ICSO 2020 INTERNATIONAL CONFERENCE ON SPACE OPTICS VIRTUAL
ICSO 30 march - 2 april 2021 https://icso2020.com/

IMAGING LIDAR SYSTEMS

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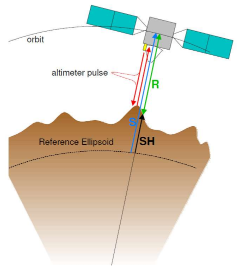
Objectives

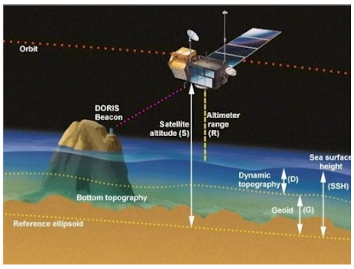
Laser Altimeters have been used in space and ground-based / aircraft applications for many years.
This presentation concentrates on recent technology developments and the possibility of exploiting the laser ranging technique in a multitude of relatively new areas:
- Bathymetry (measurement of the sea depth in shallow water zones);
- Canopy (distribution of the scattering elements from the top of canopy down to the ground);
- Snow depth mapping and ice thickness mapping;
- Global 3-D imaging.

These applications can all exploit high rep-rate multi-beam laser systems with multi-element photon-counting detector arrays with appropriate high-precision timing and image reconstruction to provide high-resolution 3-D images of the sub-orbital path.
The ability of Imaging Lidar to penetrate cloud and other obscurations can also be exploited.

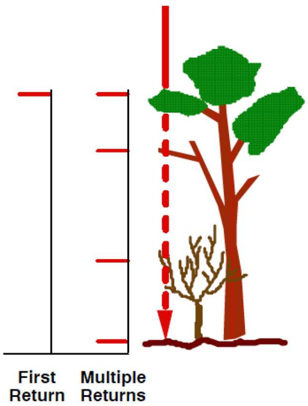
What can an Imaging Lidar System provide?
Given a clear atmospheric conditions or cloudy / foggy conditions, Imaging Lidar Provides:
Full 3-D instantaneous structure of everything within the field of view of the Imaging Lidar:-
Range for every identifiable object;
Velocity (speed + direction) for every object;
Detection, and Identification are subject to the normal rules of optical resolution / distance and signal to noise ratio etc. Fog and cloud causes blurring and diffusion in normal vision & normal camera imaging.
How does the Imaging Lidar avoid this?
The negative effects of a foggy or cloudy atmosphere on normal vision and imaging are familiar
- The outlines of objects quickly become blurred;
- Identification becomes difficult / impossible;
- Beyond 3 optical thicknesses even the outlines disappear into the fog or cloud.
- The Imaging Lidar circumvents the blurring and diffusion caused by fog and cloud by the combining of temporal and spectral filtering with image deconvolution.

THE PRINCIPLES OF THE SATELLITE ALTIMETRY AND SEA SURFACE TOPOGRAPHY

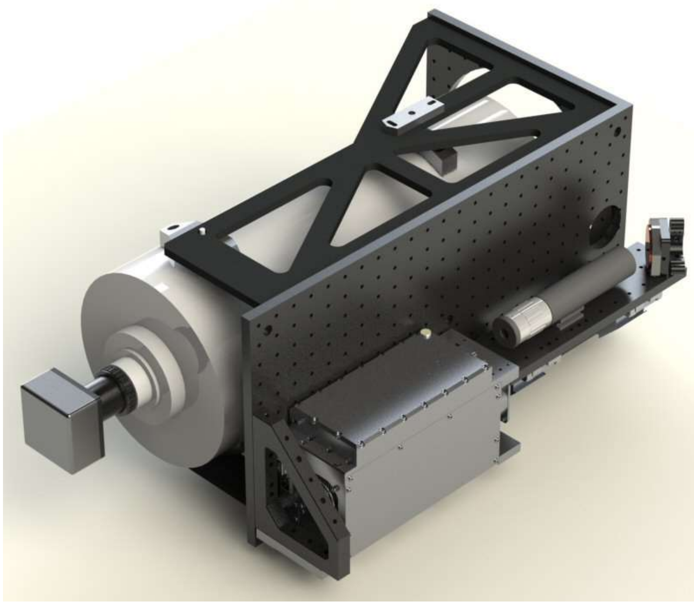




The Lidar employs a near-UV Laser (355 nm) with a short-duration pulse as the source.
The near-UV system has major advantages due to the combination of eye safety and the maturity of laser and imaging photon detector technologies.
The compact Imaging Lidar system has been demonstrated to be capable of target detection and identification far beyond the limits of normal capabilities of eye and/or camera capabilities under conditions where visibility is highly challenged by Fog or Cloud.



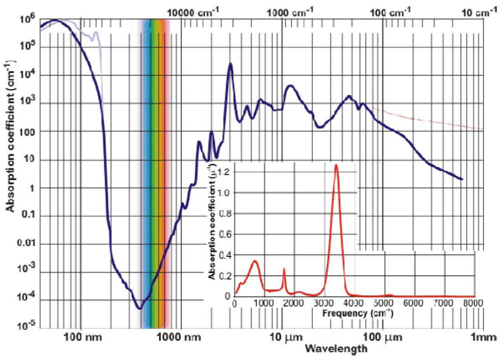
The "traditional" Laser Altimeter operates as on the left, the return signal from a low re-rate, high power laser, with analogue signal detection picks up only the 1st return – whether from ice, snow, vegetation or the ground / sea-surface.
The development of multi-element photon-counting detectors allows major improvements in spatial and range resolution:
- Not only can the Forest Canopy be detected, but the distribution of all structural (scattering) elements from the top of the canopy down to ground-level can be sensed.
- These abilities can be extended to the bathymetry
- of surface water over land areas and the study of
- sub-surface regions to depths of order 50 – 100
- metres in the Continental Margins.



Using a relatively large « spot size » and low repetition rate, the ground resolution of analogue laser altimeter systems is limited to a few hundred metres.
The high rep-rate laser / photon counting range/gating detectors allows use of a small spot size and multiple beams to obtain far better along-track and cross-track resolution.

The Imaging Lidar consists of the UV laser and beam-expander in the foreground, with the 20 cm diameter (Meade) receiving telescope in the background.
The "black box" at lower left is the Photek PCS-256 – the 32 *32 Imaging Photon Detector (currently used with 16 * 16 electronics).

WATER ABSORPTION SPECTRUM



Current and Future Developments:
A 64 * 64 element version of the current photo-detector has already been built. The development of the sophisticated signal processing electronics currently lags the development of the photo-tube by a significant factor!! The 16 * 16 version (PCS-256) is currently fully-developed by Photek, and a 16-channel photon-counting range-gating version has been developed and demonstrated by Eventech.
From prior work with this class of detector, we have demonstrated tha it is practical to reconstruct the exact arrival location of photons by comparing the amplitude of the signals in adjacent groups of three pixels. This provides highly valuable sub-pixel resolution.

Image Resolution:
The 16 * 16 image (current signal processing stage of development) may be deconvolved to provide 128 * 128 element resolution.
The 64 * 64 image (detector device demonstrated, but a future stage of electronics development) may be deconvolved to provide 512 * 512 element resolution.

Operational Requirements – footprint / beam divergence

Application	Footprint [m]			Beam divergence [μrad]		
	Threshold	Breakthrough	Objective	Threshold	Breakthrough	Objective
Altimetry - Land topography	100	50	1	250	125	2.5
Altimetry - Global ocean topography	100 km	50 km	1 km	250 mrad	125 mrad	2.5 mrad
Altimetry - Ocean bathymetry	25 km	10 km	1 km	62.5 mrad	25 mrad	2.5 mrad
Altimetry - River/lake height	500	200	10	1.25 mrad	500	25
Shallow Water Bathymetry	25	2.5	1	62.5	6.25	2.5
Vegetation canopy	50	25	5	125	62.5	12.5
Ice/snow thickness mapping	50	50	5	125	125	12.5
Fluorescent measurements	50	25	5	125	62.5	12.5
3D imaging	100	30	10	250	75	25

There is a weak "clear sky" atmospheric signal at short range.
There is a strong signal return from a tree at 4 msec (to left).