E11

Tests of trace gas concentration multi-component remote monitoring system

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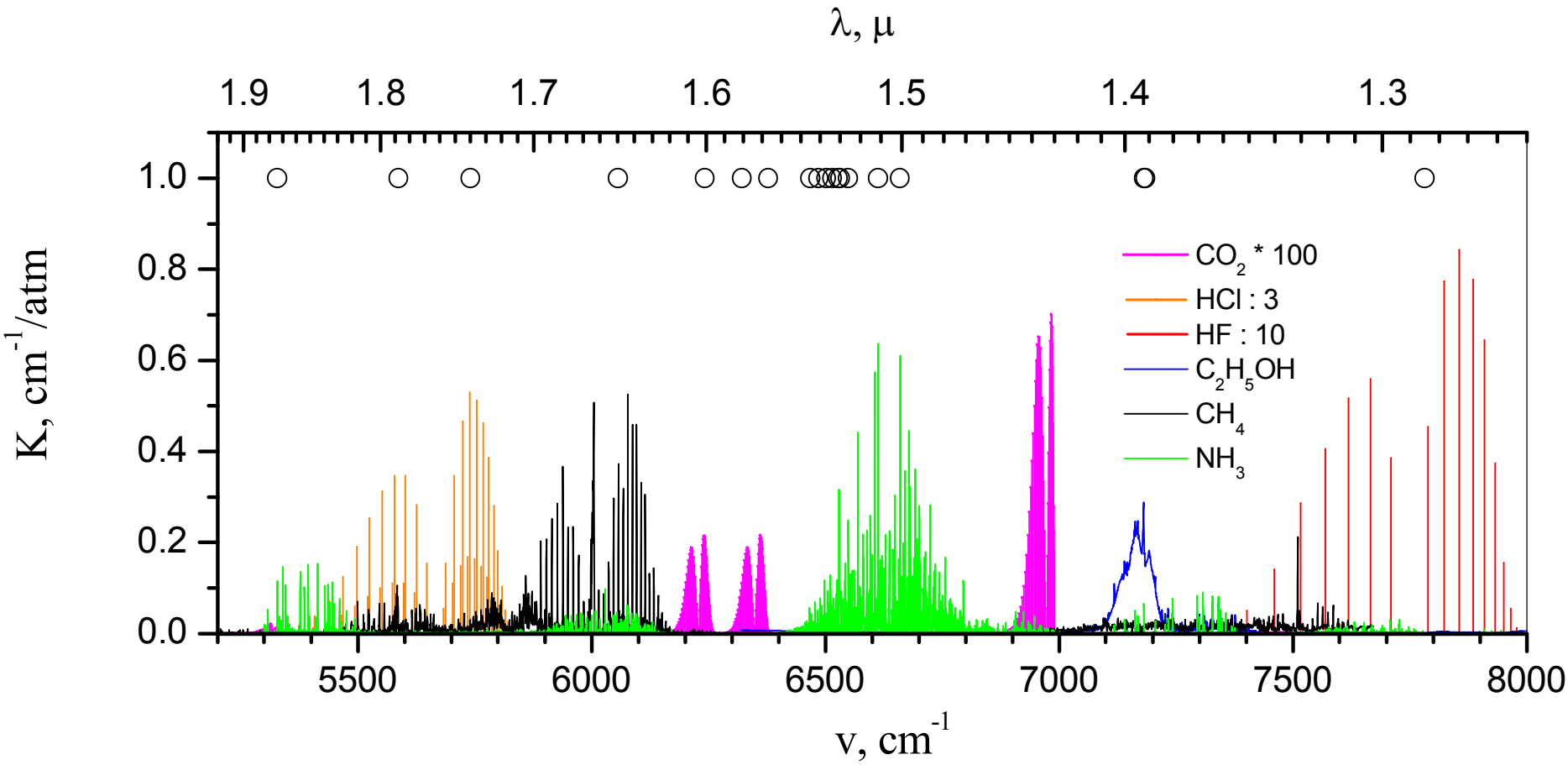
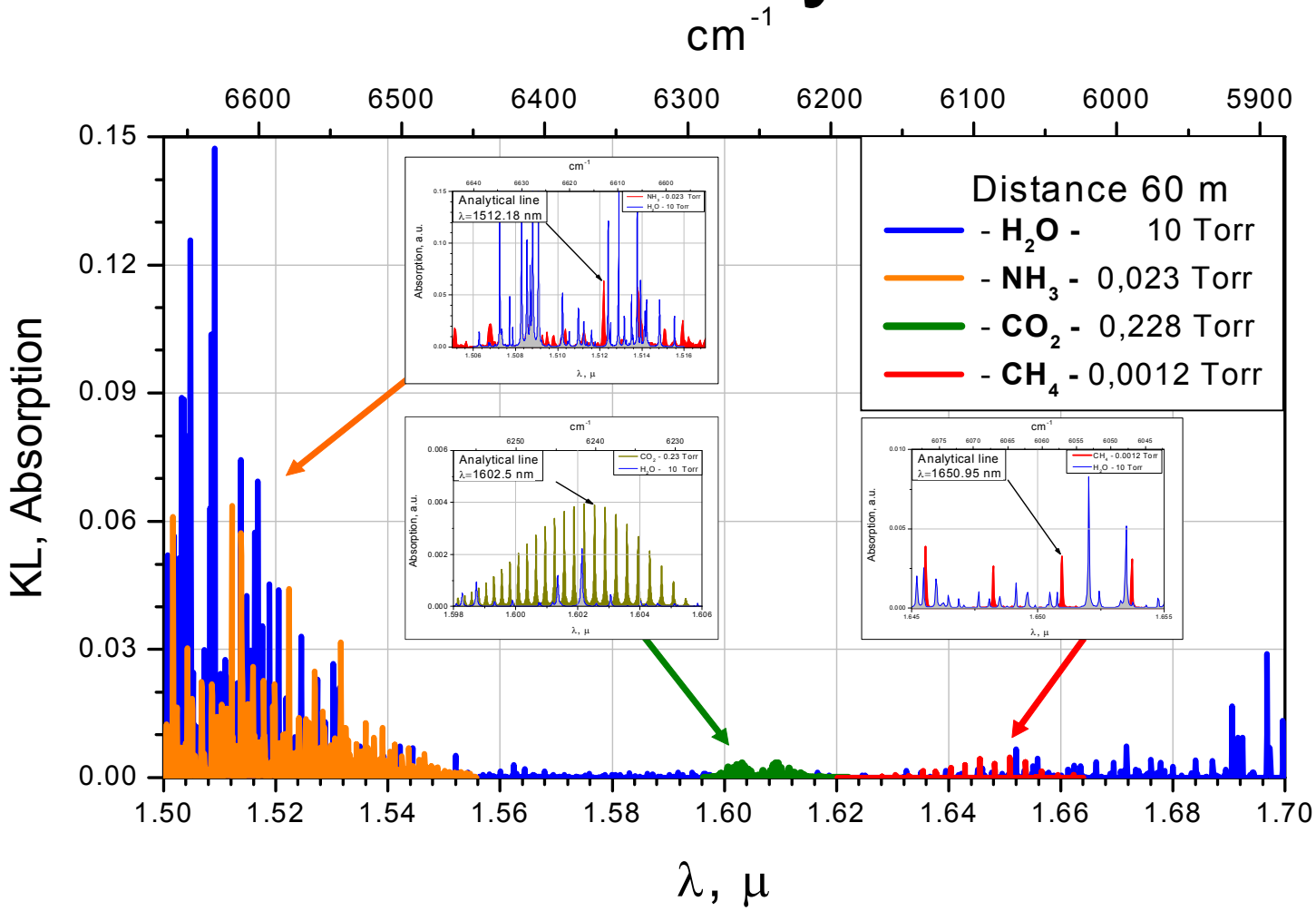
Spectra of Several Molecules in Near Infrared Spectral Range



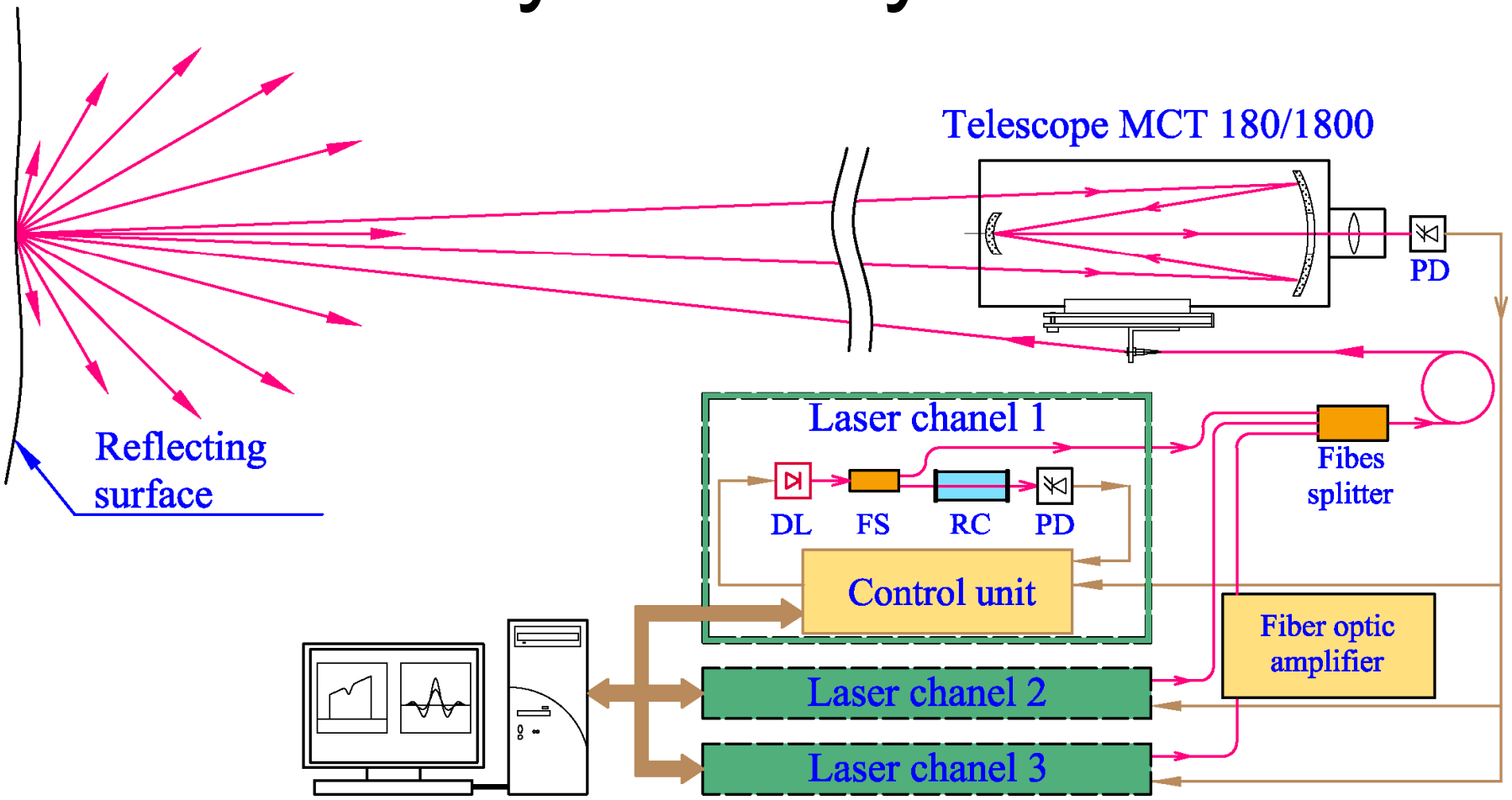
Practically all molecules absorb in near IR spectral range where bands characteristic for C-H, N-H, O-H, etc. bonds are located. Open black cycles – set of DLs available in our group.

Selection of analytical lines



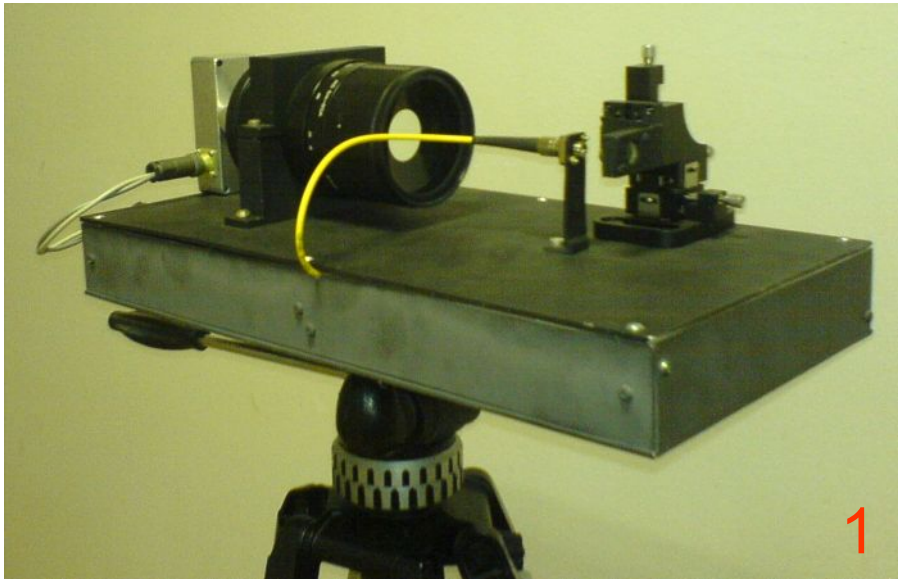
As one of applications, simultaneous detection of methane, ammonia, and CO_2 was considered. Example of analytical lines selection based on DL available and taking into account absence of interference with atmosphere water vapor absorption is shown.

System layout



Layout example of trace gas multi-component remote monitoring system
PD – photo-diode, DL – diode laser, FS – fiber splitter, RC – reference cell.

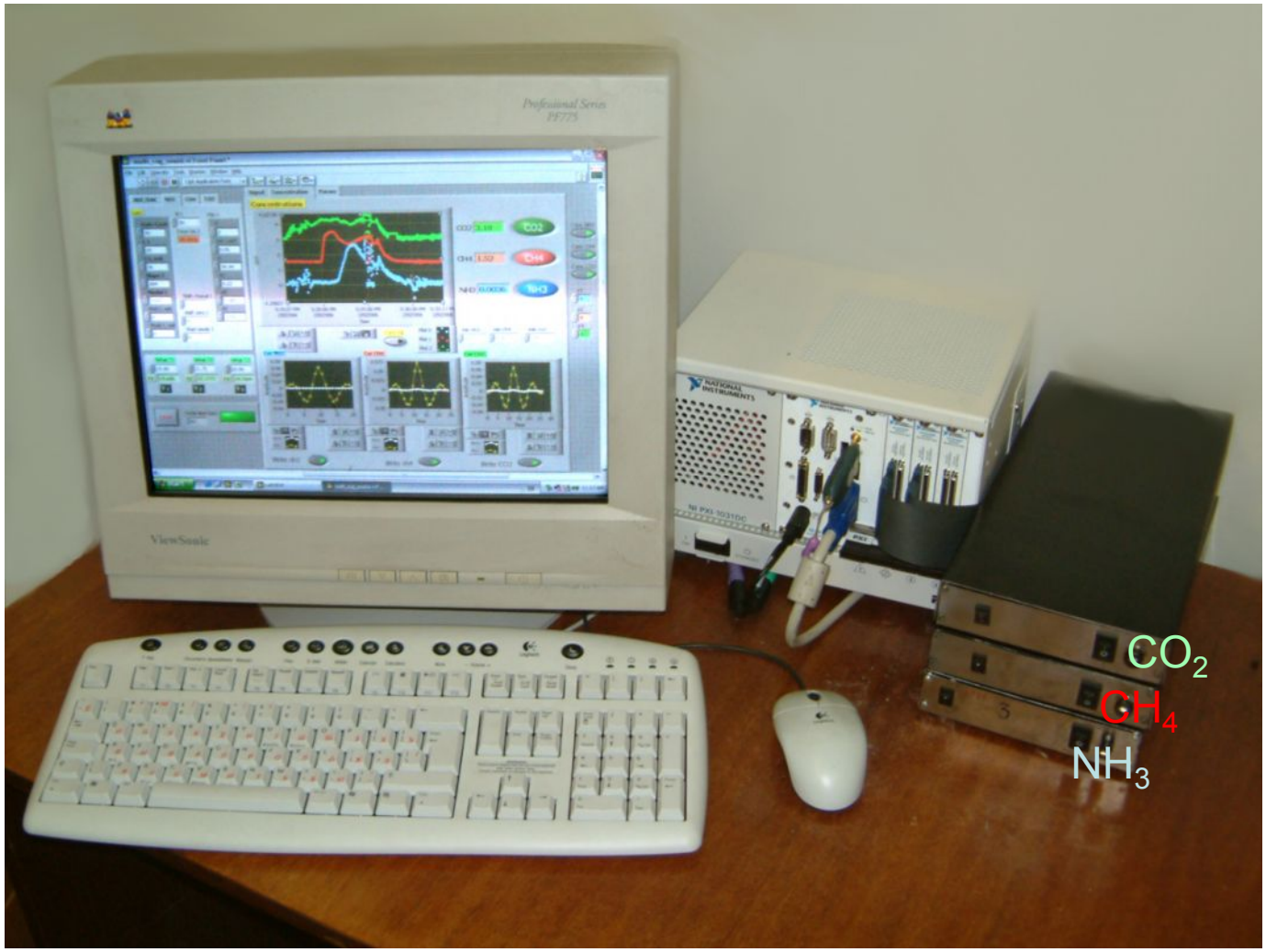
Receiving modules



Family of receiving modules was used for different applications:

1. Handle - objective diameter 5 cm
2. Vehicle - objective diameter 10 cm
3. Helicopter - objective diameter 18 cm

Electronics

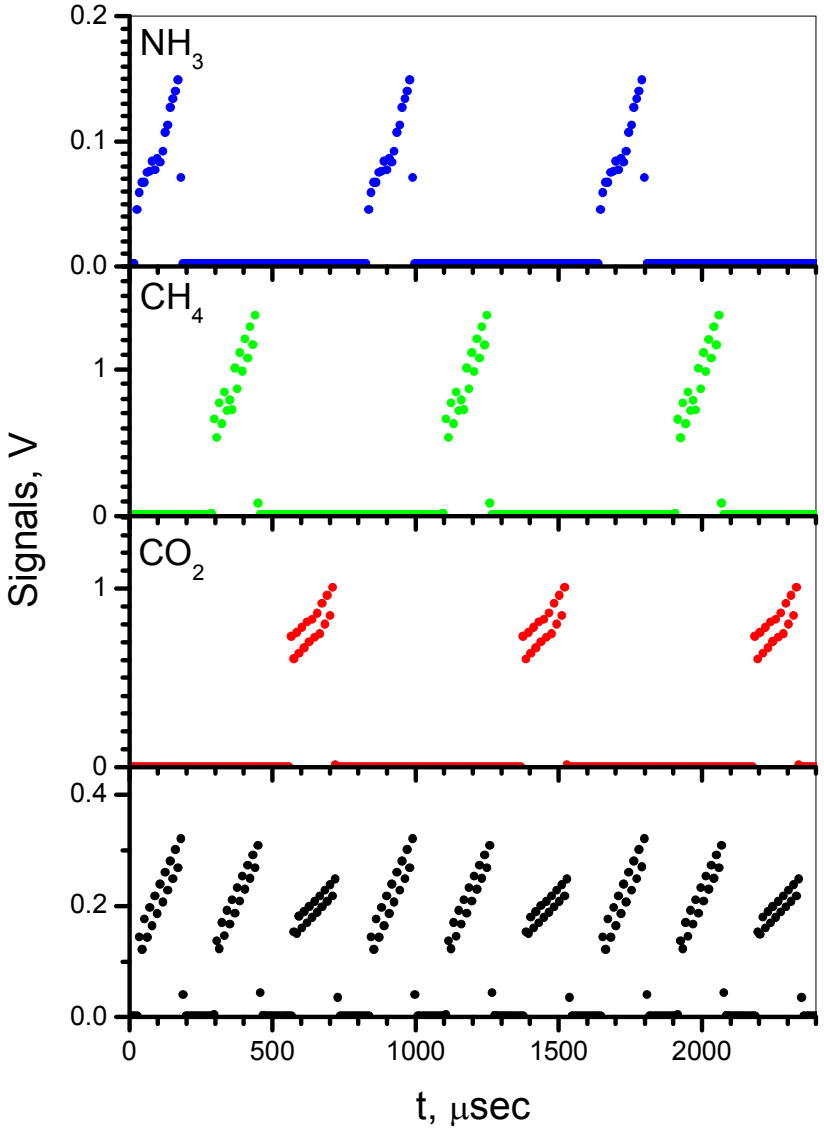


View of multi-channel electronics

1. Display and keyboard
2. NI PXI-1031DC computer station
3. Three laser channels

View of electronics of trace gas multi-component remote monitoring system (see separate poster). Three laser channels were used in present instrument to detect ammonia, methane and CO_2

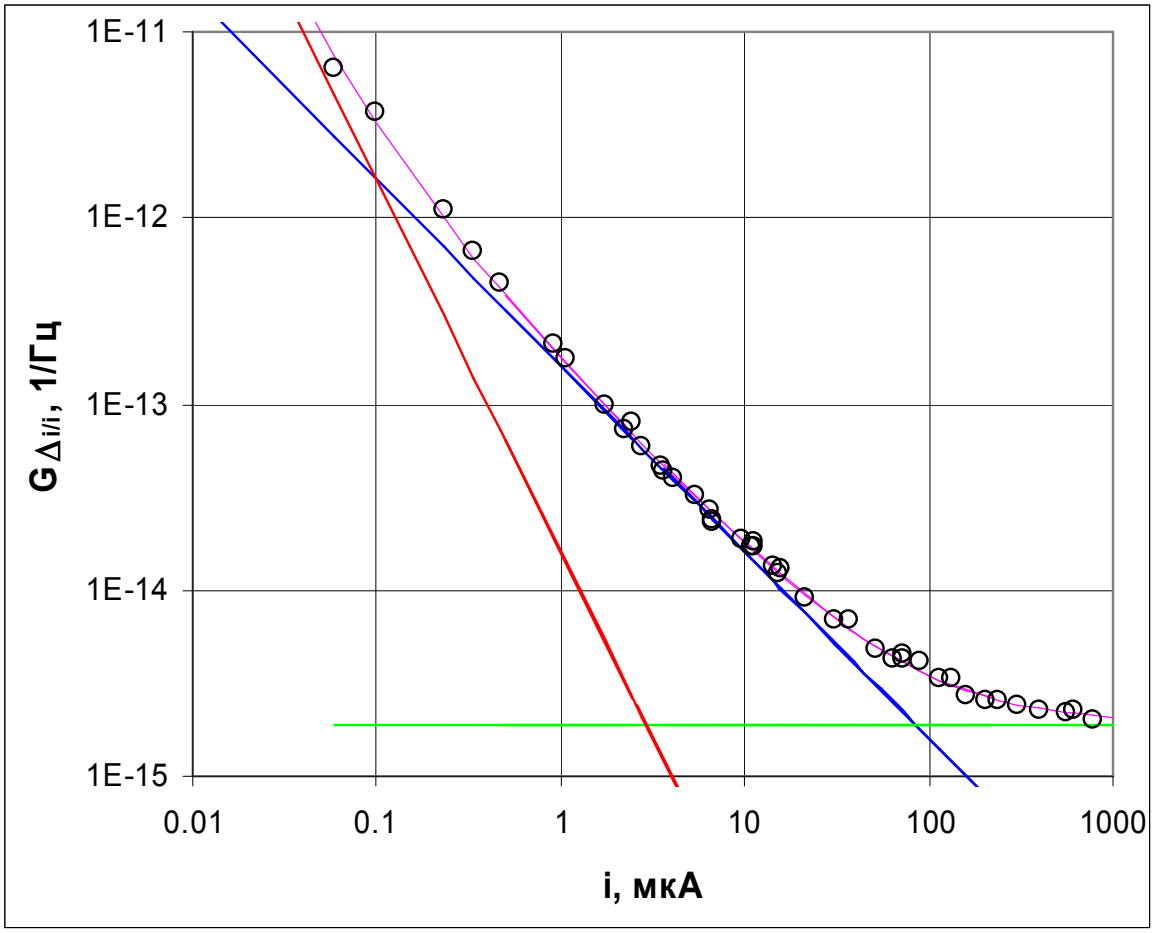
Time multiplexing operation regime



To increase selectivity of multiple molecular samples detection time multiplexing operation regime is used.
Each laser operates at different time. Three upper graphs show signals recorded in three different reference laser channels.
DL radiation from these three channels was combined in one single-mode fiber. Radiation from the fiber was collimated into parallel beam and directed to Topography Reflector (TR). Laser light scattered by TR was recorded by receiving module (lower graph).

Simultaneous real time measurements of three molecules concentrations.

Noise of DL based systems



Spectral density of photo-current relative noise as function of photo-current value (open cycles).

Main physical mechanisms of DL based systems noise.

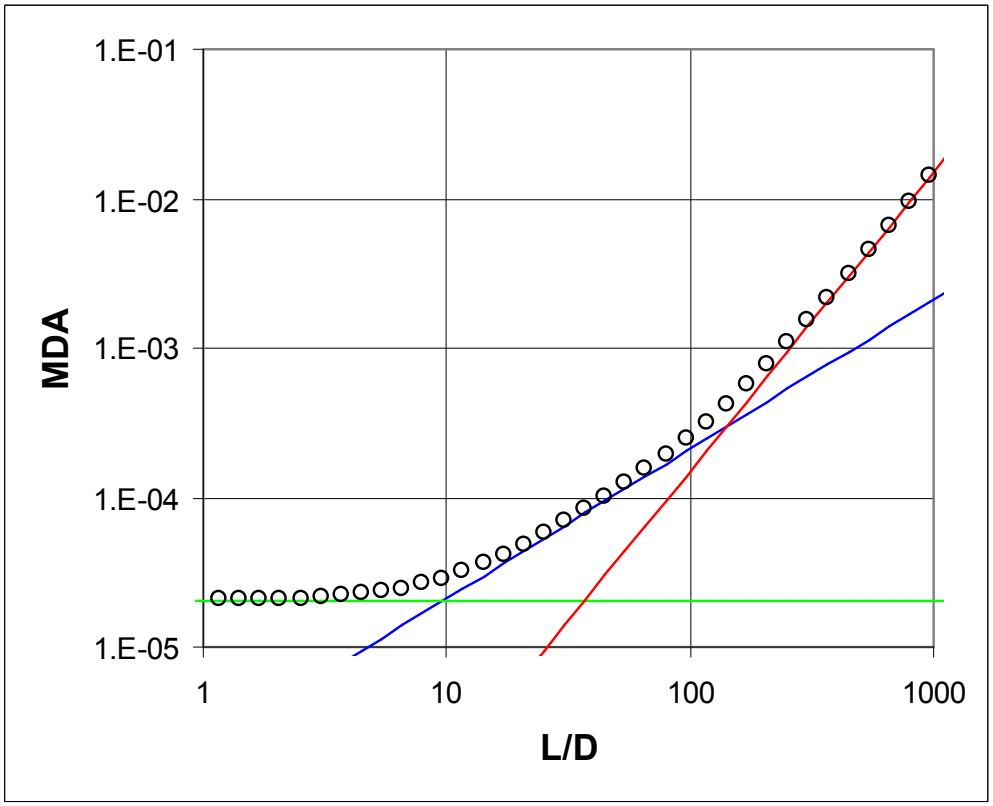
1. Thermal noise of preamplifier resistor (red) – depends on pre-amplifier in use.
2. Photo-current shot noise (blue) depends on photo-current value.
3. DL intensity quantum noise (green) is proportional to photo-current value.

Total noise density is shown as thick line. For different photo-currents different noise type dominates.

Resume: Noise in DL based systems is determined by photo-current value.

Minimum detectable absorption

As it was mentioned above, relative noise in DL based systems is determined by photo-current value - i. Portion of DL light scattered by TR and collected by receiving optics depends on A(θ) - scattering diagram, L – distance between instrument and TR, and D - receiving optics diameter.



Δi/i - Minimum Detectable Absorption (MDA) as function of L/D. In present experiments L/D varied from 10 to 3000.

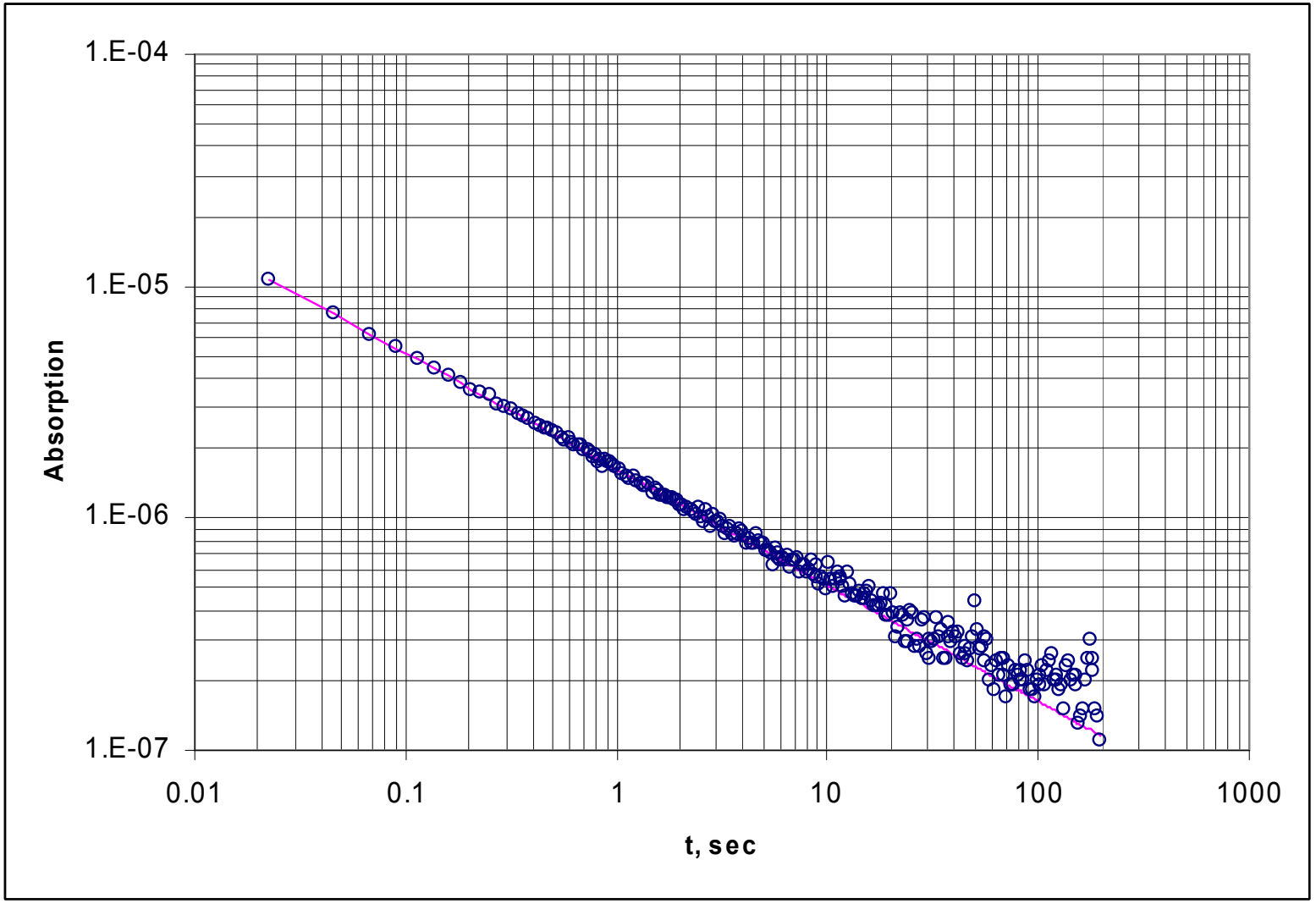
$$i = \frac{P}{P_0} i_0 = \frac{A(\theta) D^2}{4L^2} i_0$$

P_0 = 20 mW, di/dP = 1A/W, isotropic scattering with albedo = 0.4

Main physical mechanisms of DL based systems noise - Δi:

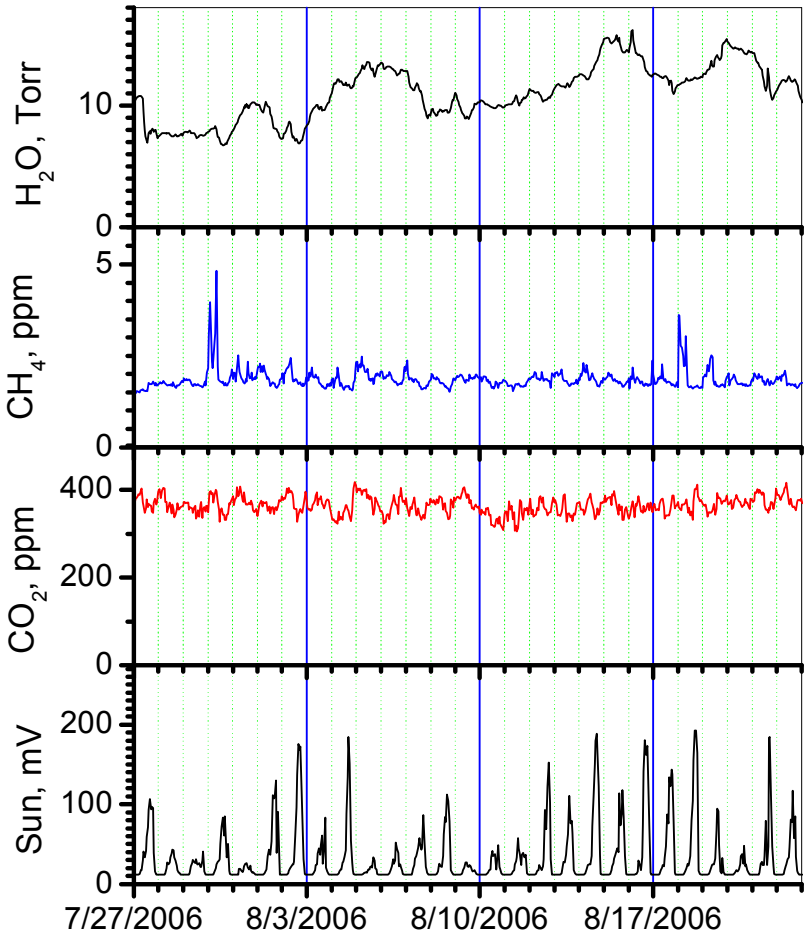
1. Thermal noise (red).
2. Photo-current shot noise (blue).
3. DL intensity quantum noise (green).

Allan plot



Allan plot of minimum detectable absorption as function of averaging time. This result was obtained for L/D = 100 (photocurrent shot noise dominated).

Long-term monitoring



Water partial pressure variations

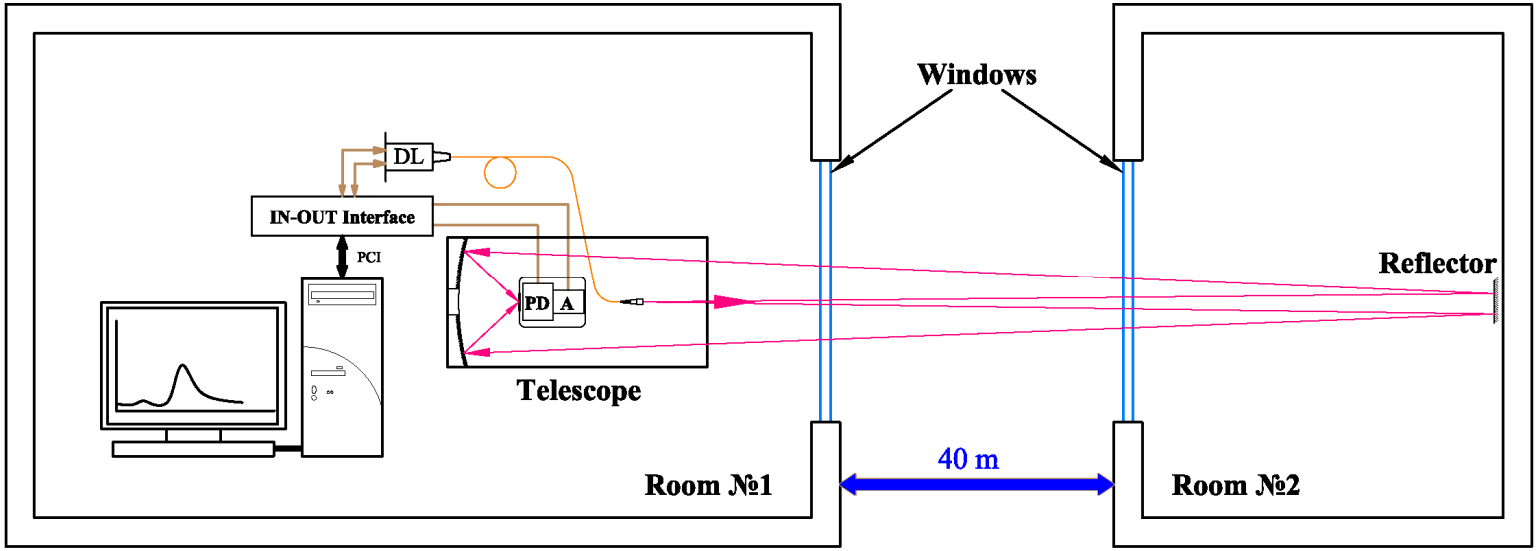
Methane. Two intensive peaks are due to methane plume from power plant (3 km from GPI).

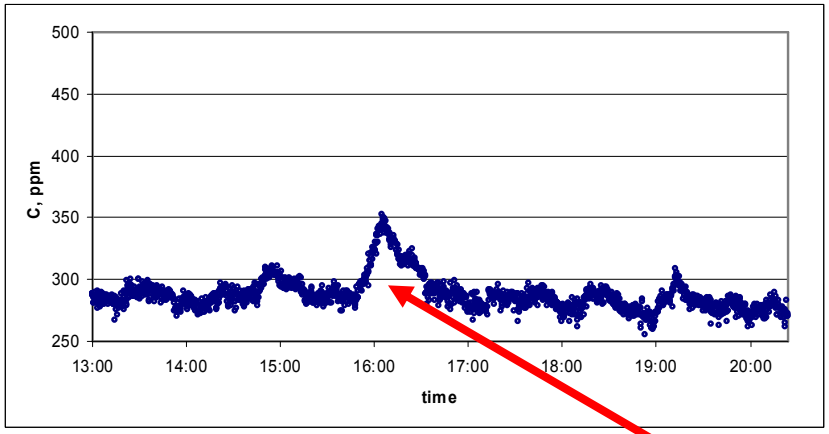
CO_2 monitoring.

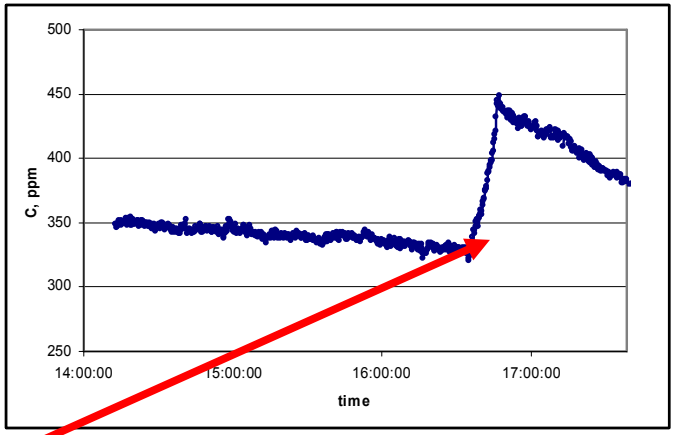
Sun illumination.

Example of one month simultaneous H_2O, CH_4, and CO_2 concentrations monitoring.

Human presence remote detection

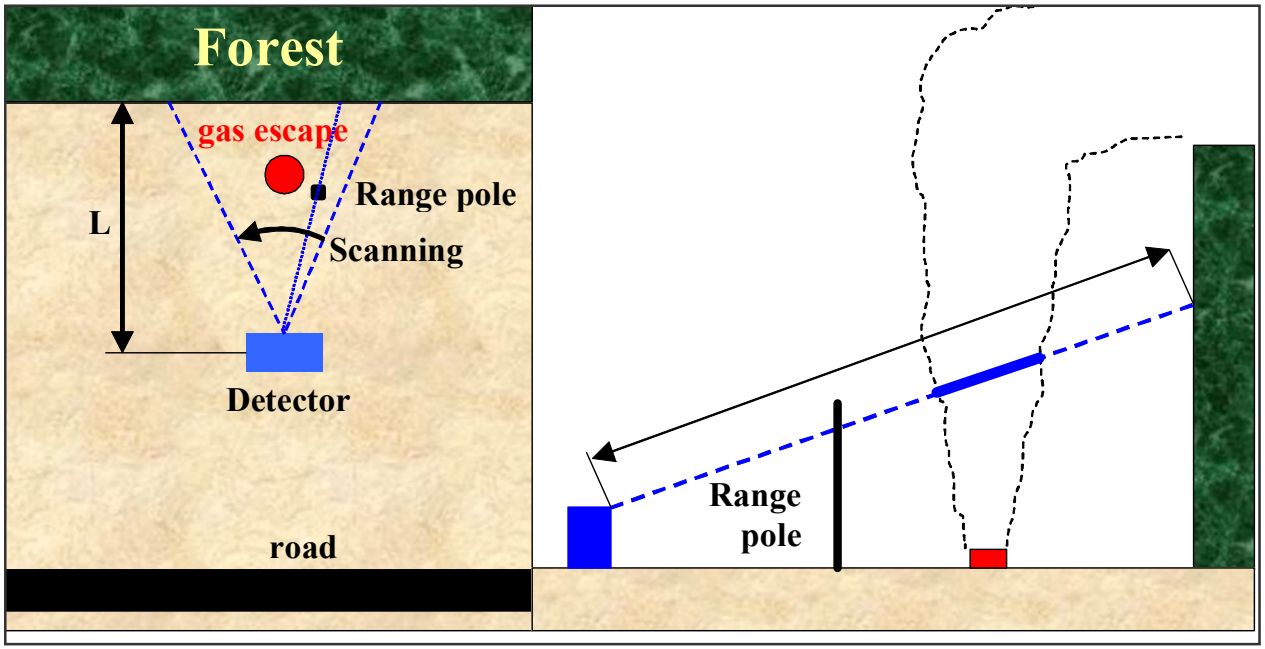


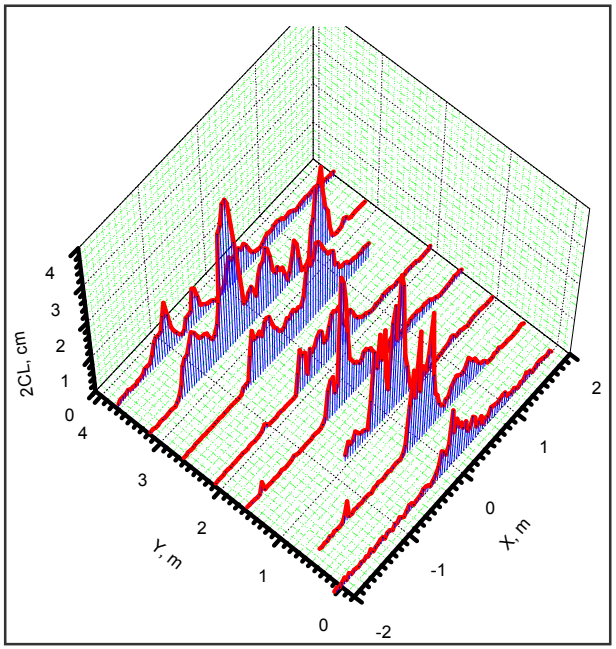




Example of remote detection of human appearance in controlled area (room №2) by measuring CO_2 concentration.

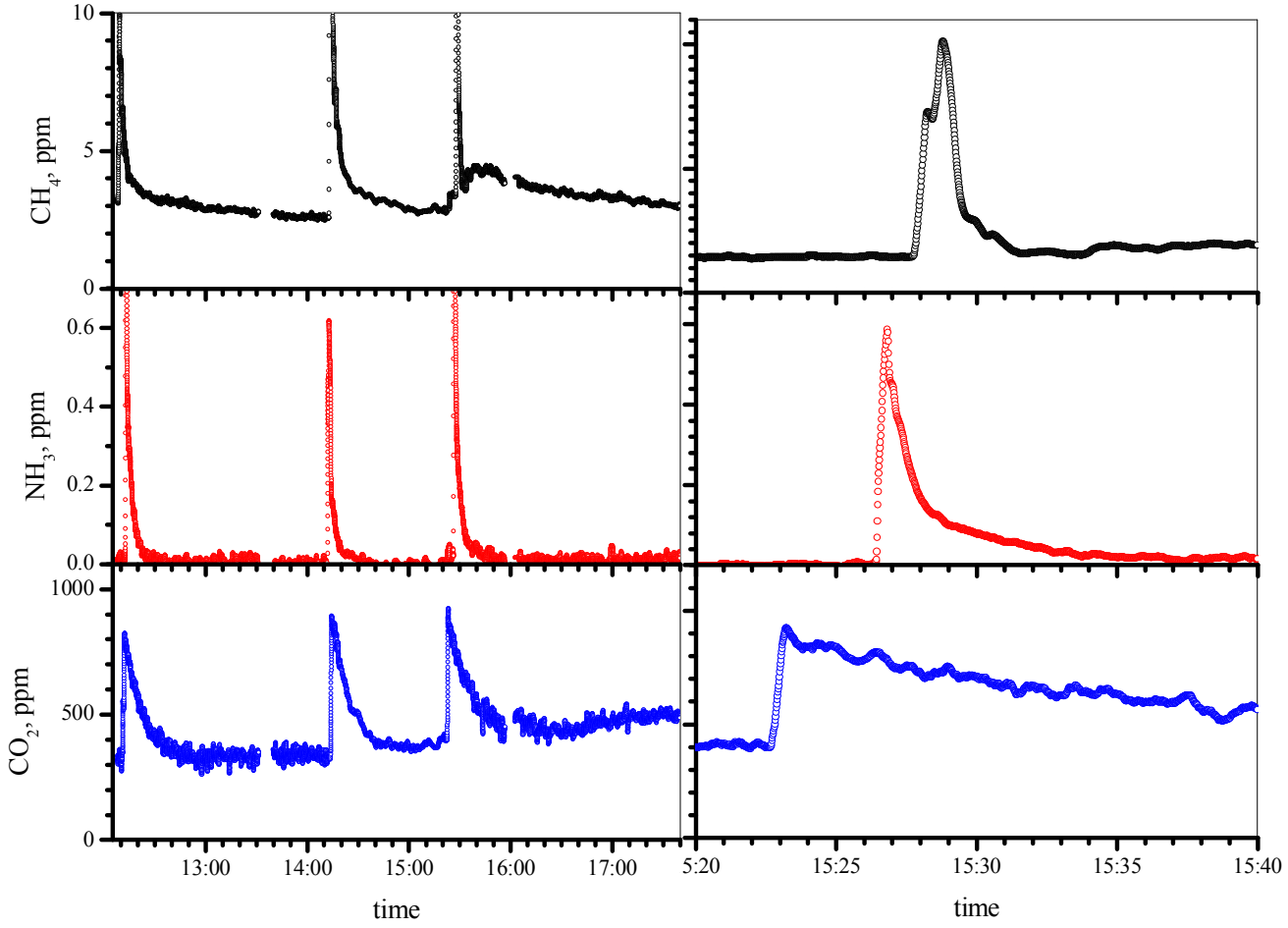
2D gas plume remote image





Using remote DL based system developed, methane concentration spatial distribution was measured in plume from calibrated leakage when forest was used as topography reflector.

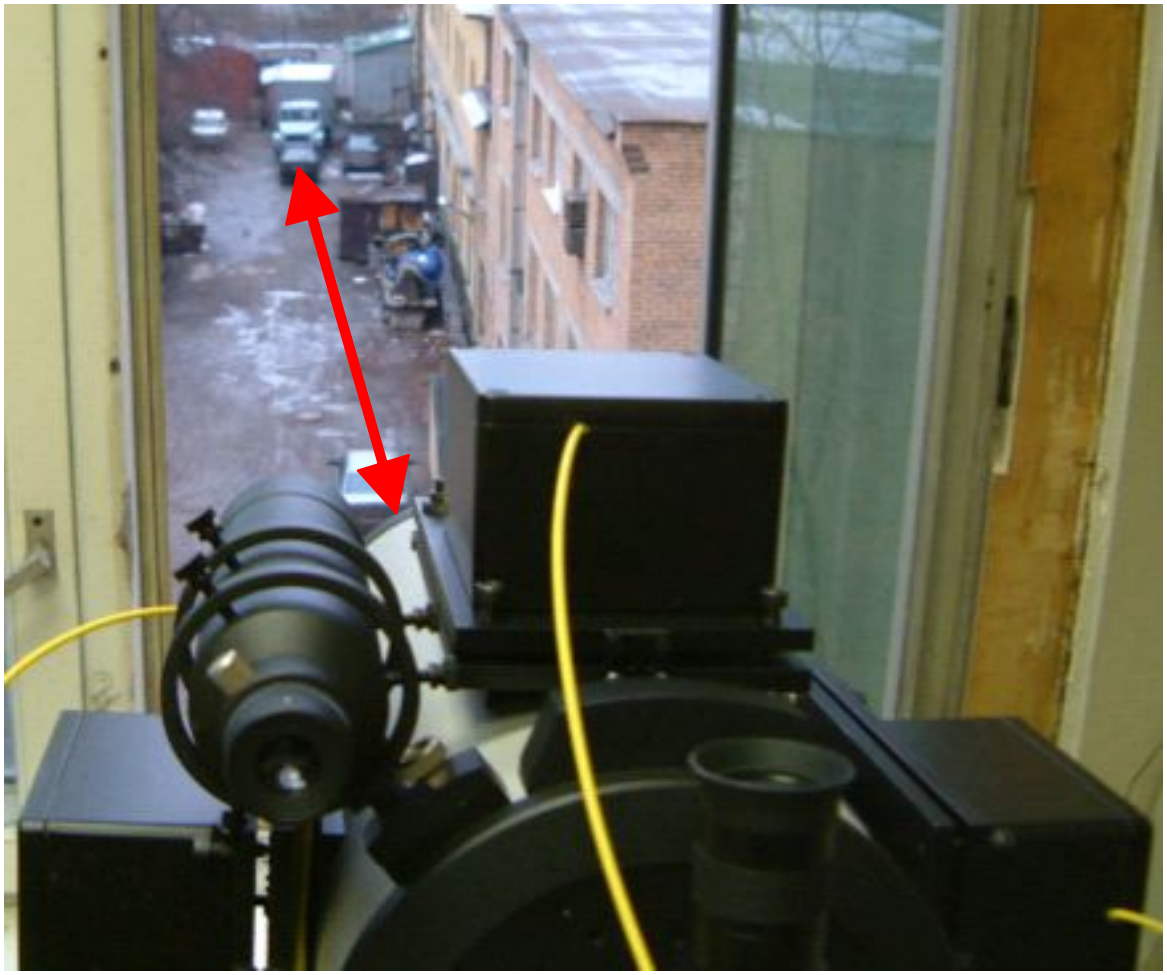
Indoor test

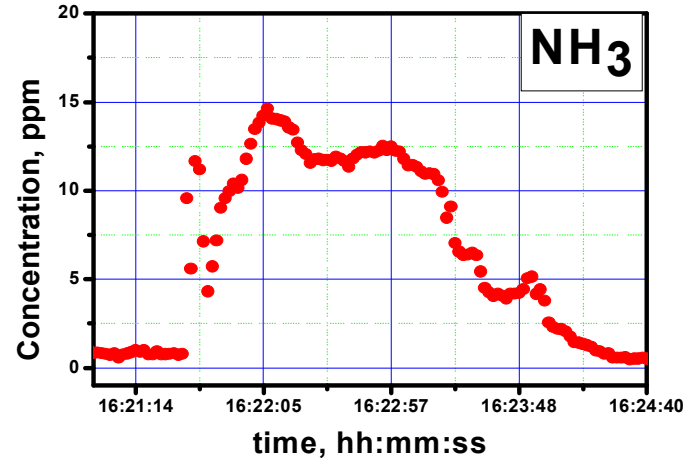


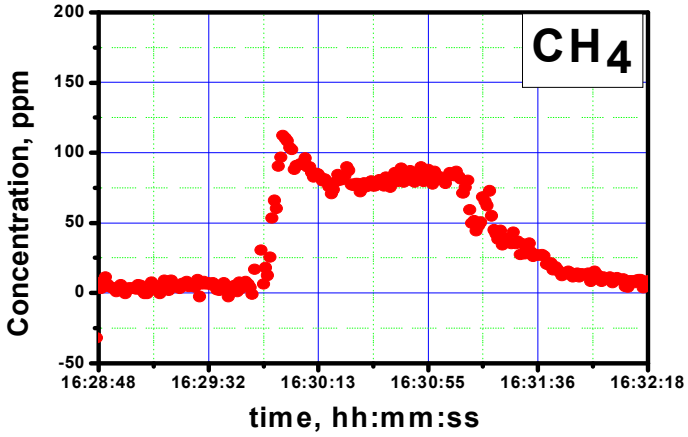
Indoor test. For test purpose the system was installed in DLS department corridor at 45 m distance from TR. Box with glass windows (car imitator) was installed in DL beam.

Simultaneous detection of methane (black), ammonia (red), and CO_2 (blue) when following samples volumes were injected in the box under investigation: CO_2 (99,96%) – 5 liters; CH_4 (99,99%)- 0,5 liter; NH_3 (99,99%) - 0,01 liter.

Outdoor test







Remote detection of ammonia and methane when sample gases were injected in vehicle located at 100 m from instrument. Fiber amplifiers were used to increase receiving signal.