Evolution of Hyper-spectral FLS™-LiDAR for Marine Applications

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4th Workshop Remote Sensing of the Coastal Zone
Chania, Greece, 18-20 June 2009

Laser Diagnostic Instruments AS, www.ldi.ee
*) Laser Diagnostic Instruments International Inc., www.ldi3.com
OUTLINE

1. LIF LiDAR & Spectral Fluorescence Signatures (SFS)
2. History of Development
3. Capability Demonstrations
4. Specification of Operational Use
5. Examples of Operation
6. Summary
KEY TECHNOLOGIES

LIDAR = Light Detection And Ranging

RADAR = Radio Detection And Ranging

LIF = Laser induced Fluorescence and

SFS = Spectral Fluorescence Signature

FLS™ = LDI Trade Mark of Fluorescent Lidar System realizing LIF & SFS techniques in remote mode
Hyper-Spectral FLS LiDAR:

Every laser shot on the target is associated with a continuous LIF spectrum.
The technology of Spectral Fluorescence Signatures (SFS)

SFS serves as a “fingerprint” identifying the substance
## DEVELOPMENT HISTORY of FLS-LiDARs

<table>
<thead>
<tr>
<th>FLS-Model / Year</th>
<th>Sampling Rate, per sec</th>
<th>Sensing wavelength, nm</th>
<th>REAL-TIME Processing capacity</th>
<th>MAX Sensing distance, m</th>
<th>Installation / Beam Scanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLS-S / 1995</td>
<td>1-5</td>
<td>308, 360-530</td>
<td>NO</td>
<td>50 (In-depth sensing)</td>
<td>Shipboard / NO</td>
</tr>
<tr>
<td>FLS-A / 1995</td>
<td>10</td>
<td>308</td>
<td>NO</td>
<td>200</td>
<td>Airborne / NO</td>
</tr>
<tr>
<td>FLS-PL / 1998</td>
<td>10</td>
<td>308, 360, 420, 480, 530</td>
<td>NO</td>
<td>20</td>
<td>Stationary / NO</td>
</tr>
<tr>
<td>FLS-AU / 2001</td>
<td>20</td>
<td>308</td>
<td>YES</td>
<td>200</td>
<td>Airborne / NO</td>
</tr>
<tr>
<td>FLS-UV / 2003</td>
<td>50</td>
<td>308</td>
<td>YES</td>
<td>20</td>
<td>Stationary / NO</td>
</tr>
<tr>
<td>FLS-AM / 2005</td>
<td>90</td>
<td>308, 360, 440</td>
<td>YES</td>
<td>500</td>
<td>Airborne / YES</td>
</tr>
<tr>
<td>FLS-AE / 2007</td>
<td>120</td>
<td>308</td>
<td>YES</td>
<td>500</td>
<td>Airborne / YES</td>
</tr>
<tr>
<td>FLS-XX / 2009</td>
<td>500</td>
<td>308</td>
<td>YES</td>
<td>500</td>
<td>Airborne / YES</td>
</tr>
</tbody>
</table>
FLS™-LiDAR Family since 1995
System specification FLS-AM

- Sensing distance - 50 – 500 m
- Sensing mode – scanning across the trajectory
- Down look port – 30 x 30 cm
- Scanned width on ground – 1/10 altitude
- Sensing spectral range - Ultra-Violet (UV)
- Detection range - UV & Visible
- Multi-spectral detector - 500 channels
- Dimensions L x W x H: 1660 x 685 x 1005 mm
- Weight: 350 kg
- Power requirements: 110/220 V AC; 28 V DC; 3-6 kVA
New Model - FLS-Ae – the lightest in weight and power consumption LIF airborne lidar - has been developed in 2007

- Sensing distance: 50 – 500 m
- Sensitivity: 1 ppm of oil in water
- Sensing mode: scanning across the trajectory (2/5 of altitude)
- Sensing wavelength: – 308 nm
- Detection: 500 channels, UV & VIS
- Dimensions: 1830 x 1345 x 660 mm
- Weight: 180 kg
- Power requirements: 28V DC; 1kVA
- Integrated: Rangefinder, GPS, digital camera
CAPABILITY DEMONSTRATIONS:

Phytoplankton diagnostics at multi-wavelengths sensing

- Analysis of group taxonomy by selective excitation of phytoplankton pigments
- 3-D profiling (horizontal and in-depth) of phytoplankton abundance
- Phytoplankton bloom analysis
CAPABILITY DEMONSTRATIONS:

Monitoring of water quality and accumulated oil pollution in the port areas

Hamilton harbor (Ontario), 2003: oil pollution profile, ppm

Tallinn cargo harbor, 2004: oil pollution map, ppm
CAPABILITY DEMONSTRATIONS:

Oil Spill on water mapping and thickness measurement

- FLS-lidar and Hyperspectral Imager (CASI) were installed onboard a Cessna 404 aircraft to map a controlled oil spill (Brittany, 2004).

- Three spills of mineral oils were detected and mapped after release at flight altitude 500 m.

<table>
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<tr>
<th>Oil slick</th>
<th>Volume (m³)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>FLS data</td>
</tr>
<tr>
<td>Day 1 / Flight 1</td>
<td>5,1</td>
</tr>
<tr>
<td>Day 1 / Flight 2</td>
<td>2,1</td>
</tr>
<tr>
<td>Day 2 / Slick 1</td>
<td>0,38</td>
</tr>
<tr>
<td>Day 2 / Slick 2</td>
<td>0,26</td>
</tr>
</tbody>
</table>
CAPABILITY DEMONSTRATIONS:

Simulated Oil Seep: Submerged Heavy Oil Detection & Classification

OHMSETT (USA) Experiments (2005) with Automatic On-Line Detection and Classification of Surface and Weathered Submerged Oil with FLS Lidar
CAPABILITY DEMONSTRATIONS:

Pollution detection in iced water

Sample SFS

SFS of Waste Motor Oil
From the Library

Typical LIF spectrum
CAPABILITY DEMONSTRATIONS:

Ground Targets location and identification with scanning FLS LiDAR

Laser Spots on the ground & targets
OPERATIONAL USE OF FLS-LIDAR

**CHALLENGES**

- Reliable detection of target (e.g. oil spill); 24 hours a day
- Real-Time Reporting
- Mapping polluted area and, evaluation of pollution volume
- Identification of target type for physical and chemical properties

**OPTIMIZATION**

- Combined use with other sensors
- Combining large-scale data with higher-resolution surveys of key locations flown with airborne FLS LIDAR
- Specifically targeted Missions

FLS LIDAR can serve effectively for surveys with specific purposes or for periodical data collection over large areas
Real-Time Spectral Recognition

- Measured spectrum
- LIDAR
- OPERATOR CONSOLE
- EXPERT SYSTEM
- LIBRARY
- LEVEL 1: Underlying surfaces
- LEVEL 2: Sensed targets
- QUANTITATIVE ANALYSIS
- PATTERNS RECOGNITION
- Forest
- Green Field
- Unidentified
- Shallow water
- Green Field
- Seawater
- Oil pollution
- Flight path

Laser Diagnostic Instruments
In-flight simultaneous detection of 4 oil types by deconvolution of LIF spectra
EXAMPLES OF OPERATION: FLS-AM in scanning mode

LIF Data Classification by Expert system

RED – GROUND

BLUE – WATER
(size of the bubbles reflects transparency)
EXAMPLES OF OPERATION: FLS-AM in scanning mode

Data Classification by Expert system

**RED** – Dissolved Organic Matter in water (size of the bubbles is calibrated by concentration)

**GREEN** – VEGETATION on land
EXAMPLES OF OPERATION: FLS-AM in scanning mode

Data Classification by Expert system

RED – Dissolved Organic Matter in water (size of the bubbles is calibrated by concentration)

PURPLE – OIL POLLUTION (size of the bubbles is calibrated by concentration)
KEY COMPONENTS

LIF LiDAR
LIF Data remote acquisition

SFS
Spectral Library for identification
LIF data calibration

On-Line
Expert System
Real-Time Alarm
Post processing
Main Features of FLS™ Lidar

<table>
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<th>SUMMARY</th>
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<tr>
<td>▪ Hyper-spectral detection – comprehensive LIF spectrum (500 channels, spectral resolution 5 nm) at every laser shot</td>
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<td>▪ Scanned Field of View – Locating the target</td>
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<td>▪ Gated Receiver – Day &amp; Night Operation</td>
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<td>▪ Additional sensing wavelength(s) – Increased Analytical Capabilities</td>
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<td>▪ Spectral data correction for the sensing distance</td>
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<td>▪ LIF Readings are accompanied with GPS coordinates</td>
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<td>▪ In-flight data pre-processing – Real-Time ALARM Report</td>
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Multi-tier model for environmental assessment

- **1-st tier:** Real-time large-scale assessment of entire regions in underway measurements with LIDAR

- **2-nd tier:** Refinement of assessment through post-mission calibration of LIDAR readings with reference points derived from a few selected samples

- **3-rd tier:** Follow-up with precision assessment of chosen locations with detailed lab testing of the samples

Example (2006):
- 1-st tier – 22,000 samples
- 2-nd tier – 18 samples
- 3-rd tier – 6 samples
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