Diode pulsed lidar-rangefinder: eye-safe measurements with ~1cm accuracy by 15 ns pulse

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- **S.Pershin, V.Linkin, V.Makarov, I.Prochazka, K.Hamal,**

"Spaceborn laser altimeter based on the SPAD receiver and semiconductor laser transmitter", Proc. CLEO, Advance Program p.120 (**1991**).

S.Pershin et al.

Compact "eye-safe" lidar for environmental monitoring, SPIE, v. 2107, 336 (**1993**)

S.Pershin

Trouble-free compactLidar for in/out door atmosphere monitoring, SPIE v. 2506, 428 (**1995**)

Micro-Joule Lidar based on diode laser and single photon detector

- **Covered by Patent of Russia -2007**

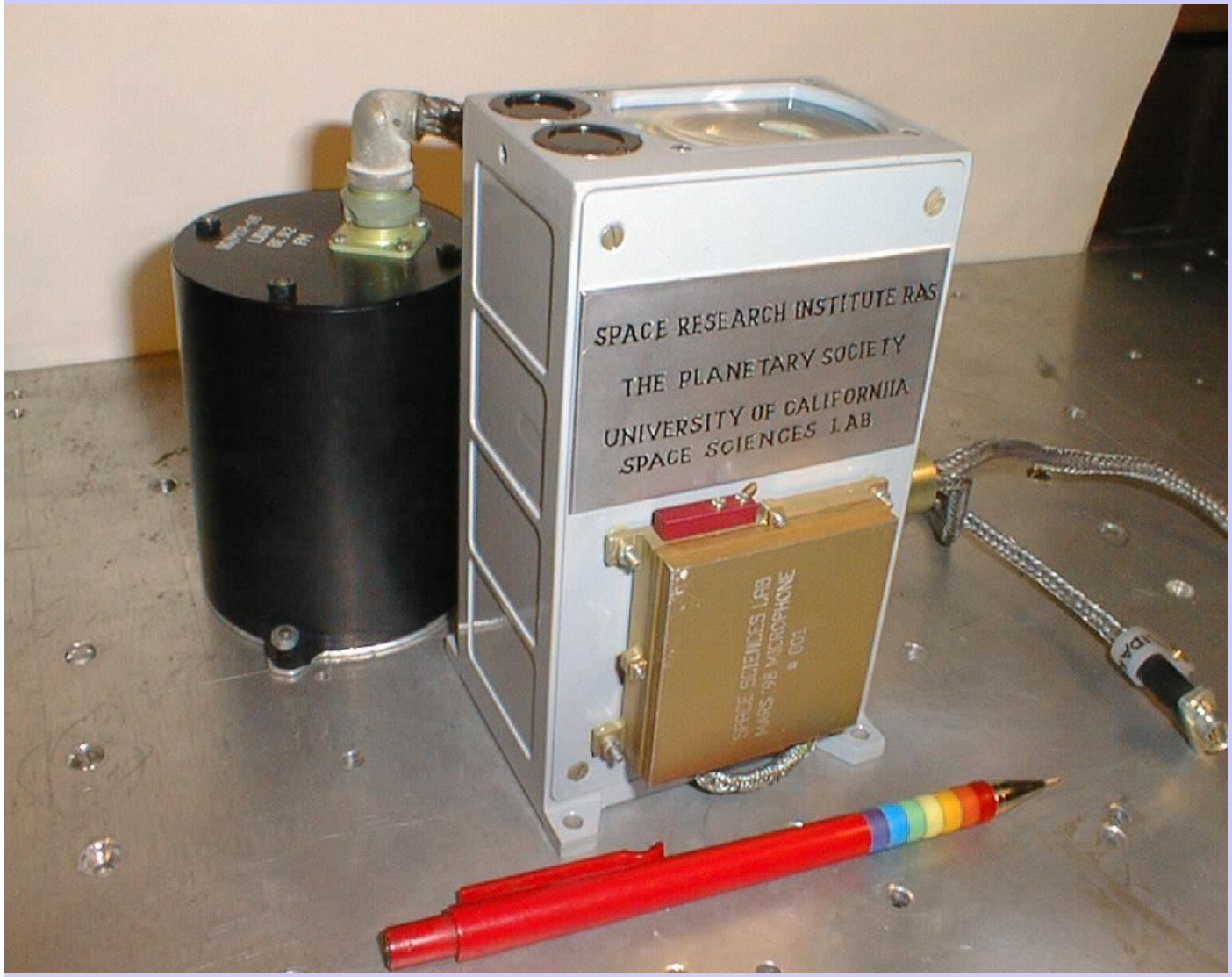
Заявка № **2007130394**

Приоритет изобретения **09 августа 2007 г.**

Outline

- Noval approach based on high repetition rate **eye-safe** microJoules pulses and quantum counter
  - **Advantages**
- High efficiency diode pulsed lasers as transmitter
- High efficiency Single Photon Avalanche Diode as receiver
  - **Results**
- **The first Lidar on Mars was the lidar of**
- **Russian Academy of Sciences**
- **which was delivered by NASA "Mars Polar Lander" mission in 1999**

Lidar LIMS for NASA project Mars Polar Lander – 99



Weight – 940 g

Consumption - 0.2 W

T = –100 +50 ^{0}C

Data volume

2kB per set

36 kB/12 sets per sol

Range 750 meters

resolution 10 m

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

SD

TO: Jet Propulsion Laboratory
Attn: 230-228/Manager, Mars Surveyor 1998 Project

FROM: S/Science Program Director, Office of Space Science
Solar System Exploration

SUBJECT: 1998 Mars Surveyor Payload Confirmation Review

I am pleased to confirm the 1998 Mars Surveyor Science Payload as previously selected for both the orbiter and lander. The orbiter payload includes the Pressure Modulator Infrared Radiometer (PMIRR) and the Mars Surveyor '98 Orbiter Color Imager (MARCI). The confirmed lander payload is composed of the Mars Surveyor '98 Descent Imager (MARDI), the complete Mars Volatile and Climate Surveyor (MVACS) package (surface stereo imager, robotic arm with camera, meteorology package, and the thermal and evolved gas analyzer), and the Russian provided atmospheric Lidar. We concur with your assessment of the adequacy of the implementation plans, schedule, and budget, and your recognition of the technical and schedule risks associated with the implementation.

Now that the payload is confirmed there should be no changes to the science payload complement without prior Headquarters approval.

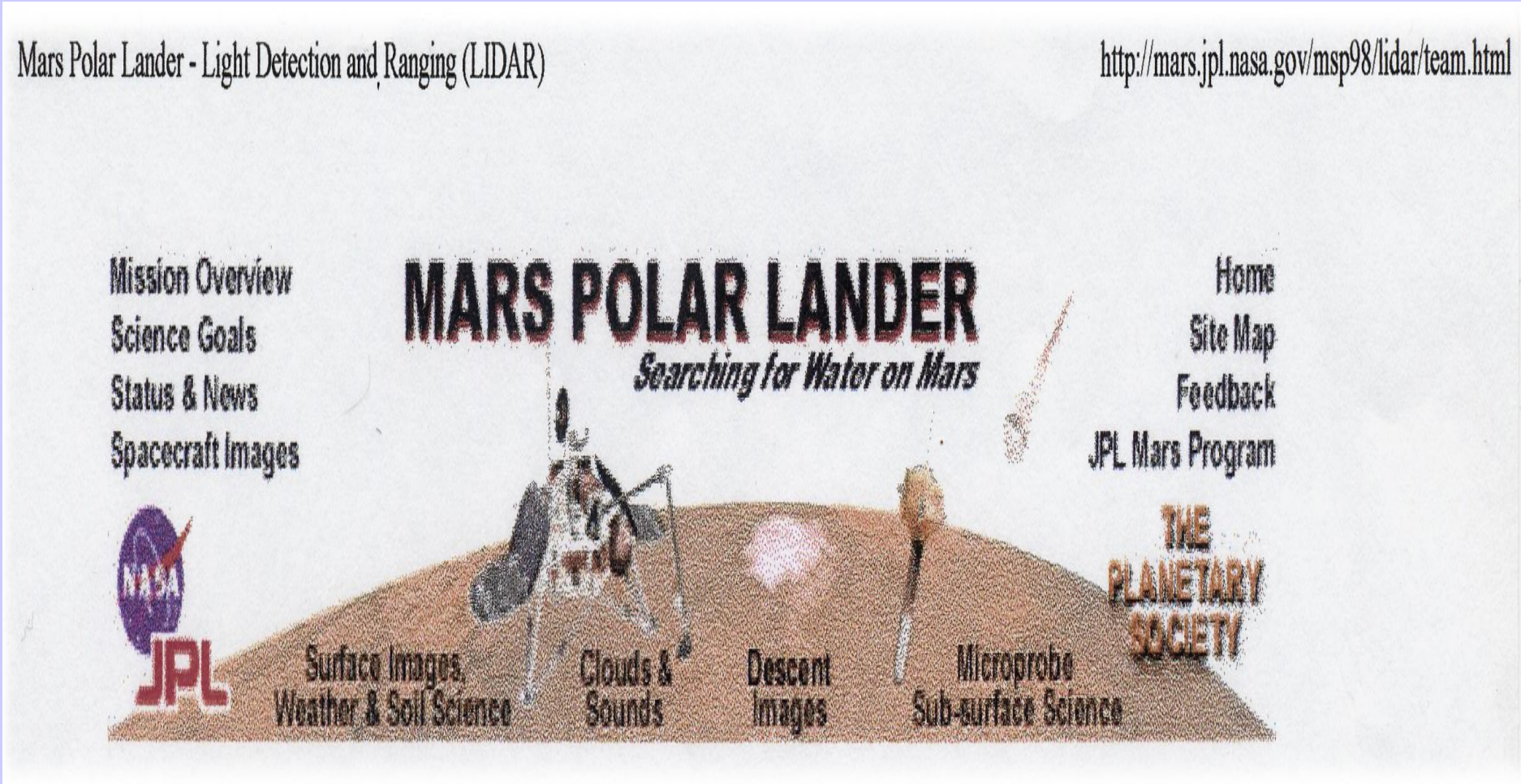
The Mars Surveyor 1998 Project and its contractor, Lockheed Martin Aerospace, are to be congratulated on the highly professional and technically comprehensive manner in which the Payload Accommodation Study was conducted over the past 5 months. I am confident that the selected payload will provide a wealth of scientific information that will be a major impetus for more comprehensive future Mars exploration missions.

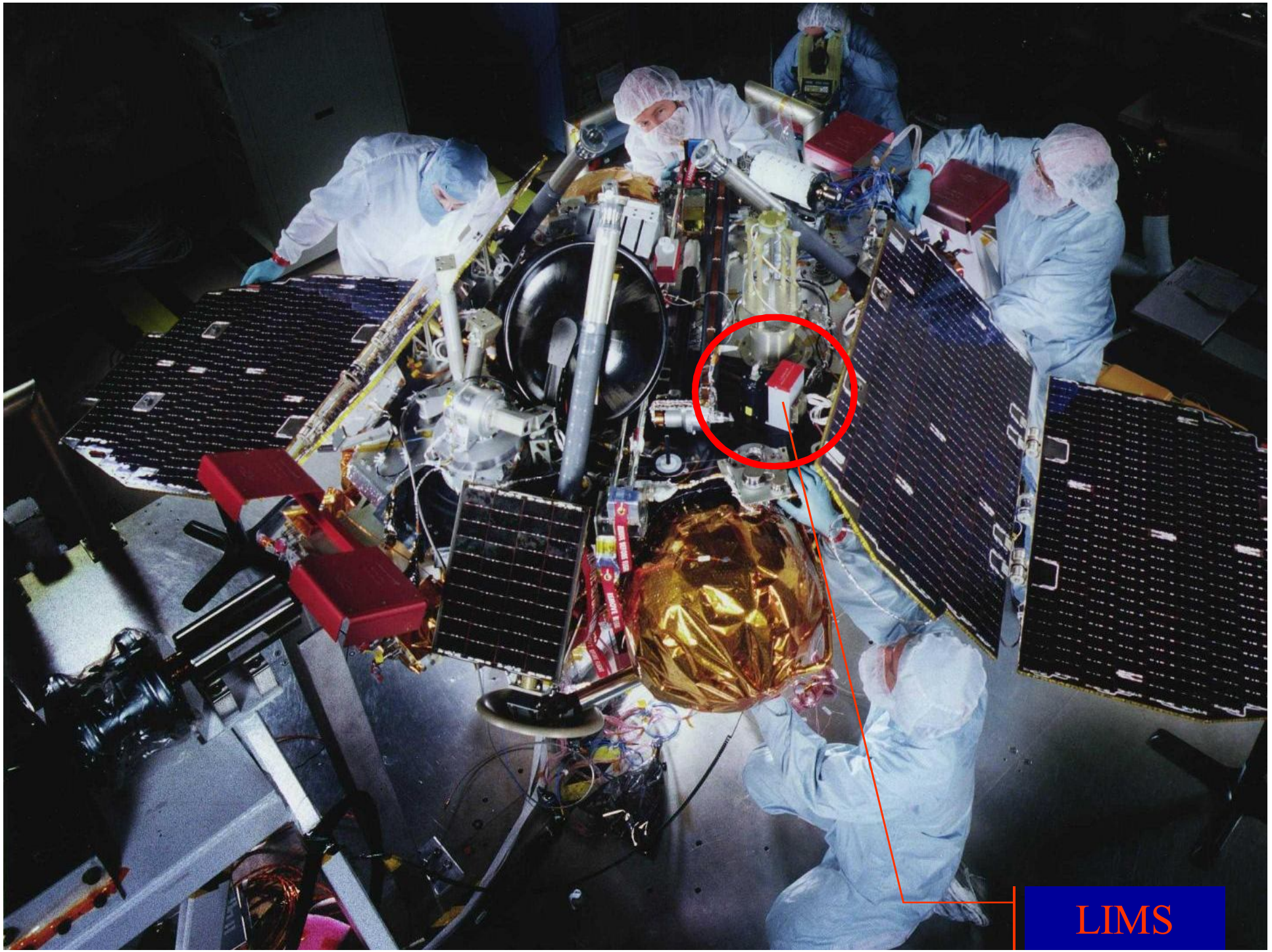
Jurgen H. Rahe

cc:
JPL/264-400/Mr. N. Haynes
JPL/169-237/Dr. R. Zurek
JPL/183-335/Dr. D. McCleese
Malin Space Science Systems, Inc./Dr. M. Malin
UCLA/Dr. D. Paige
UAZ/Dr. W. Boynton
UAZ/Dr. P. Smith
IKI/Dr. S. Pershin
IKI/Dr. A. Galeev
IKI/Dr. V. Moroz

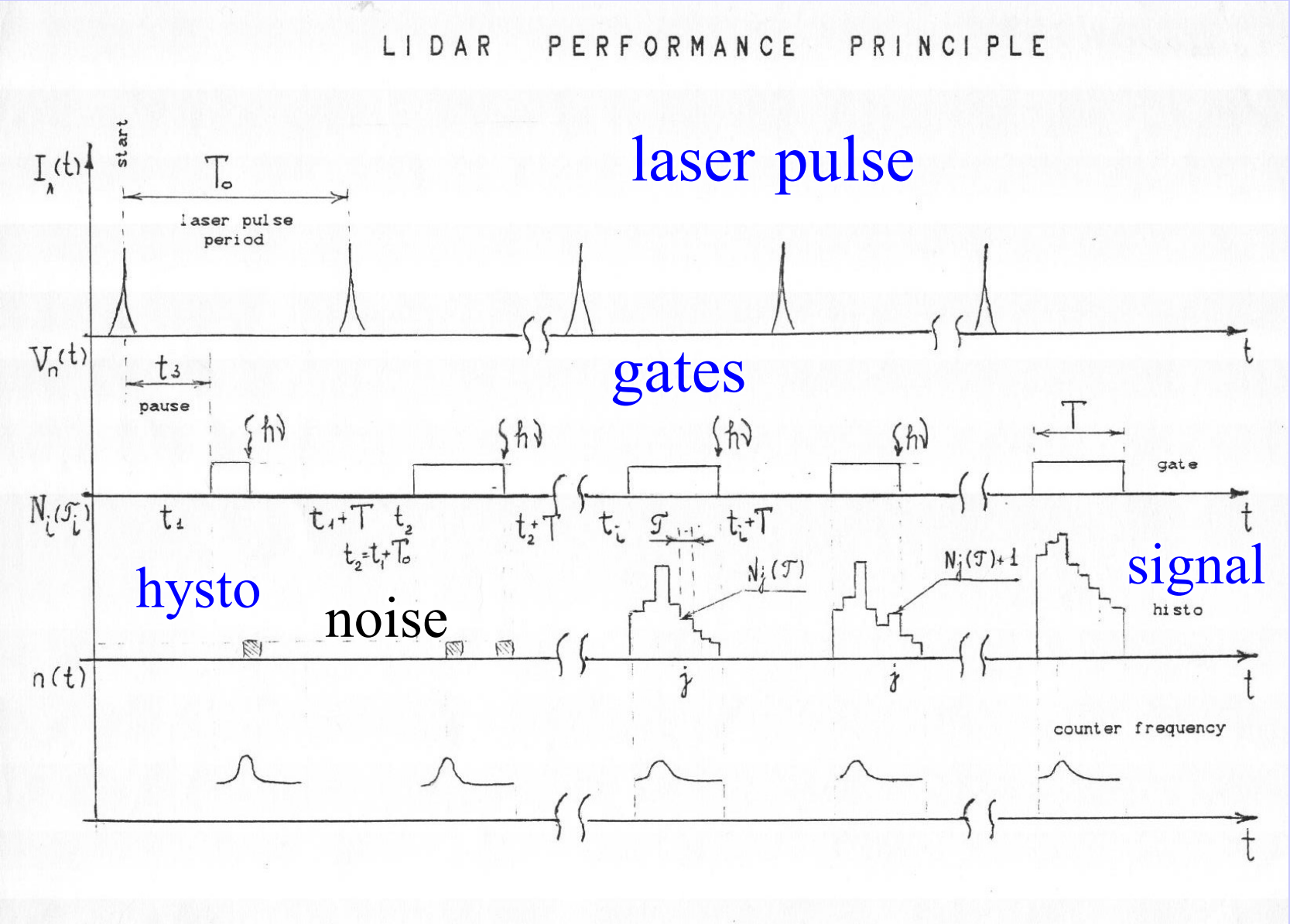
1999 - The first Lidar on Mars surface (South Pole)

Congratulations with 10th anniversary !!




LIMS

Lidar principle with Single Photon Avalanche Diode as receiver



Motivation

- Can we measured the distance
  with **centimeter accuracy**
  by τ =15 ns (~4.5m) pulsed rangefinder based on
  eye-safe diode laser and SPAD as receiver?
- distance is $$L = c\,\Delta t\,/2,$$

  where Δt **is time of flight;**

  accuracy is $$\Delta L = c\tau/2,$$

  where τ **is pulse duration (about 4.5 m)**

NEW LASER SAFETY CONCEPTS

D.SLINEY. **LASER FOCUS WORLD**. 1994. P.185

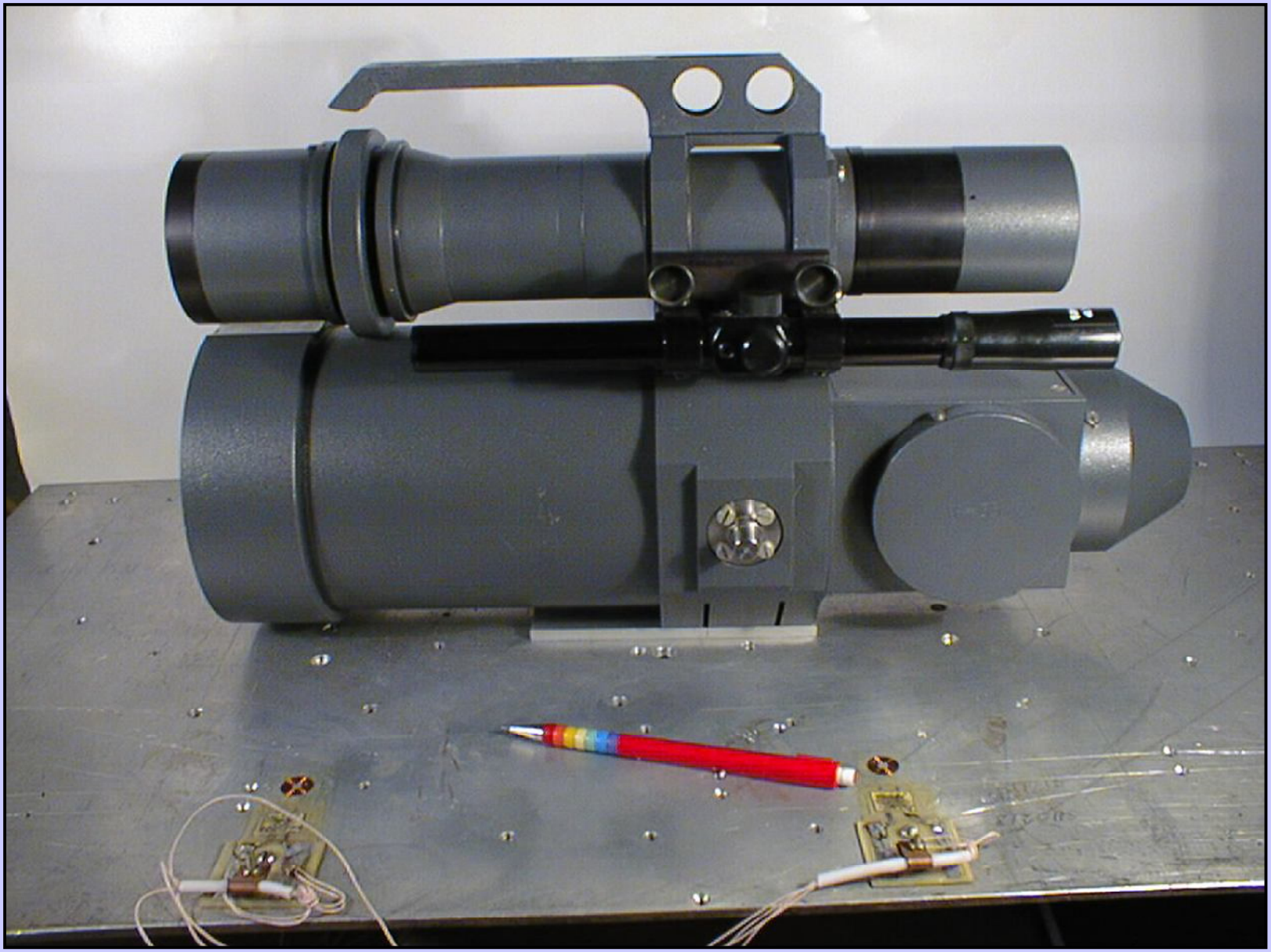
LASER TYPE	WAVE-LENGTH	Maximum permissible exposure **(MPE)**
Argon Fluoride	193 nm	3,0 mJ/cm^2 over 8 h
Xenon Cloride	308 nm	40 mJ/cm^2 over 8h
Nitrogen	334 nm	1.0 J/cm^2 over 8 h
Agron Ion Helium-Neon Kripton Ion	488, 514.5 nm 632.8 nm 568, 647 nm	3.2 mW/cm^2 for 0.1 s 2.5 mW/cm^2 for 0.25 s 1.8 mW/cm^2 for 1.0 s 1.0 mW/cm^2 for 10 s
Nd:YAG/2 Ruby	532 nm 694.3 nm	0.5 μJ/cm^2 for 1 ns to 18 μs
Diodes	850 nm (typical)	1.0 μJ/cm^2 for 1 ns to 18 μs 2.0 mW/cm^2 for 10 s
Nd:YAG	1064 nm, 1334 nm	**No MPE for t < 1 ns** 5.0 μJ/cm^2 for 1 ns to 50 μs 5.0 mW/cm^2 at 1064 nm/10 s 40 mW/cm^2 at 1334 nm/10 s
Holmium/ Thulium	1.9 – 2.2 μm	100 mW/cm^2 for 10 s to 8 h, limited area 10 mW/cm^2 for > 10 s for most of body
Carbon monoxide Carbon dioxide	5 μm 10.6 μm	100 mW/cm^2 for 10 s to 8 h, limited area 10 mW/cm^2 for > 10 s for most of body

Sourcees: **ANSI standard Z – 136.1-1993**

Micro-Lidar advantages

- **Eye-safe and full trouble-free**
- **High efficiency – diode laser & photon counting**
- **Digital circuit– high stability to environment**
- **Reliability**
- **No interference**
- **High repetition rate-short acquisition time**
- **Photon counting – discrete statistics**
- **Multilayer clouds, plume detection and smoke mass measured for forest fires, bio-mass restoration after forest fires**

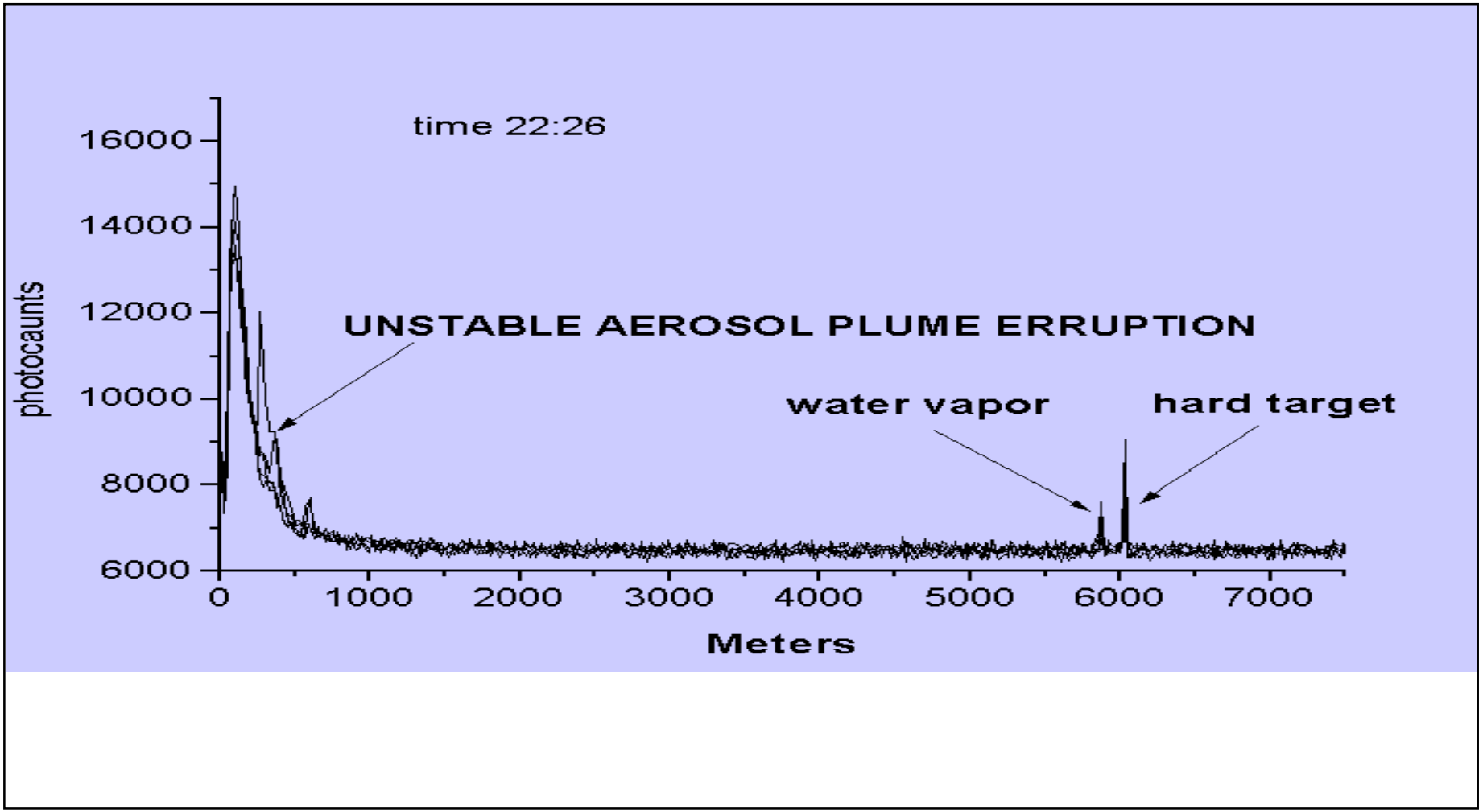
Hand-held aerosol Lidar




visor
in
LIDAR
out

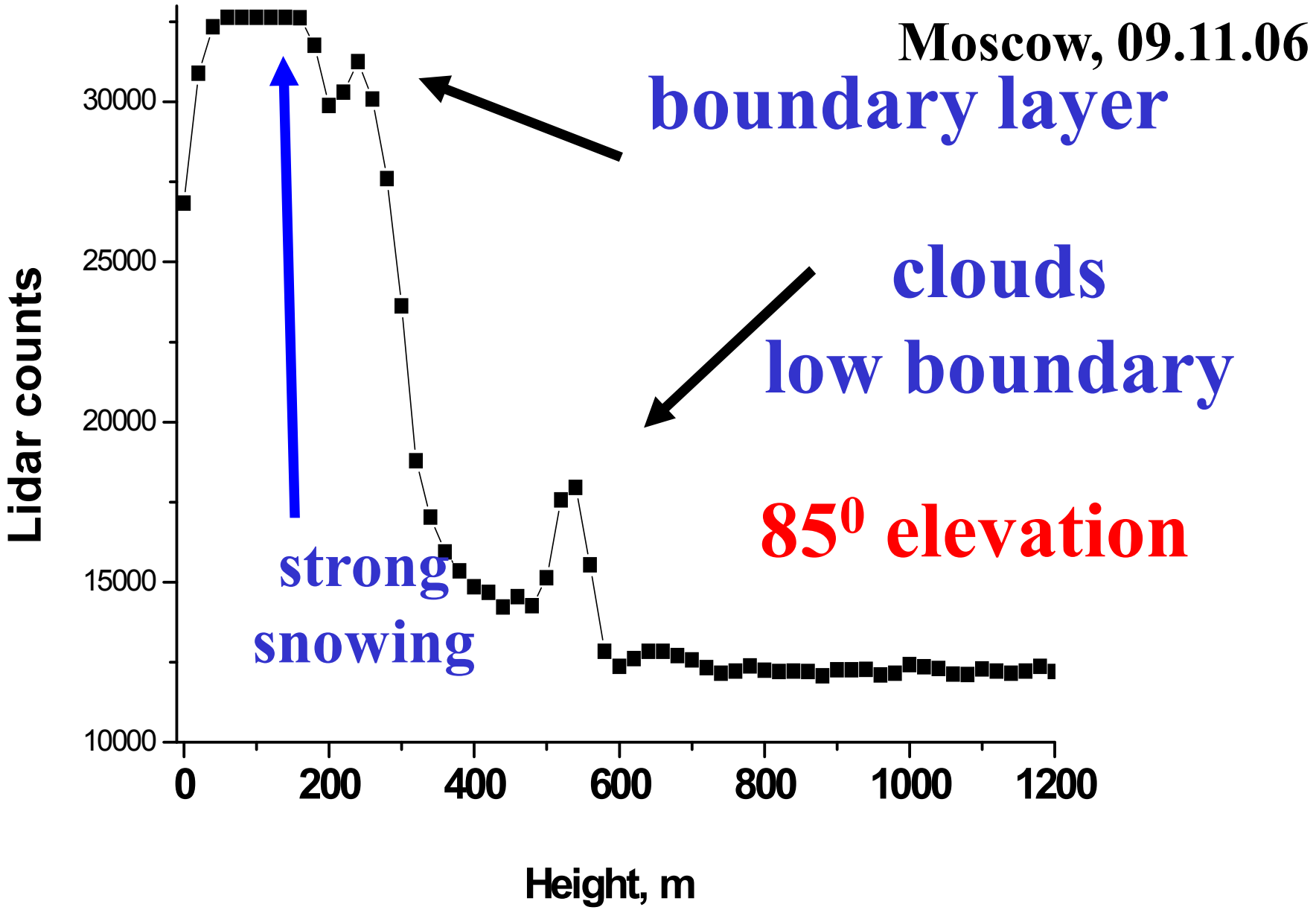
Urban aerosol monitoring

- **50 meters over the surface**



Clouds-layer monitoring

in strong snowing



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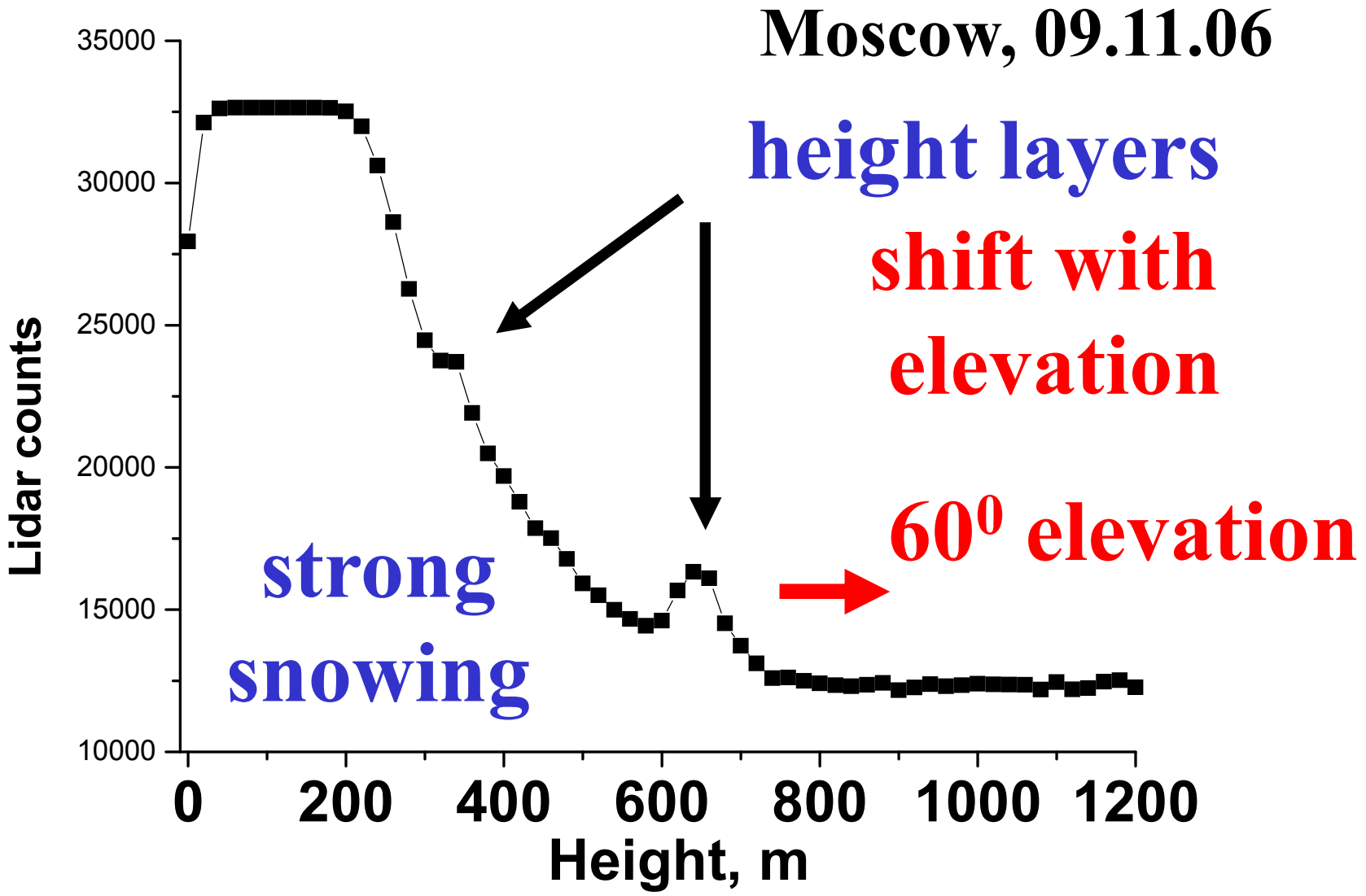
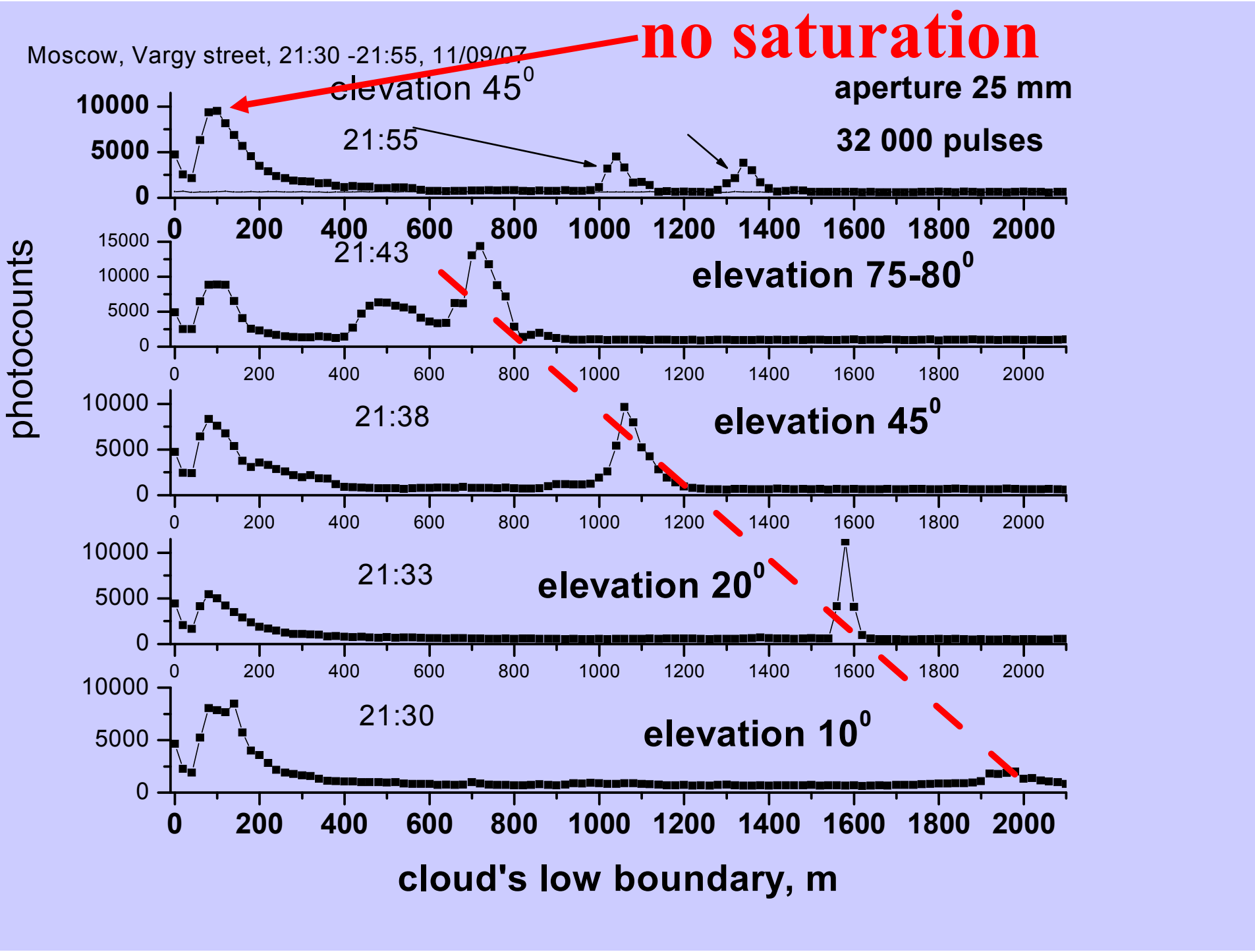
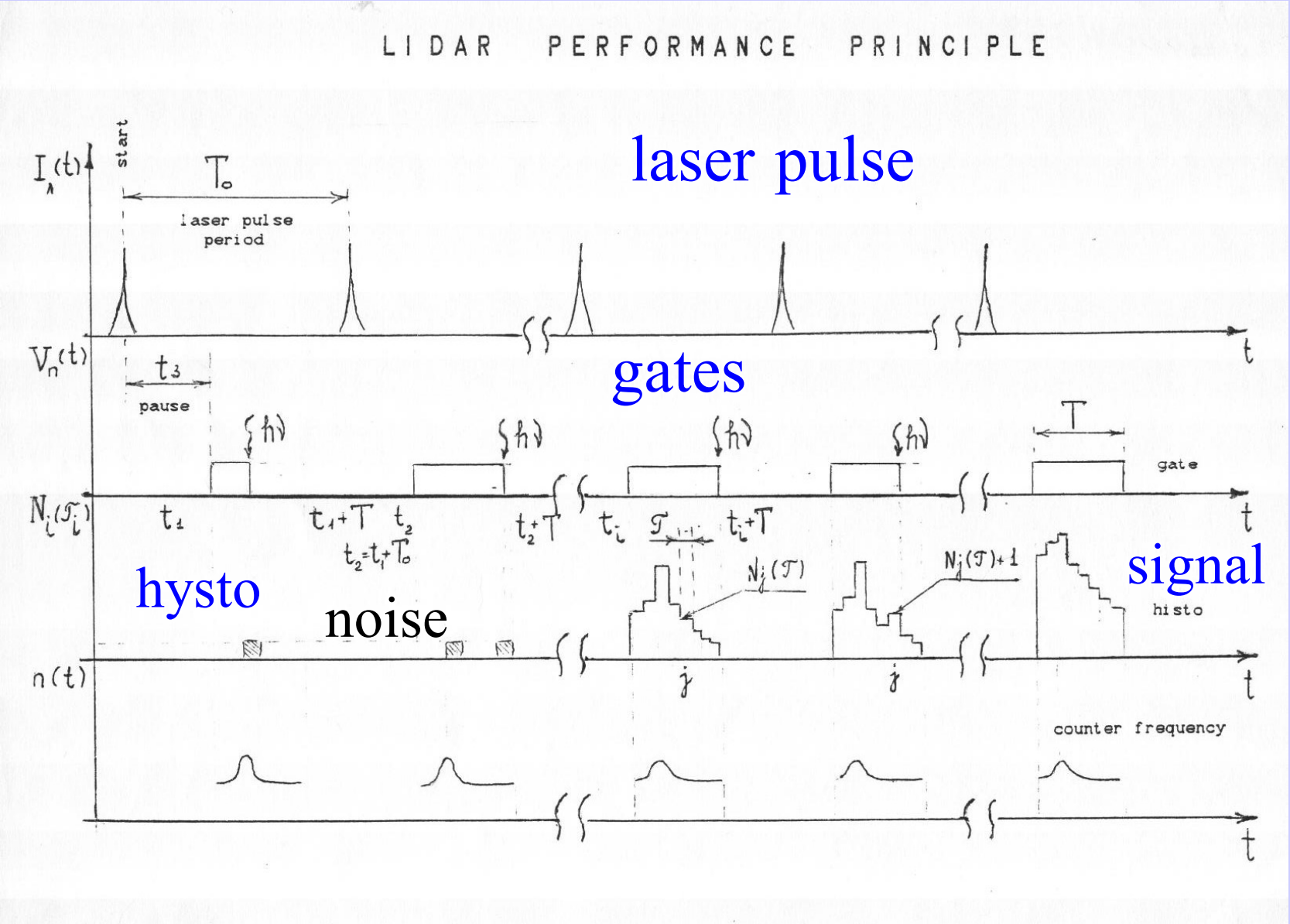



no saturation
Moscow, Vargy street, 21:30 -21:55, 11/09/07
elevation 45⁰
aperture 25 mm
32 000 pulses
21:55
21:43
elevation 75-80⁰
21:38
elevation 45⁰
21:33
elevation 20⁰
21:30
elevation 10⁰
photocounts
cloud's low boundary, m

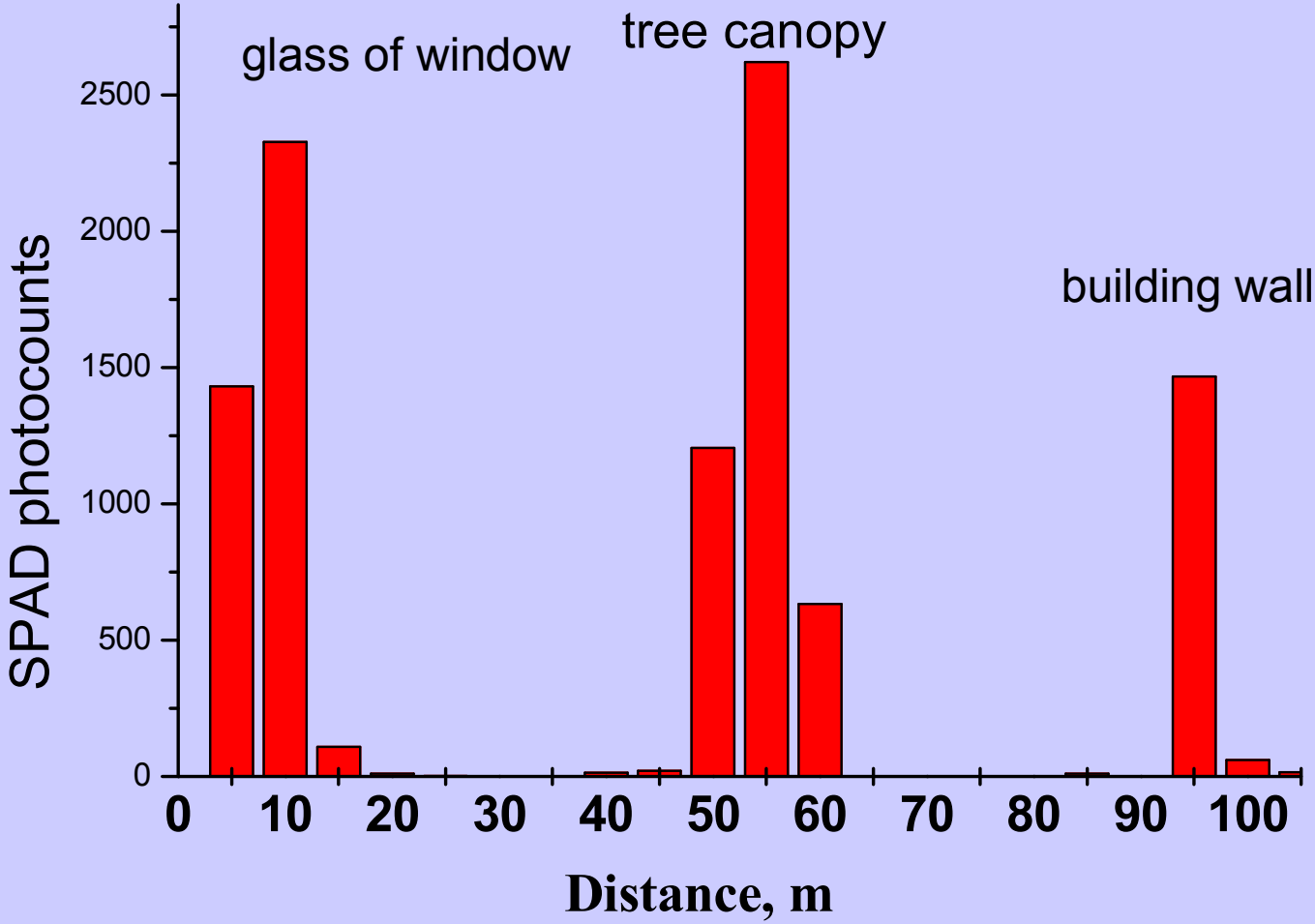
Eye-safe pulsed rangefinder

- **Improvements of space resolution**

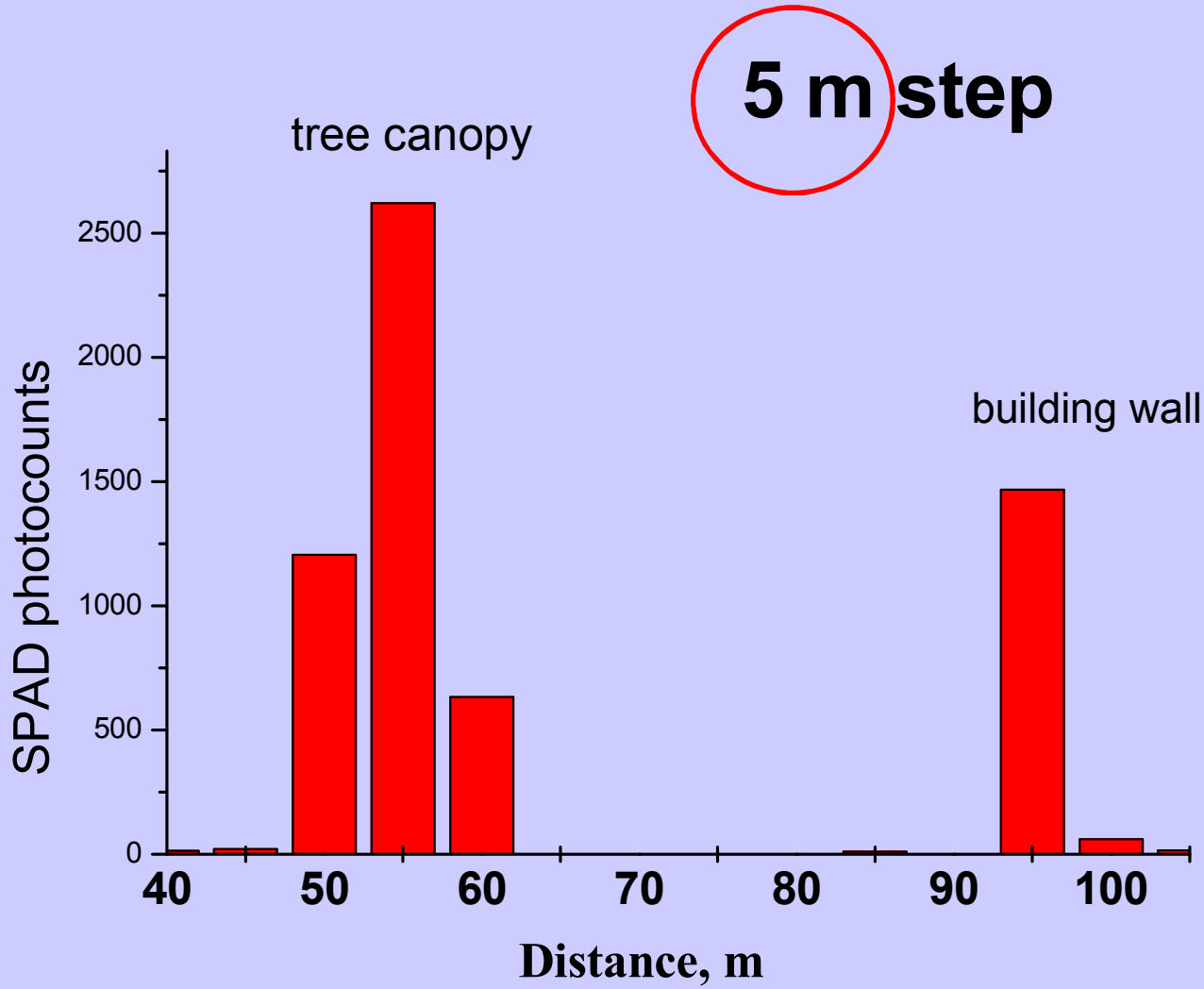
Lidar principle with Single Photon Avalanche Diode as receiver



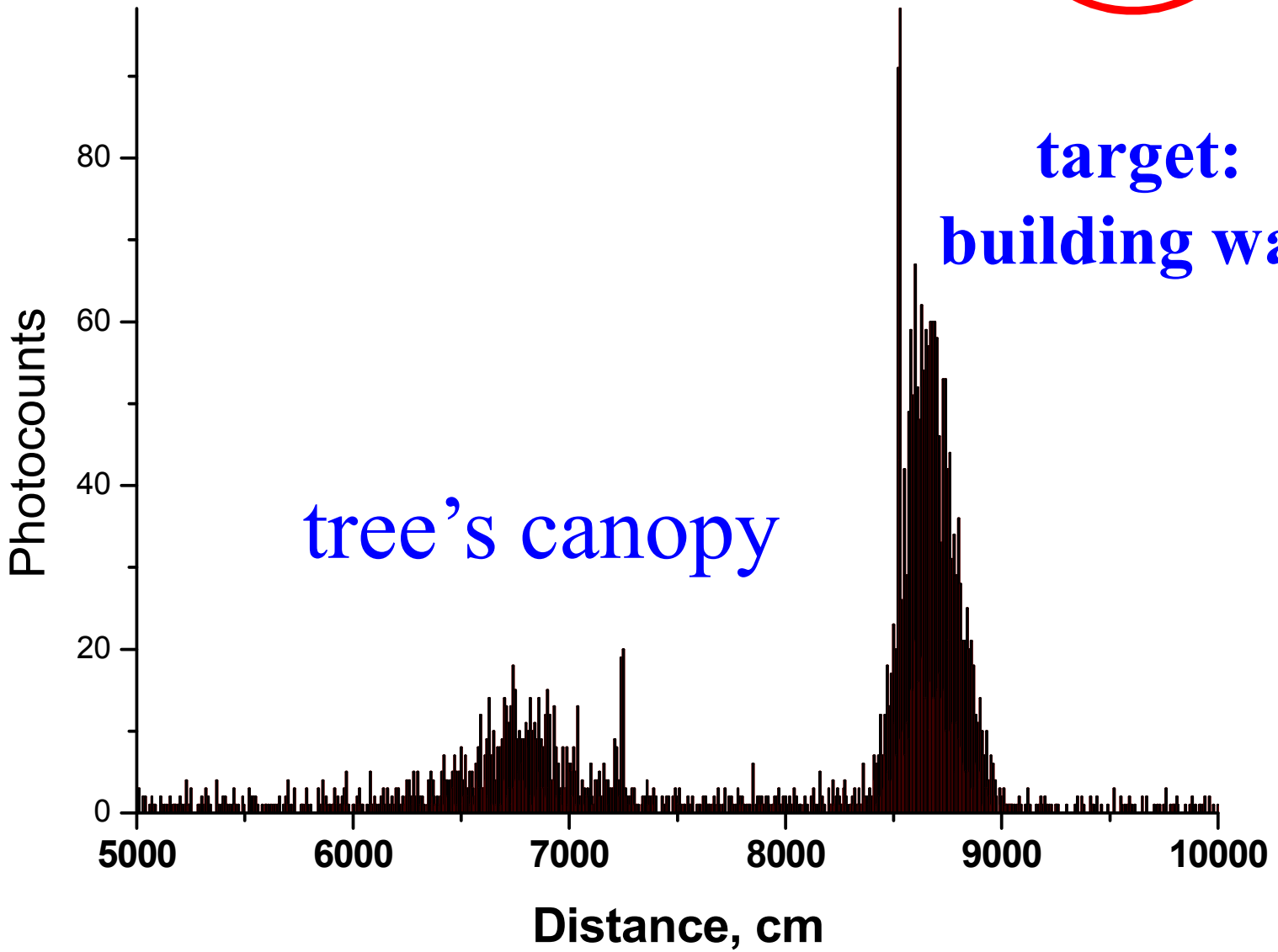
Target ranging through canopy, 5 m step



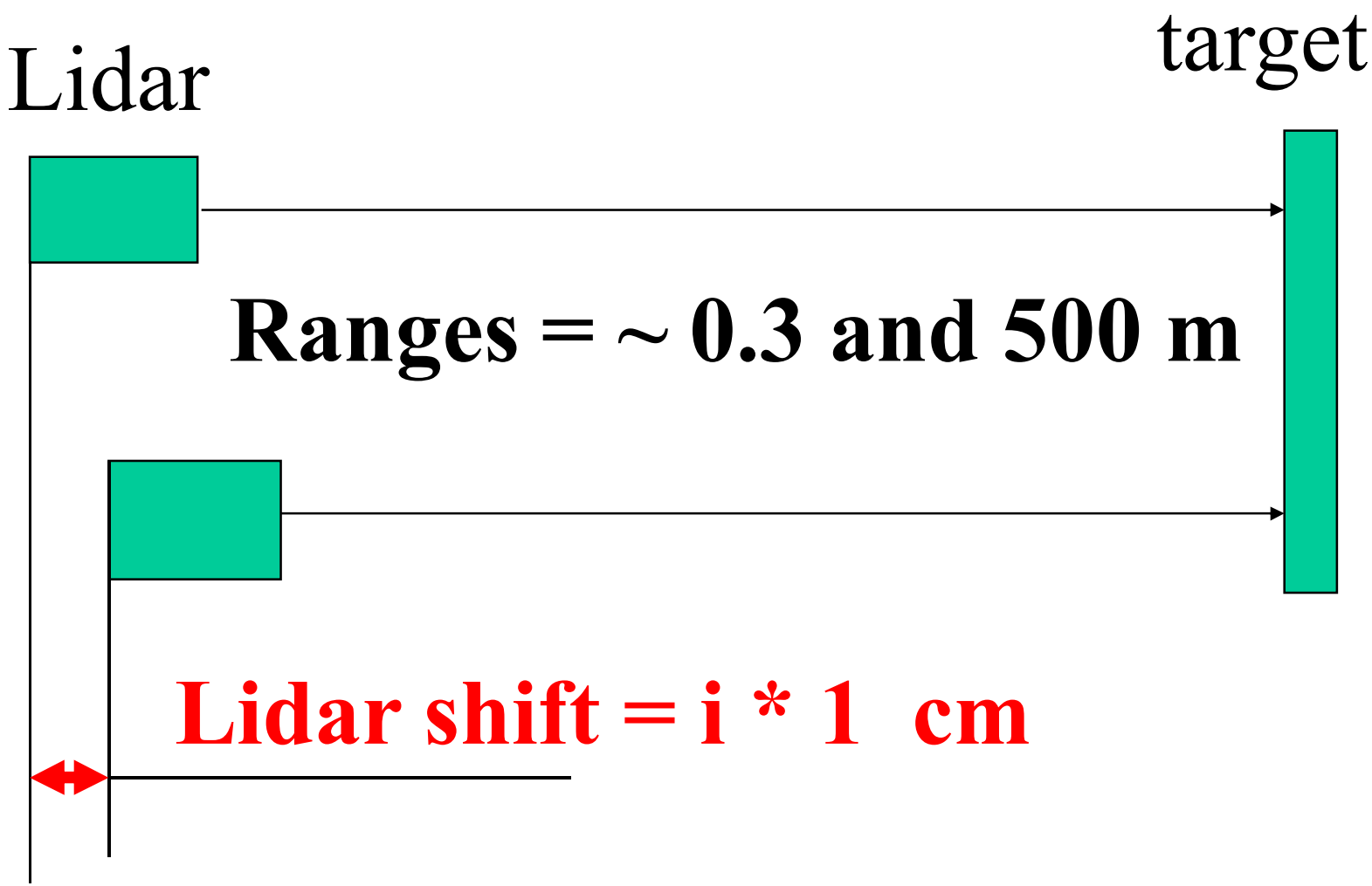
Target ranging through canopy, 5 m step



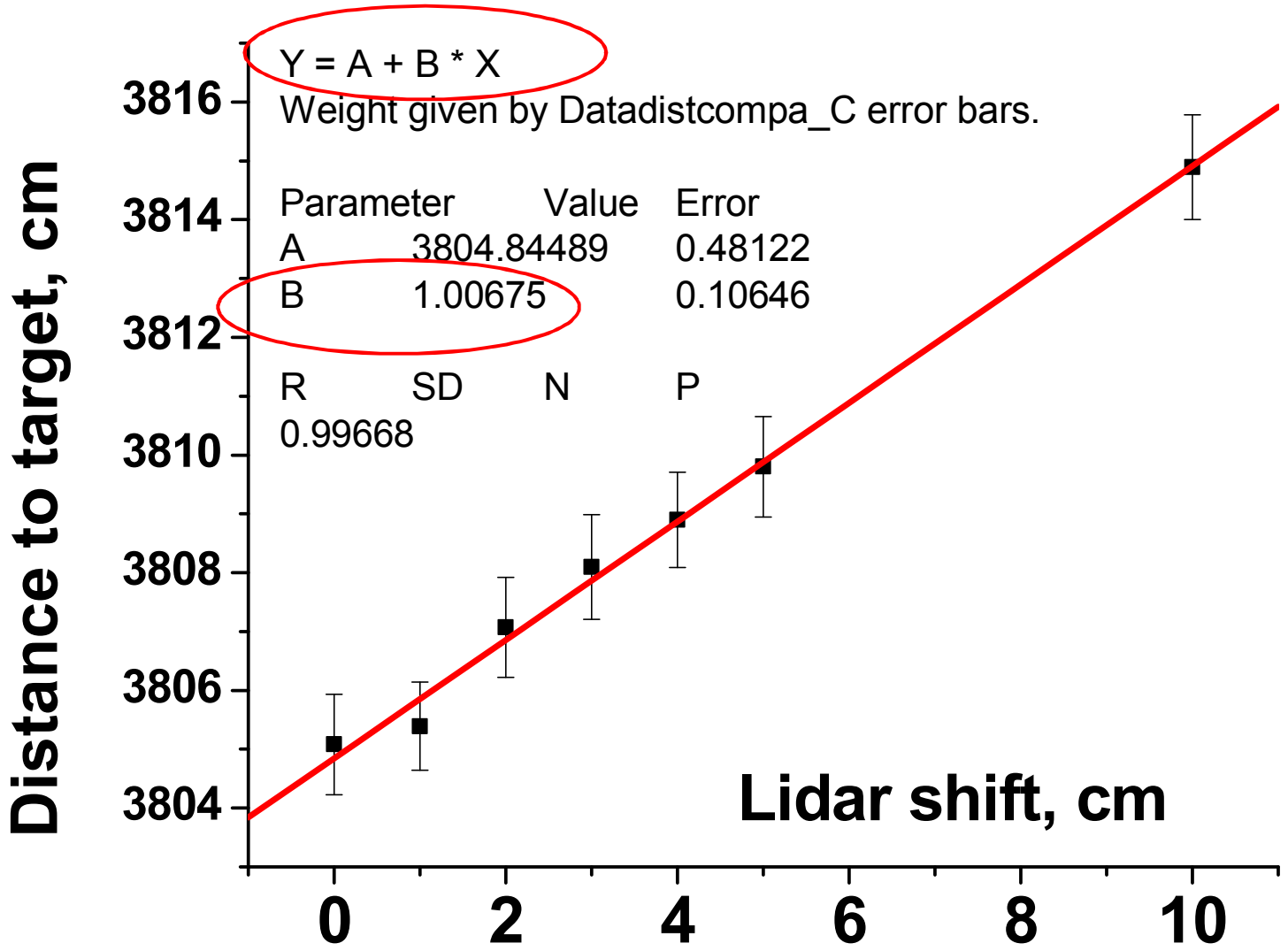
Target ranging through canopy, **5 cm** step



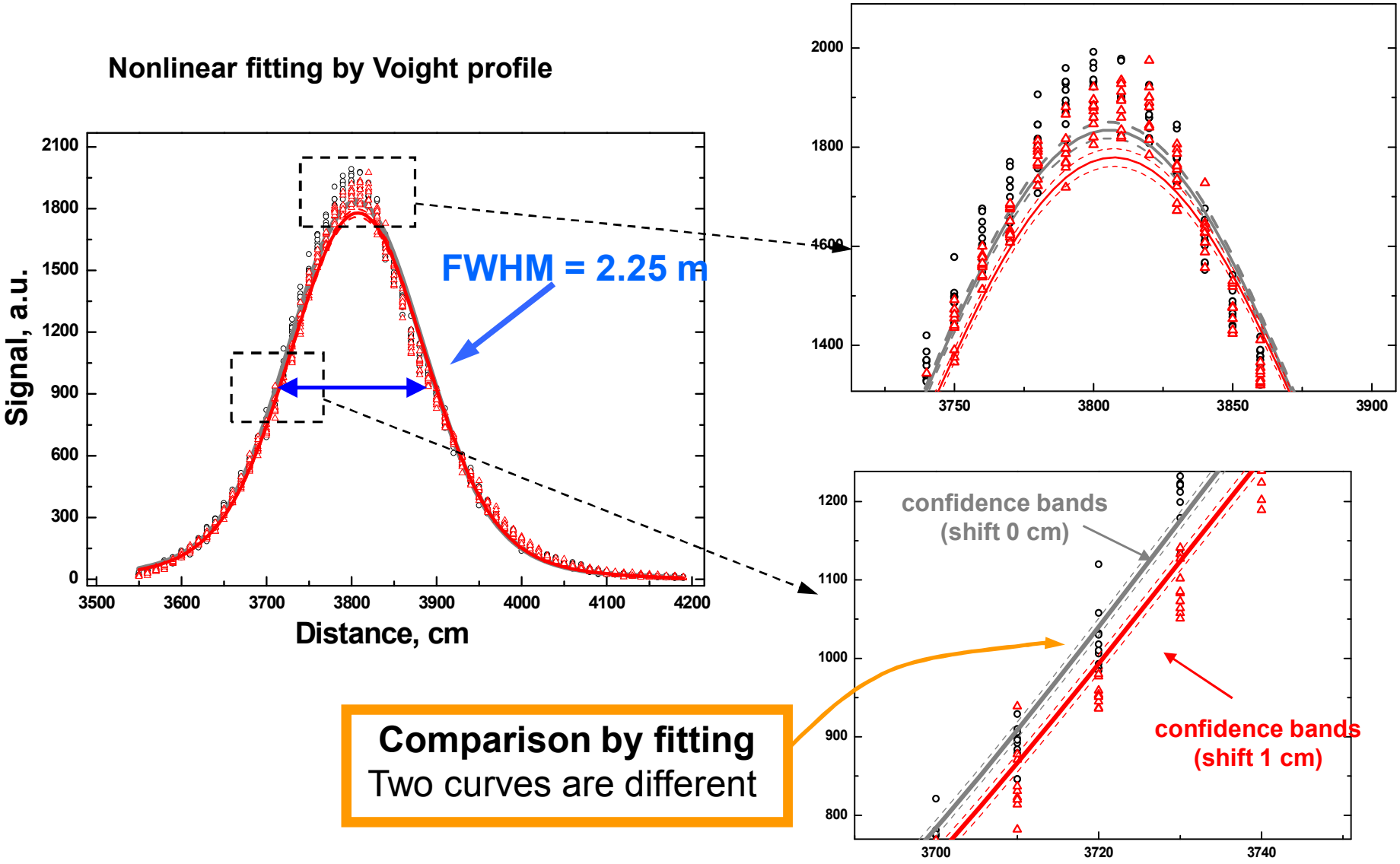
Range measurement scheme



Distance measurements



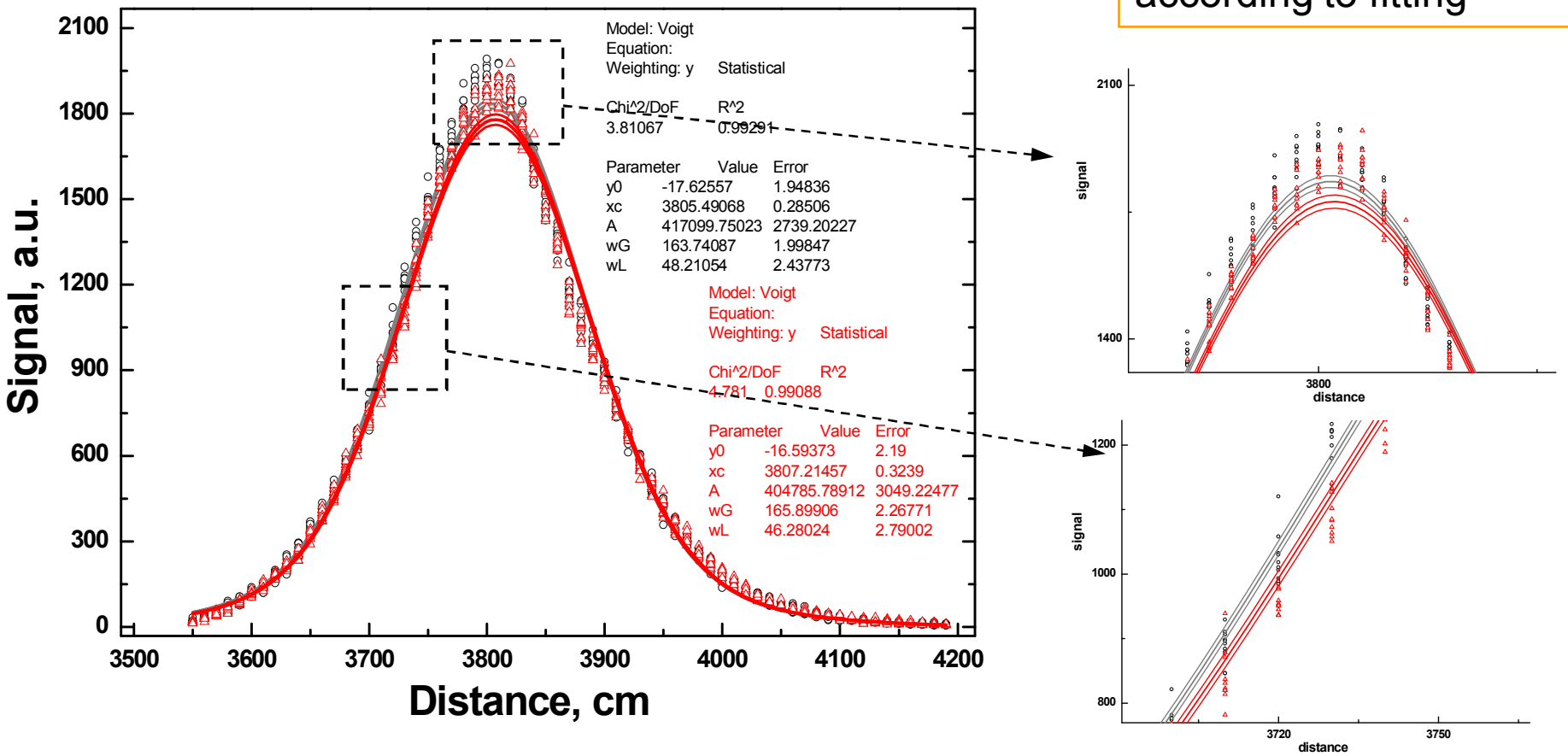
Distance measurements (curve fitting analysis)



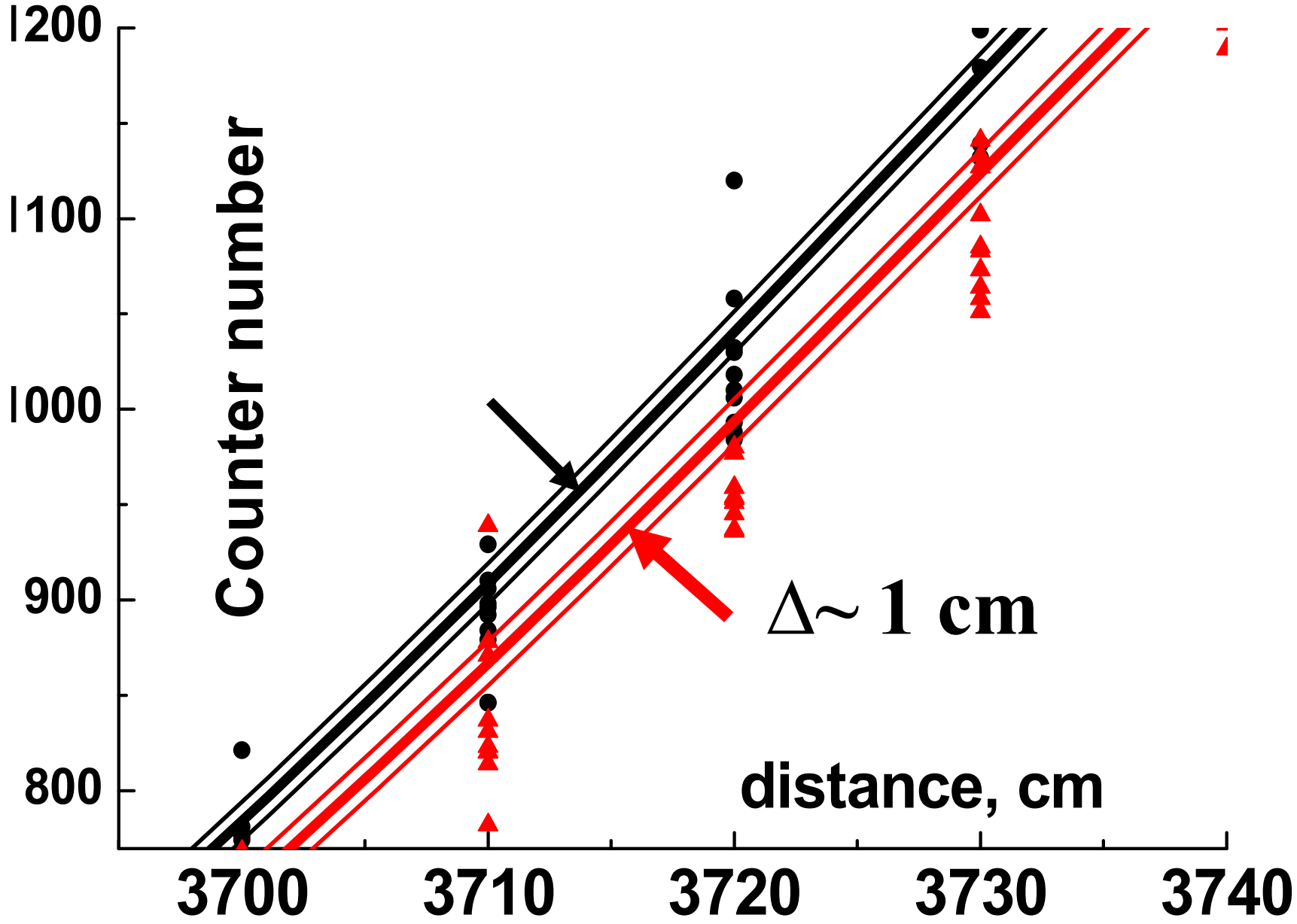
Comparison by fitting
Two curves are different

Distance measurements (curve fitting analysis)

Comparison by fitting
Two curves are different according to fitting



Signal fragment: the target shift ~1 cm



Sk Сколково

ООО «Центр исследований и разработок концерна АГАТ»
ОАО « Лыткаринский завод оптического стекла»
ЗАО НПАО «Эполар»

Skolkovo Center

Laser celeometer: cloud height

Лазерный измеритель нижней границы облаков

105275, г. Москва, шоссе Энтузиастов, д.29
E-mail: AgatLtd@list.ru
Тел./факс +7(499)5038787, 5038778

Август 2013 г.

Sk Сколково

ЛДВО - 01

- ***НАЗНАЧЕНИЕ И ОБЛАСТЬ ПРИМЕНЕНИЯ***
- ***ЛДВО-01 предназначен для оперативного дистанционного измерения высоты нижней границы облаков и вертикальной видимости.***

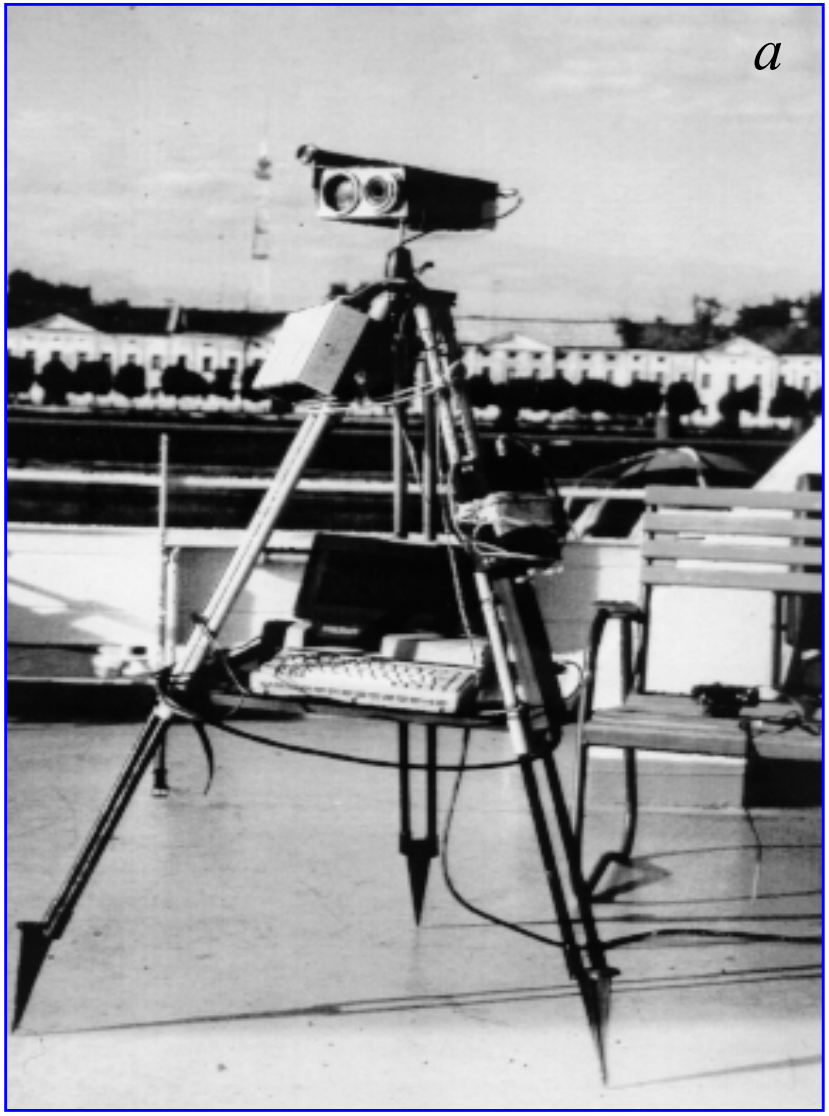
ЛДВО – 01
Общий вид опытного образца блочного исполнения

Conclusion

Micro-Joule eye-safe Lidar
can be widely used
for environment
monitoring
Without eyes protection
and
with cm accuracy ranging

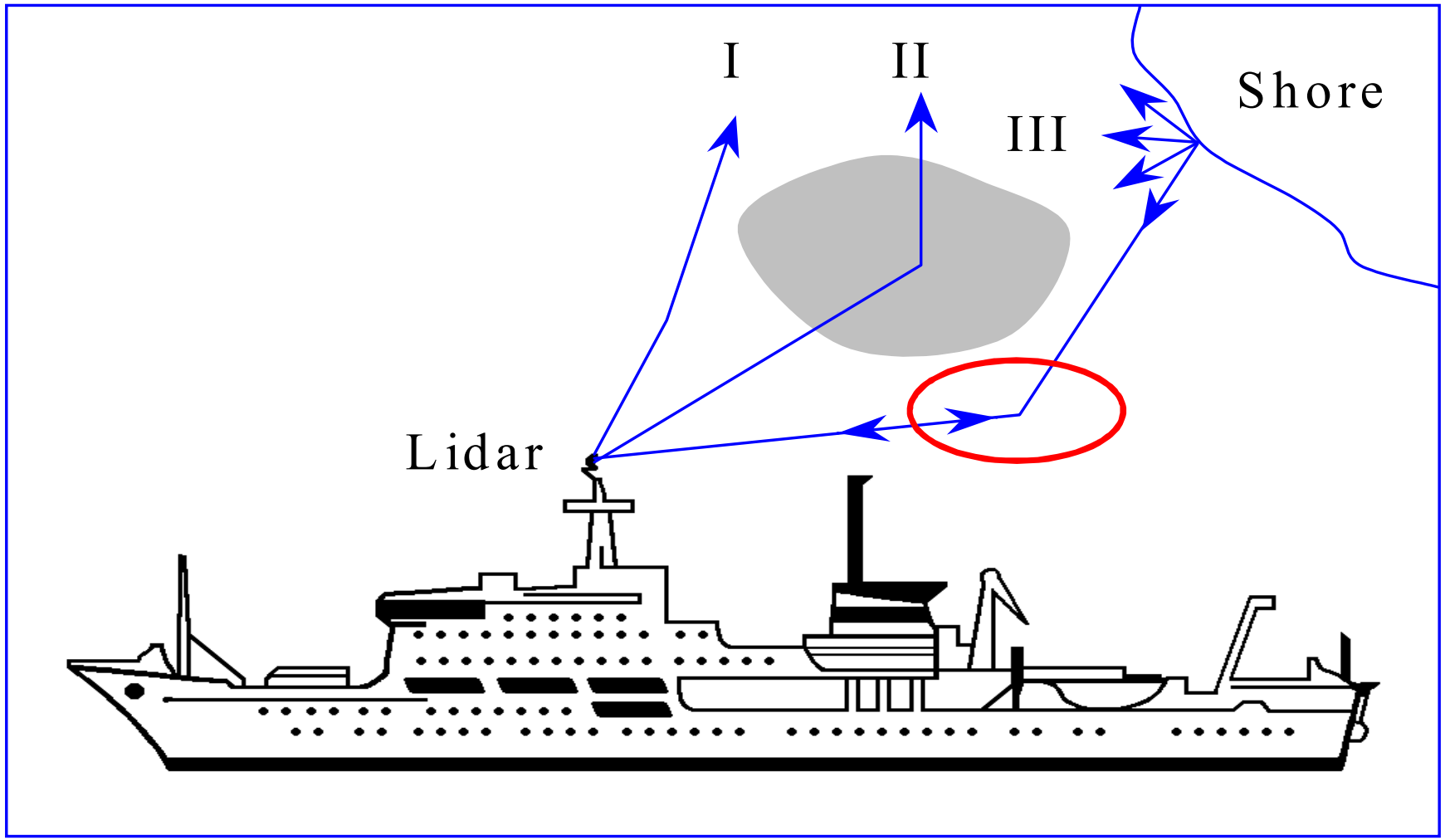
Thank for attention

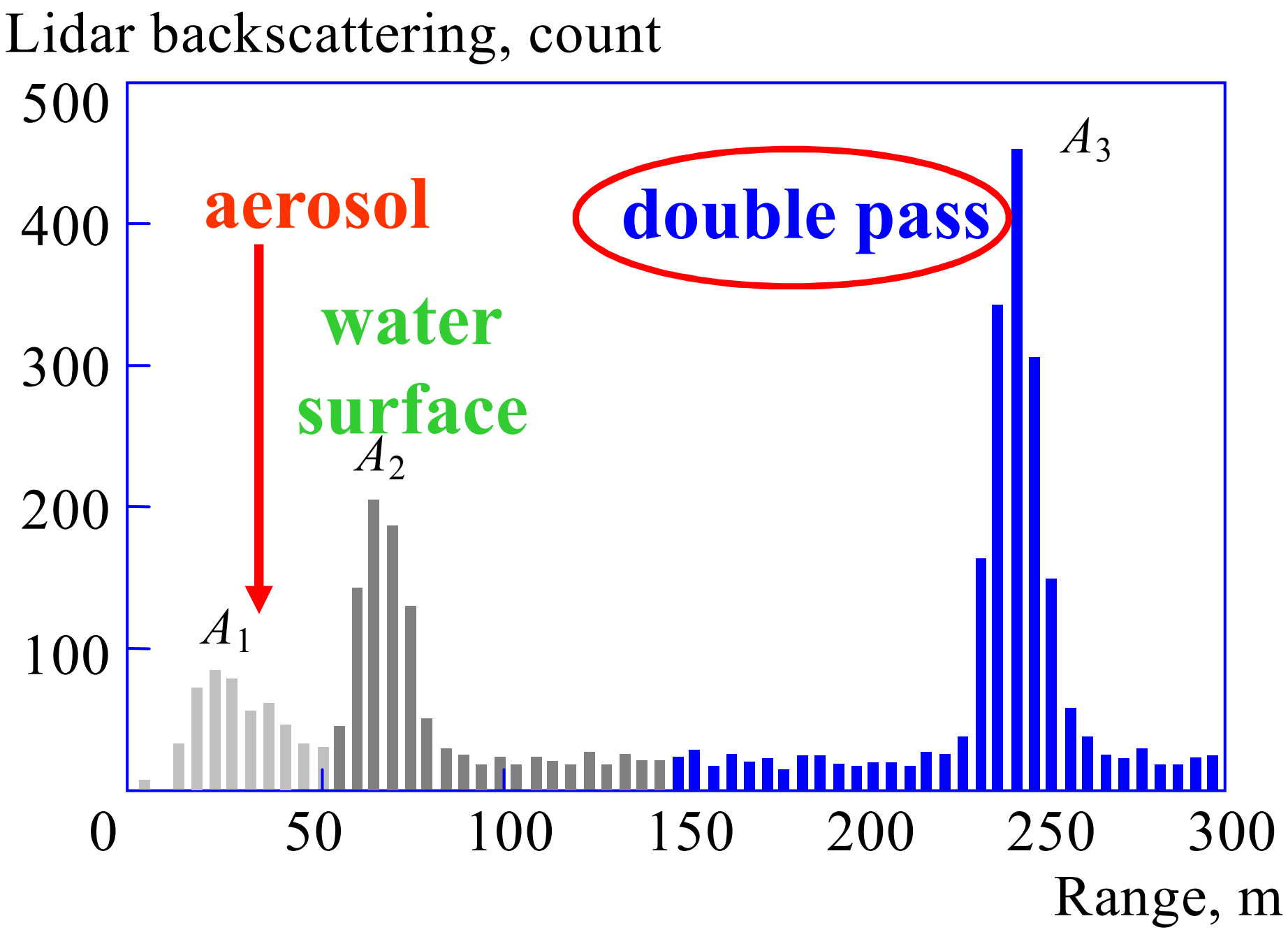
MicroJoule man-handle Lidar



Oil slick monitoring by lidar (*Volga, 1994*).

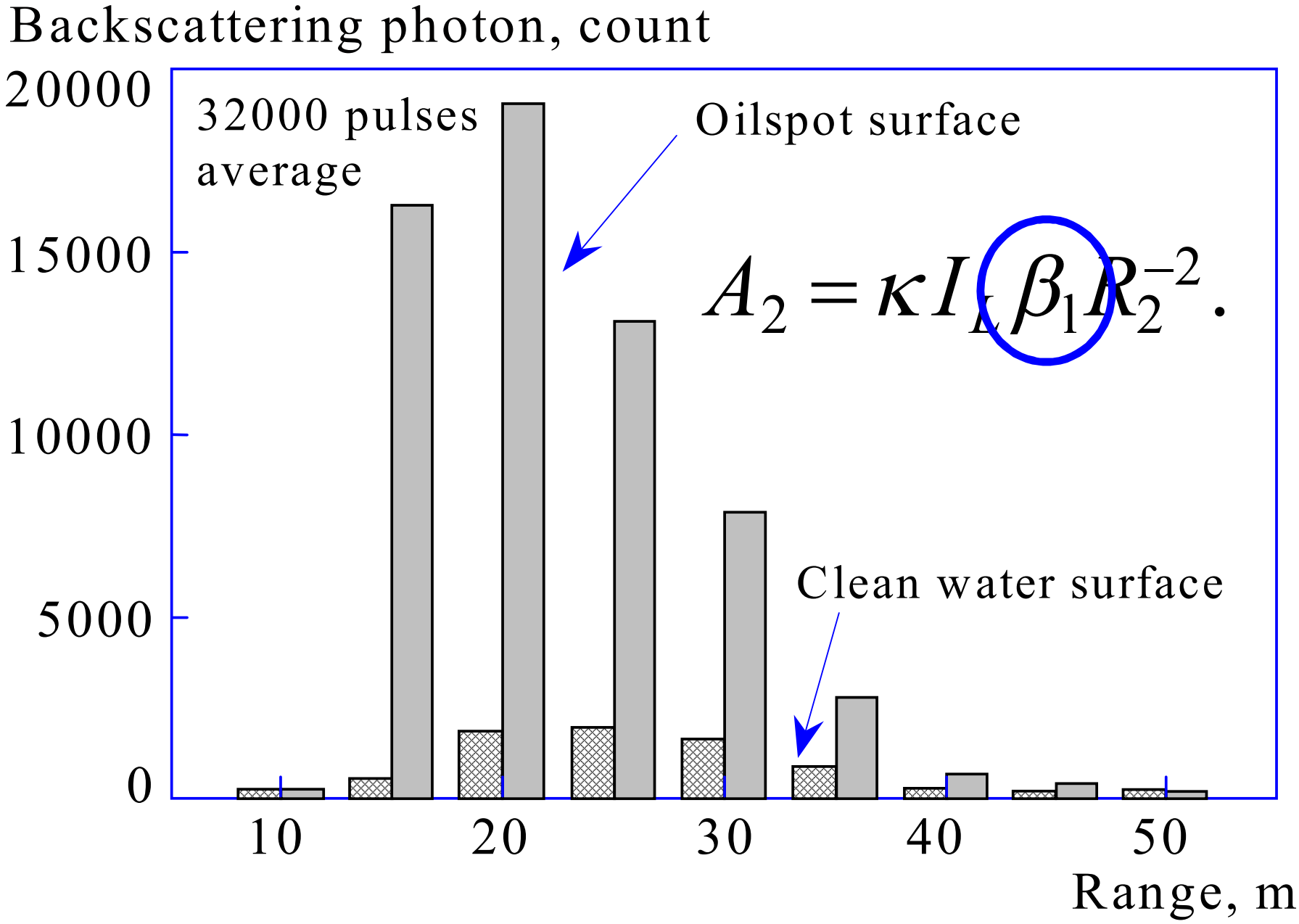
novel approach: double pass





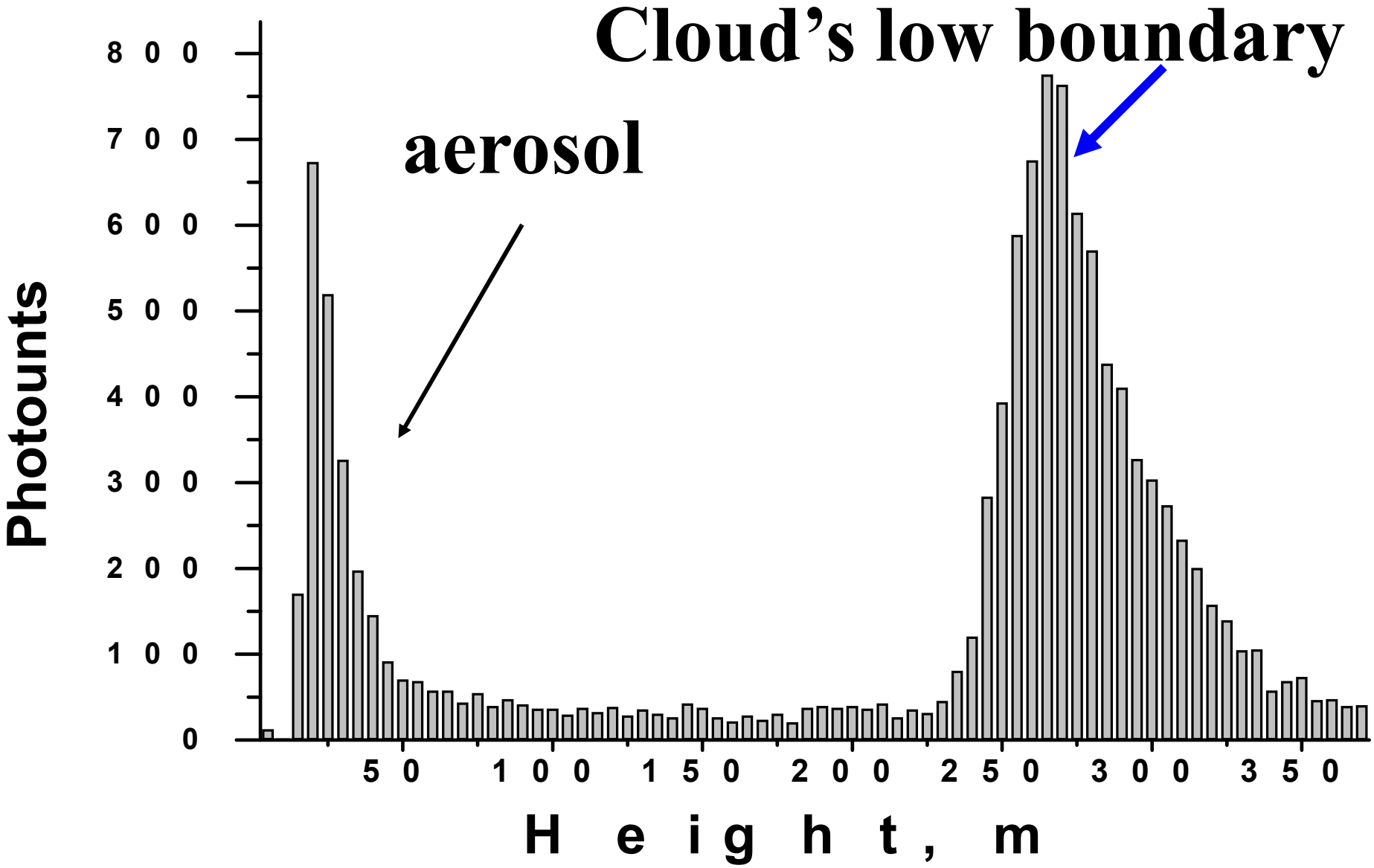
S.M. Pershin, Phys. of Vibr. V.9(3) 192 (2001)

10-FOLD increasing due to oil slick

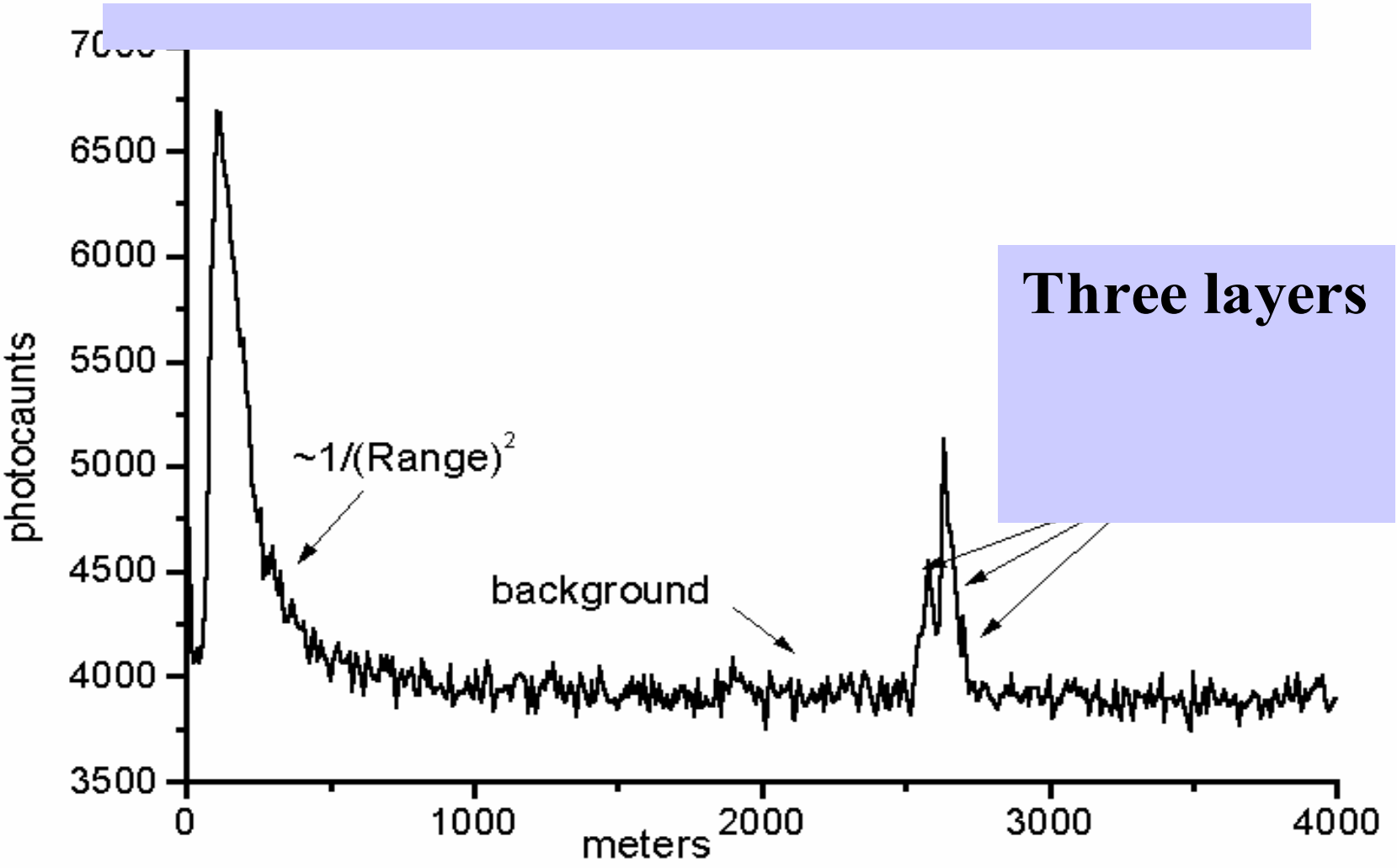


Clouds and layers monitoring

Clouds height measurements

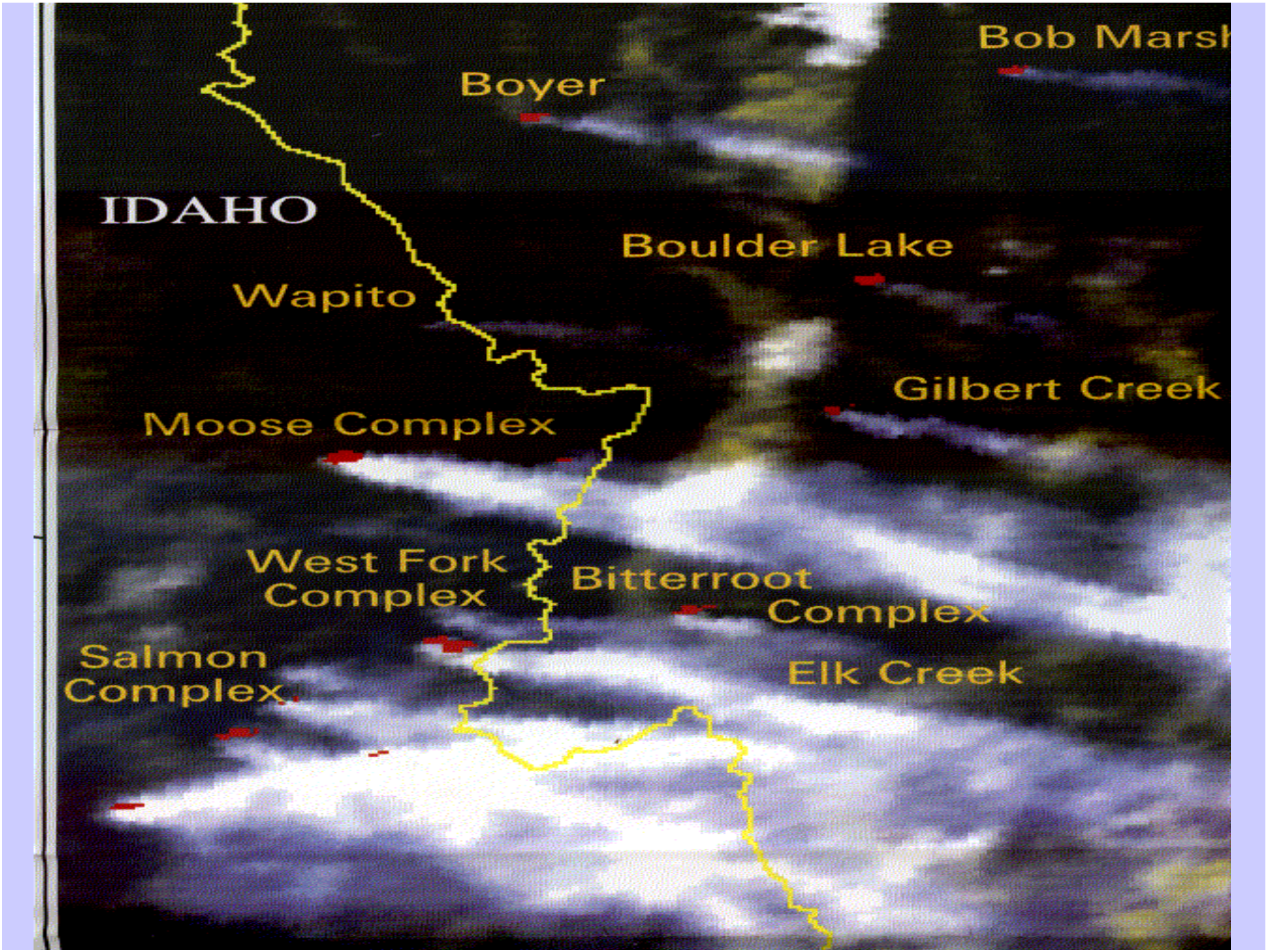


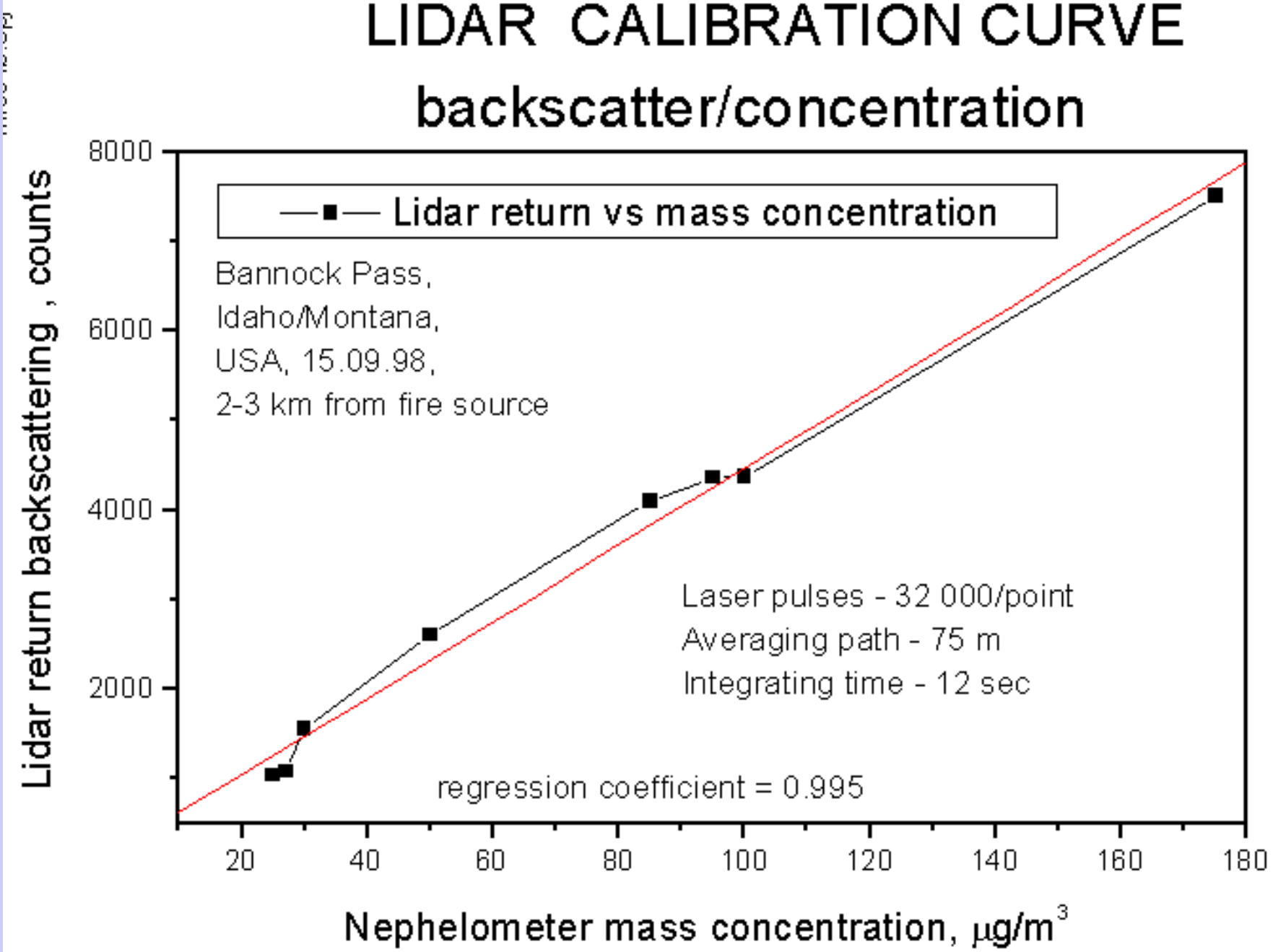
Multi-layers clouds



Forest fires monitoring

USA,
Montana-Idaho St.
Sept. 1999


Bob Marsh
Boyer
IDAHO
Boulder Lake
Wapito
Gilbert Creek
Moose Complex
West Fork
Complex
Bitterroot
Complex
Salmon
Complex
Elk Creek

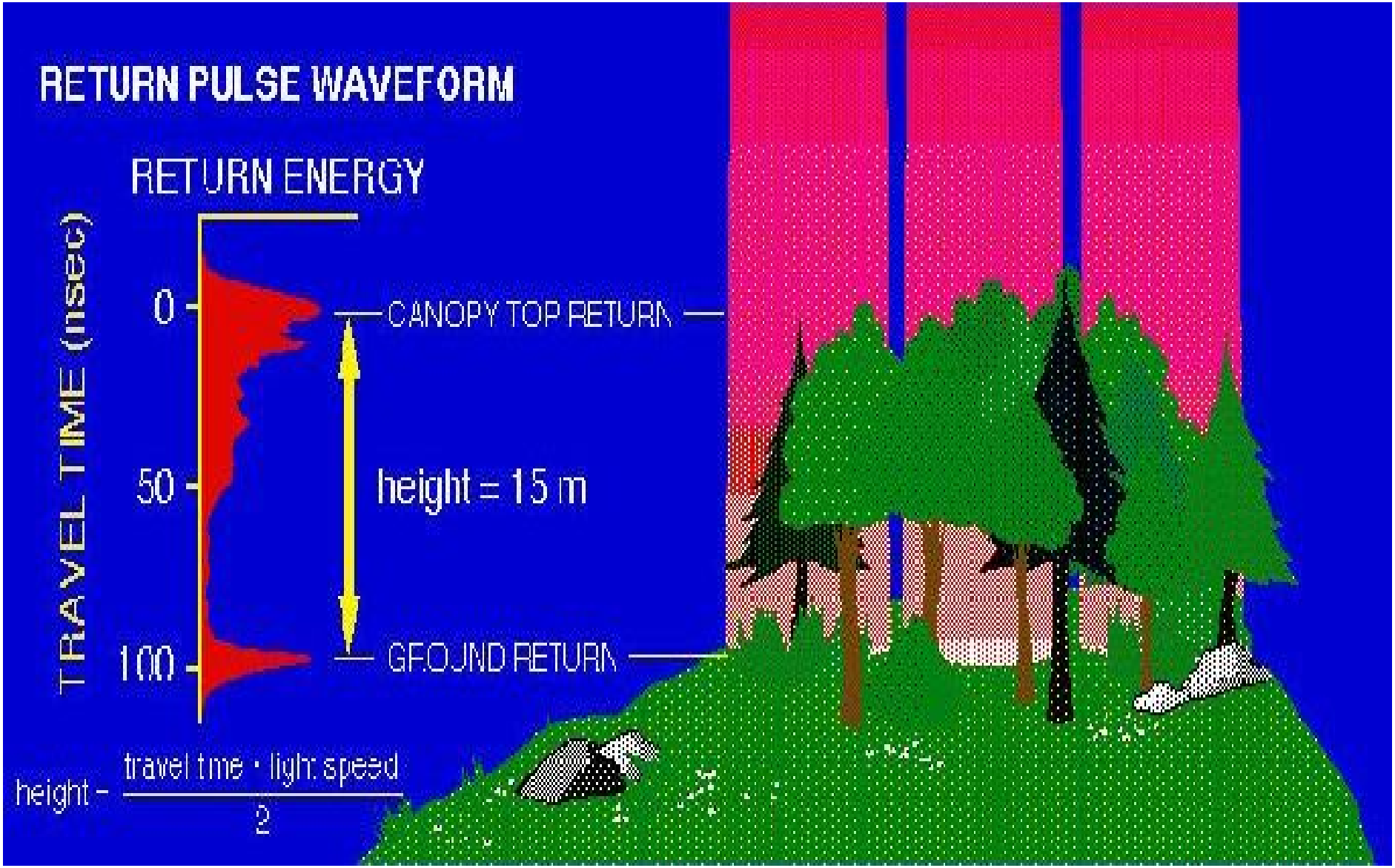

LIDAR CALIBRATION CURVE
backscatter/concentration
Lidar return vs mass concentration
Bannock Pass,
Idaho/Montana,
USA, 15.09.98,
2-3 km from fire source
Laser pulses - 32 000/point
Averaging path - 75 m
Integrating time - 12 sec
regression coefficient = 0.995
Lidar return backscattering , counts
8000
6000
4000
2000
20
40
60
80
100
120
140
160
180
Nephelometer mass concentration, μg/m3

Trees height monitoring

For biomass restoration after forest fires

Tree’s height monitoring via air-platform

Tree's biomass estimation by Lidar profiling of forest canopy

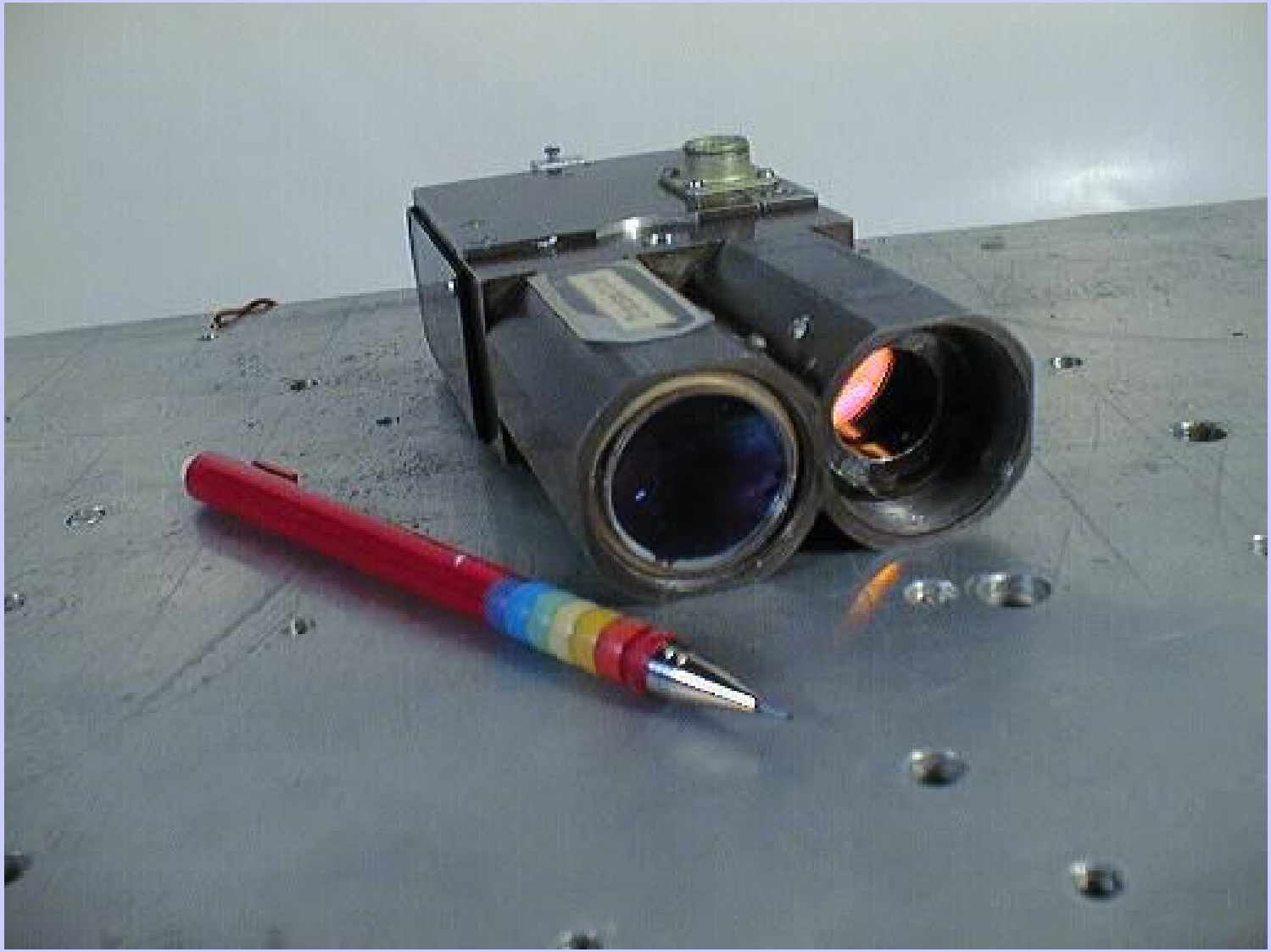


Micro -Lidar in Moscow State University,

Physics Department,

for student education courses

Compact microLidar




visor
In
LIDAR
out


visor
in
LIDAR
out

Acknowledgements

- **Makarov V.**
- **Patsaev D.**
- **Bukharin A.**
- **Nekhaenko V.**
- **Lyash A.**

Thanks for attention

Distance measurements (curve quality difference)

Nonlinear fitting by Voight profile