Hard target LIDAR calibration for SO$_2$

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Project background

- Las-R-MAP: Laser – Remote – Measurement of Atmospheric Pollutants
- Mobile laser system for remote detection and quantification of pollutant gas concentrations
- Van with most hardware required integrated and mobile
- Project Life Cycle: currently in testing stage in local "field" setup

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The LIDAR equation

$$S_\lambda(R) = \frac{cE_p\beta(R)}{R^2} e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

- S(R): signal received from distance R
- c: constant dependant on detector response, absorption by other gases, etc.
- E_p: Laser pulse energy
- β(R): Reflection coefficient at distance R
- n(R): concentration of target gas at distance R
- σ: cross section of target gas at on wavelength
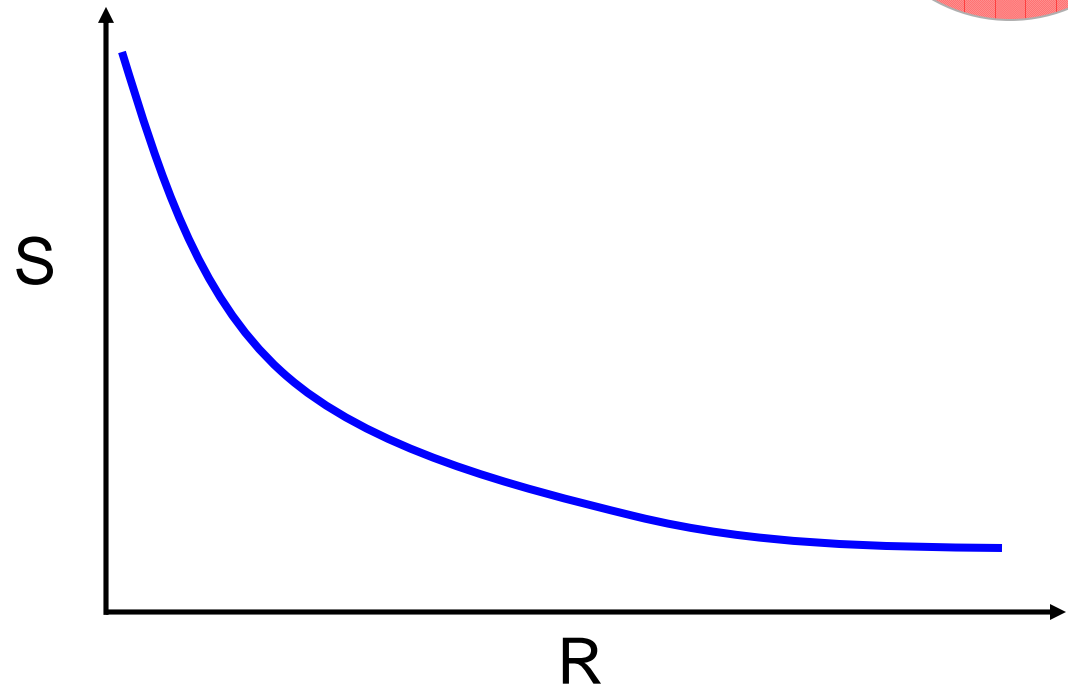
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The DIAL principle

$$S_\lambda(R) = \frac{cE_p\beta(R)}{R^2}e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

$$\int_0^R n(R)dR = \frac{1}{2(\sigma_{on} - \sigma_{off})}\ln\left(\frac{S_{off}}{S_{on}}\right)$$

- Two wavelengths: "on" and "off"
- Close together in wavelength: $\beta_{on} = \beta_{off}$

- The known difference in absorption, measured difference in S, all else the same, used to calculate concentration (n).

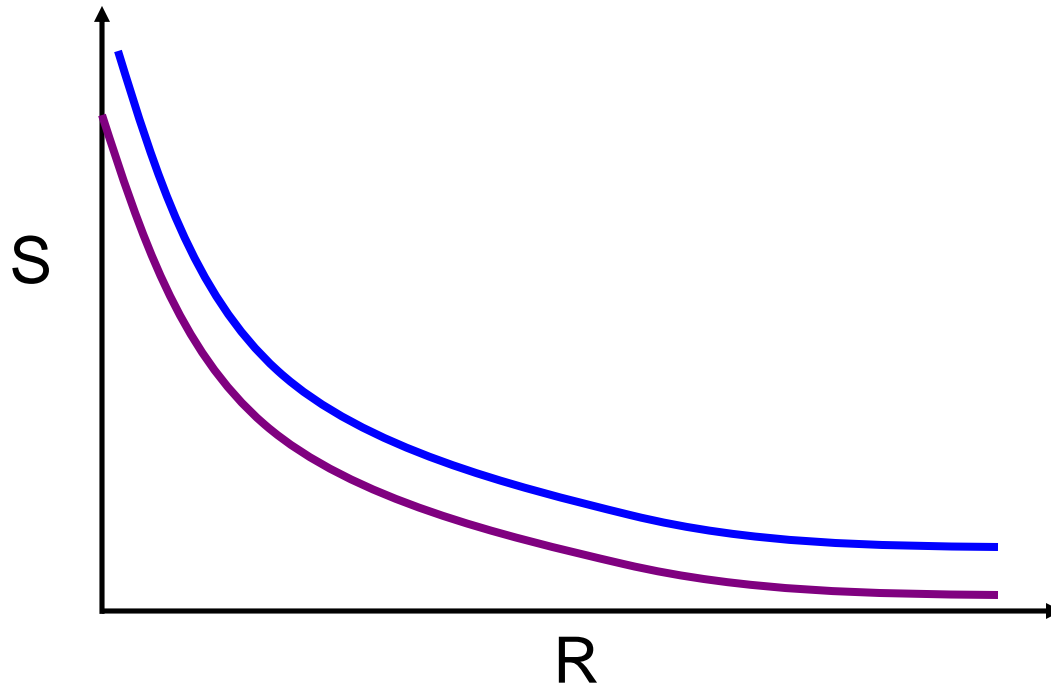- In this work "off" is chosen as zero absorption due to no gas present

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Atmospheric backscatter

$$S_\lambda(R) = \frac{cE_p\beta(R)}{R^2} e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

S

R

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Atmospheric backscatter

$$S_\lambda(R) = \frac{cE_p\beta(R)}{R^2} e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

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Atmospheric backscatter

$$S_\lambda(R) = \frac{cE_p\beta(R)}{R^2}e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

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Hard target backscatter

$$S_\lambda(R) = \frac{cE_p \beta(R)}{R^2} e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

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Hard target backscatter

$$S_\lambda(R) = \frac{cE_p\beta(R)}{R^2} e^{-2\int_0^R n(R)\sigma_\lambda dR}$$

S

R

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Las-R-MAP hardware: laser system

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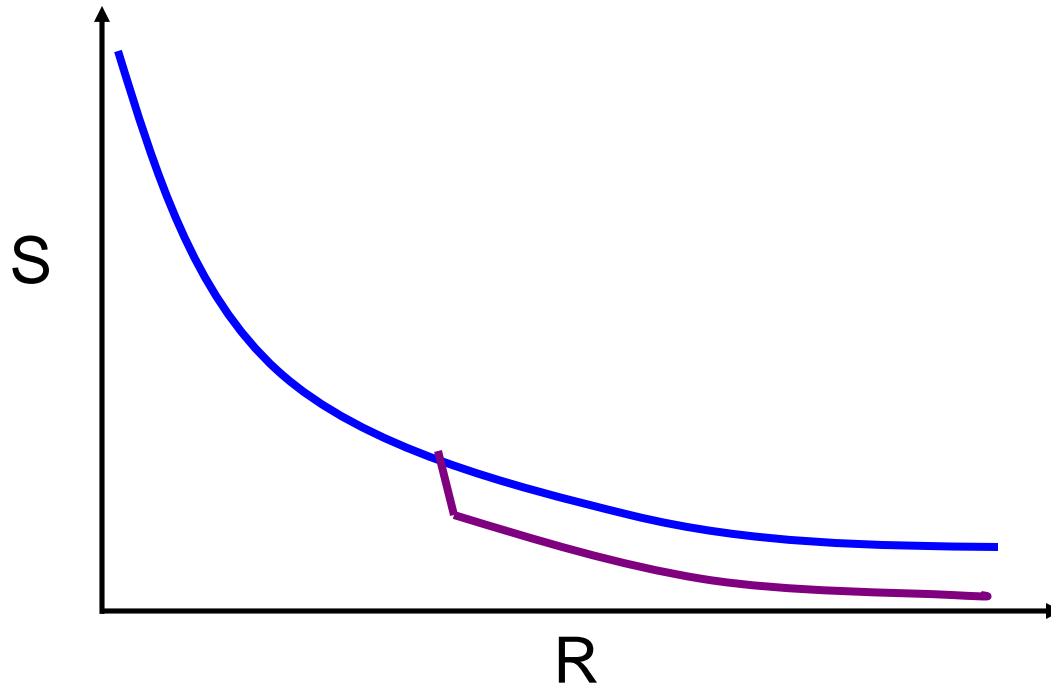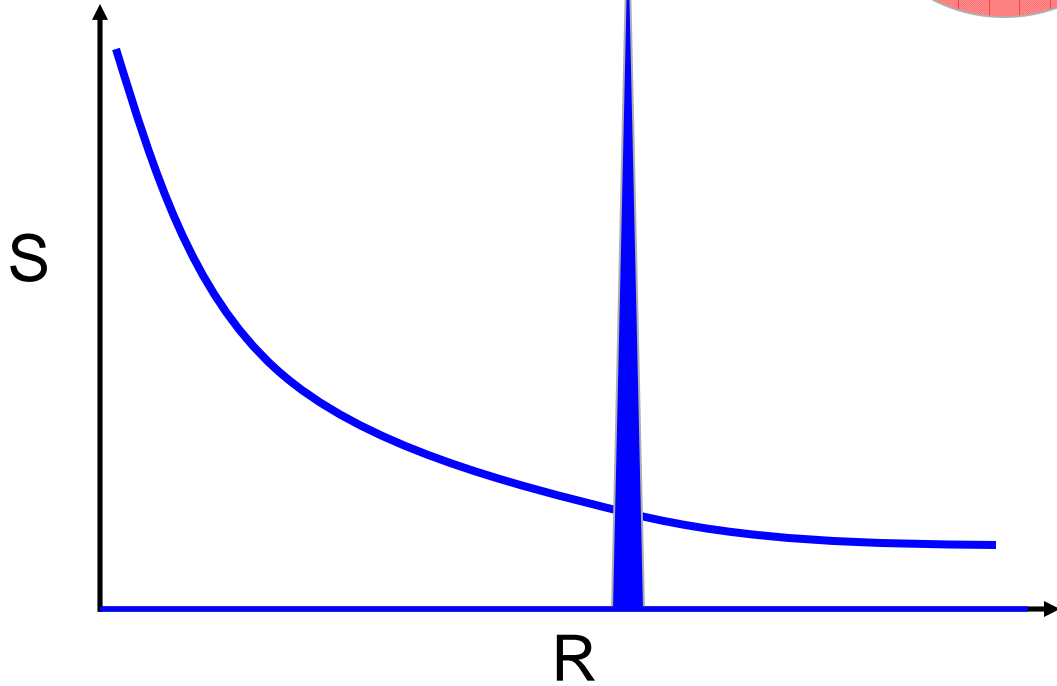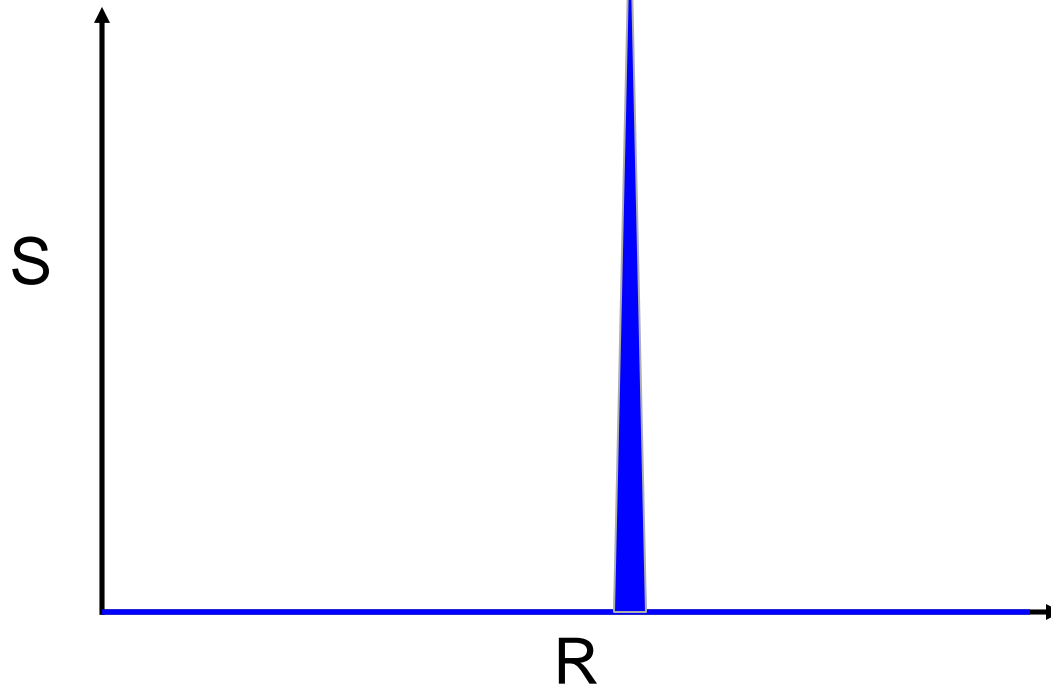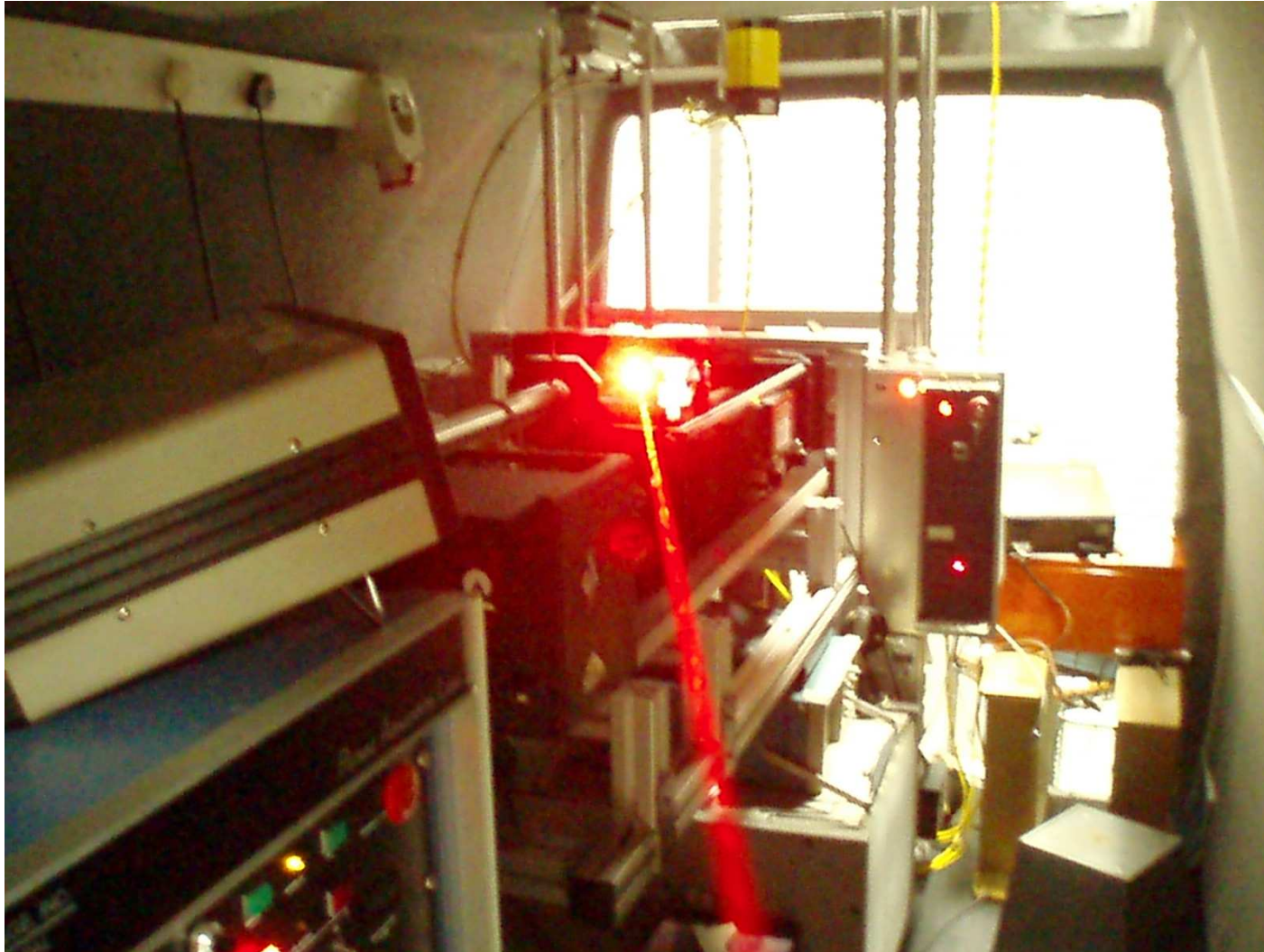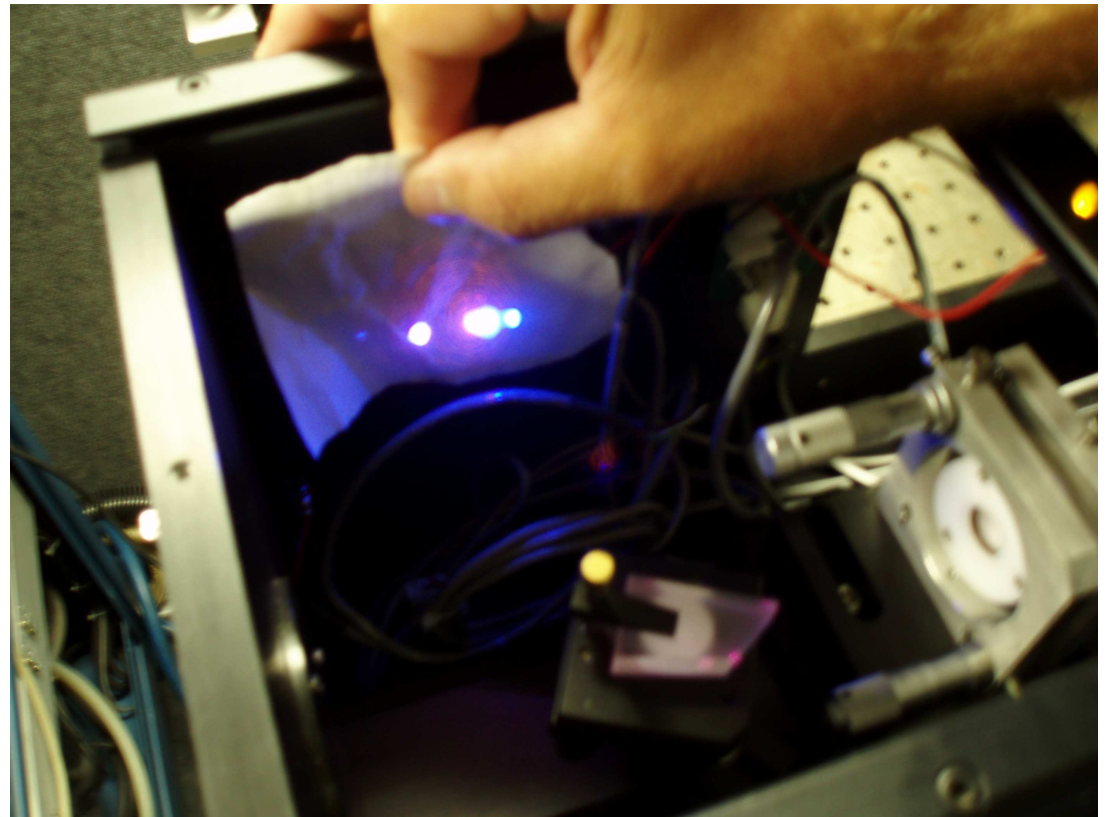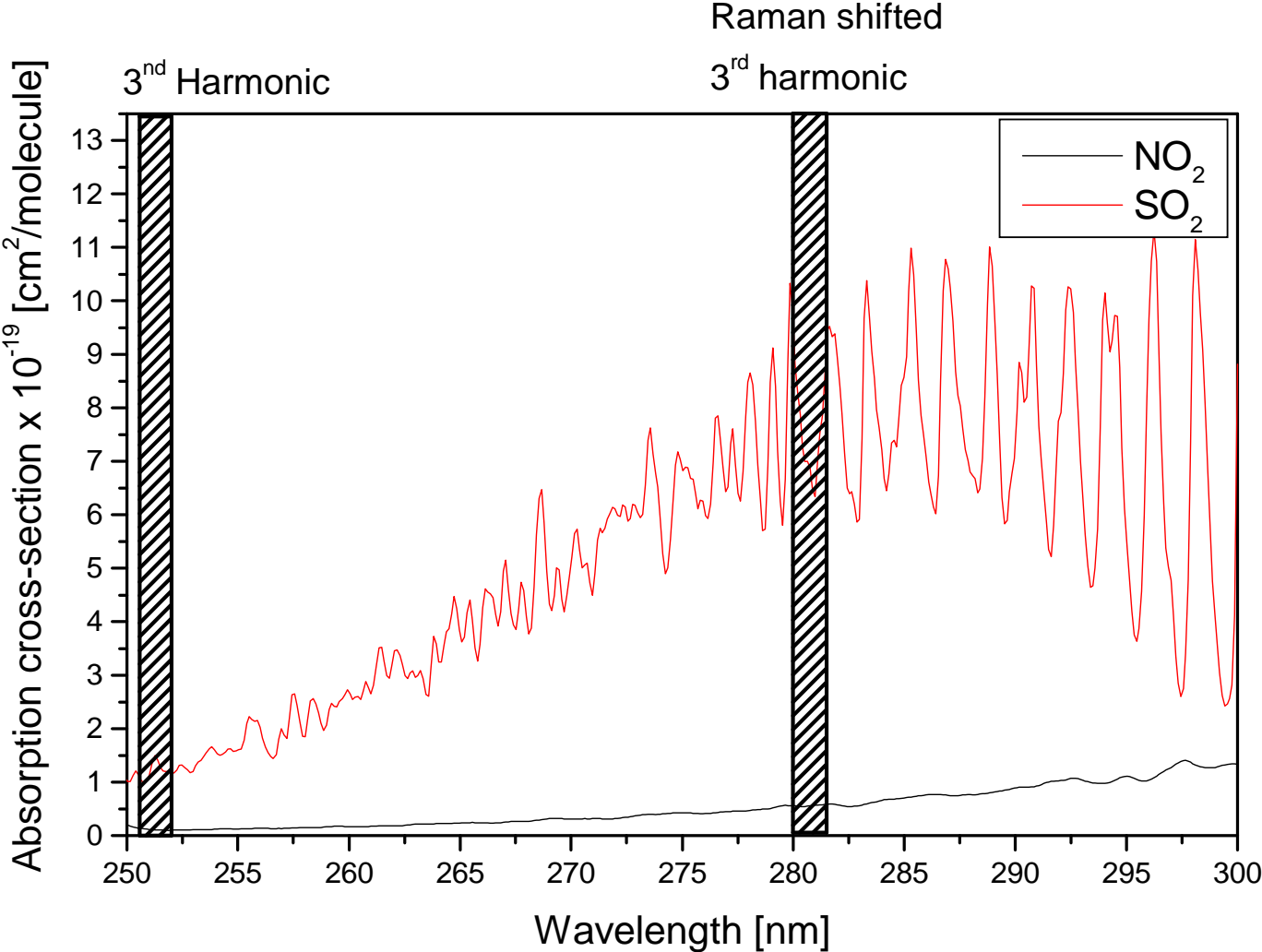
Las-R-MAP hardware: laser system

- Tunable Alexandrite:
- Fundamental @ 750 nm
- 2nd Harmonic @ 375 nm
- 3rd Harmonic @ 250 nm

- Hydrogen Raman cell @ 75 bar
- Raman-shifted
  3rd harmonic @ 280 nm

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Choice of wavelength

SI

Las-R-MAP hardware: detection system

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Las-R-MAP hardware: local "field" setup

Las-R-MAP hardware: pipe
 - Side view of pipe
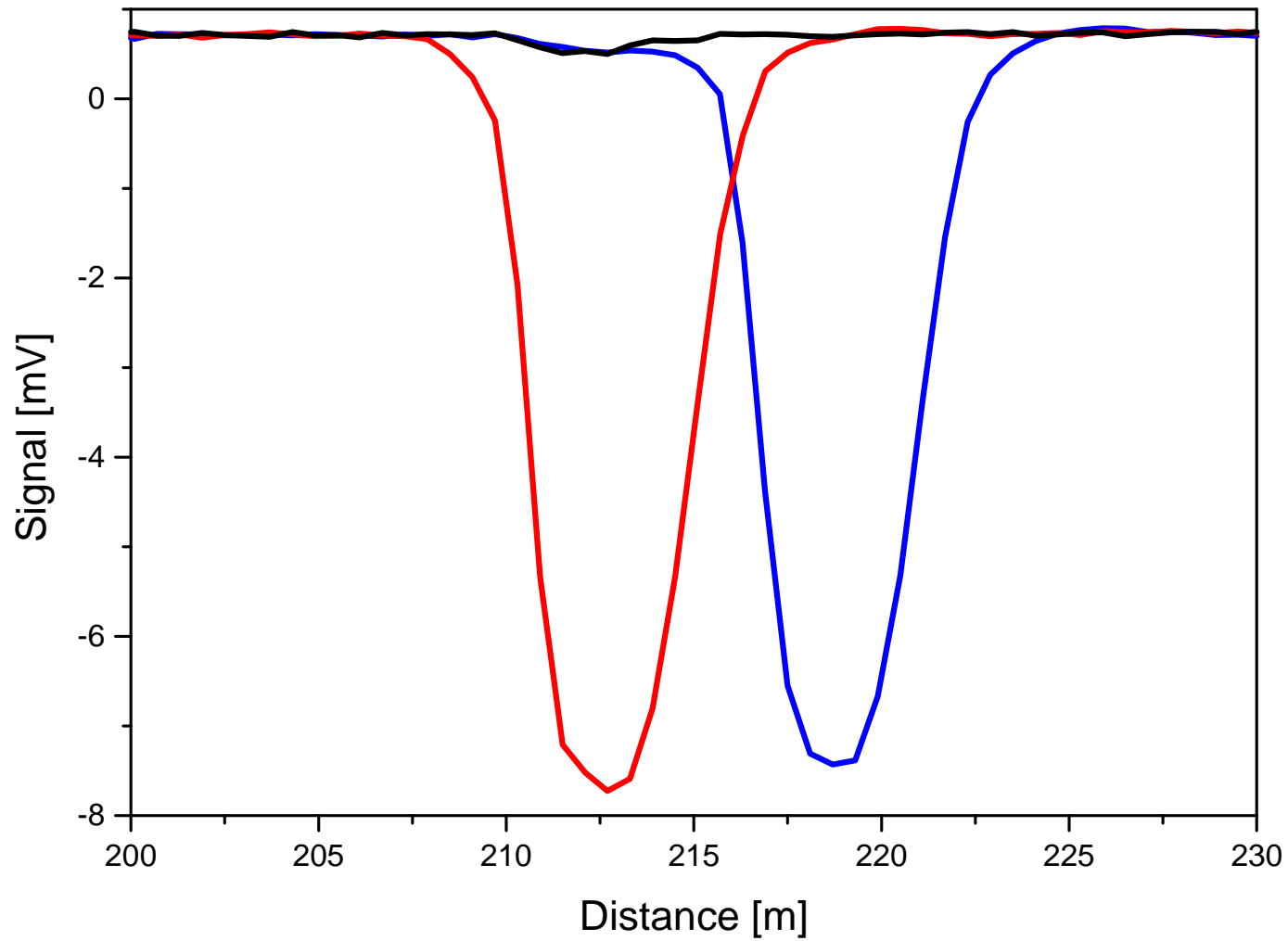
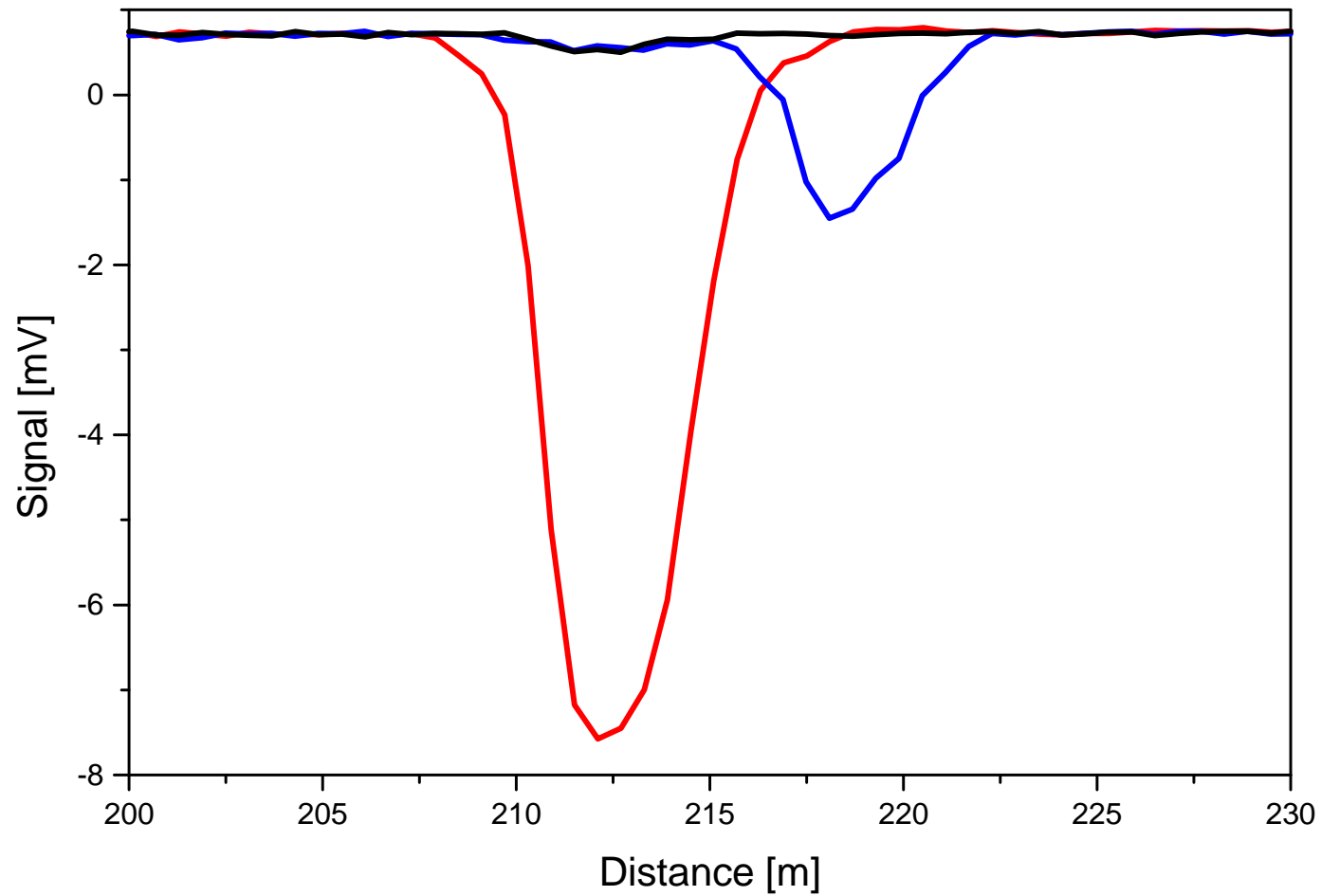# Las-R-MAP hardware: pipe
- Front view of pipe

Las-R-MAP hardware: pipe
- Manager's view of pipe
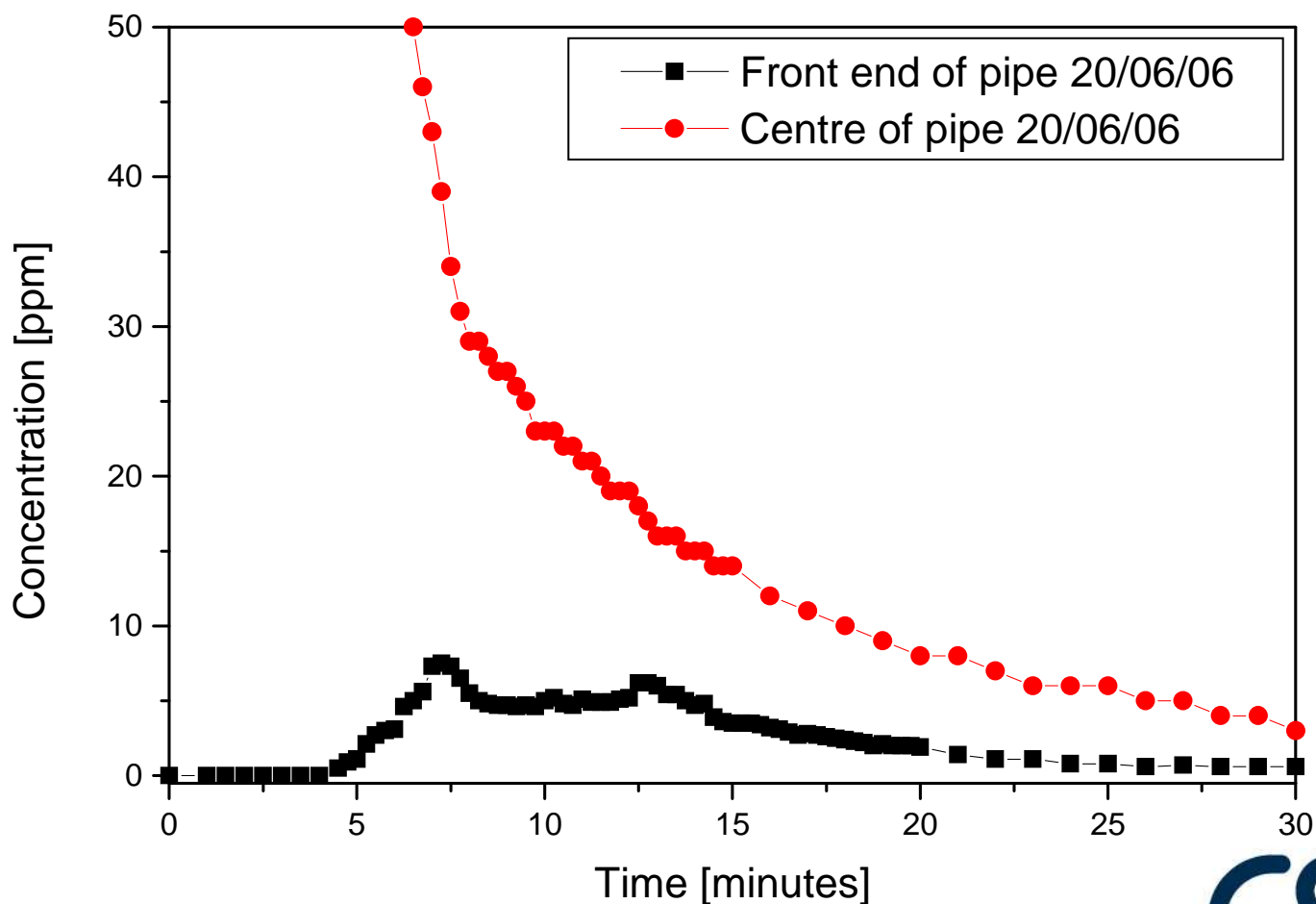
Results: hard target backscatter

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Results: Estimated 20 ppm SO$_2$

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Las-R-MAP hardware: pipe
- Measurement of SO$_2$ density

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Results: 2nd harmonic hard target

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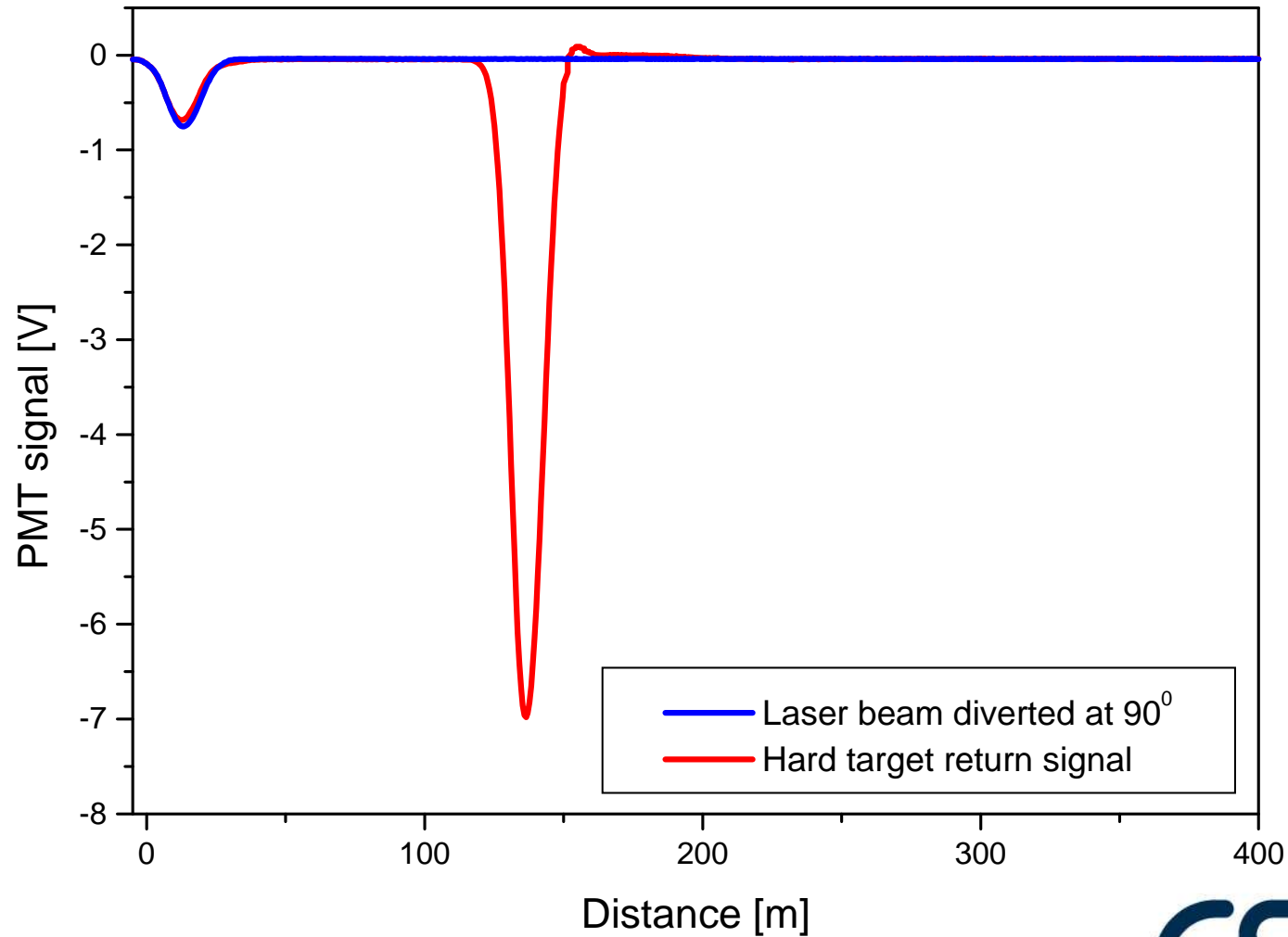
Results: atmospheric backscatter

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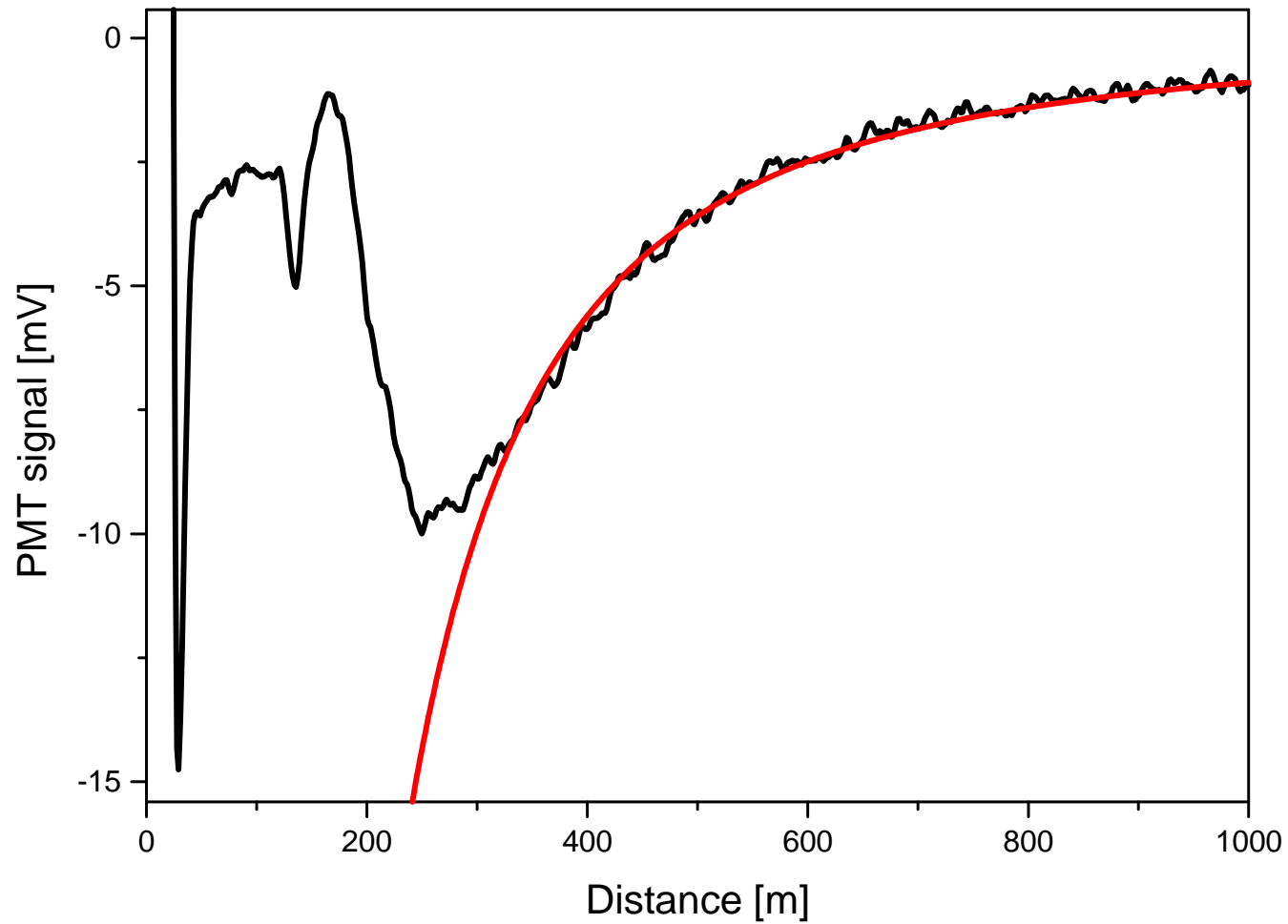
Las-R-MAP hardware: pipe
- improvement of pipe

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Conclusions & outlook

- SO$_2$ has been detected, and calibration attempted (Hard Target technique)
  - Detection sensitivity 10-50 ppm
  - Low detection limit: laser energy and pulse-to-pulse variation
  - Upper detection limit: cross-section
- Calibration limitation is leak rate from pipe
  - Continual pipe improvement
- NO$_2$ next target gas, due to higher laser pulse energy
- Hard target technique used for first real field measurement
  - October 2006
  - Large hard target mirror has been designed

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The End

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