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# On the use of a pulsed-laser source in laboratory seismic experiments

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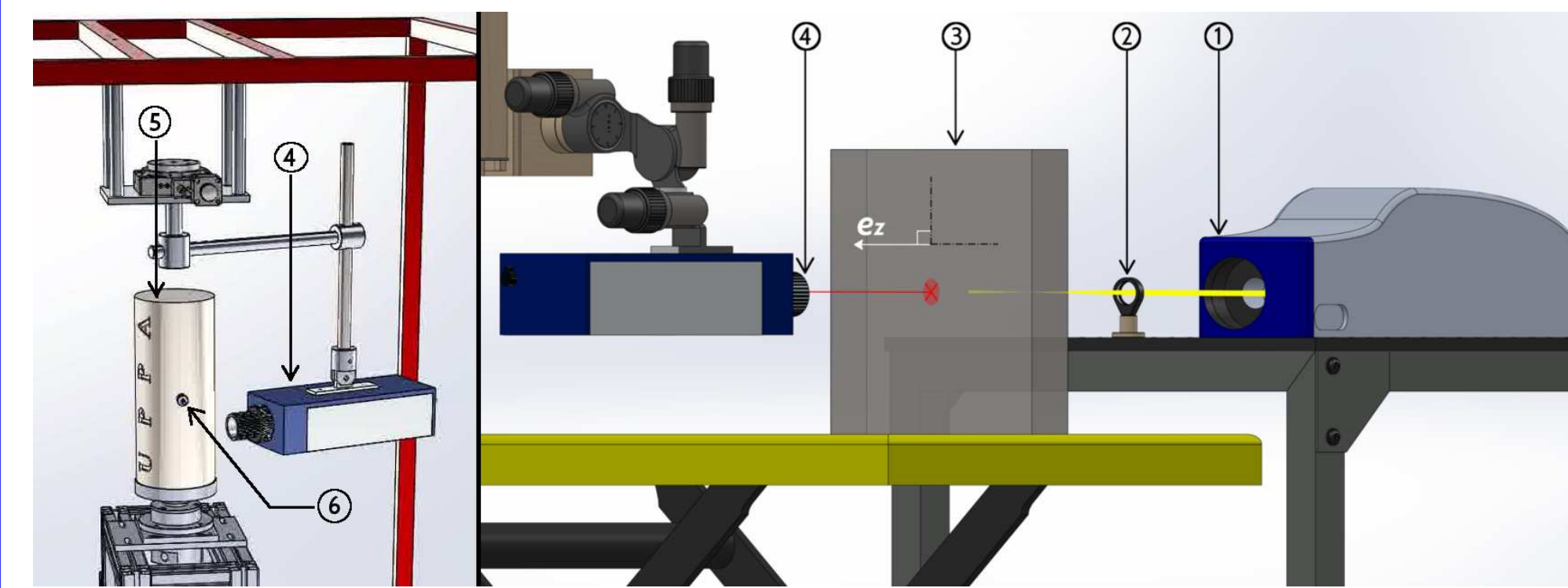
- 1) CNRS/ TOTAL / Univ Pau & Pays Adour/E2S UPPA, Laboratoire des Fluides Complexes et leurs Réservoirs – IPRA, UMR5150, 64000, Pau, FRANCE
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## Research context & objectives

Reproduction of large-scale seismic exploration at laboratory-scale with controllable sources is a promising approach that could not only be applied to study small-scale physical properties of the medium, but also contribute to significant progress in wave-propagation understanding and complex media imaging at exploration scale via upscaling methods. We seek to characterize the properties of a laser-generated seismic source for new geophysical experiments at laboratory scale. This consists in generating seismic waves by pulsed-laser impacts and measuring the displacement wavefield by laser vibrometry. Parallel 2D/3D simulations using Discontinuous Galerkin discretization method and analytic predictions have been done to match the experimental data.

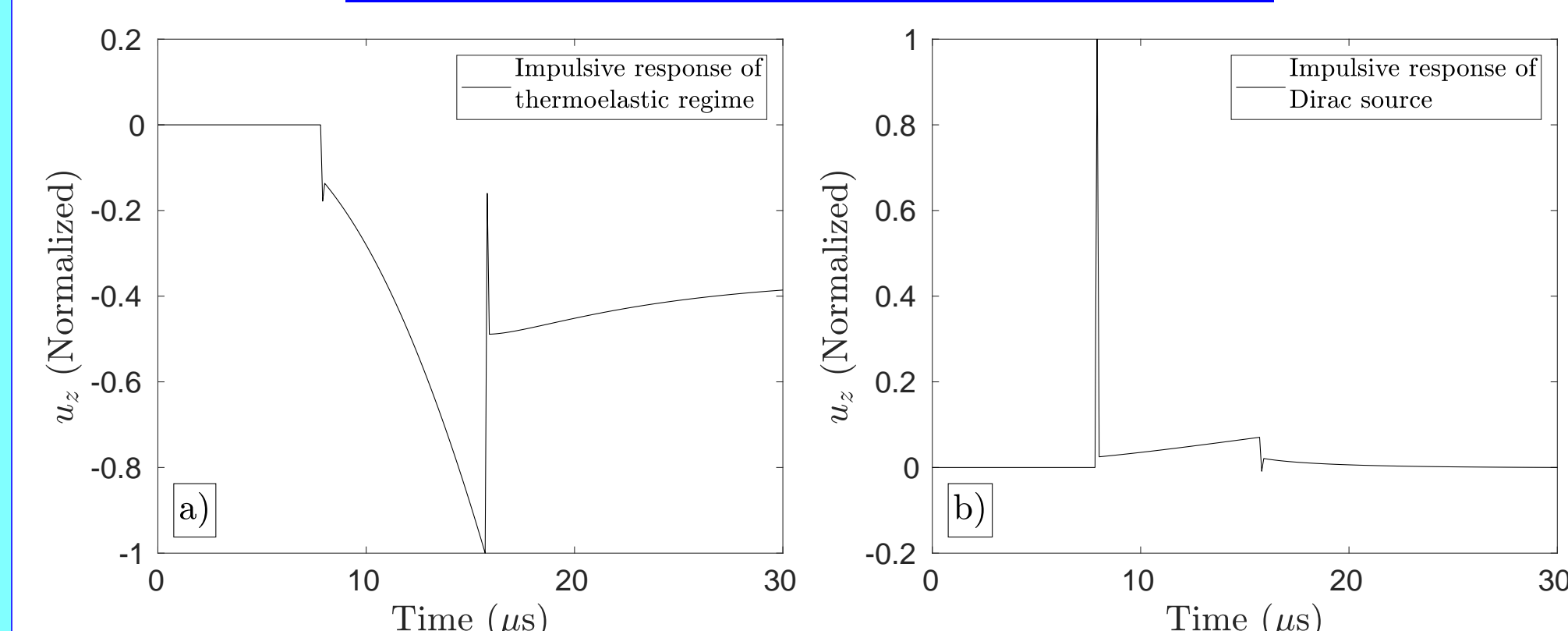
## Pulsed-laser source : General

### Lab set-up for pulsed-laser source characterization



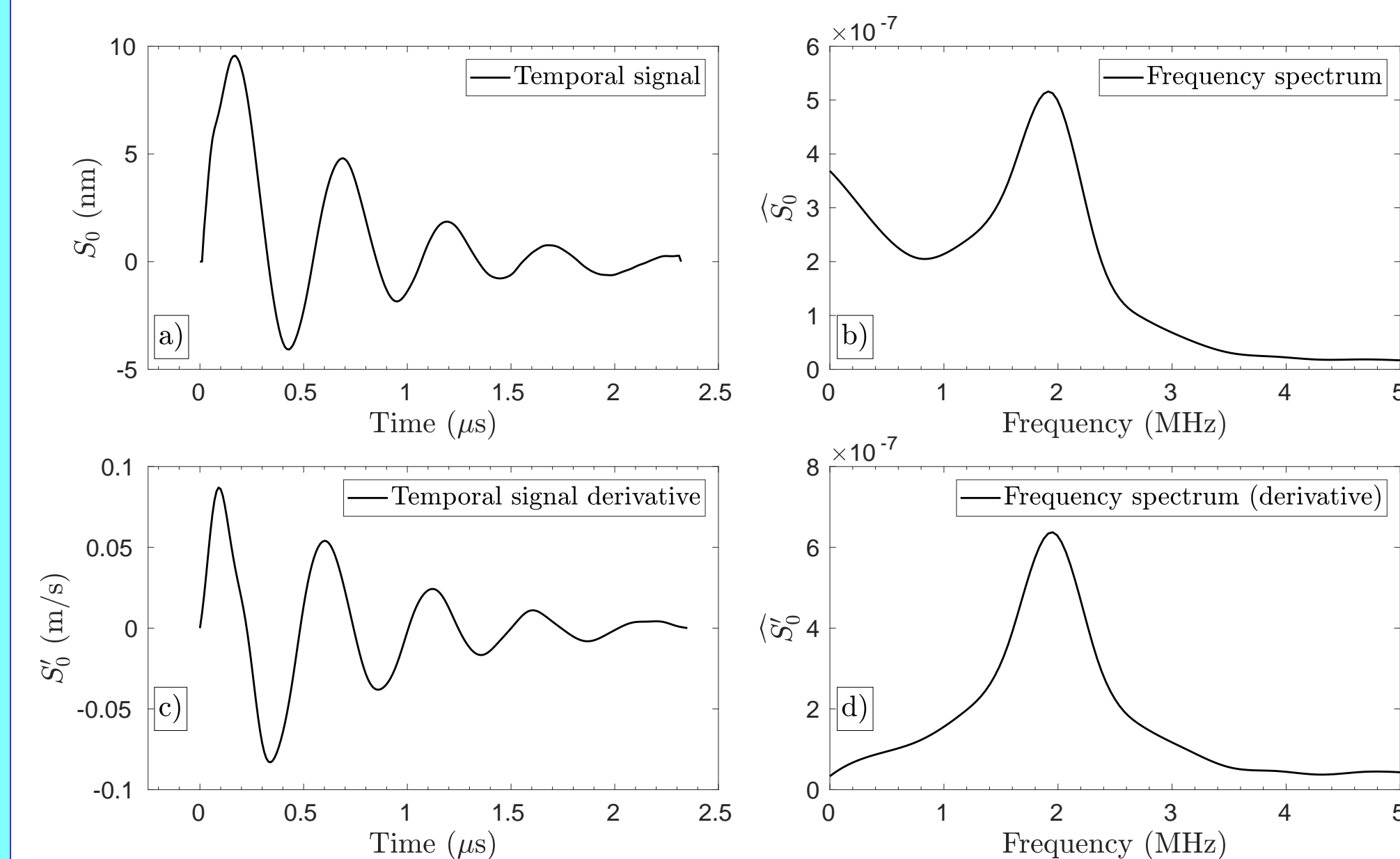
Two different experimental tools were mounted to investigate in Cartesian coordinates or in cylinder coordinates. ① : Q-Switched laser generator; ② : convergent lens; ③ : Aluminum cuboid samples of various thickness (10, 50, 100 mm),  $V_p \approx 6350$  m/s,  $V_s \approx V_p/2$ ; ④ : single point Laser Doppler Vibrometer (LDV); ⑤ core sample; ⑥ piezoelectric source.

### Theoretical and analytical signals



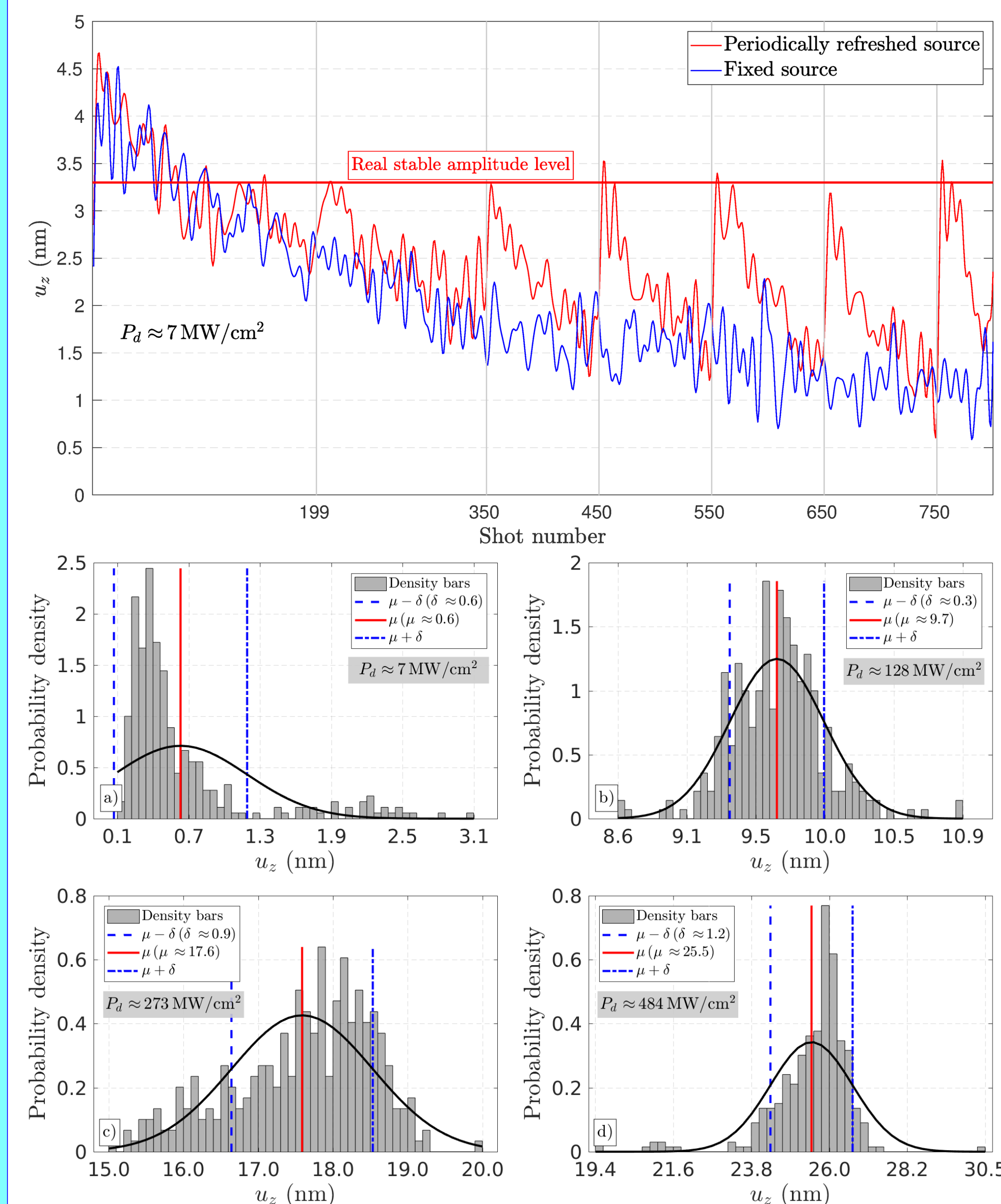
a) : laser-generated seismic source under thermoelastic regime with displacements computed by combining the wave equation and the thermoelastic equations [2, 3, 5]. b) : laser-generated seismic source under ablation regime which is modelled as a point-source [1, 2].

### Zoom on the measured ablation-regime pulse



a) : Temporal laser-generated source  $S_0$  retrieved from a record on the 50 mm thick aluminum block. b) : Frequency spectrum  $\hat{S}_0$  of the same source. c) First order time derivative of  $S_0$ , thus showing the surface vibration velocities. d) Frequency spectrum of  $S_0'$ .

### Source stability and reproducibility



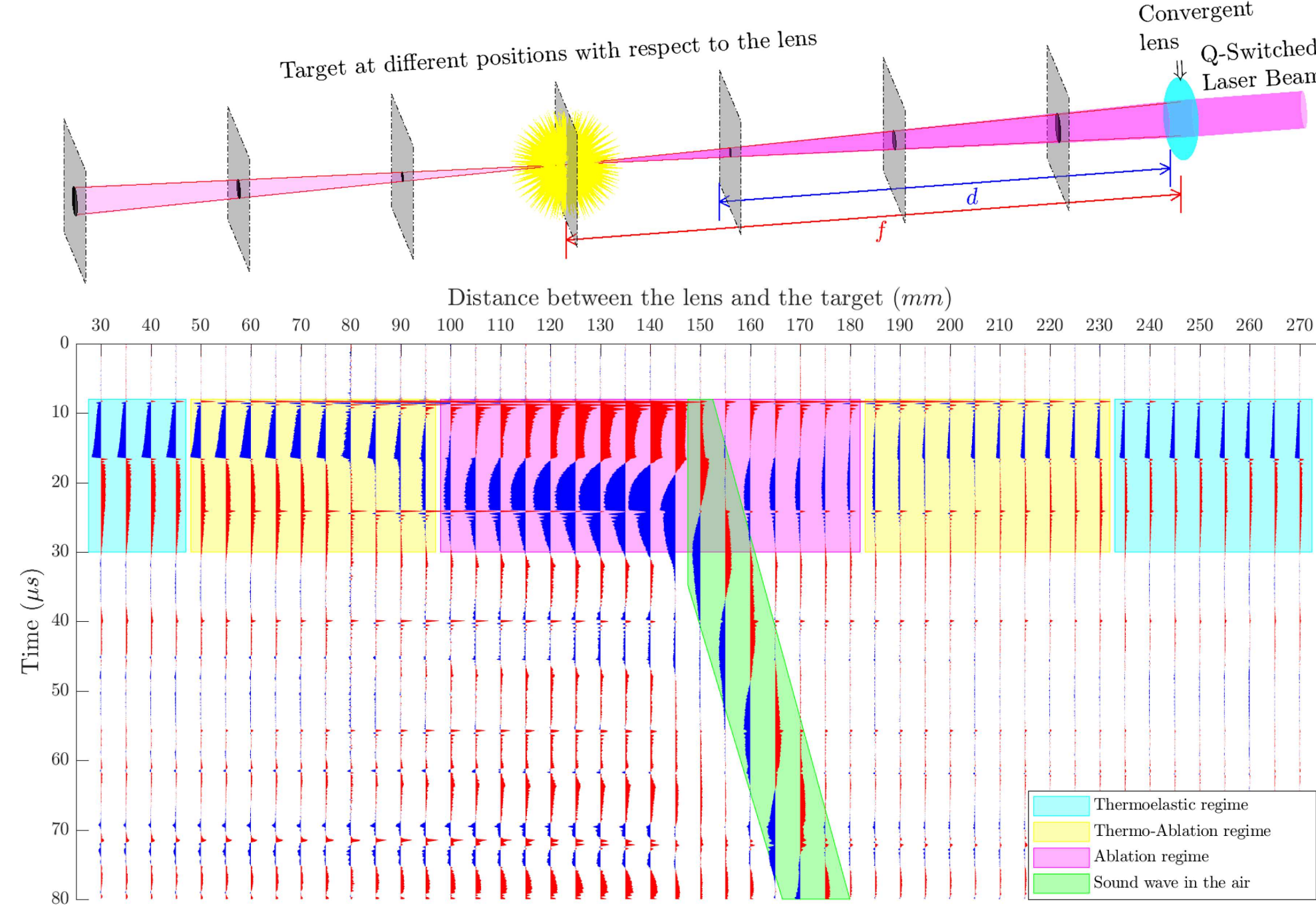
Distribution of first arrival seismic wave amplitudes  $u_z$  measured by LDV at the epicenter of the 10 mm thick aluminum block.  $P_d$  denotes the incident power density.

## Pulsed-laser source : Seismogram

### All regime

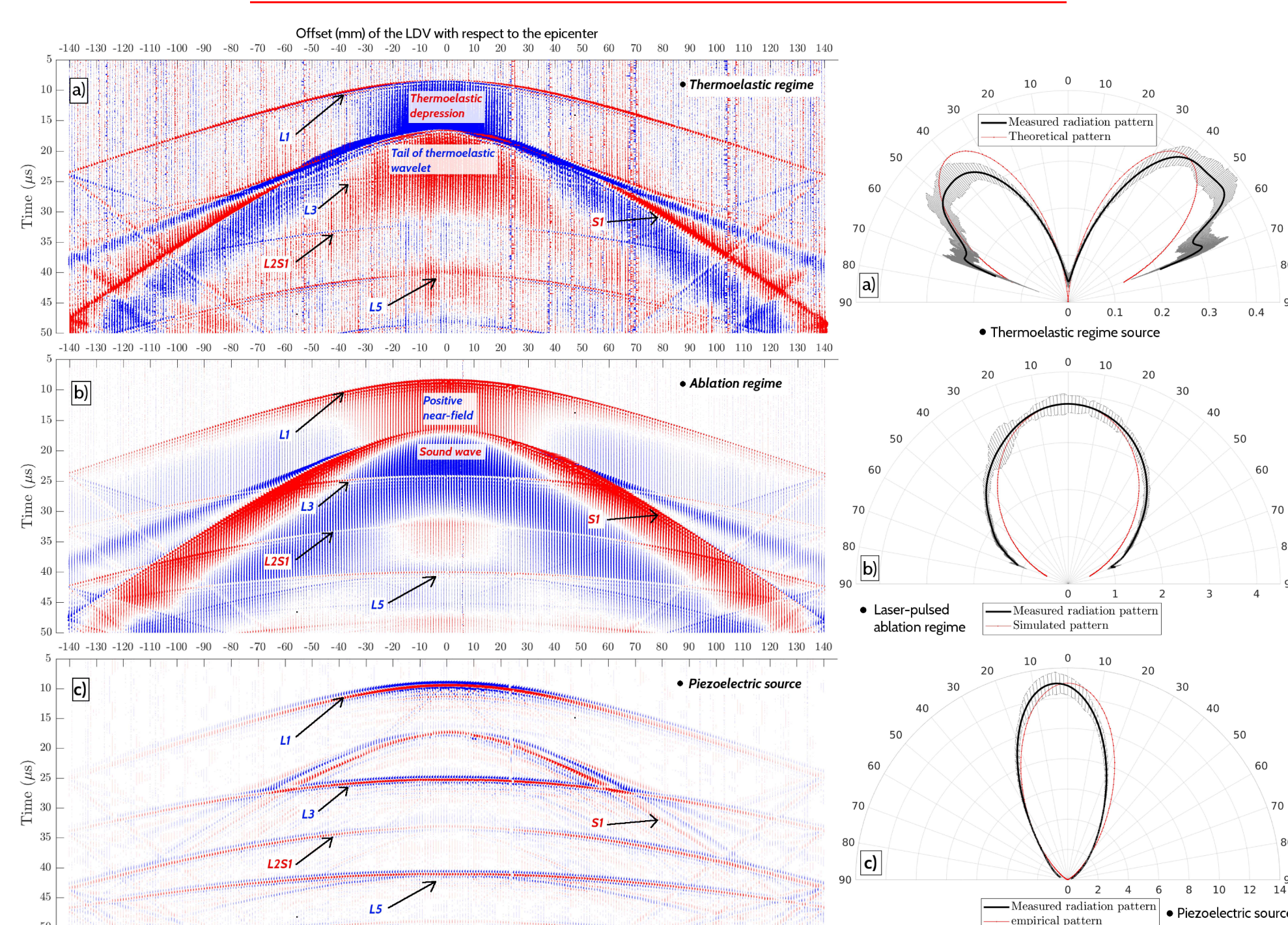
Two major parameters control the regime :

- 1) The incident energy; 2) The laser spot size



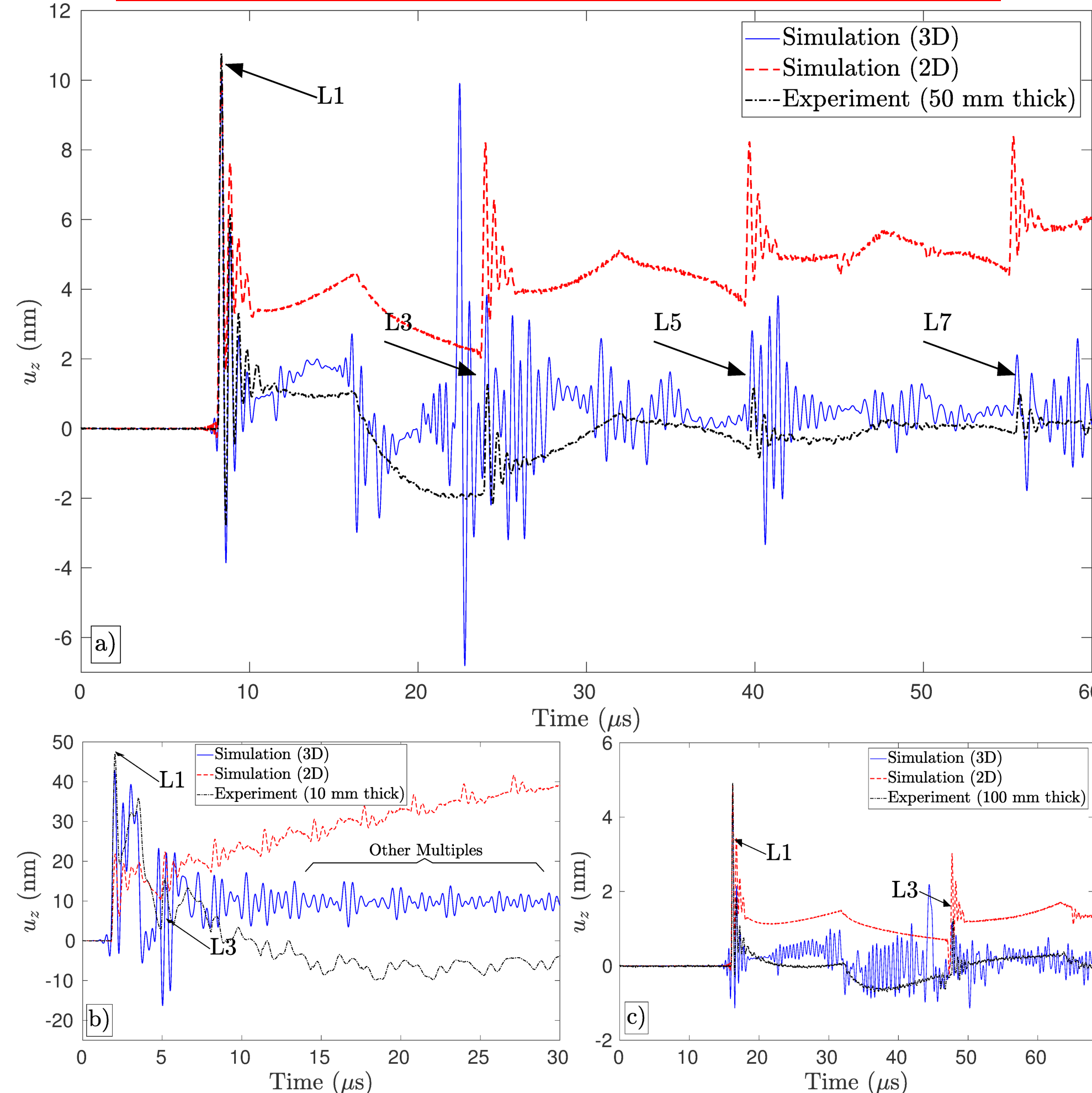
Regime evolution with  $d$  under constant input energy. Since the spot size depends on  $d$ ,  $P_d$  varies. However, the observable regime cannot be determined unilaterally by  $P_d$ .

### Seismogram and radiation patterns



Seismogram measured along linear receivers on the 50 mm thick aluminum block with different sources, accompanied by simulated/modelled radiation patterns. a) : radiation pattern of a point source (laser ablation); b) : radiation pattern of a piezoelectric source ( $\Phi \approx 10$ mm); c) : radiation pattern of a typical thermoelastic source [4] under laser irritation.

### Epicentral records under the ablation regime



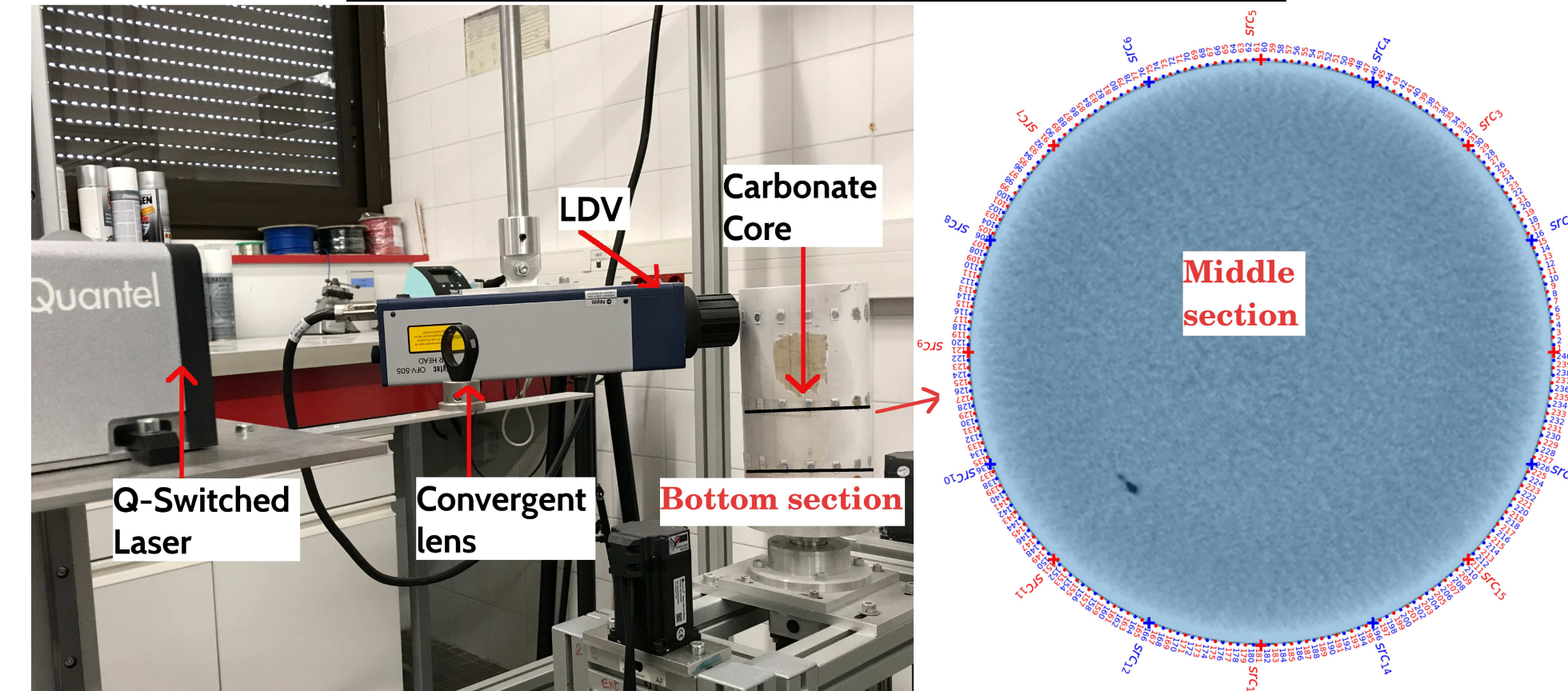
Overview on single experimental/simulated seismic traces (normal components). 2D/3D simulations are done by FE schemes featuring Discontinuous Galerkin (DG) with Interior Penalty (IP).

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## Pulsed-laser source : Application

### Tomography on a carbonate core



Application of the pulsed-laser ablation source on a carbonate core ( $\Phi \approx 120$ mm). We used the point-source point-receiver setup. 16 sources (aluminum flakes) are uniformly distributed along the circumference of each normal section. Each source covers  $300^\circ$  (101 receivers @  $3^\circ$ ) in a symmetric manner. Thousands of shots are received by each source flake due to averaging recording.

### First arrival time base tomography

