RECENT DEVELOPMENTS IN LASER-ACOUSTIC DETECTION OF BURIED LANDMINES

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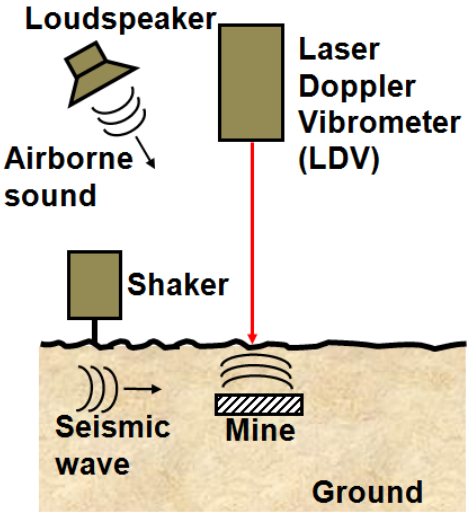
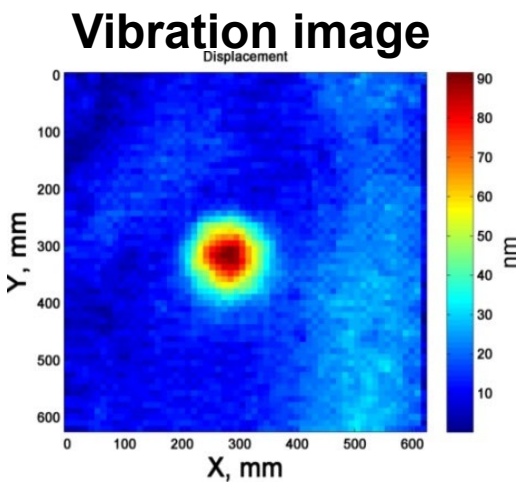
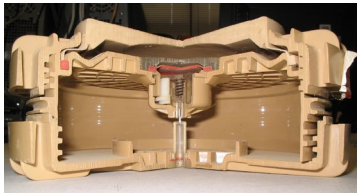
Outline

1. Introduction: Laser-acoustic detection of buried landmines
2. Challenges of traditional Laser Vibrometers used for detection
3. Novel Laser Multi Beam Differential Interferometric Sensor (LAMBDIS) for laser-acoustic detection of buried objects with low sensitivity to sensor motion
4. Experimental results: laboratory and field

Laser-Acoustic Detection of Buried Landmines

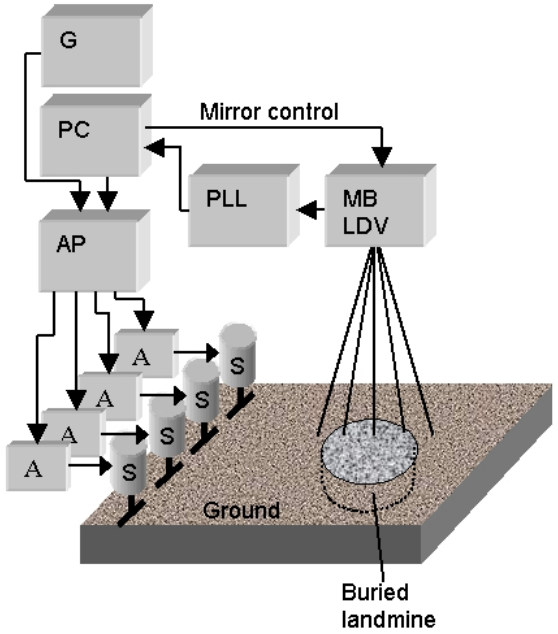


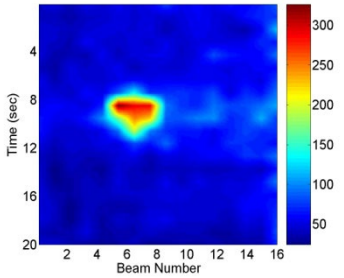




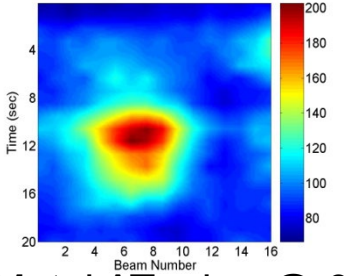
- Probability of detection 95%, low false alarm rate, 0.03/m^2
- Single beam scanning LDV measurement time >3 minutes for an 16x16 array of points
- LDV requires operation from a stationary platform

Multi-Beam LDV for Detection of Buried Landmines





Plastic AT mine @ 6in, dirt. 170-180Hz

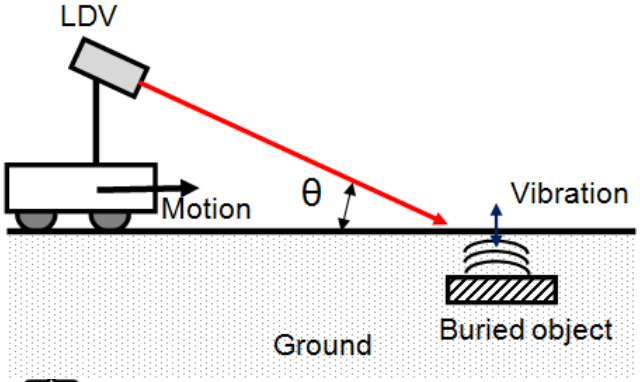


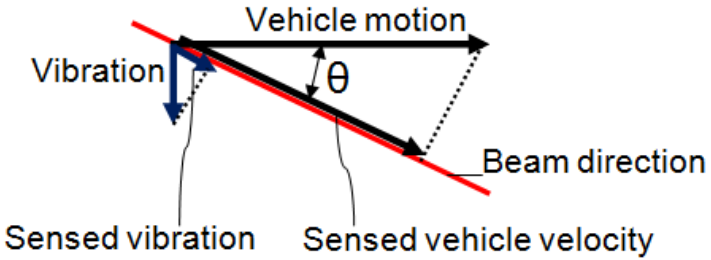
Metal AT mine @ 6in, gravel,135-145Hz

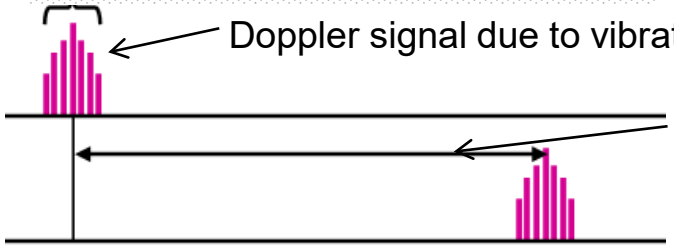
- **Time to record a vibration image is ~20 sec.**
- **Requires operation from a stationary platform**

LDV challenges: Operation from moving platform

LDV operation from moving vehicle induces Doppler shift in the LDV signal, which can significantly exceed Doppler shift caused by object vibration



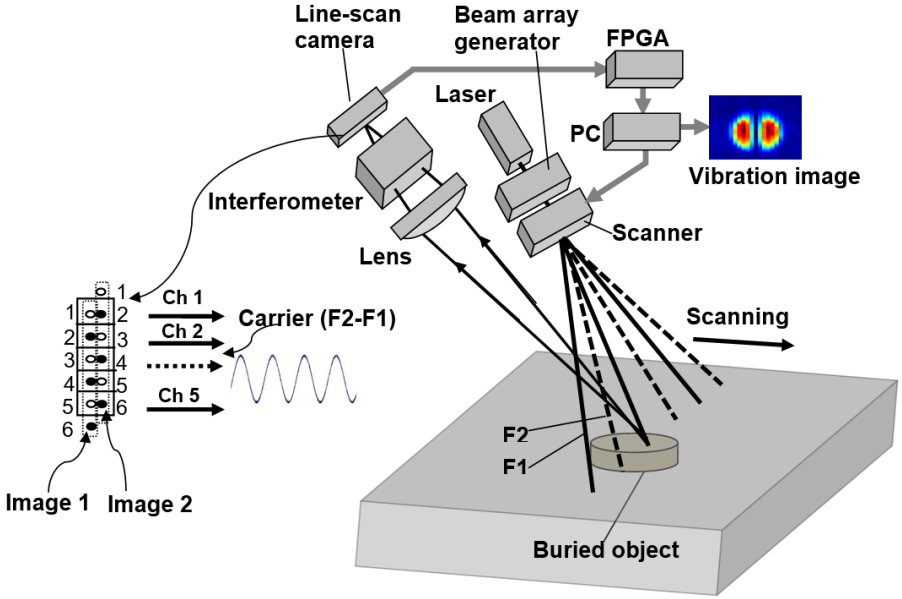




Doppler signal due to vibration (Bandwidth: ~5 Hz to 500 Hz)

Doppler shift due to vehicle motion: ~15 MHz for θ =13°and vehicle speed 4 m/s (9 mph)

LAMBDIS Principle of operation

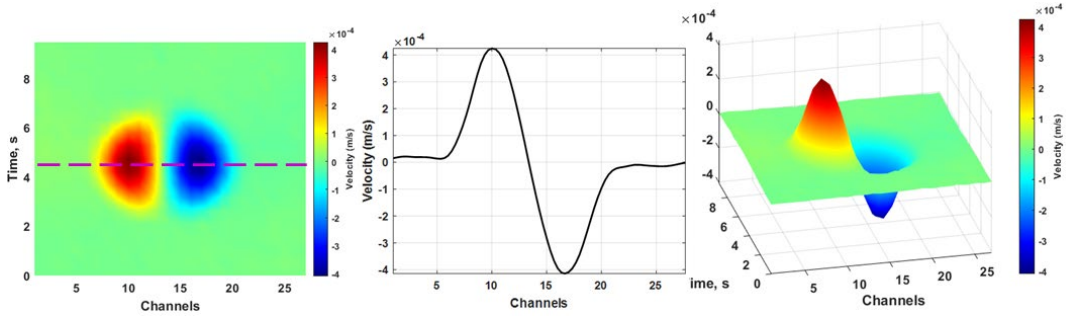


- Laser Multi Beam Differential Interferometric Sensor (LAMBDIS) simultaneously measures relative velocities between object points illuminated with a linear array of 30 beams.
- Doppler shift caused by the sensor motion is practically the same for all beams and cause small frequency shift in the output signals.

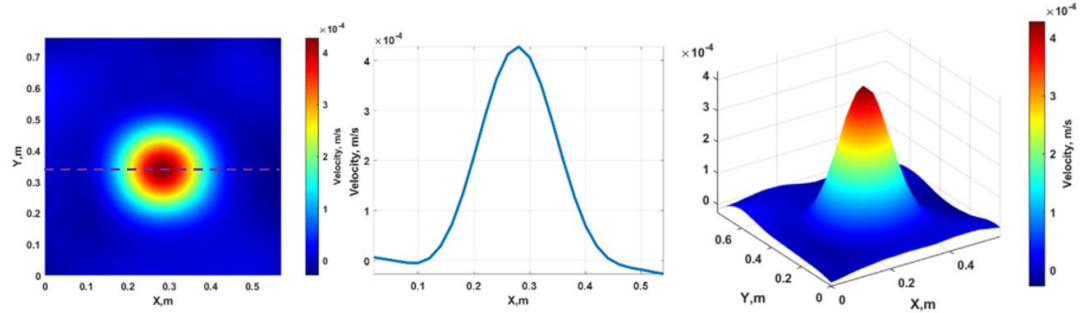
Vibration image obtained with LAMBDIS

Vibration images of circumferentially clamped circular plate obtained with LAMBDIS and scanning LDV

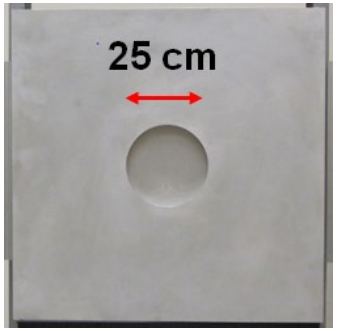
Vibration image obtained with LAMBDIS



Vibration image obtained with scanning LDV



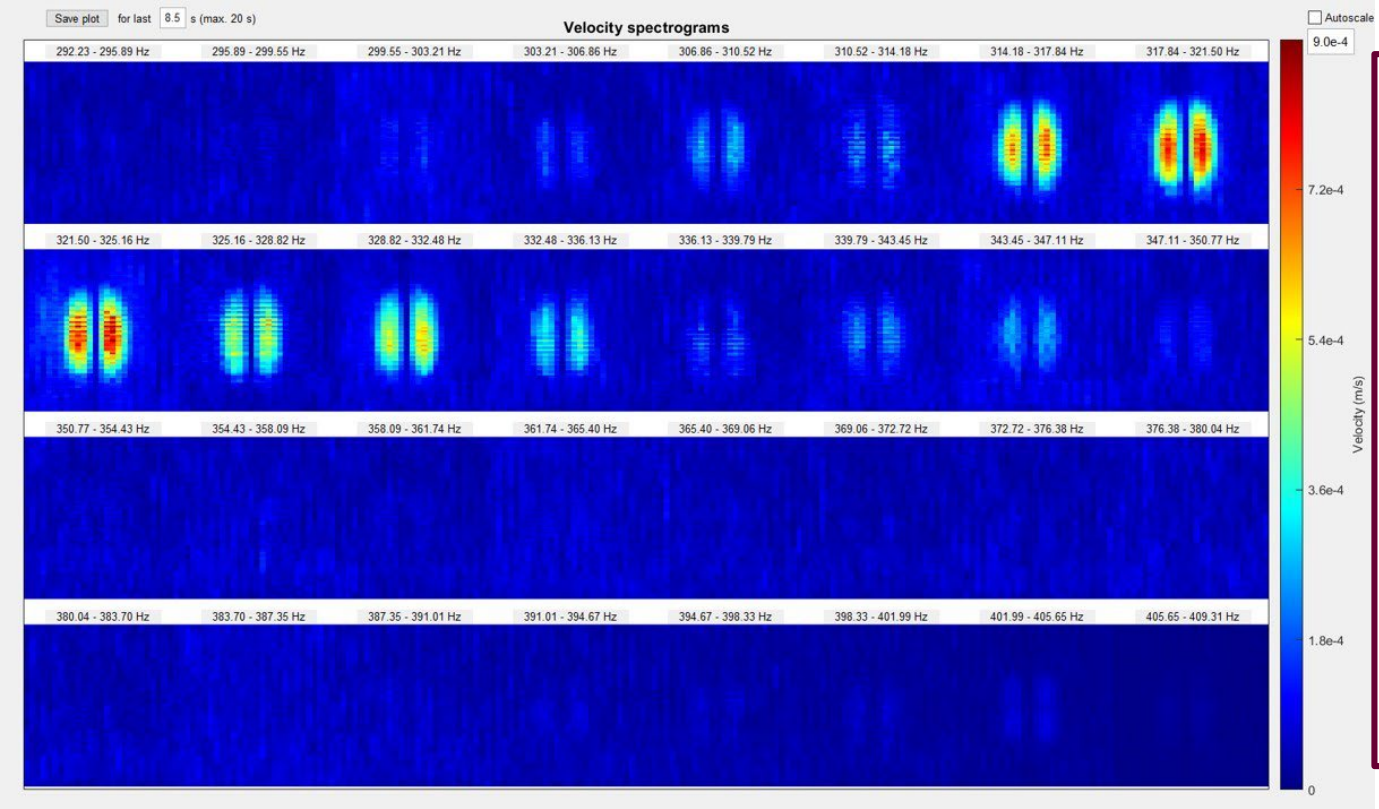
Circumferentially clamped plate

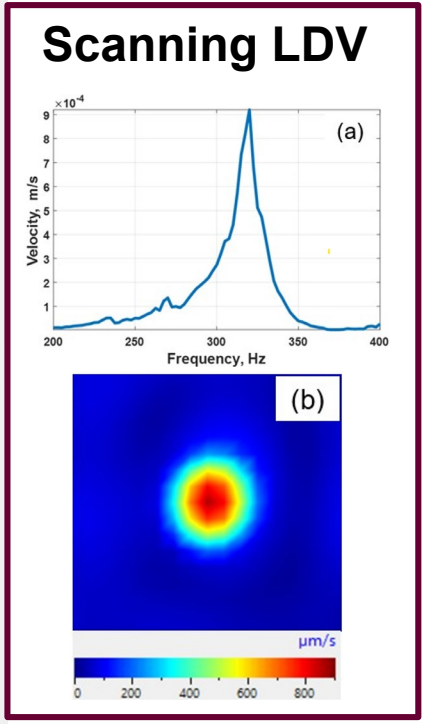


LAMBDIS beams scanning over target: Video

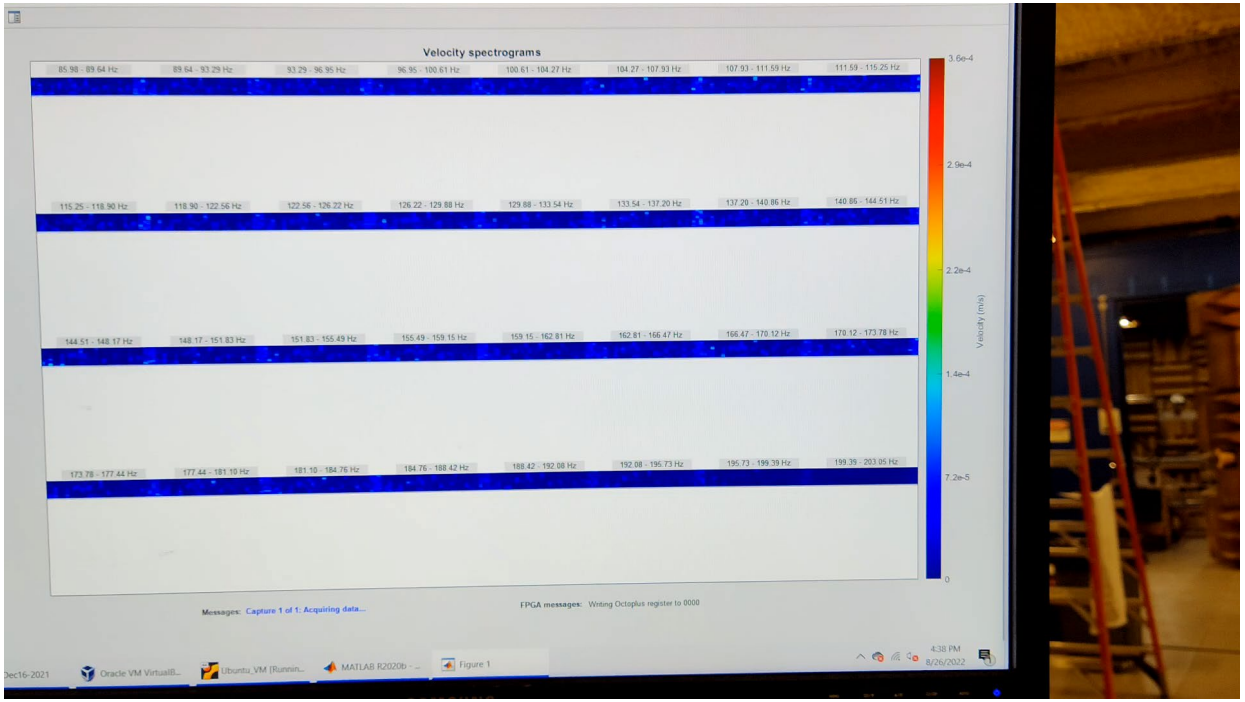
Vibration images of vibrating plate in 32 frequency bands

Frequency range: 292 – 409 Hz, bandwidth: 3.66 Hz

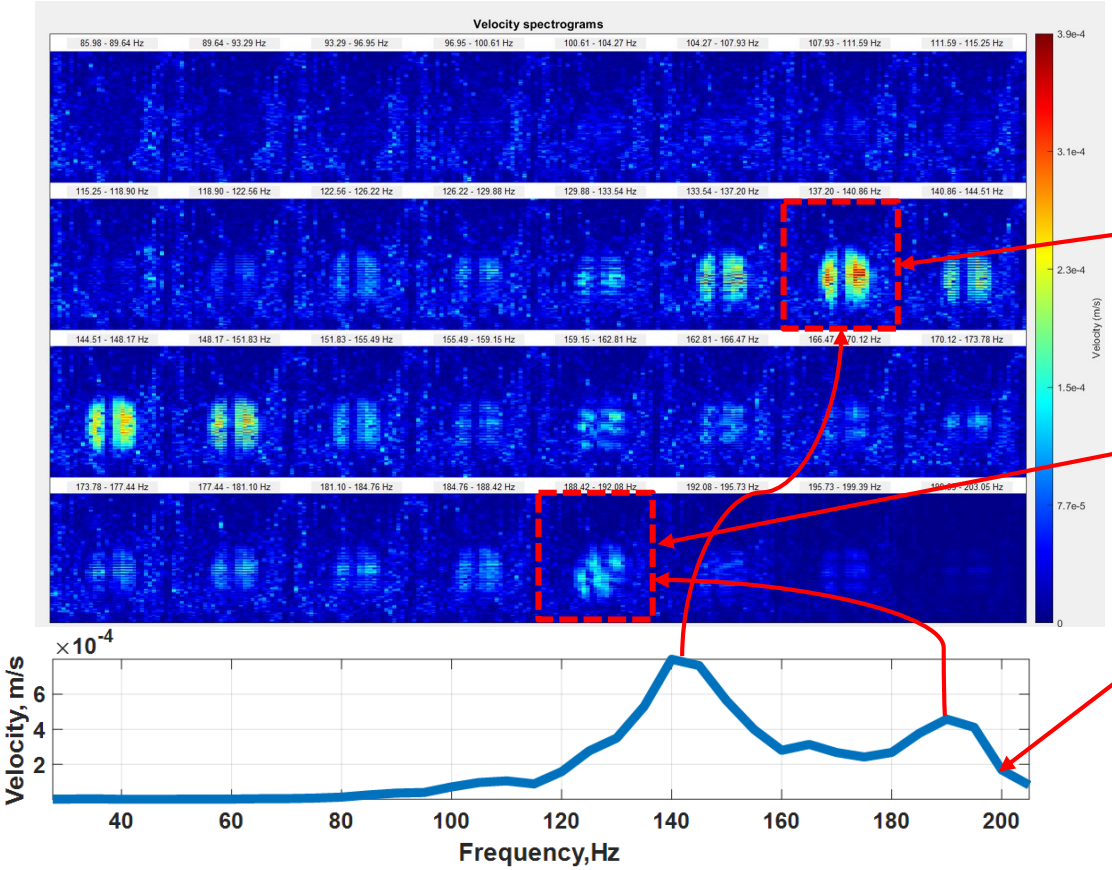




Real-time continuous visualization of buried object in 32 frequency bands for broadband excitation from 85 to 205 Hz, Video.



Real-time vibration images of buried object in 32 frequency bands for broadband excitation from 85 to 205 Hz

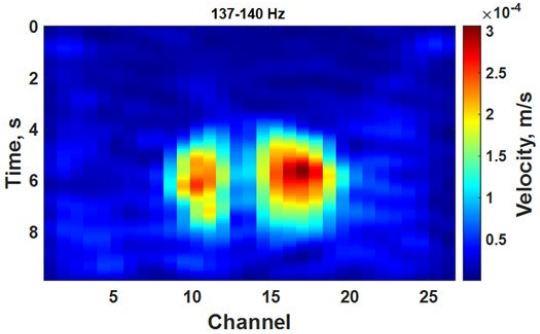
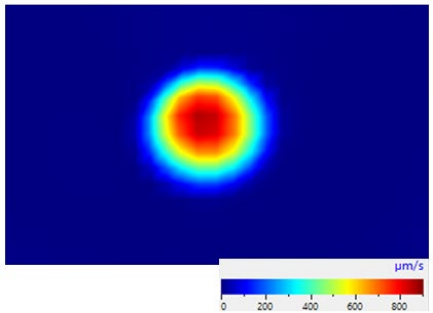
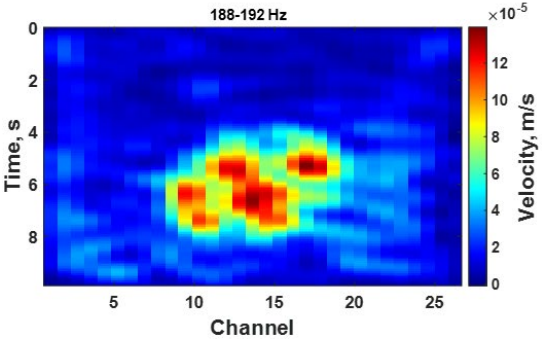
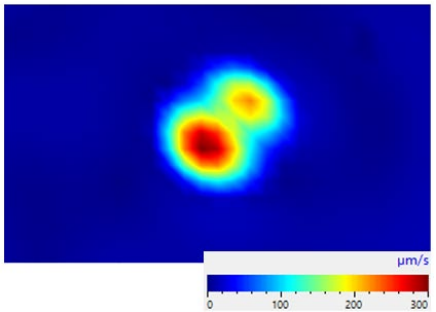


137-141Hz

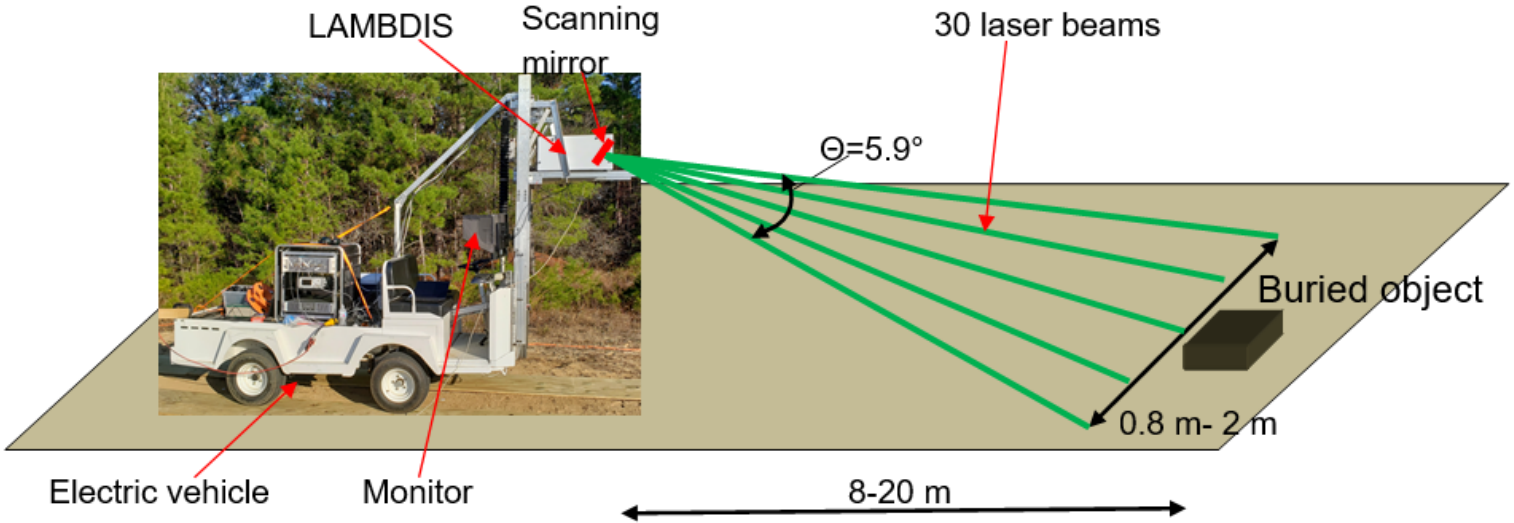
188-192 Hz

Frequency response measured with LDV

Vibration images at selected frequency bands: comparison with scanning LDV

	LAMBDIS	Scanning LDV
137-141 Hz		
188-192 Hz		

LAMBDIS field experiments: measurements geometry

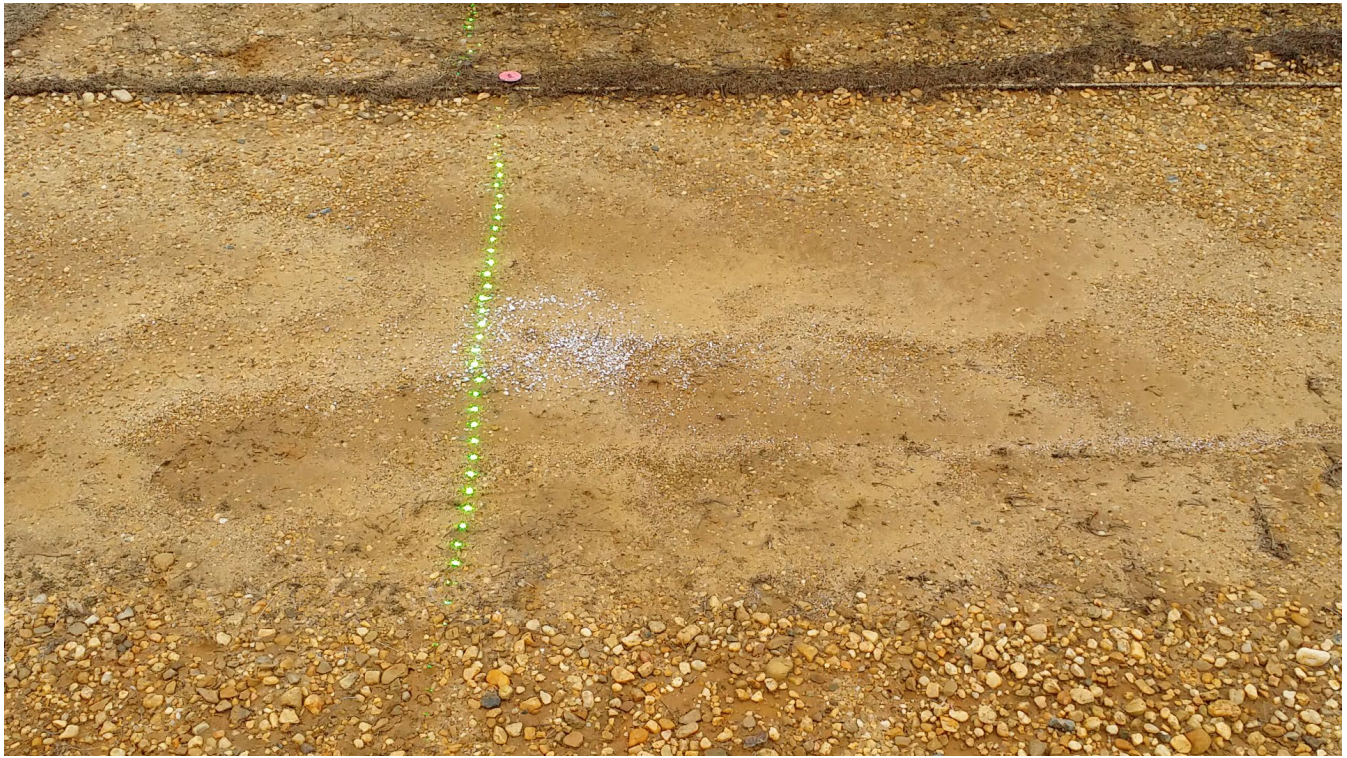


For standoff S = 10 m: spread of beams D = 103 cm, spacing d= 36 mm, grazing angle 13.5 deg.

Modes of operation:

1. **Moving mode. Beams scan the ground due to the vehicle motion.**
2. **Scanning mode. Vehicle is stationary. Scanning mirror scans the beams along the track.**

LAMBDIS beams scanning over target, video

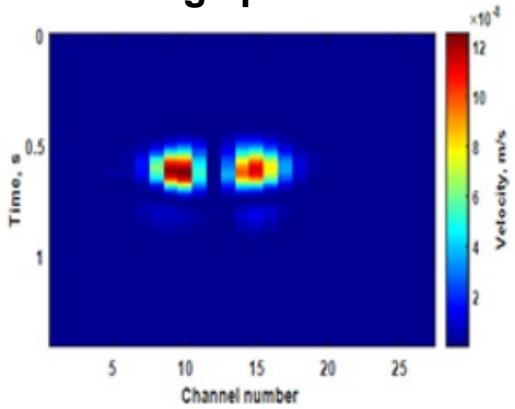


Collecting data from moving vehicle, video

Field measurements from stationary and moving vehicle

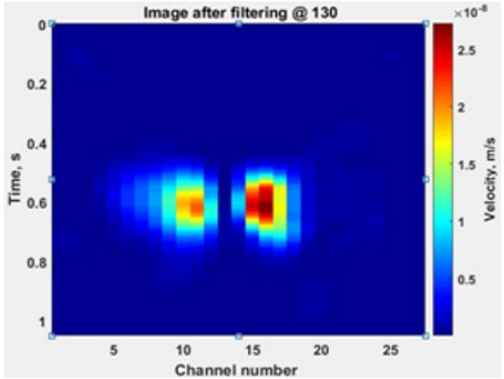
Stationary vehicle

Scanning speed 1 m/s

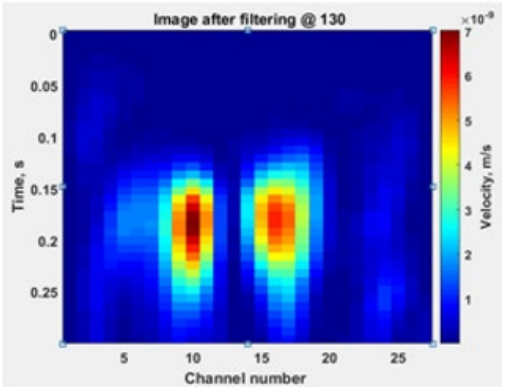


Moving vehicle

1 m/s



3.4 m/s



Summary

- A novel Laser Multi Beam Differential Interferometric Sensor (LAMBDIS) allows for detection of buried objects from a moving or a stationary vehicle in a forward looking scenario.
- The LAMBDIS has low sensitivity to sensor motion and measures vibration velocity difference between object points with interferometric sensitivity.
- The sensor provides real-time continuous measurement and visualization of vibration images of ground surface in 32 frequency bands.