"Development and optimization of high-accuracy multi-wavelength LIDAR systems: The producer's point of view"

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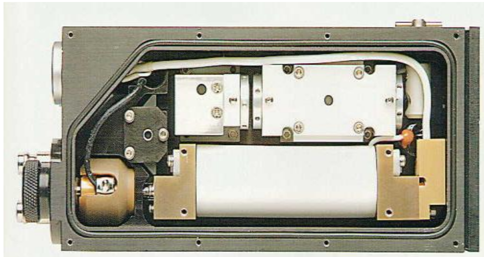
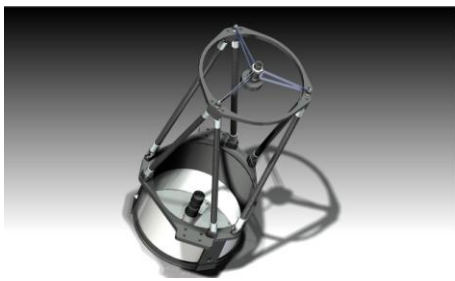
LIDAR COMPONENTS


Pulsed Laser Source


Beam Expanders & HR mirrors


Telescope

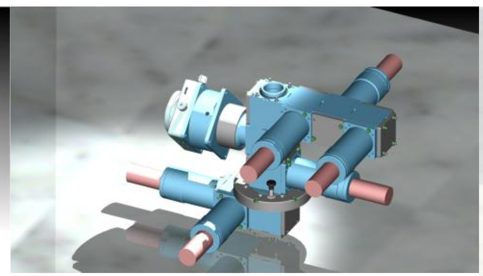
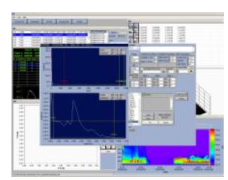

Detection unit


Photo Sensors


Digitizers


Computer


Software

Outline

1. Lidar Critical Components

   a. Laser
   b. Telescope
   c. Electronics

2. Common consideration
   a. Overlap
   b. Sensor no-homogeneity
   c. Mechanical realization

3. Conclusions

LIDAR COMPONENTS – Laser Source

Q-Switch Nd:Yag

Advantages

-High power -> better SNR -> higher you can “look”, better time resolution

Disadvantages

-High Cost

-Not eye-safe (not suitable for unattended operation)

DPSS

Advantages

-Lower cost

-Eye Safe (suitable for unattended operation

Disadvantages

-No good SNR

-No good energy stability, pointing stability and divergence

-Expensive to be replaced

LIDAR COMPONENTS – Receiver/Telescopes

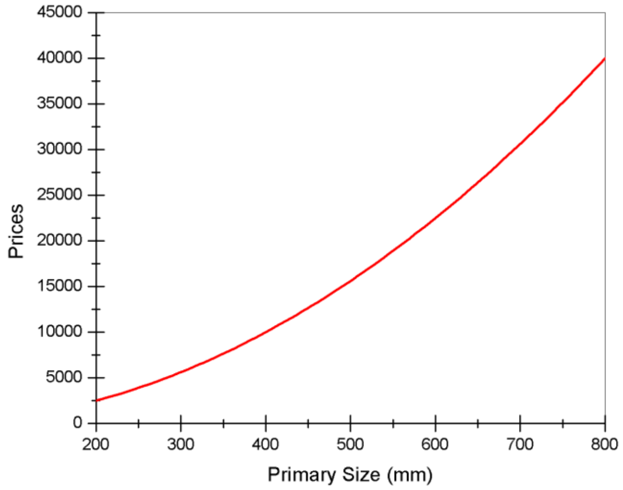
Bigger Telescopes:

More power-> higher effective range
better time resolution

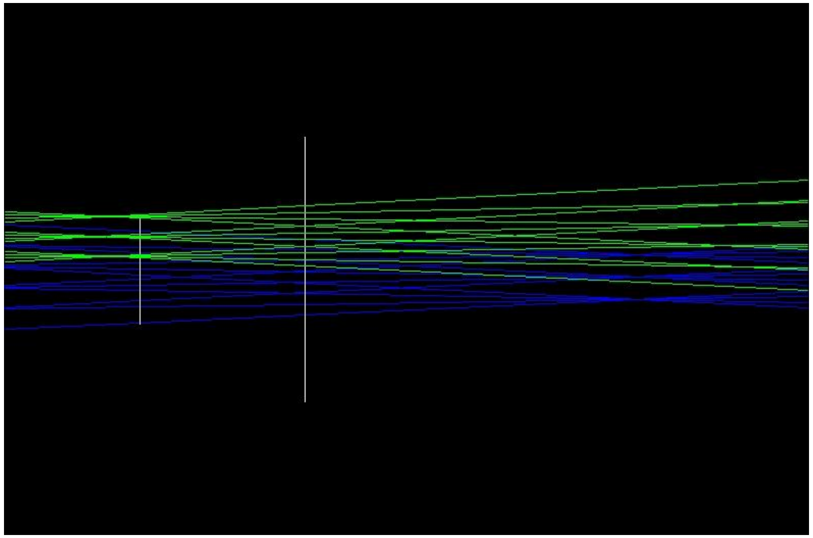
Bigger Telescopes:

Prices are analog to $\mathbf{R^2}$ (general for optics)

Not easily transportable



No telescope is capable to cover very low altitudes up to stratosphere (defocusing)



Solution: Two telescopes (one for near ranges and one for far ranges)
- -More expensive
- -Not transportable
- -Usually double electronics

User application needs (and budget) usually define the size and the type of the telescope

LIDAR COMPONENTS – Electronics

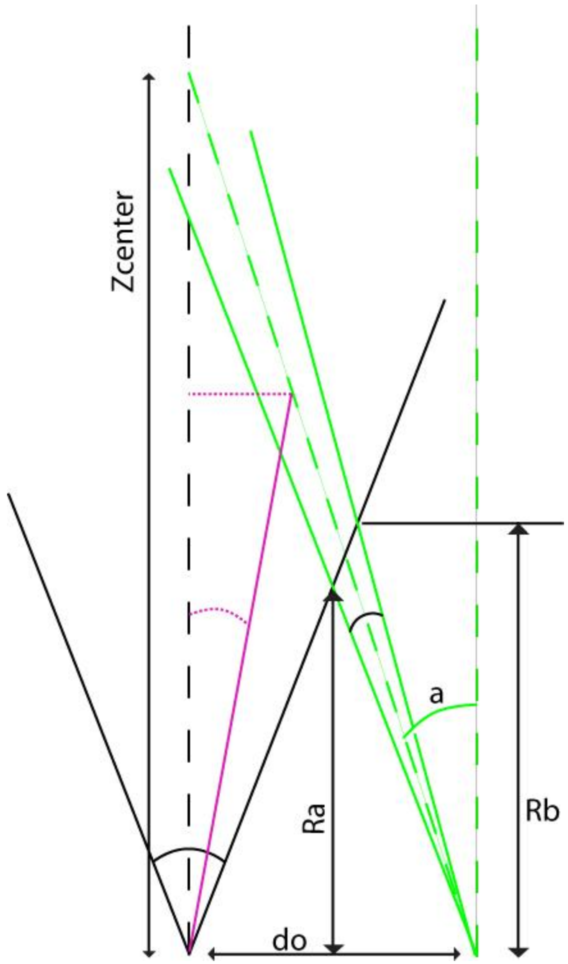
$$P(r,\lambda) = P_0 \frac{c\tau}{2} An \frac{O(r)}{r^2} \beta(r,\lambda) \exp\left[-2\int_0^r a(r',\lambda)dr'\right]$$

Detection of light signals ranging over 5 orders of magnitude
In LIDAR sensors looks at a laser pulse sent out into the atmosphere.
The high dynamic range of up to five orders of magnitude is one of the challenges in the detection of LIDAR signals
From strong signal (near range) to single photon detection in a few microseconds (100 us for 15 Km)

Solution: Simultaneous detection of analog and photon counting

-Expensive

Lidar manufacturer common considerations



The full ovelap distance for every LIDAR plays a crucial role in atmospheric measurements, especially when the LIDAR scientist wants to estimate atmospheric parameters in the lowest troposphere.

Lidar desinger and manufacturer common considerations

Overlap

Optics Acceptance Angles

Sensor no-homogeneity

Size vs prices

LIDAR Overlap

How to decrease the full overap:

-Field of View

Bigger FOV better overlap

More background noise (daytime)

-Laser beam divergence (smaller is better)

BEXP solves the problem but introduce complexity

-Distance between the two axis

Mono-axial systems:

Difficult to manufacture (especially for operational lidars)

Biaxial-systems: easier

(Radial displacement - paralax, increased)

LIDAR Overlap

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-Field of View

Big FOV better overlap

More background noise (daytime)

-Laser beam divergence (smaller is better)

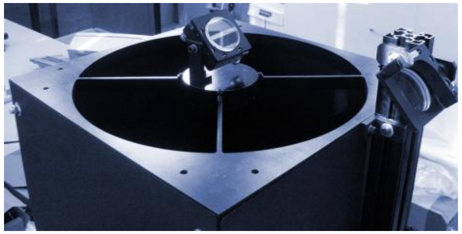
BEXP solve the problem but introduce complexit

-Distance between the two axis

Mono-axial systems: more challenging for the manufacturer (introduces errors)

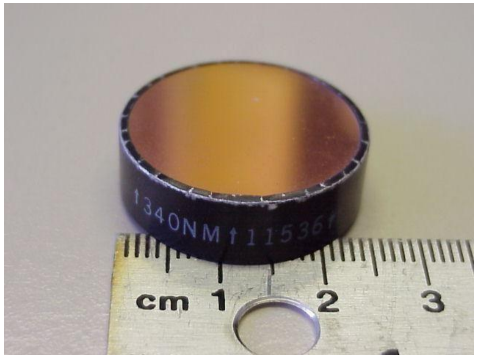
Biaxial-systems: Easier to be build

(Radial Displacement -> Bigger Diaphragm)



LIDAR Receiver Optics - IFF

Lidars require a narrow transmission band filter together with strong rejection of light outside the transmission band. These requirements limit the practical filters to interference filters and spectrometers. But for “compact”, transportable lidars, only interference filters seem to be a reasonable choice since they are smaller and relatively inexpensive in comparison with the spectrometers.



1) An IFF requires illumination with collimated light perpendicular to the surface of the filter.

2) Smaller the bandwidth, higher the cost, higher the temperature dependence.

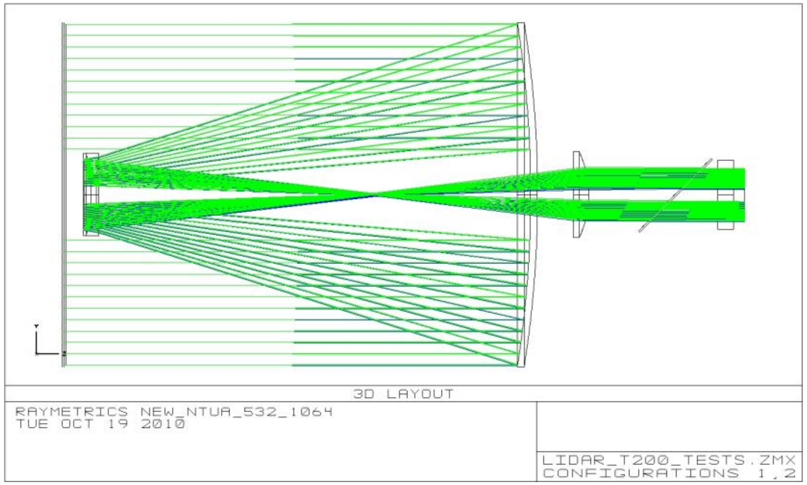
LIDAR IFF

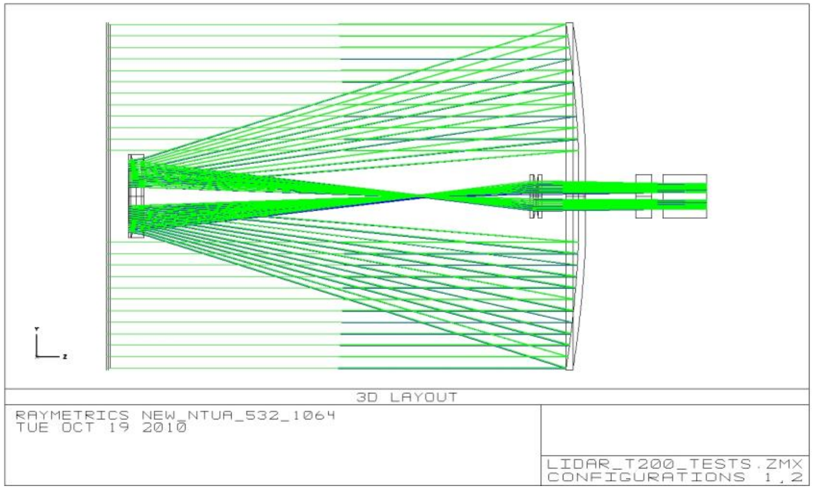
Wavelength (nm)	Initial (A)	Optimized (A)
1064	2.46	1.14
607		1.24
532	2.5	1.35
408		1.54
387		1.66
355	2.12	1.7

An easy way to optimize
Collimate the light that come from telescope with larger focal length lens

Larger optics -> higher cost
Longer distances

LIDAR IFF


3D LAYOUT
RAYMETRICS NEW_NTUA_532_1064
TUE OCT 19 2010
LIDAR_T200_TESTS.ZMX
CONFIGURATIONS 1,2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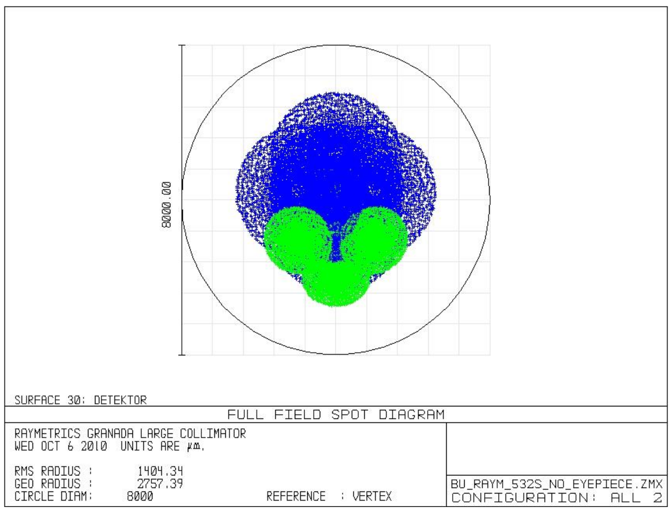
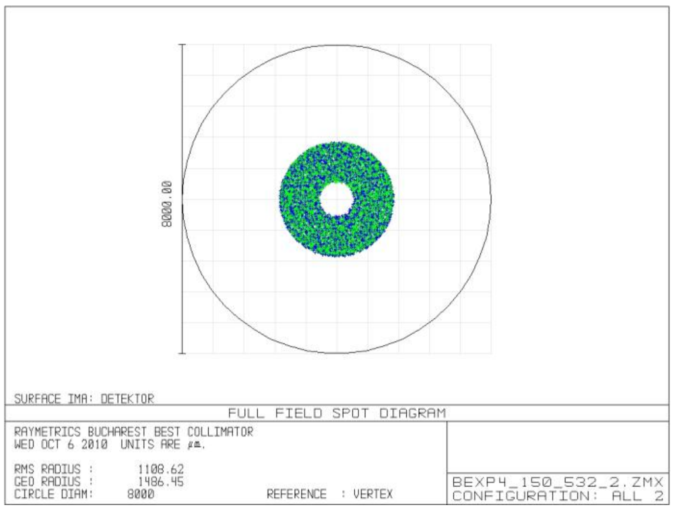
LIDAR PMT non-homogeneity

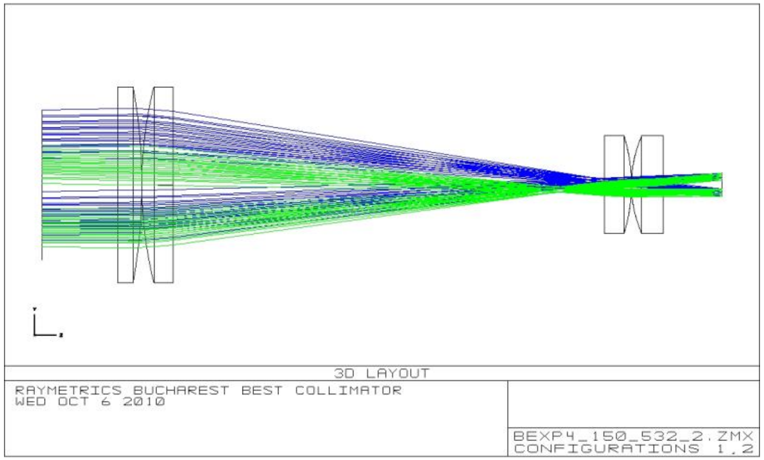
The spatial uniformity of the PMT is defined as the variation of its sensitivity with the position of incident light on the photocathode. The use of a PMT with spatial nonuniformity for detecting lidar signals may cause artifacts due to the reason that different areas of the photocathode detect the lidar signal from different distances.

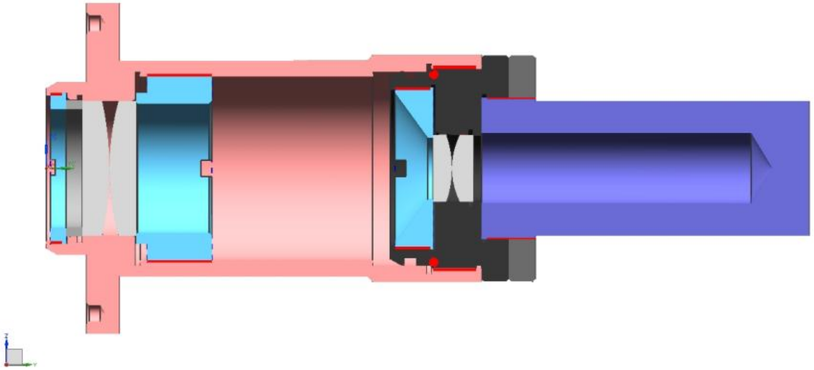




LIDAR PMT non-homogeneity

Solution: eye-piece in front of the PMT





Very demanding in terms of opto-mechanical accuracy
Extra cost for each detected wavelength

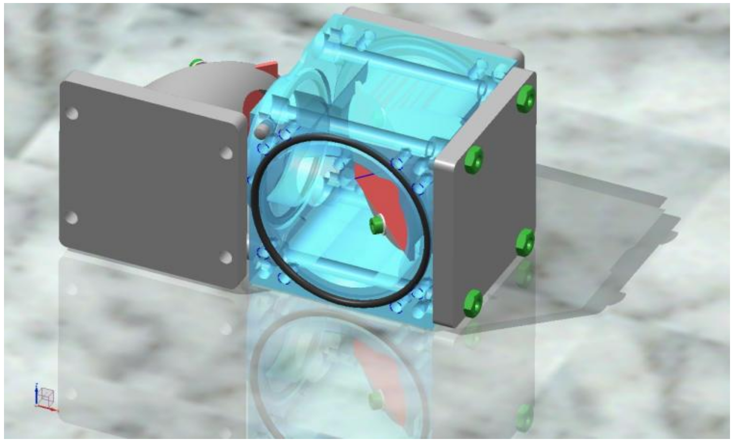
Opto-mechanical realization

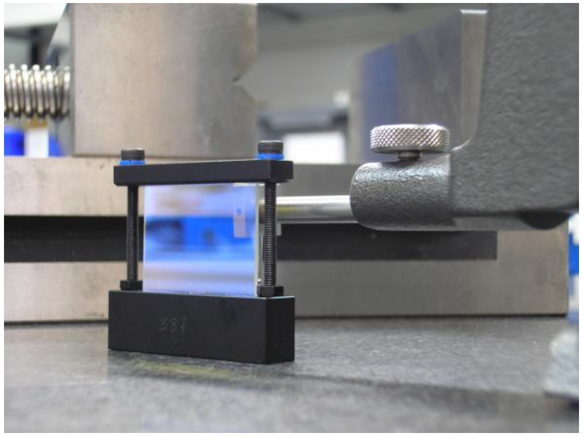
In order to achieve good precision, two things should be considered:
-smart design of the mechanical parts
-the best possible manufacturing process together with quality control.

Taking into consideration design requirements, there is no other choice but to follow a highly accurate manufacturing process.

The parts are all machined in high precision CNC turrent lathes equipped with a tool turrent.
In combination with the design, all crucial positions should be machined in one phase (if it is possible), achieving a position tolerance less than 0.01mm.

Finally, the quality check of the material (certificates) and the quality control of the machining process are necessary to be done.



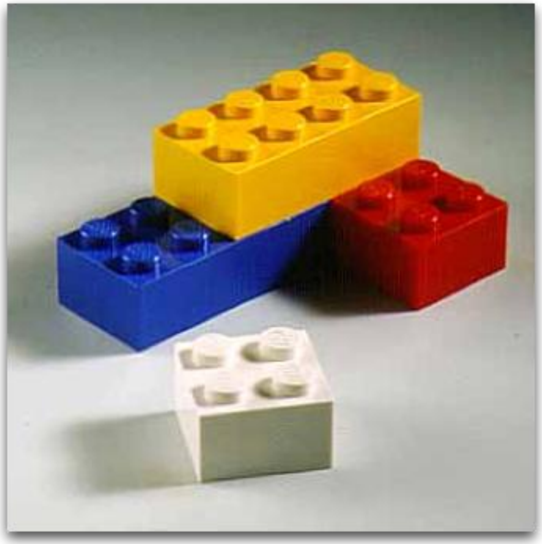


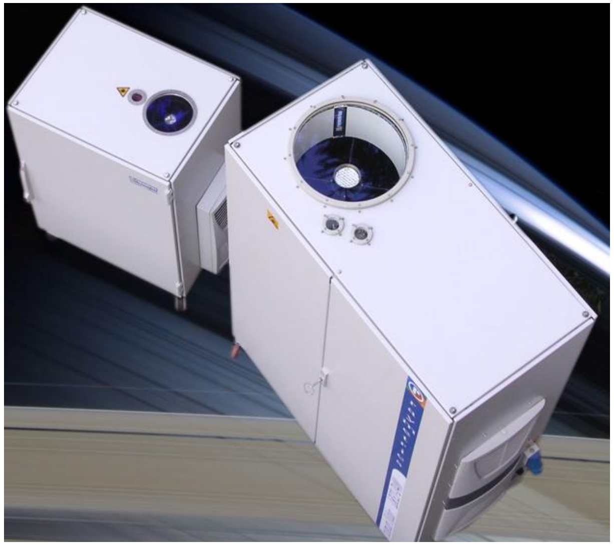
Conclusions

In a lidar system all the "components" are "interconnected"

Building a lidar is not like putting bricks together

Is a multi-parameter "problem" without obvious solutions





Conclusions

- Effort
- Cost
- User Friendliness

- Specifications
- Accuracy

Conclusions

Before any kind of manufacturing or optimization procedures system should be fully defined in terms of:

- Effective Range
- Number of detected channels
- Type of operation
- Size
- Cost

The use of ray-tracing program and sophisticated 3D mechanical design engineering software in conjunction with smart design of the mechanical parts and best possible manufacturing process are necessary procedures in order to optimize a lidar without needs to change expensive optical parts. Keeping the cost of any type of optimization low is very important to upgrade existing lidar systems but also for new systems which are being deployed for operational use.