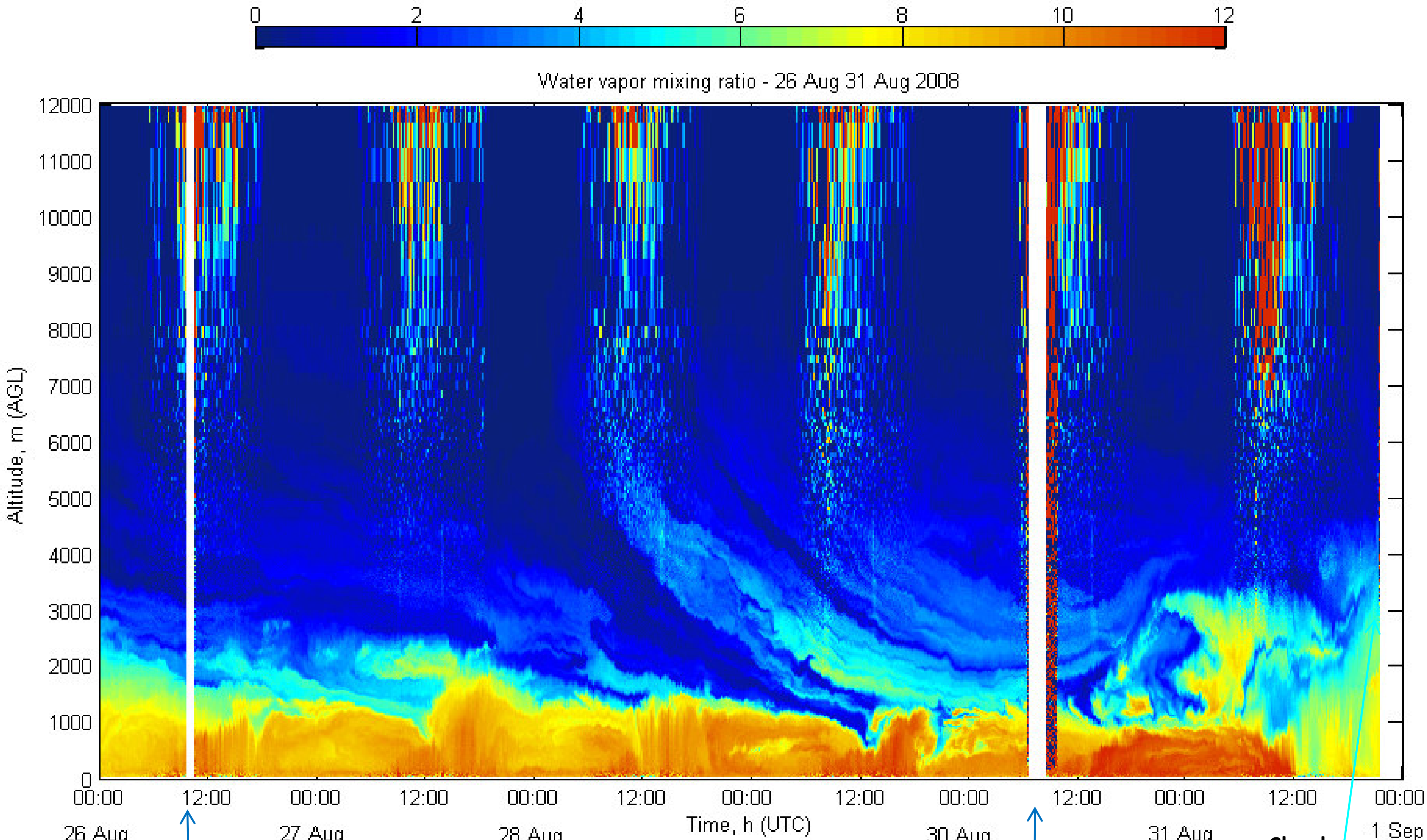


ÉCOLE POLYTECHNIQUE



Inauguration

'Rain stop'
Clouds/Fog < 500 m

Clouds,
Rain

Time resolution - 10 min,
Vertical resolution - 30 m up to 4 km
60 m up to 7 km and 120 m above

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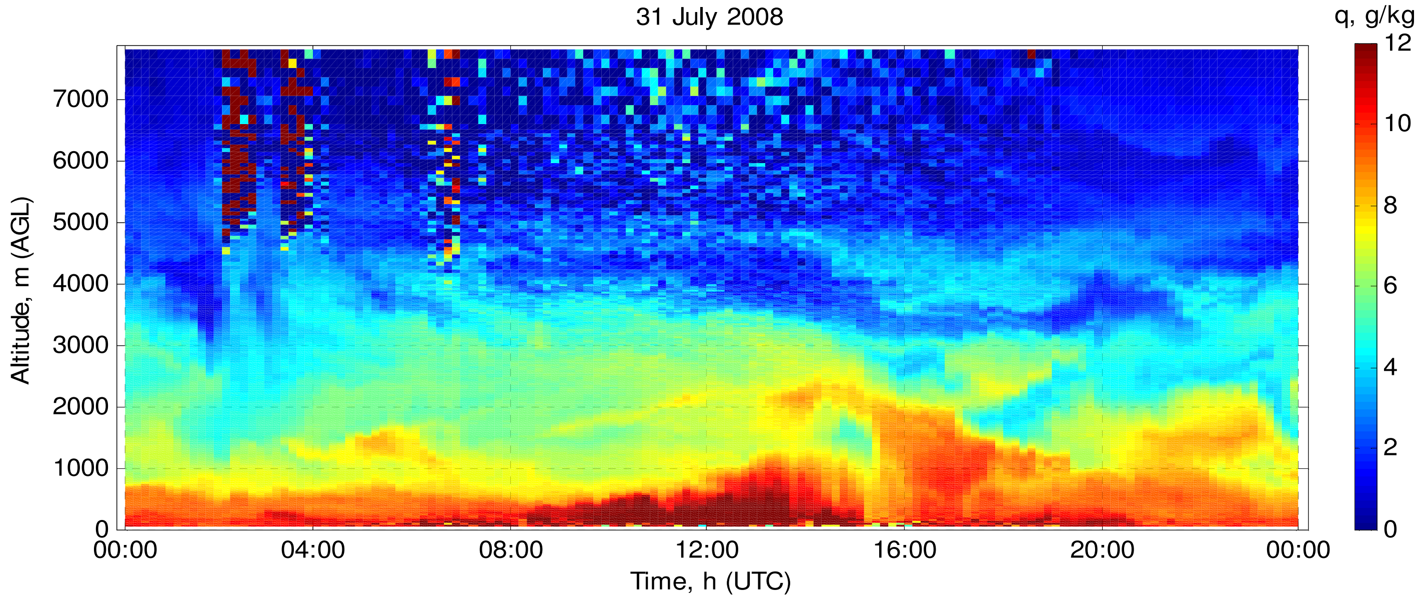
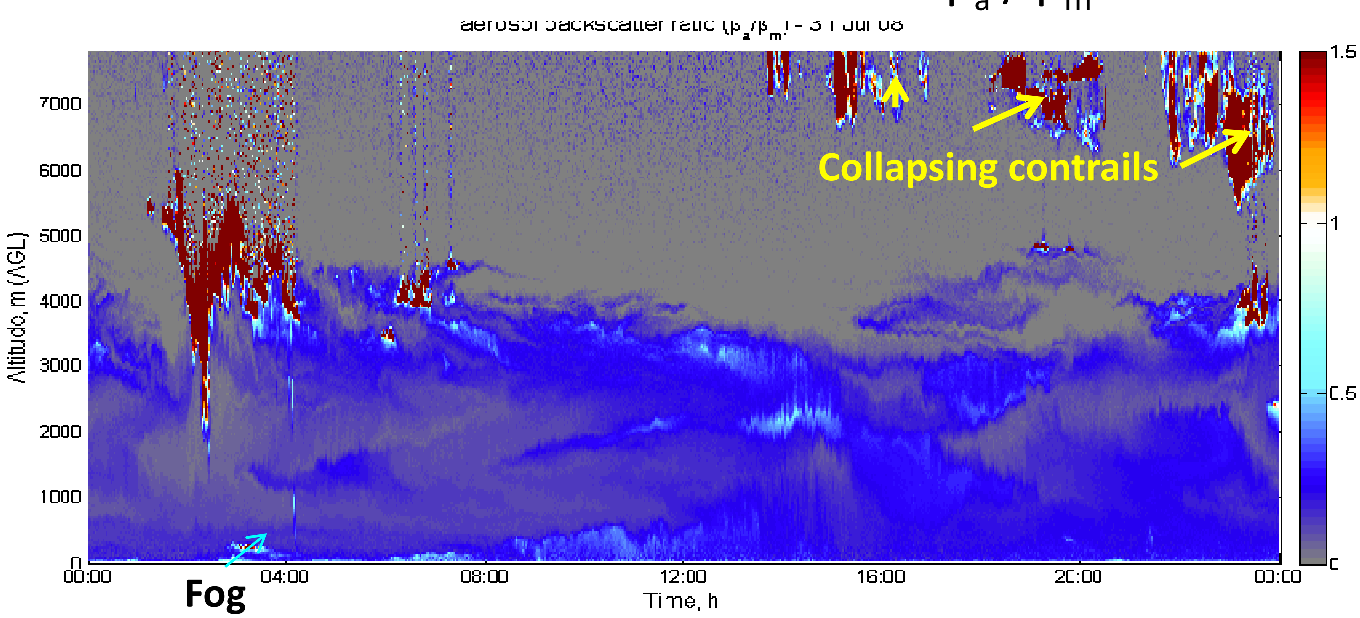


Aerosol Backscatter Ratio β_a / β_m



Conclusion and outlook

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- Automated Raman lidar for water operational measurements was developed and built
- The lidar is in continuous operation in the main aerological station of MeteoSwiss since August 2008
- Work on data assimilation in the NWFM COSMO 2 of MeteoSwiss is ongoing
- Ongoing update with temperature and aerosol channels

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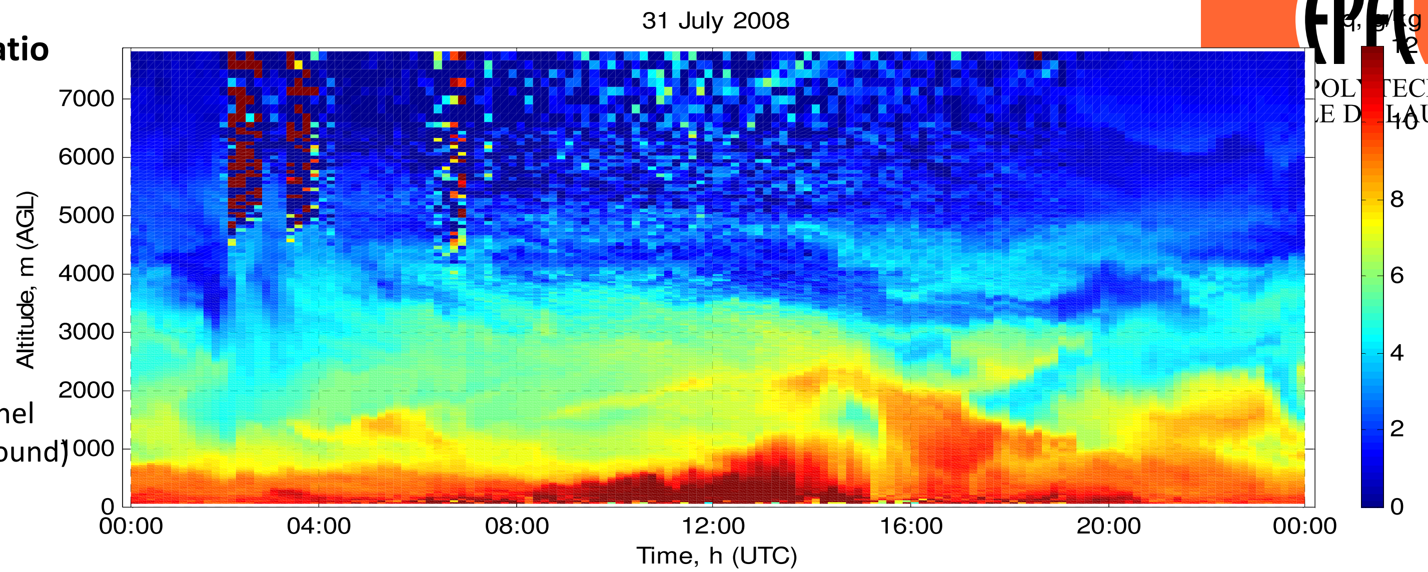
Thank you

Water vapor mixing ratio

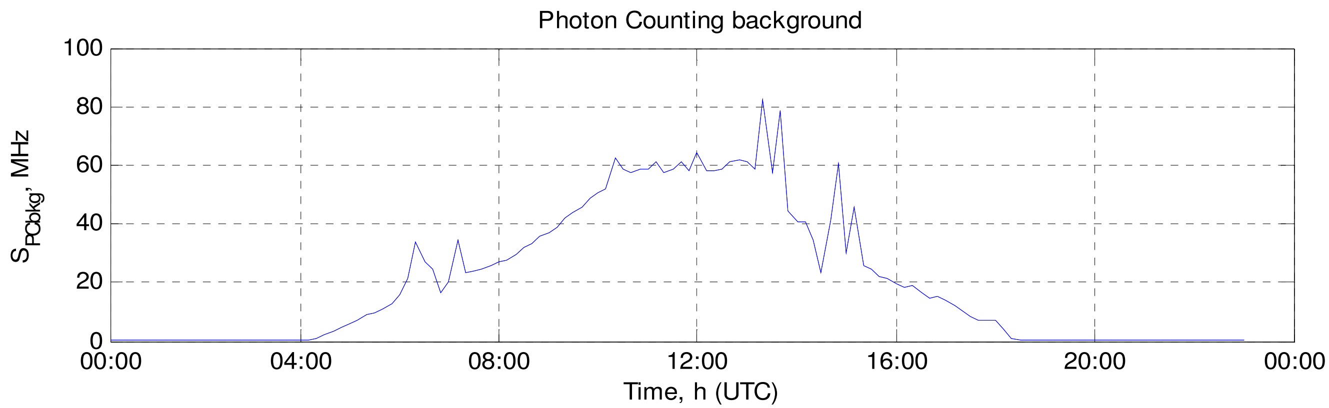
- 10 min average
- 30 m vertical resolution (up to 4 km)
- 60 m vertical (from 6 to 7.8 km)
- First point at 50 m
- Fixed desaturation

  $f = 1/\tau$
- Analog signal - WV channel (above 5 MHz PC background)
- No smooth, no interpolation



PC background in WV channel

Desaturated !
- 10 min average



Laser power

Minute average
- No lamps HV adjustment
- No crystal alignment

  $\Delta P / P \approx 1\ \%$