



JNRR 2016 | 3D Laser Imaging | 20151022

3D LASER IMAGING TECHNIQUES

Advantages, limitations, technological and scientific challenges

Nicolas Riviere

THE FRENCH AEROSPACE LAB

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Laser Imaging


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Our business, expertise in the field and facilities

▪ **Performance Analysis of Sensors at ONERA**

- ☑ Based on laser sources, ONERA develops **new systems** and **models** for **remote sensing applications** (imaging or not)
From concepts to development of prototypes ⇒ **Evaluation** and **validation** using numerical tools
- ☑ **Challenges**
To evaluate **original** and **complementary** imaging techniques vs conventional imaging systems
To identify **new concepts** (3D, hyperspectral...) using new sensors
- ☑ **Our Physical approach**
Models to evaluate new concepts and developments of specific post-processing...
Measurements of "innovative" laser signatures (i.e. Hyperspectral, polarization, ultrashort femtosecond laser pulses)
Transfer of the concepts from the lab to an outdoor device
Integrate and test (calibration) the systems or the technological components (LIMA platform)
Expertise to end users (French MoD, DGA, industry...)





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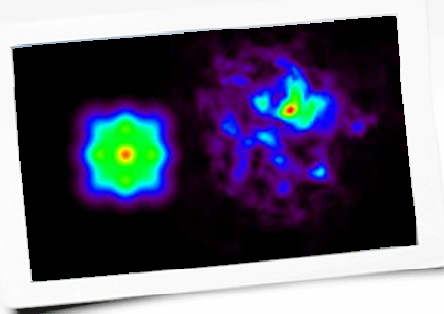
Laser Imaging


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Our business, expertise in the field and facilities

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Introduction to Laser Imaging Techniques





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Introduction to Laser Imaging Techniques

▪ How can we image our environment ?

What happen without natural lights ?

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Introduction to Laser Imaging Techniques

▪ What happen without natural lights ?

Several technologies are used for **night vision**

- Passive imaging with **ultra-sensitive detectors** (Back-illuminated CCD, low light level CCD...)
- Devices equipped with **image intensifier**

✓ Highly efficient techniques for imaging under very low light (moon, stars ...)

Coating None MgF2	Input Window Quartz Glass Fiber Optic MgF2	Photocathode Selenide S20 (1A) S20 Broadband Hot S20 S-gate (S-gate S20)	Active @ (mm) 18 20 40	MCP None Single Double Double	S01 S01 S01 S01	Phosphor P22 P24 P43 P47	Power Supply Standard fixed gain ESAC (ext gain mode) Autogating ESAC + ext gain ESAC with gain unit
				Output Window Straight fiber optic Turned fiber optic Glass			

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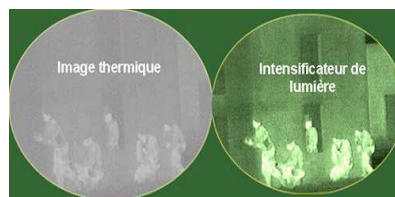
✓ Highly efficient techniques for imaging under very low light (moon, stars ...)

- **Thermal imaging** techniques based both on the body of emissivity as well as their thermal radiation
IR bands 3–5 μm and 8–12 μm

✗ Require integration time of several milliseconds excluding many embedded applications



▷ SOPHIE: Thermal camera from Thales



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- An **artificial light source** can be associated with a camera

Short integration time constraint \Rightarrow A light source capable of delivering high power is a **LASER SOURCE**



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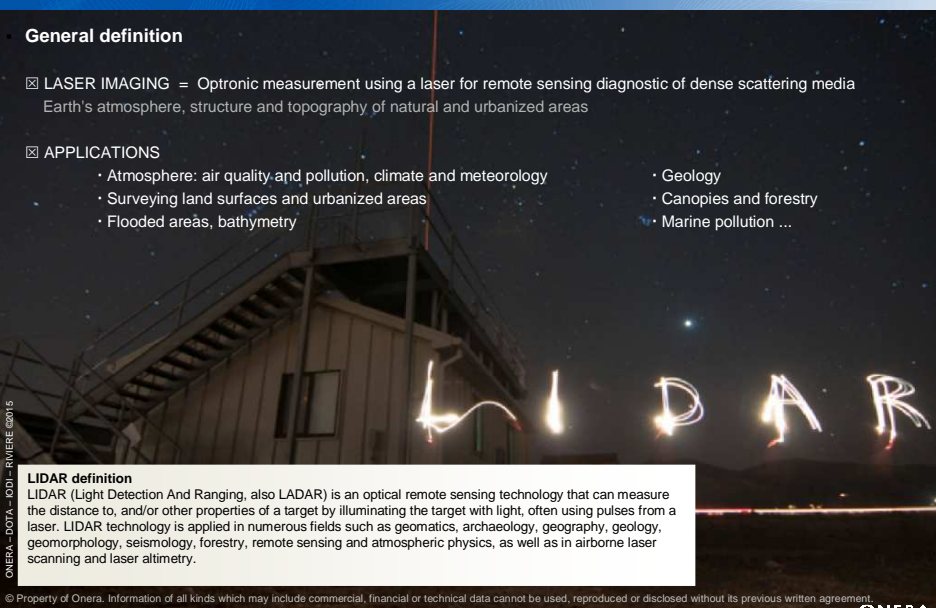
Introduction to Laser Imaging Techniques

General definition

☑ **LASER IMAGING** = Optronic measurement using a laser for remote sensing diagnostic of dense scattering media
Earth's atmosphere, structure and topography of natural and urbanized areas

☑ **APPLICATIONS**

- Atmosphere: air quality and pollution, climate and meteorology
- Surveying land surfaces and urbanized areas
- Flooded areas, bathymetry
- Geology
- Canopies and forestry
- Marine pollution ...




LIDAR definition

LIDAR (Light Detection And Ranging, also LADAR) is an optical remote sensing technology that can measure the distance to, and/or other properties of a target by illuminating the target with light, often using pulses from a laser. LIDAR technology is applied in numerous fields such as geomatics, archaeology, geography, geology, geomorphology, seismology, forestry, remote sensing and atmospheric physics, as well as in airborne laser scanning and laser altimetry.

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Introduction to Laser Imaging Techniques

▪ **Advantages and Capabilities of laser imaging**

- ☑ Vision under bad weather conditions (rain, snow, fog, smoke ...)
- ☑ Vision through vegetation and camouflage applications
- ☑ Identification and classification of objects (to the targeting concept)
- ☑ Creation of digital terrain models (towards recognition)


▪ **Three major classes of systems**

1. Observation	Long range	2D Video mode	2D Flash	Identification
2. Tactical 3D mapping	Medium range	3D Single Image	3D Scanner	Recognition
3. Perception	Short range	3D Video Mode	3D Flash	Detection

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2D Flash Laser

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2D Flash Laser

▪ **Principle**

This technique captures an **entire scene** with a single laser pulse. It can significantly increase data capture rates.

With 2D FLASH LASER systems, the scene is flooded with a diffuse laser light and a focal plane array (FPA) is used as a detector to acquire a frame of data each time the laser is fired.

- ✓ Observation at long range
- ✓ 2D Video mode
- ✓ Identification
- ✗ Resolution and SWaP ?

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2D Flash Laser

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Systems

▪ **Current existing systems for terrestrial / aerial applications**

Long range (up to several kilometers) for military applications
Targeting, camouflage, observation, up to identification

- LTIP, Lightning attack pod
- AFRL systems
- Long-Range Identification System (LRID) programs, US Army & Northrop Grumman
- SELEX UK
- Standoff Precision Identification in 3D (SPI-3D)
- ONERA : GIBI, IAAIS systems
- Sagem / Thalès / DGA : MILPAT system
- ...

2D active imaging system

Burst illumination imaging system combines active laser illumination with time gating

« 2D flash laser »



AFRL



MILPAT



SPI-3D



LRID



GIBI

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2D Flash Laser

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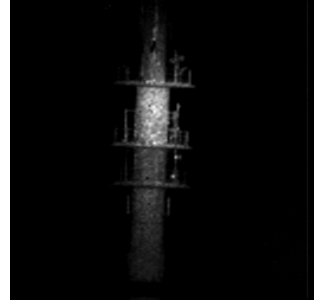
2D active imaging system

Burst illumination imaging system combines active laser illumination with time gating

« 2D flash laser »




Vehicle vs camouflage.
ONERA images



Jolimont Tower in Toulouse, France.
Range 3 km. ONERA \ GIBI images

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2D Flash Laser

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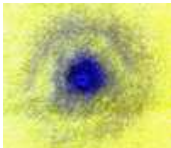
Short range for civilian applications
Medical (melanoma detection), security (forensic) , underwater...

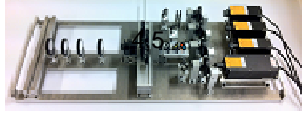
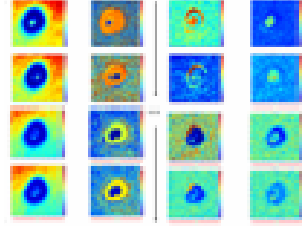
2D active imaging system

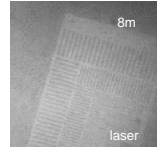
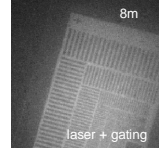
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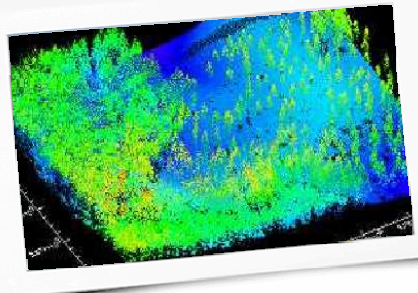
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3D Laser Scanner

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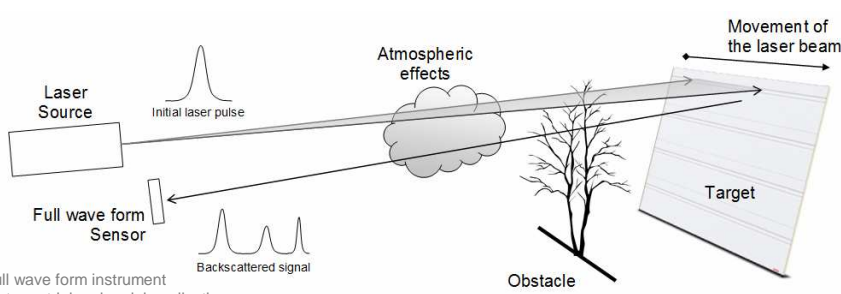
3D Laser Scanner

▪ **Principle**

The purpose of a 3D scanner is usually to create a **point cloud** of geometric samples on the surface of an object. Then, these points can be used to extrapolate the shape of the object.

These technique considers the photon Time Of Flight (TOF)

- ✓ Observation at short / medium range
- ✓ Recognition
- ✓ Full wave form information, not only first or last echoes
- ✗ Single image



⇒ Full wave form instrument for terrestrial and aerial applications

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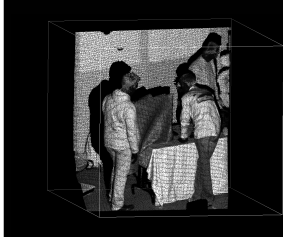


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3D Laser Scanner

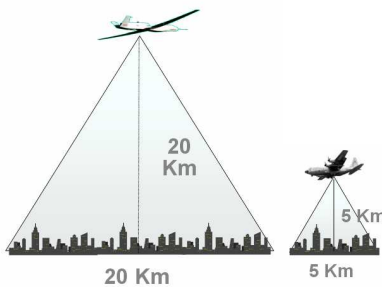

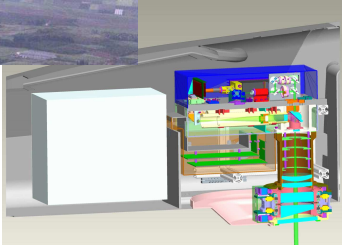
Systems

▪ **Current existing systems for terrestrial / aerial applications**

- ✓ Airborne applications, object detection ⇒ Detection Recognition Identification 3D or 4D data (including full wave form)
- Continuous Urban Surveillance : drone for 20km² @ 1Hz detection of human activities (résol. 0,3 m)

3D active imaging system


3D laser scanner combines range estimation using pulsed laser and scanner in order to obtain 3D point clouds restoring the shape of the target

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3D Laser Scanner

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Systems

- **Current existing systems for terrestrial / aerial applications**
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- ALIRT USAF System, for *mapping*

3D active imaging system

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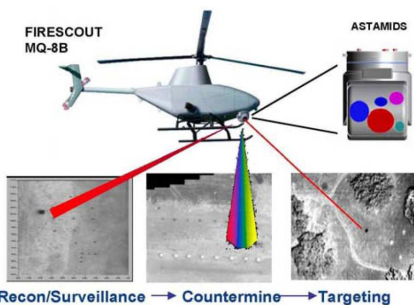
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Systems


- **Current existing systems for terrestrial / aerial applications**
- ✓ Airborne applications, object detection ⇒ Detection Recognition Identification 3D or 4D data (including full wave form)
- ASTAMIDS (US Army) to detect mines and obstacles
Multi-spectral imaging system including laser sources (app. day/night)
34 kg

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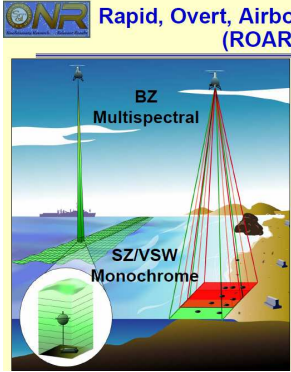
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- ROAR by BAE Systems



Rapid, Overt, Airborne, Reconnaissance (ROAR)®

BAE SYSTEMS

- COBRA Block II
- Optimized for surf zone
- Active multi-spectral
- True 3-D LIDAR system
- Multi-look scan pattern
- Compact design for UAV
- Team Includes:
 - BAE Systems
 - Lite Cycles
 - ASC
 - NSWC PCD
 - SAIC

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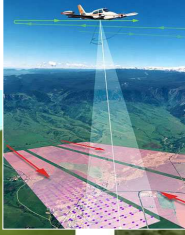

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Systems

▪ **Current existing systems for terrestrial / aerial applications**

✓ Airborne applications, object detection ⇒ Detection Recognition Identification 3D or 4D data (including full wave form)

✓ Precise mapping of surfaces and canopy (forestry application)
Accurate telemetry
Airborne Lidar:
high sampling rate $\pm 15^\circ$, High resolution (15 cm horizontal, vertical 25 cm)
(eg 50 kHz)

3D active imaging system

3D laser scanner combines range estimation using pulsed laser and scanner in order to obtain 3D point clouds restoring the shape of the target

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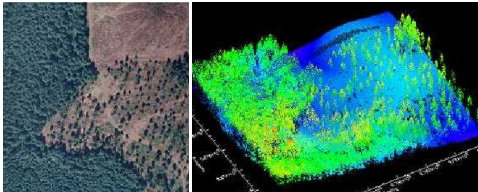
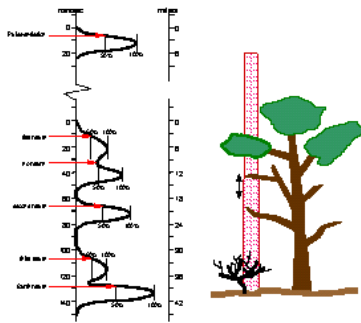
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- ✓ Foliage penetration
First or last echoes / FWF
Archeology, military applications


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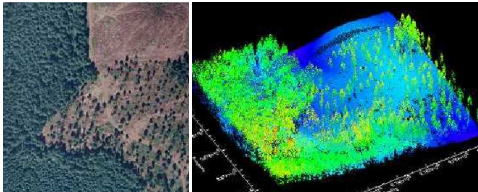
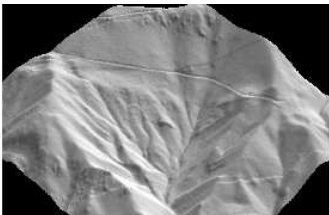
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3D Laser Scanner

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3D Laser Scanner
Applications

Architecture
Real time 3D data fusion
Static / mobile (vehicle, drone, A/C)
Reflectance of the material



VIDEO

VIDEO


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3D Laser Scanner
Applications

Camouflage applications



VIDEO


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Applications
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Camouflage applications

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Applications
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Embedded systems for A/C applications
Obstacle detection, navigation and mapping


Airport experiments (taxiing, take off)

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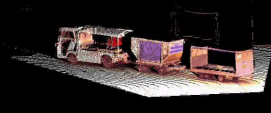
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3D Laser Scanner

Applications


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Embedded systems for airplane applications
 Reflectance of the material at the laser wavelength
 Data fusion from passive and active sensors




ONERA
Ceolato - Rivière - Tanguy

VIDEO



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3D Laser Imaging under bad weather conditions

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3D Laser Imaging under bad weather conditions

- **Adverse Conditions and A/C Environment**
- ✓ Return on the A380 / CRJ700 accident on JFK airport...
 - ➔ Bad visibility and night vision
 - ➔ Bad weather conditions (rain)
- ✓ In all visibility conditions taxiing has to deal with risks

➔ 11 April 2011 An A380 clipped the wing of a smaller A/C


Amateur footage has captured the moment when an Air France A380, taxiing along the runway of JFK Airport in New York, clipped the wing of a smaller Comair CRJ jet, sending it into a spin.

Air France said 495 people and 25 crew members were on the Airbus A380 bound for Paris, while the Comair regional jet, which had just landed, was carrying 62 passengers and four crew members. There were no reports of injuries.

Both aircraft have been grounded pending an investigation.

VIDEO





➔ 11 April 2011 An A380 clipped the wing of a smaller A/C
➔ 10 August 2012 on Dulles Airport

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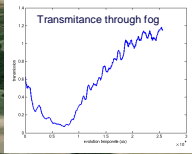

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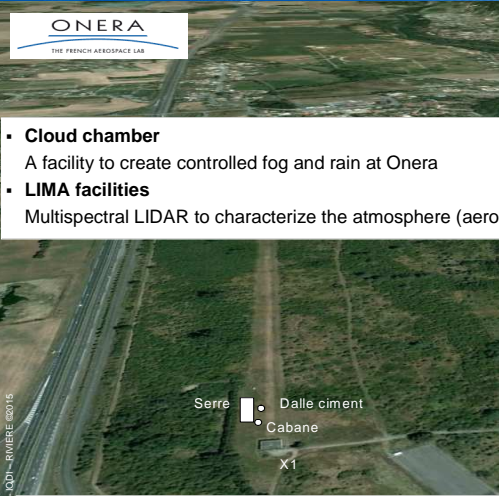




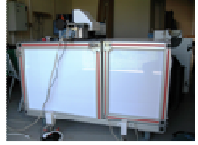
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Specific Test Benches

- **Cloud chamber**
A facility to create controlled fog and rain at Onera
- **LIMA facilities**
Multispectral LIDAR to characterize the atmosphere (aerosols, water...)








Controlled meteorological phenomena

Temperature, Humidity, Wind speed, PSD, Solar radiance, Pressure, Precipitation...

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Specific Test Benches

- Experimental observations under bad weather conditions



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3D Laser Imaging Experiments

FOG particles can be removed from the image

Thanks to the optical properties knowledge
and the full wave form signal



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3D Laser Imaging Experiments

Advantages

- Increase the surrounding perception
- Detection of obstacles with high resolution
- To see through dense scattering media

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3D Laser Imaging Experiments

Natural conditions

- SNOW particles
- FOG particles

VIDEO

VIDEO

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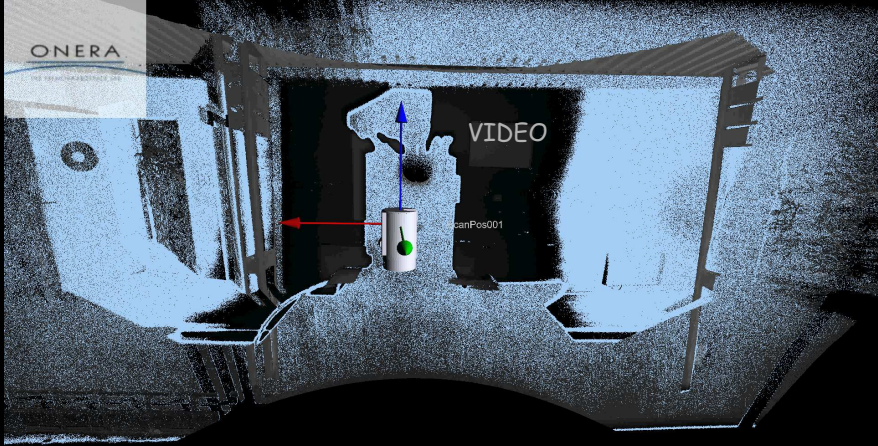
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3D Laser Imaging Experiments

Natural conditions ➔ SNOW particles



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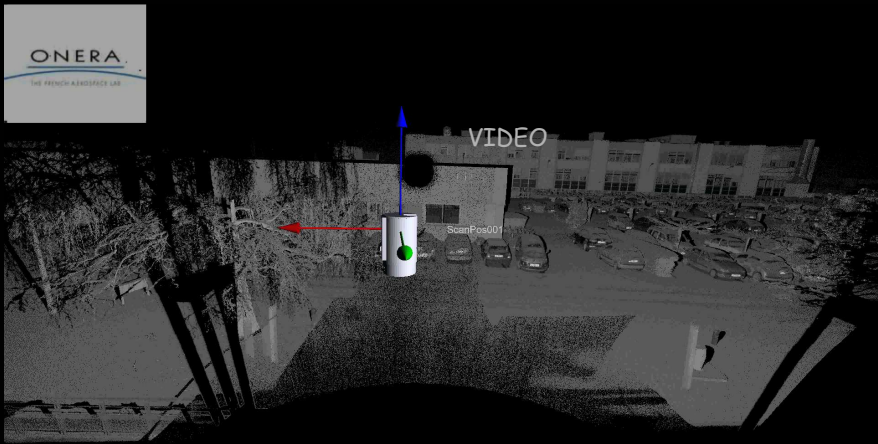
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3D Laser Imaging Experiments

Natural conditions ➔ SNOW particles



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3D Focal Plane Array

The future for the 3D Laser Imaging systems

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3D FPA Laser Imaging Systems


▪ **Principle**

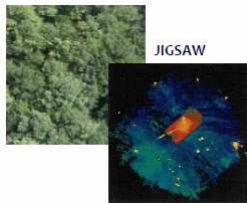
Research and Development have led to the conception of **multi-pixel 3D arrays** (eg. photon counting avalanche photodiodes) able to provide a **3D laser image with one single large laser beam**, thanks to the temporal independence of each pixel on the matrix.

3D Geiger-mode Avalanche PhotoDiode (GmAPD) array offers **single photon detection** ability.

Research and first concepts : TRL 3-4

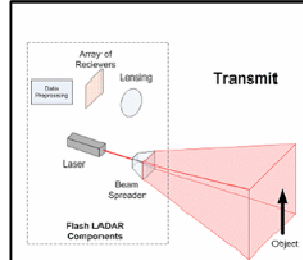
- ✓ Observation at very long range (a pencil at 7km)
- ✓ 3D Video mode
- ✓ Object detection and surveillance applications
- ✓ Real-time accurate DSM generation
- ✗ Small matrix size (128x32pxl)
- ✗ Big data storage



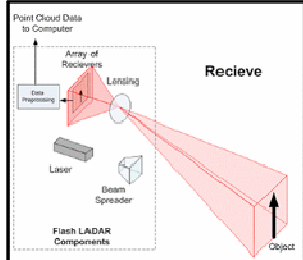


JIGSAW


Transmit



Recieve



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3D FPA Laser Imaging Systems

Applications

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3D FPA Laser Imaging Systems

▪ **Applications**

Frame 1

Target

VIDEO

Range, m

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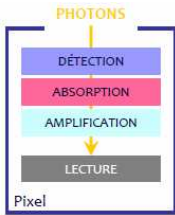
3D FPA Laser Imaging Systems

- To enhance the vision for Security and Defense applications
 - **Obstacle detection for long range**
Development / design of new 3D FPA system
Modelling of the complete chain
Sources, transmission through the atmosphere, optical properties of materials, sensors post-processing)

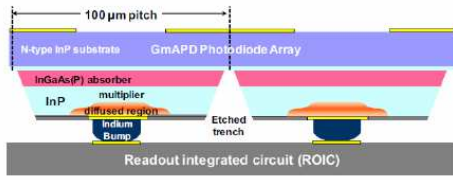
Système développé par l'Onera incluant un imageur laser à plan focal 3D



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Itzler, 2010

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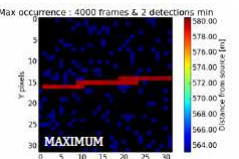


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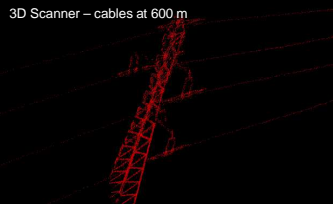
3D FPA Laser Imaging Systems

- To enhance the vision for Security and Defense applications
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Modelling of the complete chain
Sources, transmission through the atmosphere, optical properties of materials, sensors post-processing)


Application to the detection of cables by day/night



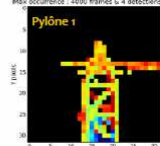
Max occurrence : 4000 frames & 2 detections min



3D Scanner – cables at 600 m




3D FPA – Cables at 3 km



Max occurrence : 4000 frames & 4 detections min

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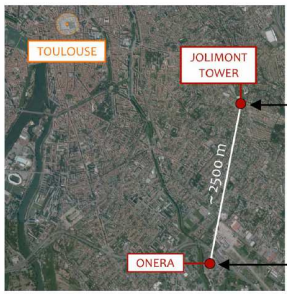
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3D FPA Laser Imaging Systems

- **To enhance the vision for Security and Defense applications**
 - **Enhanced vision**
 - Embedded systems with Eye Safety
 - Complementarity of laser sources / detector / Optics with other functions
 - Vision through all types of adverse conditions
 - Real-time display (3D video mode)
 - Recognition (people and objects)
 - Airborne, terrestrial and underwater applications




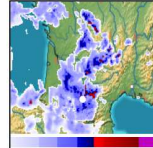
TOULOUSE

JOLIMONT TOWER


~ 2500 m

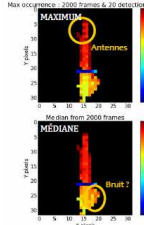
ONERA





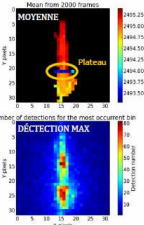
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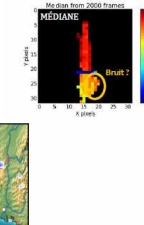
Max occurrence: 2000 frames à 20 détecteurs/min

Antennes



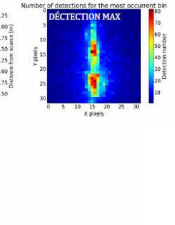
Mean from 2000 frames

Plateaux




Median from 2000 frames

Médiane

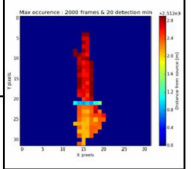


Number of detections for the event occurred

DETECTION MAX



Pluie d'orage (8.1mm)




Max occurrence: 2000 frames à 20 détecteurs/min

ONERA - DOTA - IODI - 2015


Imagerie laser sous pluie d'orage - Onera 2014
Apport de l'imagerie plan focal 3D embarquée pour l'amélioration de la cartographie haute résolution


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Questions


Thank you for your attention



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3D LASER IMAGING TECHNIQUES

Advantages, limitations, technological and scientific challenges

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