B3

TDLS BASED EXPLOSIVES DETECTOR: DEVELOPMENT AND TESTING

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Introduction

Remote explosives detection is extremely important goal. A lot of researchers are working in this area. However, the problem is not solved [1, 2].

1. J.Steinfeld, J.Wormhoudt, Explosives detection: a challenge for physical chemistry, Annu.rev.Phys.Chem., 49, 203-232 (1998)

2. “Existing and potential standoff explosives detection techniques.” http:/www.nap.edu/catalog/10998.html

Ammonia is universal marker of nitrogen-contained explosives (see A1). In this poster we’ll present results of based on this approach explosives detector development and testing.

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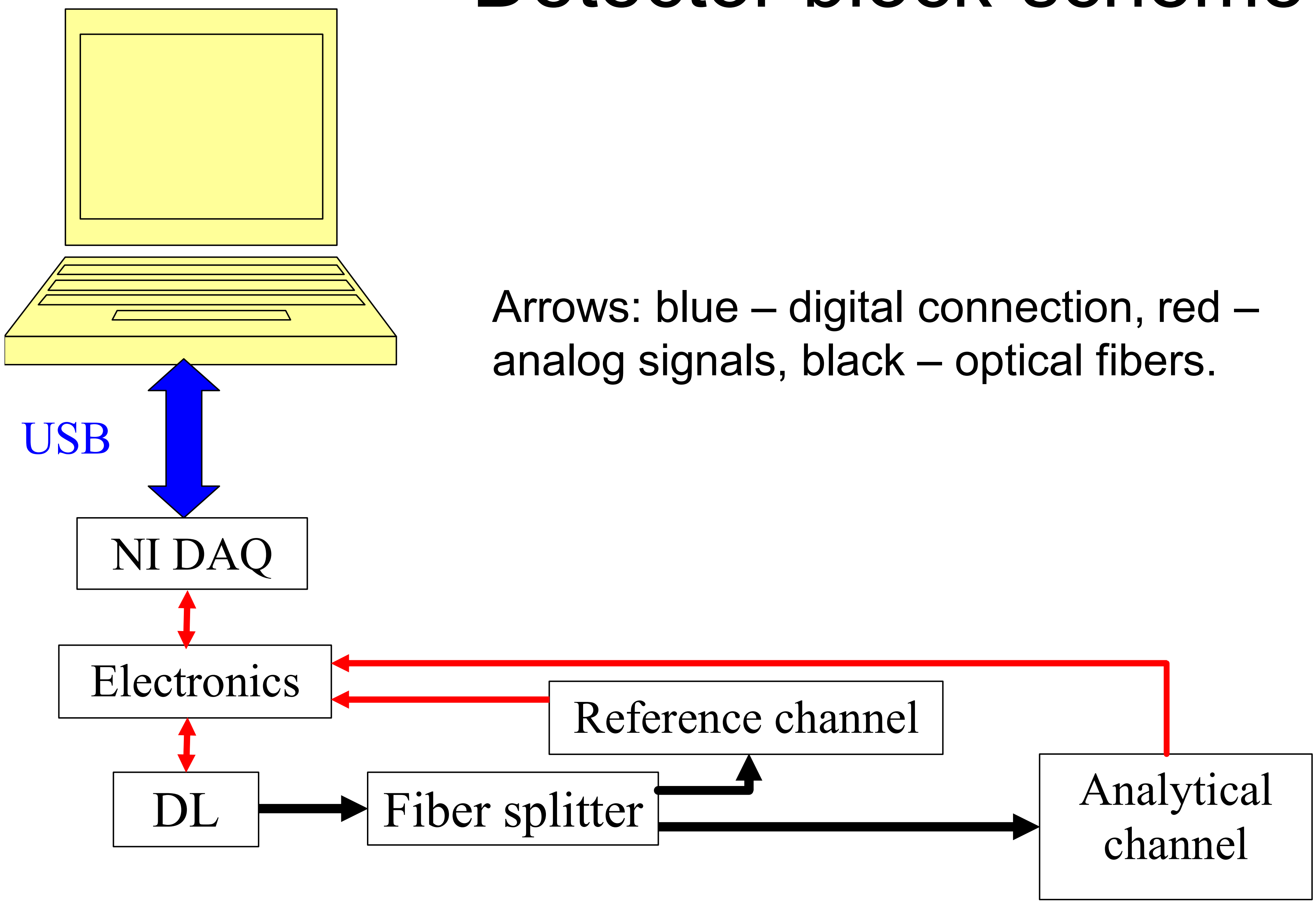
Detector block-scheme

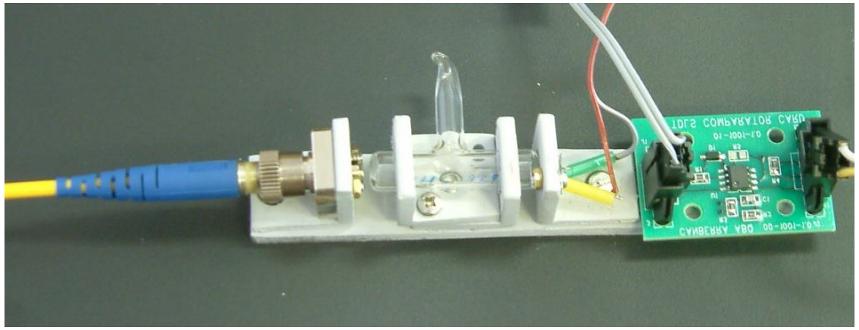


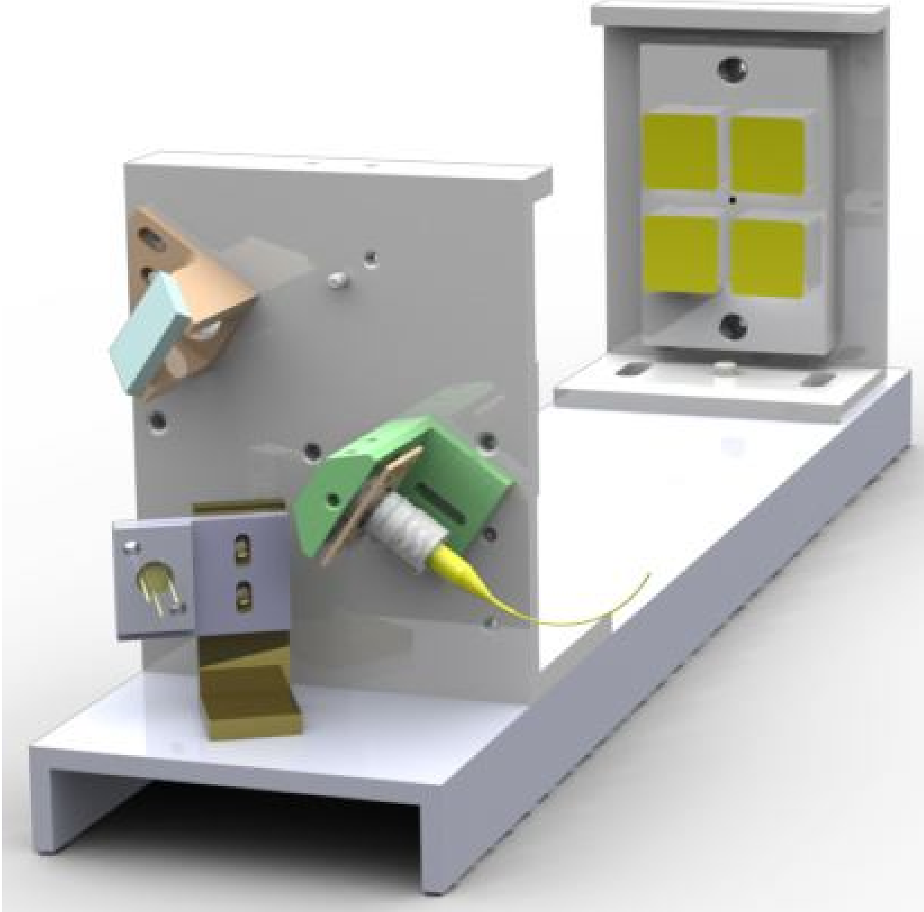
Arrows: blue – digital connection, red – analog signals, black – optical fibers.

Analytical and reference channels

Reference channel module view. Total length - 10 cm.

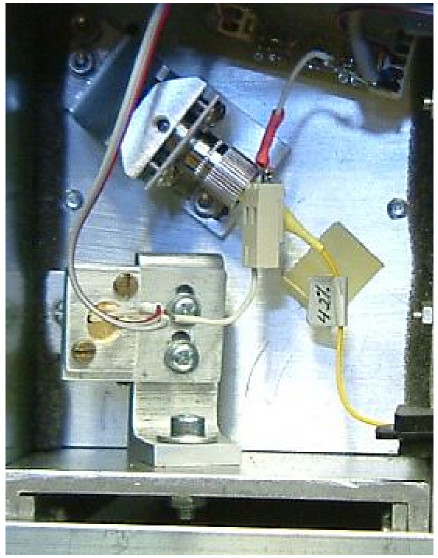
Left to right: fiber cable from DL, reference cell, PD, and preamplifier.



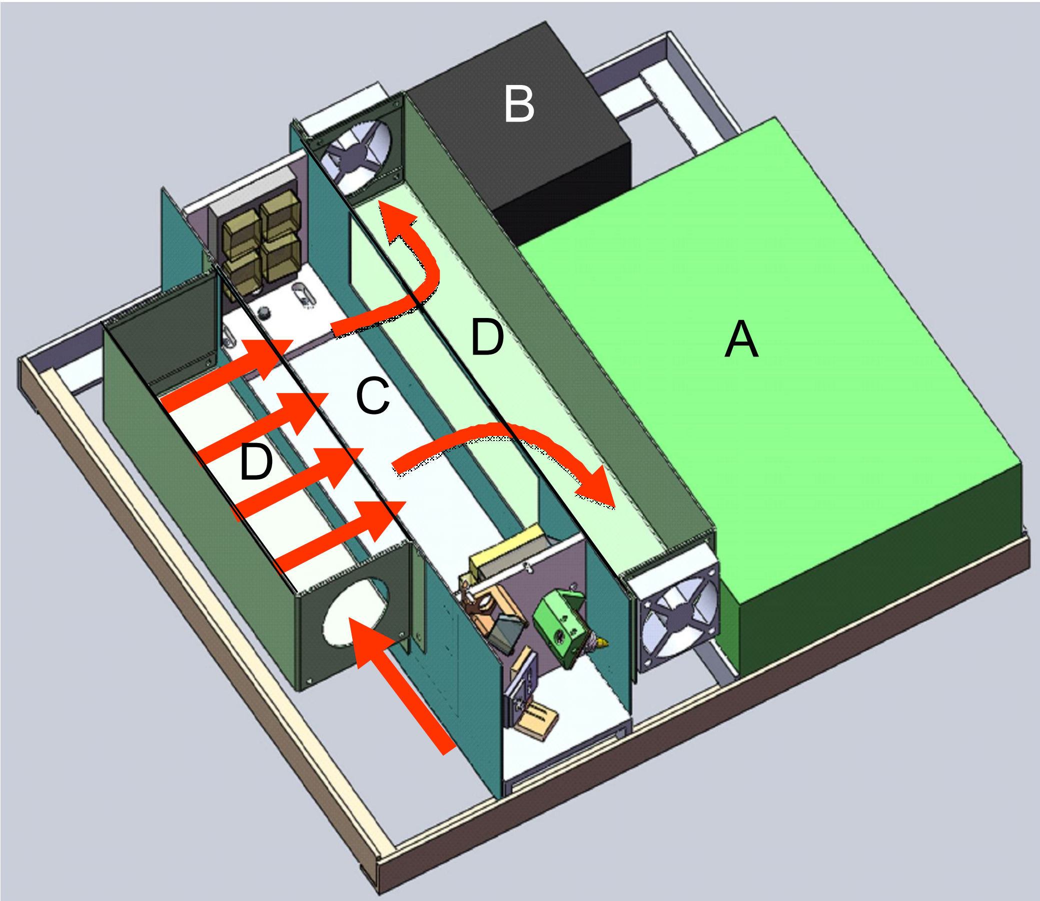


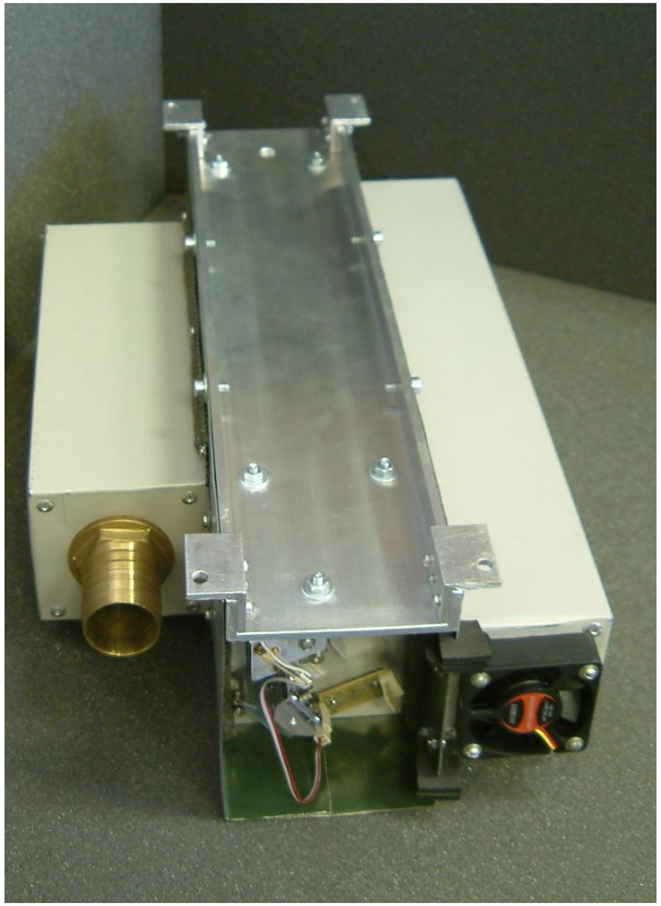
Analytical channel module layout drawing: “Chernin” matrix optical system (L = 39 m), DL fiber input into cell, mirror, and PD to detect DL light from cell.

Analytical channel module view with DL fiber input, mirror, and PD



Explosives detector development

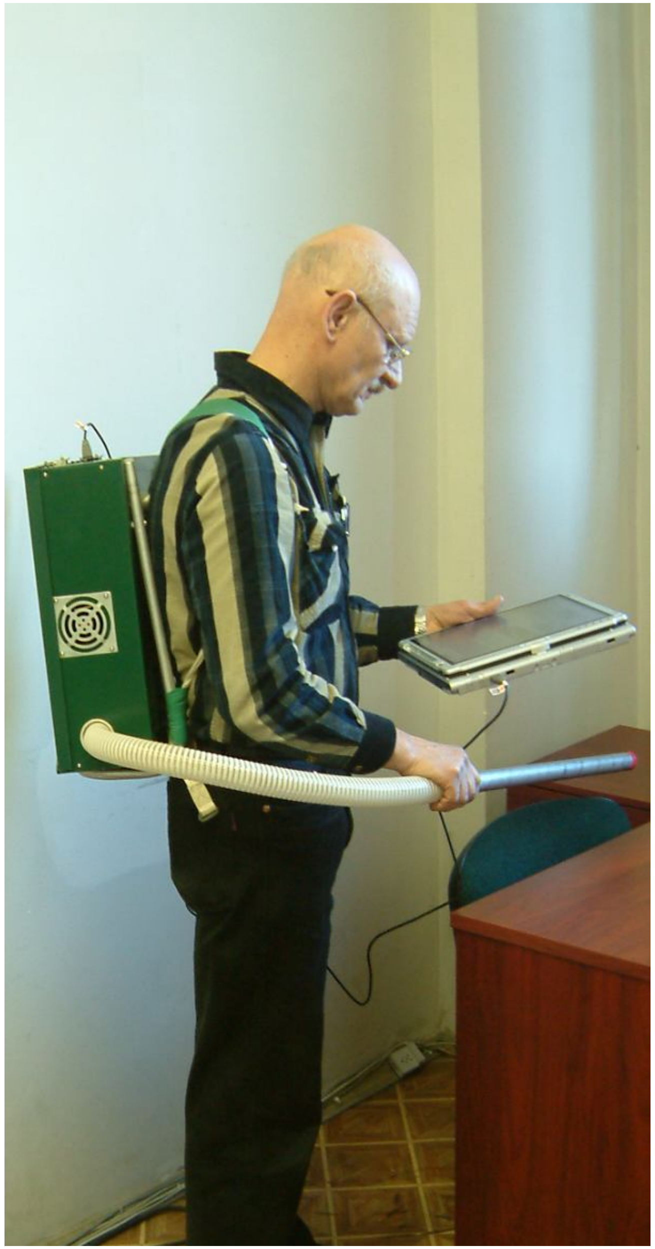




Instrument developed layout drawing. Module A contains DL, fiber splitter, reference channel, and electronics; module B – batteries; C – “Chernin” multi-pass cell. Aim of D module is to organize laminar air flow (arrows) through the “Chernin” cell.

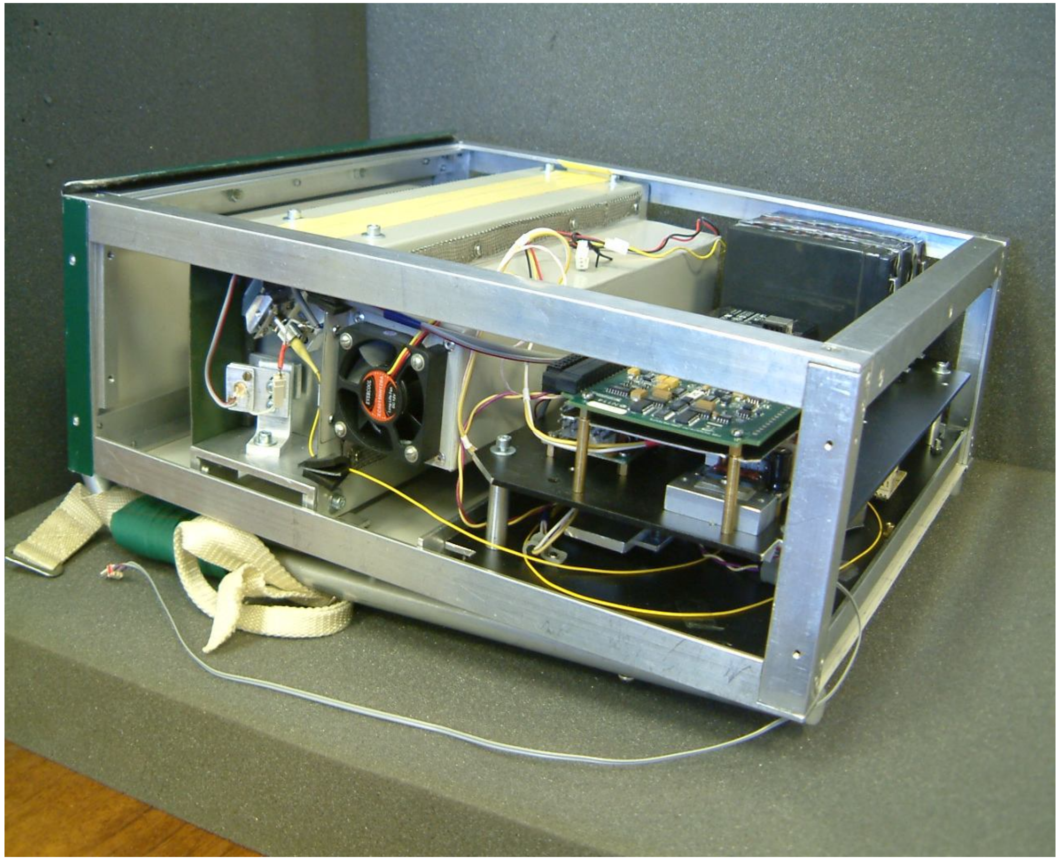
View of D-C-D parts of instrument developed. Aim - organize laminar air flow through the cell (arrows on left picture).

Backpack prototype development



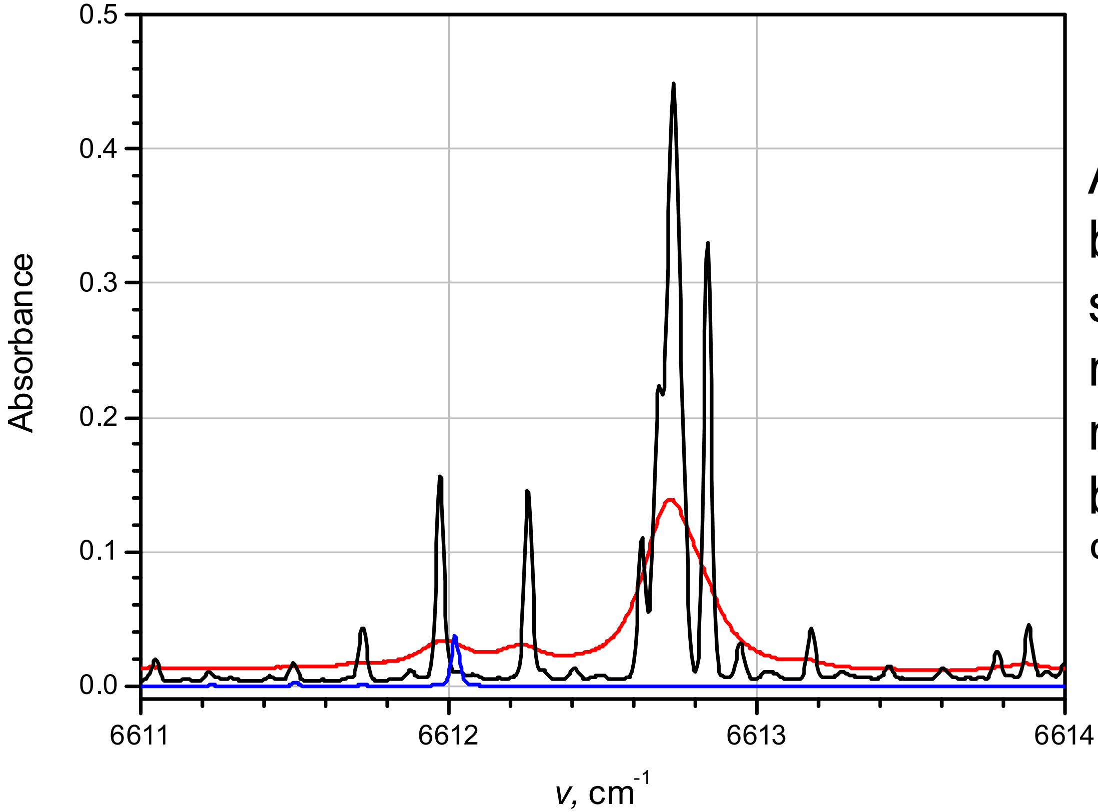
Backpack prototype for remote explosives detection in field environment was developed using electronics manufactured by Aquila (Canberra).

Total backpack weight with batteries is 8 kg.



Analytical spectral range to detect NH_3

Analytical spectral range for ammonia detection was selected using “Line-by-Line” software developed for spectra simulation (see C2). Selection requirements: intensive NH_3 line, minority influence of humidity.

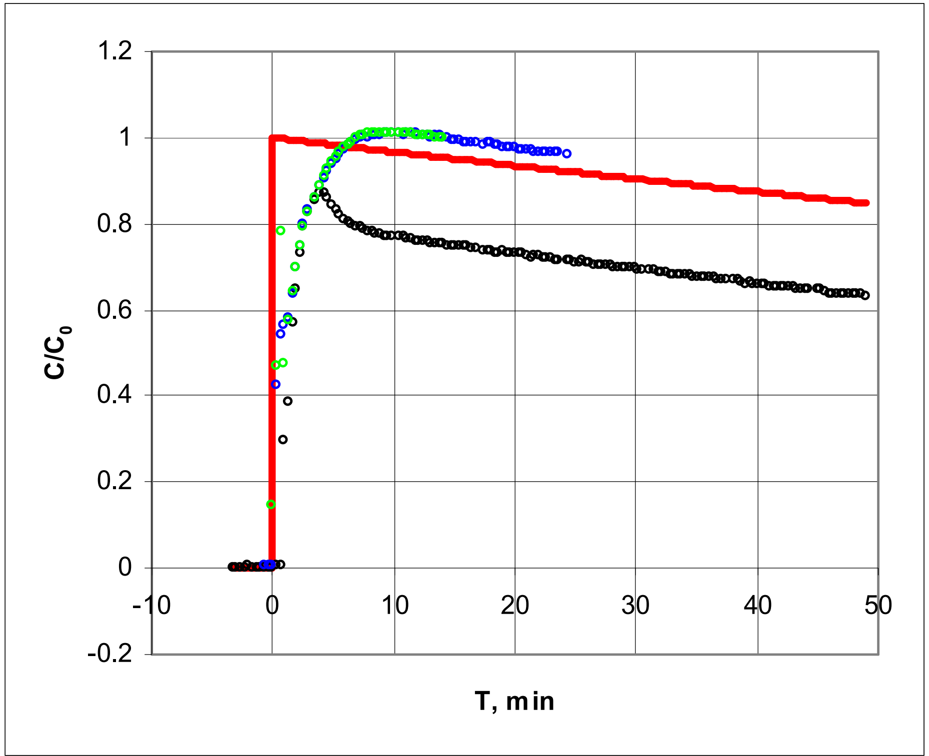


Absorbance spectra recorded by DL in use for spectral range selected: L = 2 m; black – 2.13 mBar of pure NH_3; red - 2.13 mBar of NH_3 in 1 Bar of air; blue – atmosphere air with 50 % humidity.

Analytical spectral line to detect explosives. At the beginning data from http://vpl.astro.washington.edu/spectra were used for ammonia absorption cross-section (accuracy ~ 10 – 20 %).

NH_3 cross-section calibration

To improve accuracy, NH_3 cross-section calibration was performed. In volume V with air in glass box at time t=0 by syringe was injected calibrated volume v of pure ammonia. TDLS measured C using PNNL cross-section data (see above).



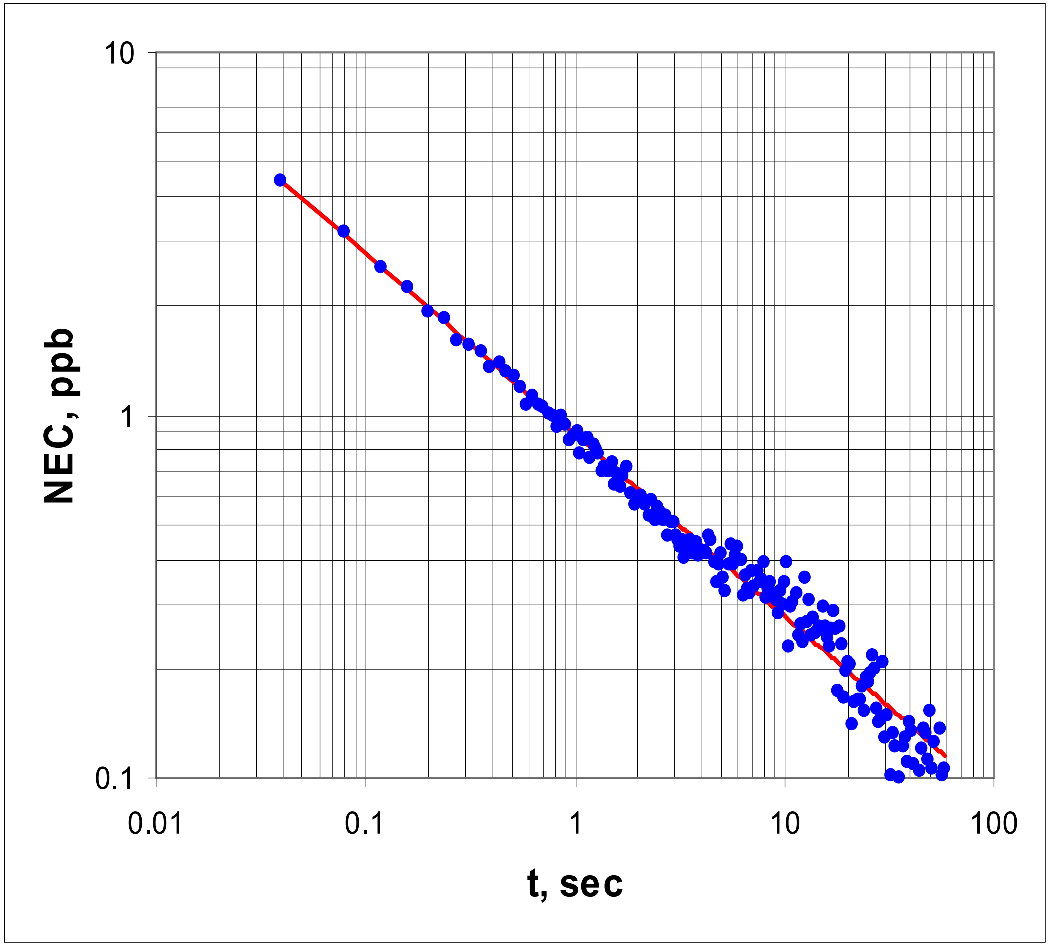
Concentration by definition is:

$$C_0=v/V$$

Circles are result of TDLS measurements for first (black), second, and third injections. Just after injection one can see concentration increase due to molecular diffusion. After 10 min diffusion process is finished. Difference between first and other injections is due to one ammonia molecular layer absorbed on glass walls.

For second and third injections very good reproducibility can be observed with concentration decrease. So, concentration can't be considered as calibrated one. However, its interpolation to t = 0 provides NH_3 cross-section calibration with accuracy better than 1 %. Previously used value was corrected by 5 %.

Minimum detectable concentration



NH_3 NEC (Noise Equivalent Concentration) for instrument developed as function of averaging time.

NEC is determined by fundamental limit due to DL quantum noise.

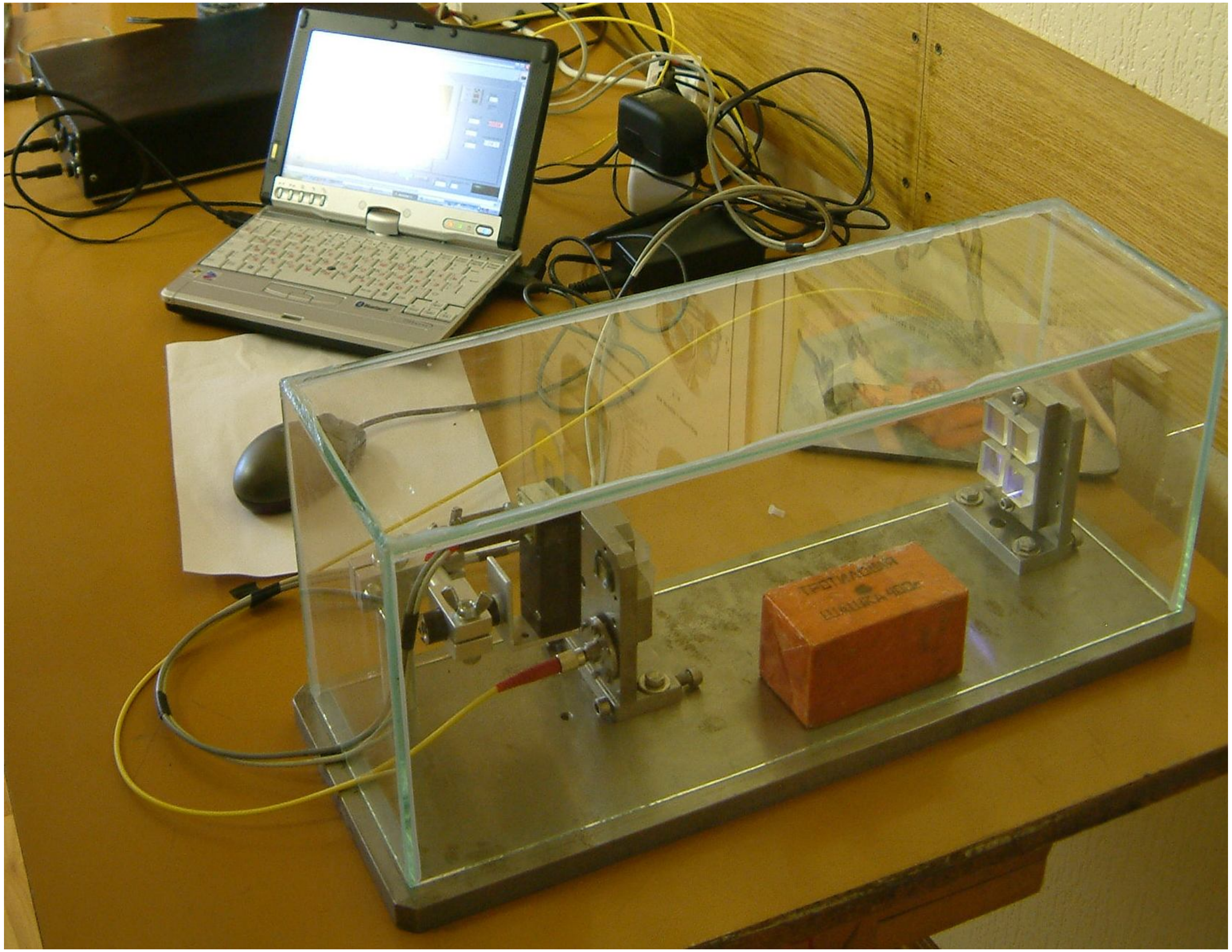
For explosive sample detection time of single measurement below 1 sec is acceptable. For these averaging times for instrument developed minimum detectable ammonia concentration is around 1 ppb.

Lab and field tests

Several scenarios of explosives detection were considered and tested:

- Different explosive samples detection both in laboratory and field environment.
- Explosive samples detection in open air.
- Explosive samples detection inside facility.
- Determination of explosives sample location inside building.
- Etc.

Explosives detection in laboratory



Non-contact TNT sample detection in laboratory environment, M = 400 g.

<u>All explosives samples investigated (more than 20) were detected using instrument developed.</u>

Explosives detection in open air

10 kg explosive sample installed in garage was found using marker molecule gas flow detection through holes. 300 kg explosive sample in wrapping was detected at 120 m distance down wind.

Explosives presence in facility

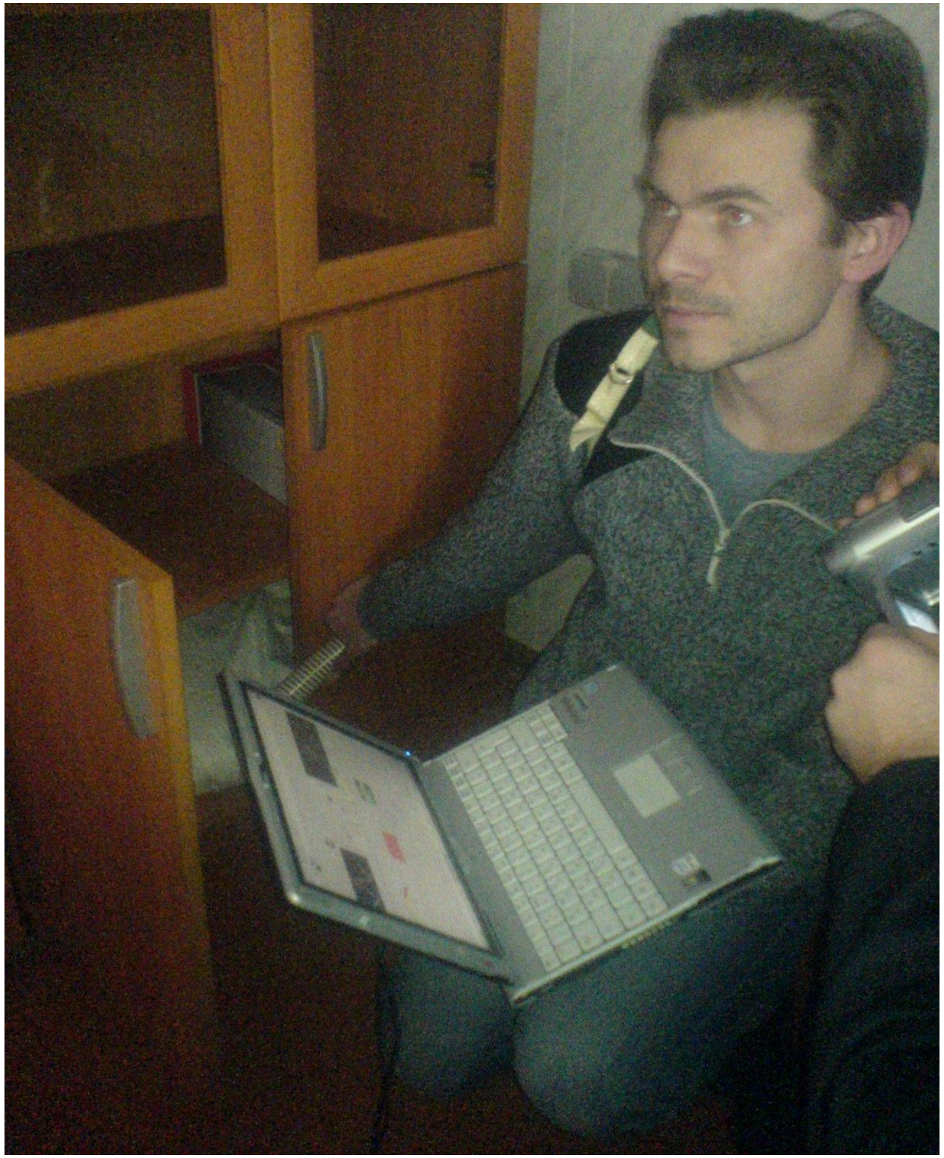
50 kg explosive sample installed in facility was found using marker molecule gas flow detection through holes. Important scenarios of explosives detection were tested: explosives in elevator well, or above ceiling panel, etc.

Explosive sample detection in vehicle

400 g TNT sample detection in vehicle luggage space.

Explosive sample location

Detection of explosive sample location inside building is important goal of instrument developed.



Explosive sample installed in building generates marker molecules concentration distribution inside facility under investigation.

Using marker molecules concentration gradient during operator movement location of explosive sample can be determined.

<u>Location of 2 kg AN explosive sample inside building was found following marker molecules concentration gradient.</u>

Conclusion

Sensitive backpack ammonia detector based on TDLS technique was developed. Total backpack weight with batteries is 8 kg.

Laboratory test of the instrument: NEC (Noise Equivalent Concentration) - 0.5 ppb for 1 sec averaging time. Indoor and outdoor tests were performed both at General Physics Institute and at test polygon near Moscow. Possibility of detection was demonstrated for different types and amounts of explosives.

Several scenarios of explosive sample detection using instrument developed were analyzed and tested: 400 g TNT sample was detected in vehicle luggage space; 2 kg AN explosive sample was found inside building by following concentration gradient; 300 kg explosive sample in wrapping was detected at 120 m distance down wind, etc.