MULTI-SPECTRAL LIDAR SYSTEM - DESIGN, BUILD AND TEST

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Abstract

Long range, combined UV-IR LIDAR system was built and tested. The system was developed to operate as a multi-wavelength DIAL in the IR (8-11 µm), dual wavelength excited LIF LIDAR in the UV, and aerosol map and track at 1.5 µm.

The IR transmitter is a continuous tunable solid-state Tandem Optical Parametric Oscillator (OPO) [1]. The first OPO stage generates the 1.5 µm beam and the second OPO stage pumped by the first, generates the IR band. In the UV the transmitter generates and transmits either the 266 nm or the 355 nm wavelengths sequentially. All the outgoing laser beams are pre-aligned to ensure geometric overlap of the measured paths. Energy reference is measured for each beam on every pulse.

The receiver is based on a single reflective telescope with coatings optimized for both the UV and the IR. The optical signal is routed between the different detection packages by means of a computerized optical scanner mirror. The receiver-transmitter layout is based on periscope geometry and is equipped with a large θ-φ scanner.

Computer control enables fast switching between the different measurements and wavelengths, data acquisition and spatial scan as well.

The system was built in a mobile trailer and was field tested. Design consideration, preliminary results of subsystems and system performance in field experiments to measure and discriminate aerosol types[2], will be presented at the conference.

System design and build

The basic design approach was to have an "all in one", multi-spectral LIDAR system that can be operate in different measuring modes in the atmosphere. The basic concept layout is shown in Figure-1.

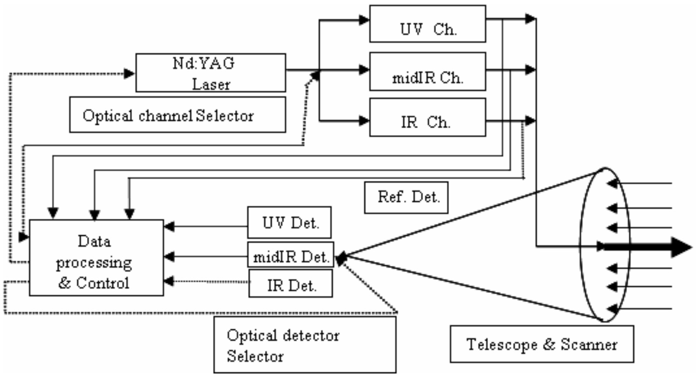

Figure.-1. System schematic layout

Transmitter and receiver parameters are summarized in Table I and Table II

Table I. Transmitter parameters

Parameter	IR	midIR	UV
$\lambda_{Transmitter}$	8.2-10.8 µm	1.5 µm	266 / 355 nm
$\lambda_{Receiver}$			300-480 nm, 8ch
E_{pulse} [mJ]	5	100	80 / 100
Pulse width	~15 nsec		~9 nsec
Pulse rate	10 Hz		
θ_{Beam} [mrad]	1	2	1
ϕ_{Beam} [mm]	150	10	8

Table II. Receive parameters

Parameter		IR	midIR	UV
Detector	Type	MCT/LN_2	InGaAs	MCP 8 ch
	Bandwidth	2 MHz	20 MHz	2 MHz
	Ref. detector	Pyroelectric PD		
Telescope		21” Newtonian, f=2.4 m, R>95%		
Scanner	Azimuth	$\pm 220^0$		
	Elevation	$\pm 7^0$		
	Speed	$20\ ^0$/sec		

The system was built in a large mobile trailer Figure-2.

Figure-2. System's mobile platform

Figure-3 shows the artist-concept. It has basically three levels installed on a vibration isolated plate. Bottom floor contains the telescope and the detection packages. The mid floor contains the transmitter with the different wavelength generators and the beam handling optics. The third level (outside the trailer) contains a large θ-ϕ scanner.

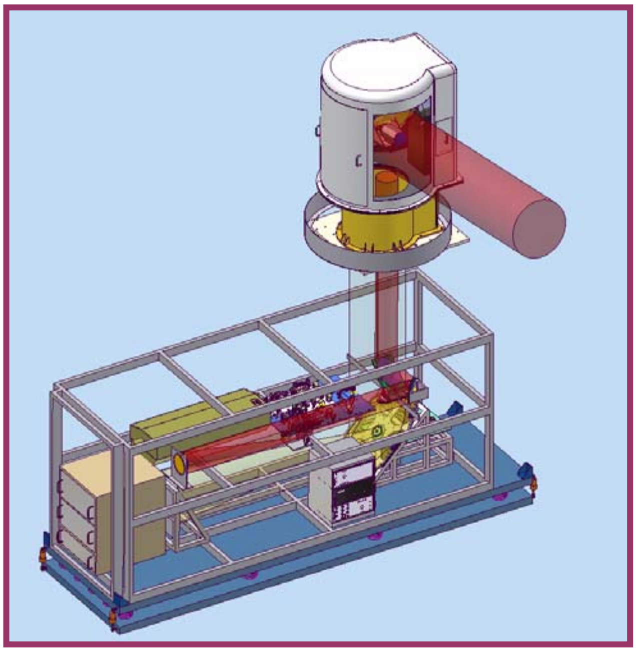

Figure-3. Basic design

The scanner and the inner sub-assemblies are optically linked by two large periscope-like mounted mirrors.

The main features of our design are: (1) fast switching between the optical channels (2) high energy, continuously tunable IR source[1] (3) optimized and stable mode of operation for the 3rd and 4th harmonics from a single YAG laser.

Two types of electro-mechanical elements are used for the optical switching. For time critical measurements we used fast magneto-galvanic scanners to change optical paths in the between two sequential laser pulses (< 100 msec switching time). For non time critical measurements we use electro-mechanic kinematic mirror mountings (switching time ~ 1sec). Both types are computer controlled and synchronized. The repeatability and beam pointing stability was measured to be ~20 μrad for the slow type and ~5 μrad for the fast type.

Figure-4 shows the transmitter level. It contains the Nd:YAG laser, UV harmonics generators (shown in white), IR OPOs and IR beam expander and the handling optics.

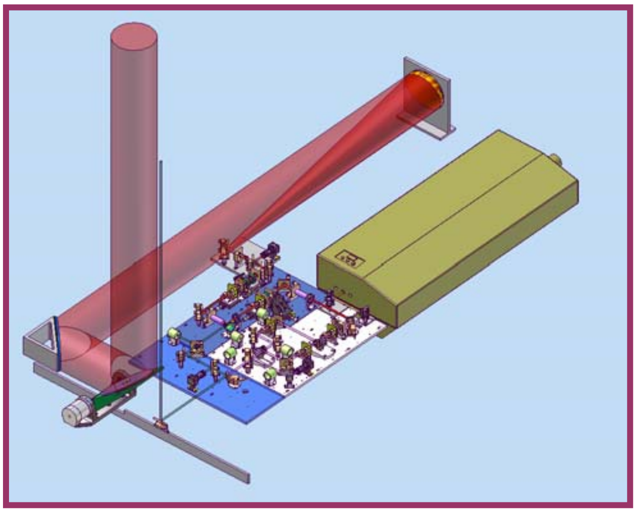

Figure-4. Transmitter and beams handling system

The IR source was described in previously publications[1,3-4]. Its main features are Tandem OPO where the first OPO stage is at the eye-safe wavelength of 1.574 μm used also for aerosol and cloud scanning. This OPO stage is based on a Non-Critical Phase-Matched cut KTP placed in a single pass, non-tunable, stable resonator. The second OPO stage is pumped at the first stage wavelength and tunes continuously over the IR band by fast angle turning of the OPO's crystals. This second OPO stage contains two $AgGaSe_2$ crystals placed in a non-stable resonator (positive branch) in order to improve beam quality. The wavelength tuning is done by anti-parallel rotating the two crystals in order to compensate for beam angular shift while tuning. The beam pointing shift, when tuning the entire IR band, was less then 100 μrad.

The UV source even though more straight-forward then the IR source, it still was a challenge. The second harmonic generator is based on a type II KTP crystal. The 3rd and 4th harmonics are generated by BBO crystals cut at the appropriate angles. The main operational constrains implemented into the UV design were: 1) fast sequential operation of the 3rd and 4th harmonics 2) high conversion efficiency for both UV wavelengths right from the first pulse when switching to IR back and forth 4) use of one common YAG laser. Simultaneous maximization of energies for both UV wavelengths from one YAG laser is not possible without readjusting the 2nd harmonics generation. The 4th harmonic one would need only to be adjusted to maximize the 2nd harmonic, and the 3rd requires to balance between the 2nd and the fundamental. In our case the UV generation was fixed optimized just to get sufficient energies to make the measurements possible. Another UV issue to deal with was the thermal influence on the efficiency of the 4th harmonic. There is a small 266 nm absorption by the crystal that causes a shift in the phase matching. As a result, large changes in the efficiency can take place according to how the crystal was pre-aligned and the mode of operation. By balancing the crystal alignment between totally "cold" on one hand and fully thermally stabilized on the other hand, and utilizing a "keep alive" mode of operation, we were able to minimize this effect to less then 20% as shown in Figure-5.

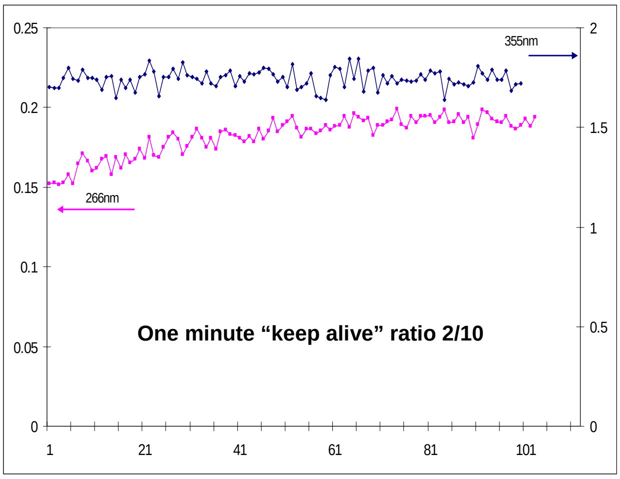

Figure-5. UV energy

The receiver consists of a Newtonian telescope which is coupled to the detection package by means of a scanning mirror as seen in Figure-6. The detection package contains: 1) UV detector composed from a 1/8 m monochromator coupled with a multi-anode photomultiplier, UV detector which measures ~200 nm of the fluorescence spectrum starting from 280 nm divided in 8 channels (The detector is protected from the elastic scattering, when the 355 nm wavelength is used to excite the fluorescence, by means of a jumping filter); 2) IR detector which is a standard MCT LN cooled; 3) midIR detector which is a 1 mm InGaAs, fast pin photodiode; 4) and a CCD camera placed in order to aid the alignments. All the detectors are placed in positions so, that by turning the scanning mirror at the appropriate angles it is possible to engage the detector corresponding to the transmitter's wavelength.

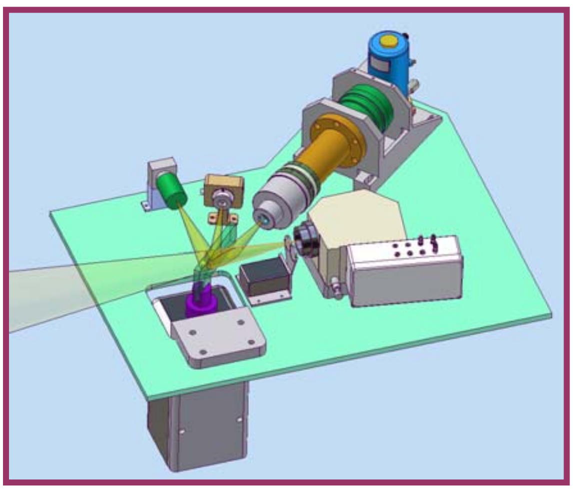

Figure-6. Detection package

System performance

Several performance tests were run at different locations to demonstrate system capabilities to measure signals in all bands in order to calculate SNR. This was done by looking at both returns from aerosols and hard targets. The hard targets we used were made from aluminum sand blasted or rolled. For UV fluorescence measurements we coat the target with white paper which is fluorescent in the visible (blue). The midIR return is very strong and for measurements of several kilometers we had to use ND filters placed in front of the detector (we rather not change the transmitter energy). Typical midIR return is shown in Figure-7.

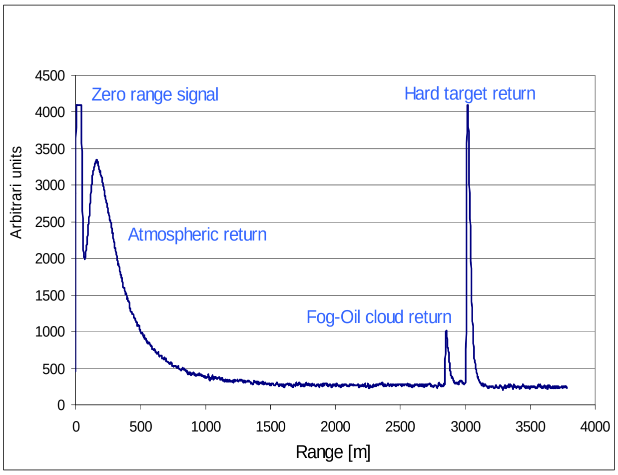

Figure -7. Near IR signal (single pulse)

For the IR returns, we are able to measure with SNR~10 aerosol clouds over the entire spectral band. Figure-8 shows hard target return from buildings at over 10 km.

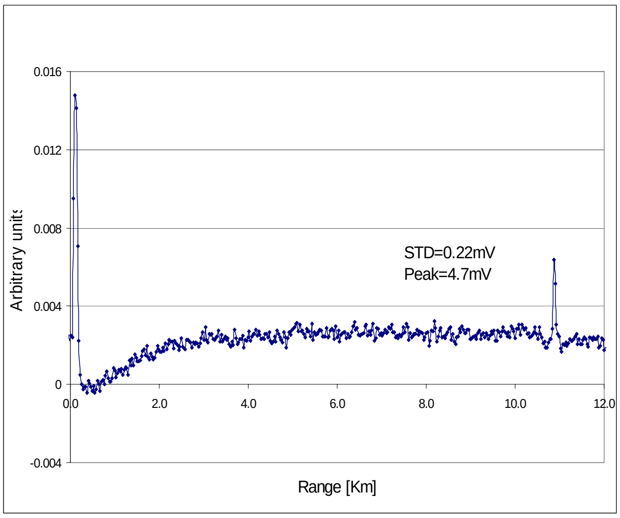

Figure-8. IR signal (9 pulses average) from buildings over 10 km away

Summary

Long range, multi-spectral UV-IR mobile system was demonstrated. Through it's spectral bands the system demonstrated combined multiple interaction capability. Fast switching between modes of measurements enables "on line" investigation of aerosols, gases and hard targets.

Acknowledgments

This work was carryout with the collaboration of the Israeli Institute For Biological Research. We would like to thank S. Egert, D. Pery, and N. Gilad for their collaboration.

References

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