Development of PDV measurement at 830 nm

DE LA RECHERCHE À L’INDUSTRIE

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PDV User Workshop

Santa Fe, February, 2023

Overview

- Why did we choose this wavelength ?
- Development in laboratory
- How did we measure the performances ?
- Presentation of the GCLT
- Results at 830 nm and 1550 nm
- Conclusion and perspectives

Why this wavelength ?

Limit of a PDV diagnostic => STFT analysis

Measurement uncertainty => Gabor inequality : $\Delta f \cdot \Delta T \geq \frac{1}{4\pi}$

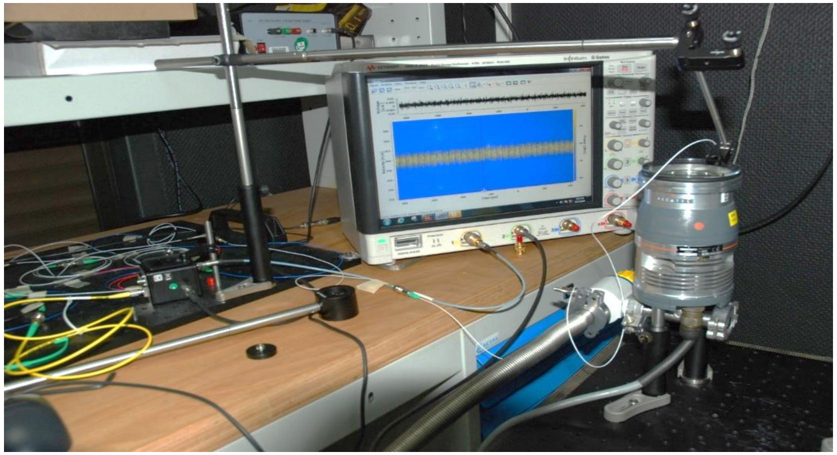
Wavelength (nm)	400	532	830	1064	1550	2000
Gabor limit (ns.m/s)	16	21	33	42	62	80
dT for dV = 10 m/s (ns)	1,6	2,1	3,3	4,2	6,2	8,0

Wavelength (nm)	400	532	830	1064	1550	2000
Attenuation (dB/km)	50	15	5	1,5	0,2	20

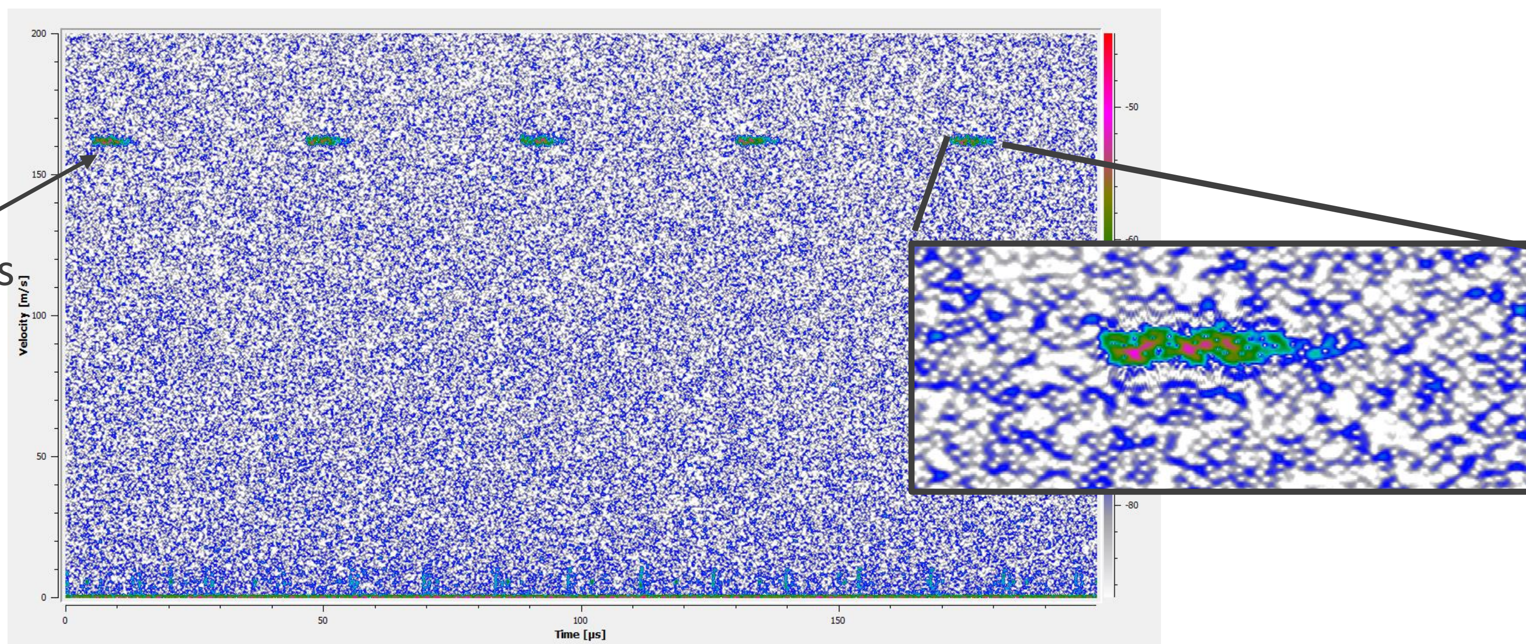
830 nm is a good agreement between attenuation in fiber, resolution (in time and velocity) and availability of components.

STFT : Short-time Fourier Transform

Development in laboratory



Test at constant velocity : light reflected by rotating blades (vacuum pump)

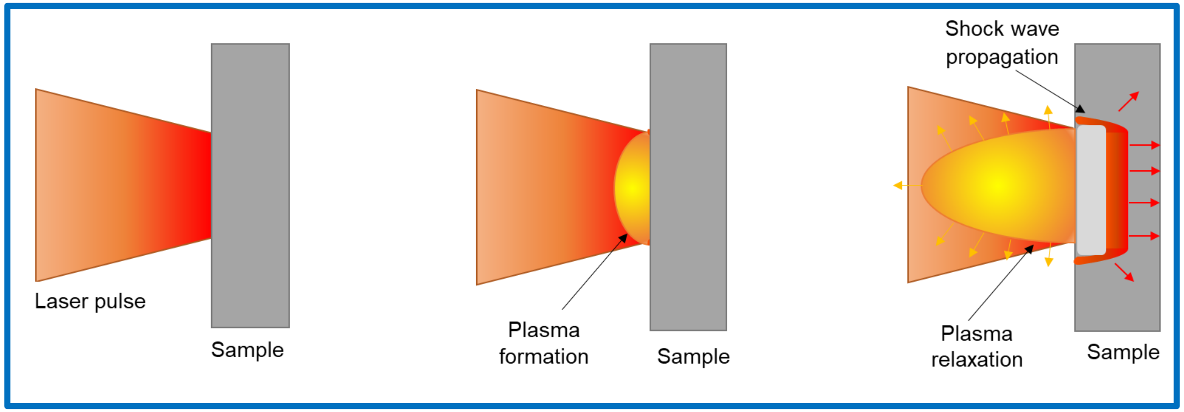


V = 162 m/s

How to measure the performances ?

- Generation of shocks waves in a sample and observation of vibrations.
- Choice of a specific metal and thickness in order to decrease the transit time of the release waves => allows reach the limit of visibility of the PDV setup.
- Laser shock wave = Low damage and good power stability.
- Comparison between 1550 nm PDV and 830 nm PDV by simulation (1D Lagrangian code : ESTHER).

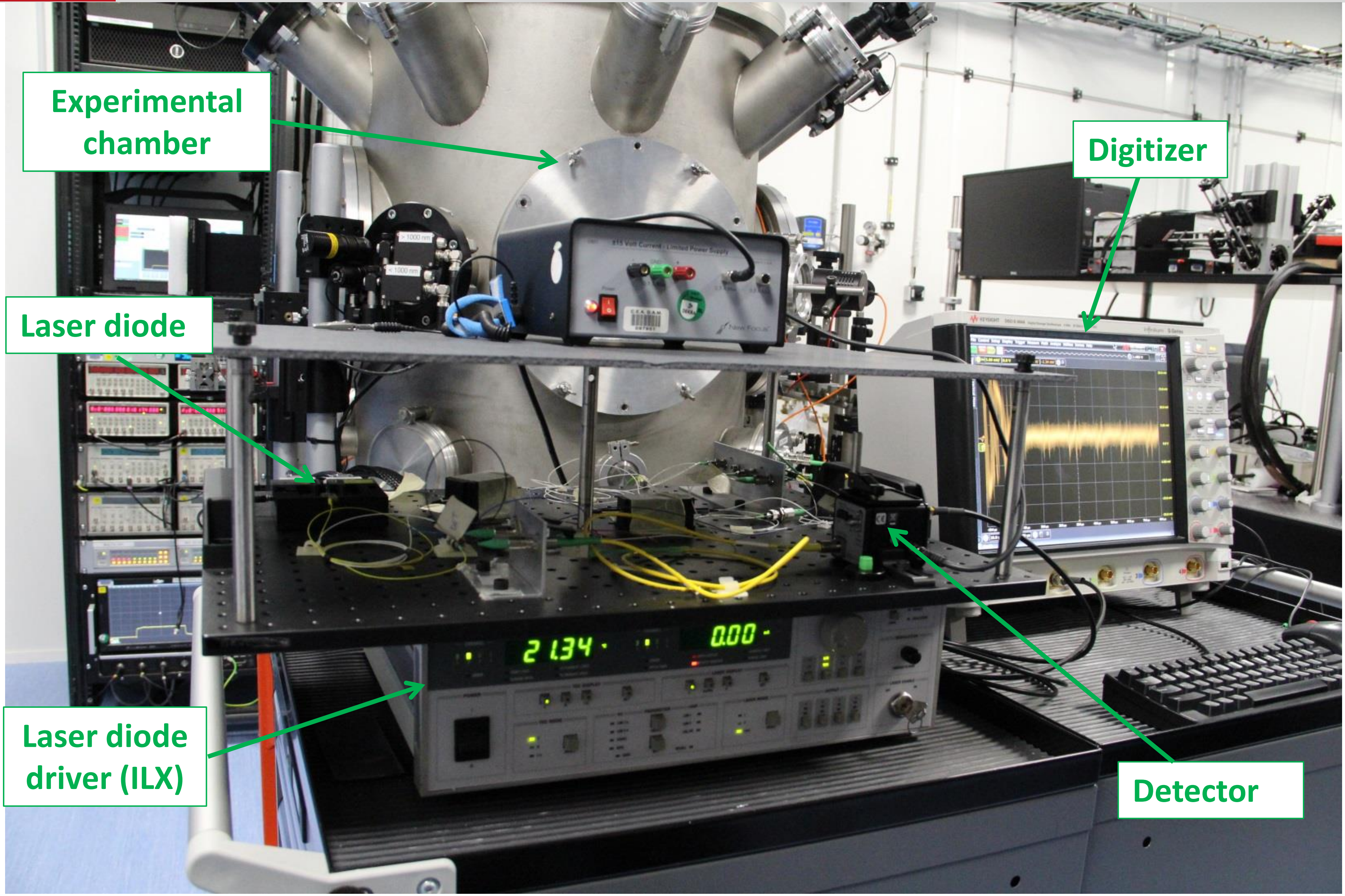
How do we generate shock waves with laser pulses ?

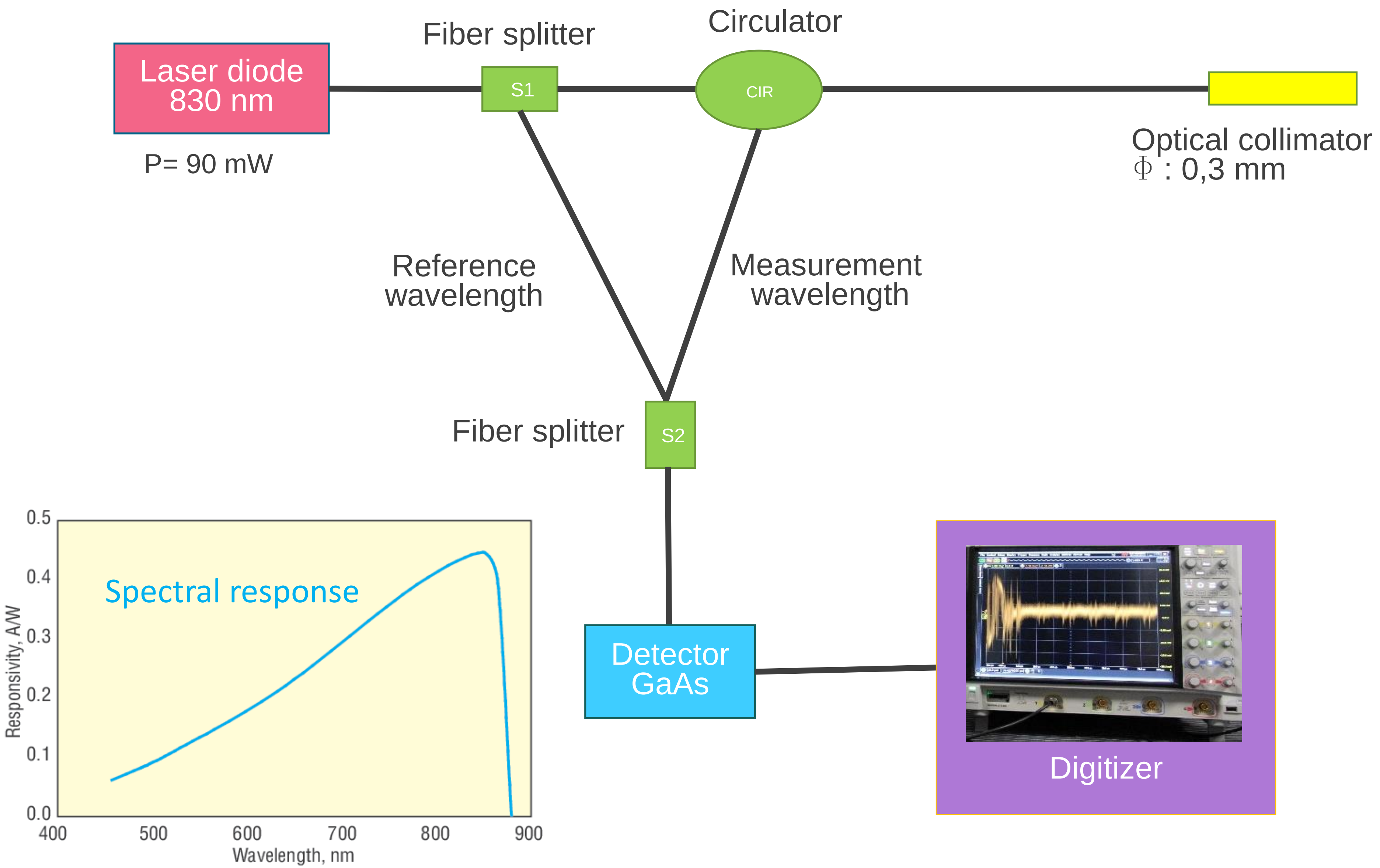


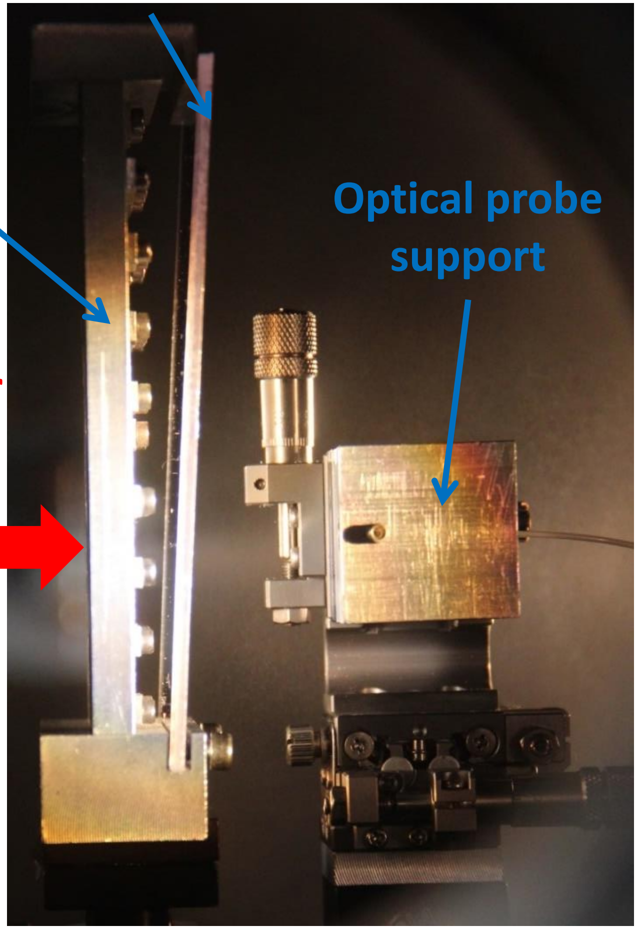
Main characteristics :

- λ : 1053 nm
- Max energy : 100 J
- 4 ns < Pulse width < 100 ns
- Spot size ~ 0,5 mm
- Power > 3 TW/cm²
- Shot frequency > 10 / day

View of experiment area in GCLT




Fiber splitter
Circulator
Laser diode
830 nm
S1
CIR
P= 90 mW
Optical collimator
Φ : 0,3 mm
Reference
wavelength
Measurement
wavelength
Fiber splitter
S2
Spectral response
Responsivity, A/W
0.5
0.4
0.3
0.2
0.1
0.0
400
500
600
700
800
900
Wavelength, nm
Detector
GaAs
Digitizer



Probe support in vacuum

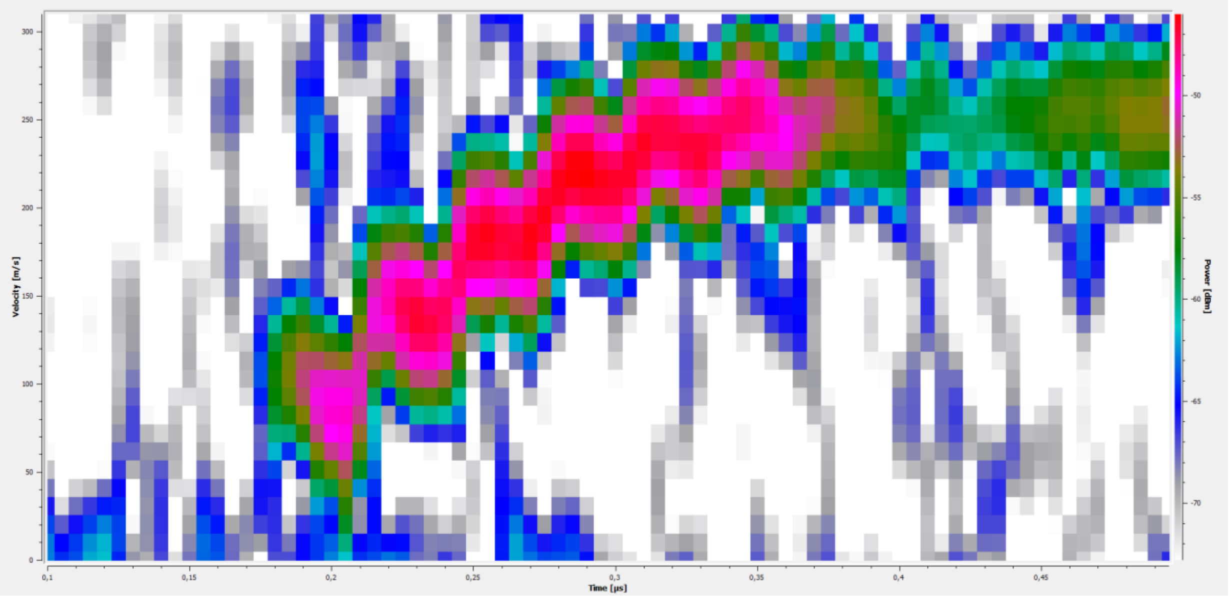
Samples after shot

<u>Limitation of the setup:</u> only one wavelength (1550 or 830 nm) may be tested by shot. Then, we compare the results for a same incident laser energy

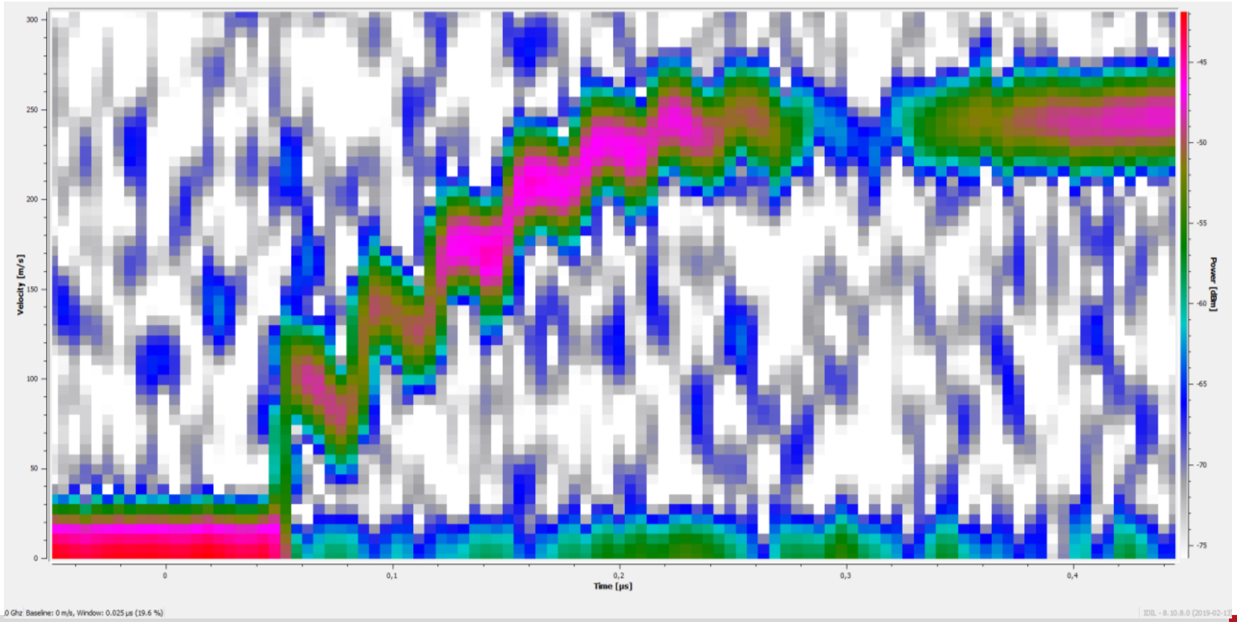
Results at 830 nm and 1550 nm

Spectrograms Al sample (thickness 100 µm)

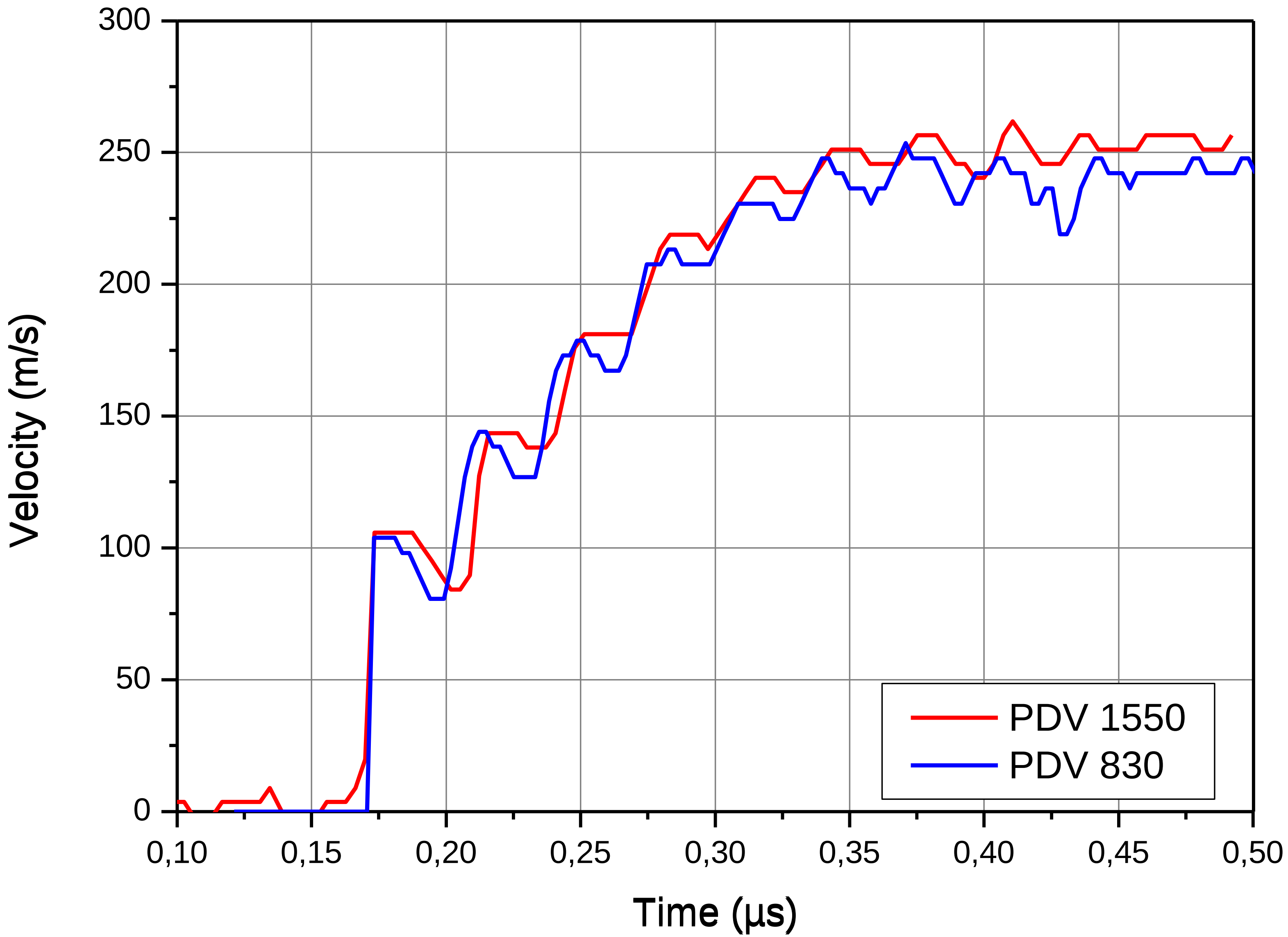
1550 nm
P_{PDV} > 100 mW
(1520 J/cm²)



830 nm
P_{PDV} < 10 mW
(1473 J/cm²)

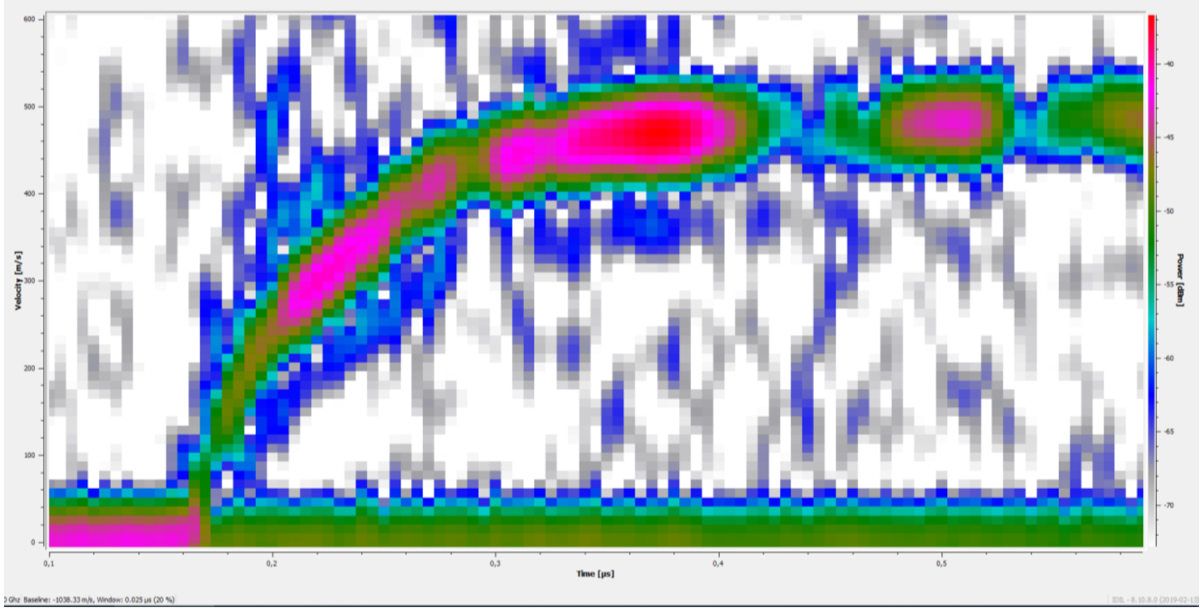


PDV comparison (Al 100 µm)

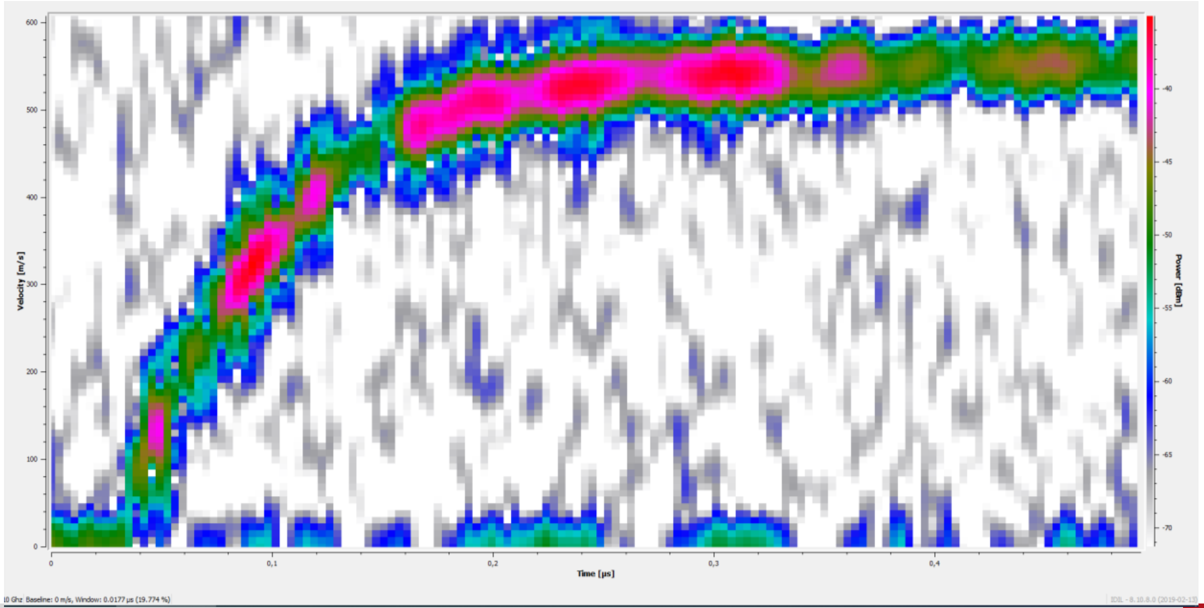


Spectrograms of Ti sample (thickness 25 µm)

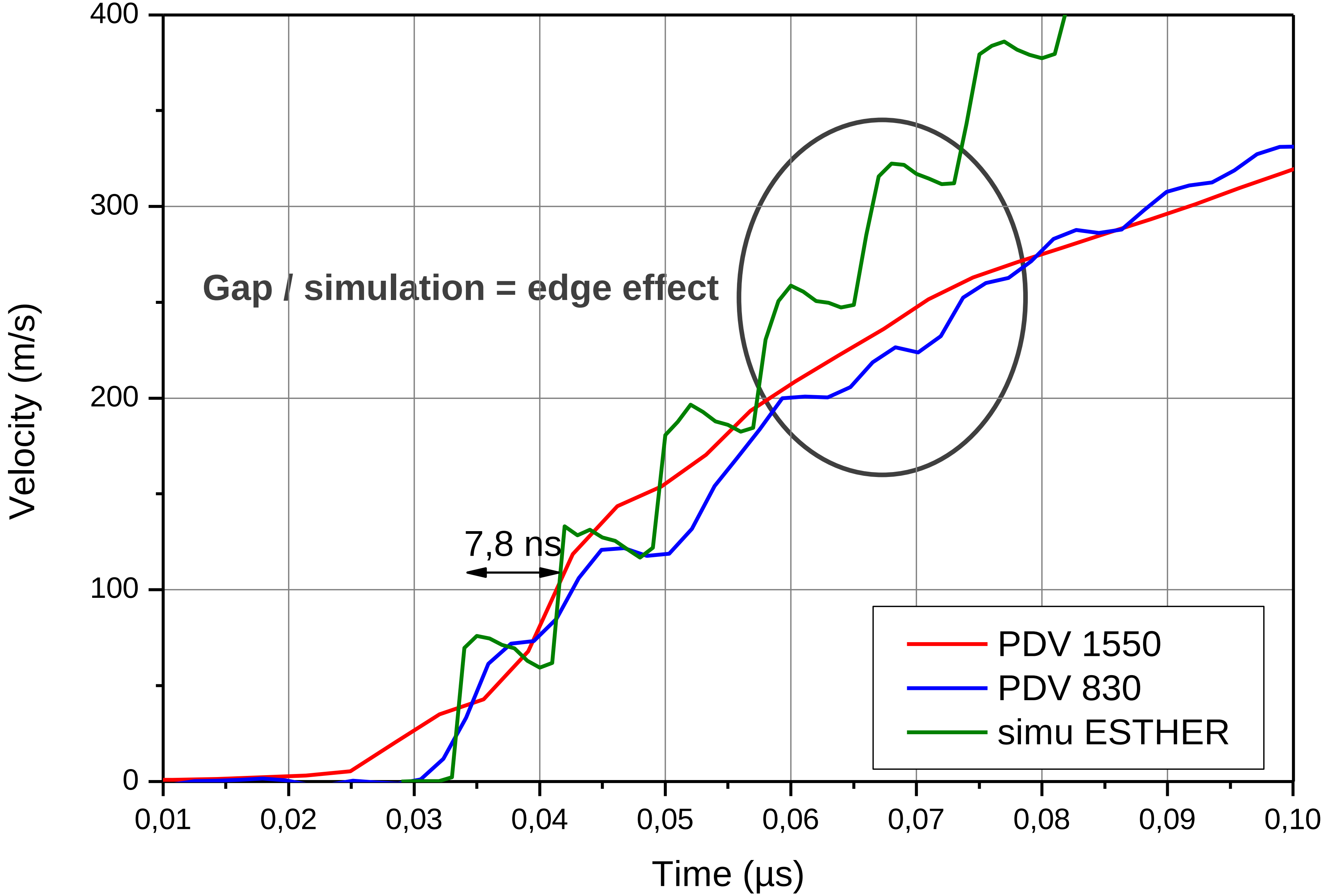
1550 nm
P > 100 mW
(1436 J/cm²)



830 nm
P < 10 mW
(1459 J/cm²)

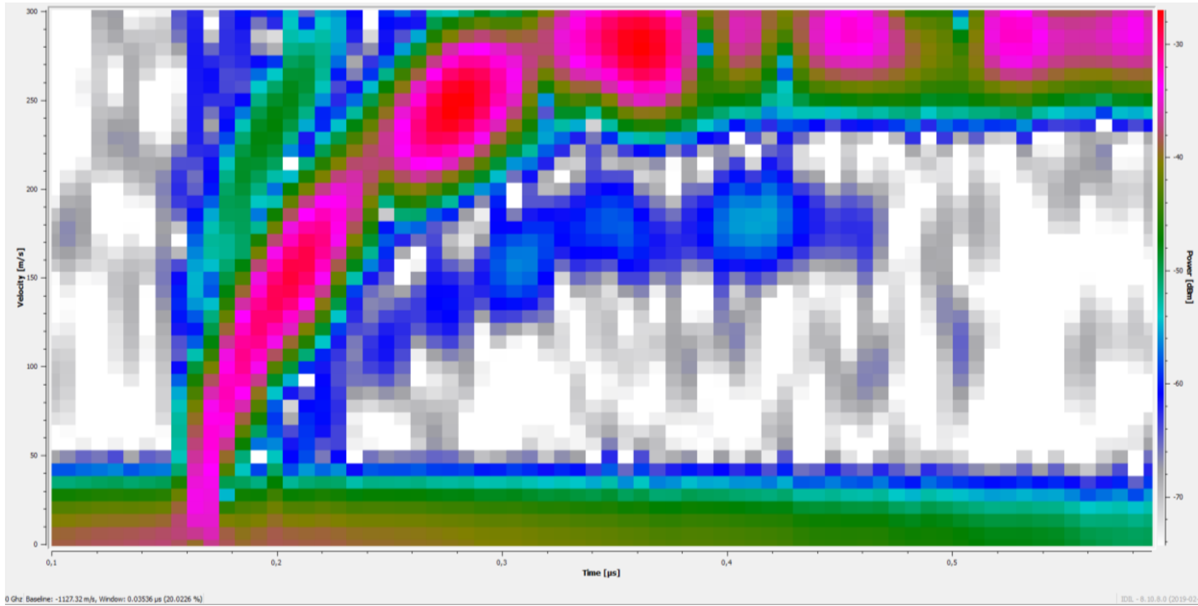


PDV comparison with simulation (Ti 25 µm)

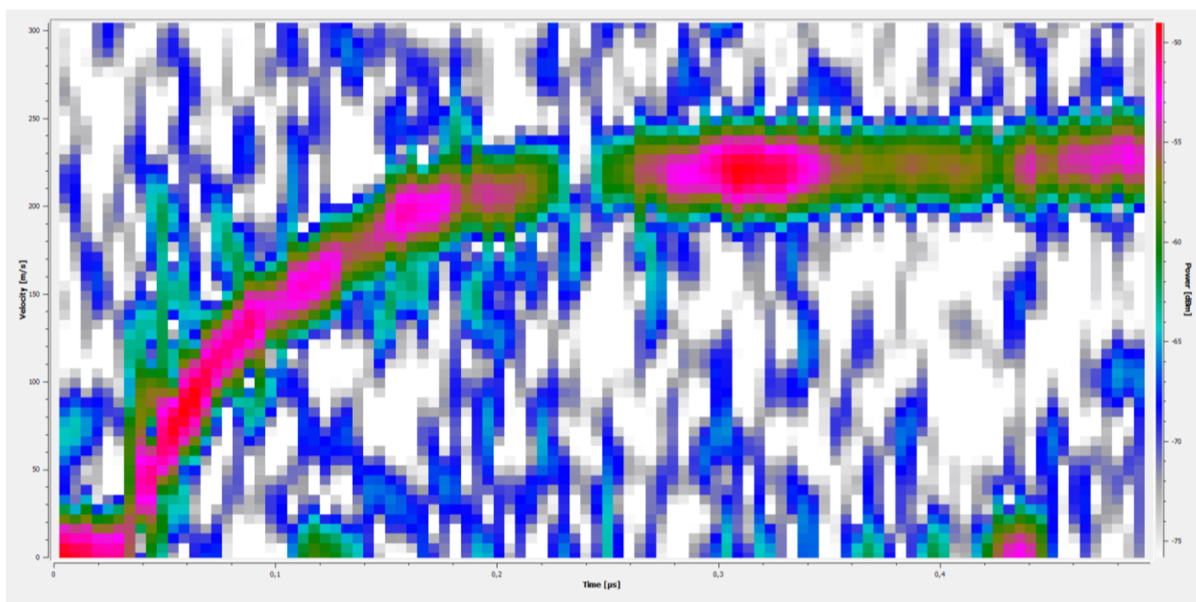


Spectrograms for Fe sample (thickness 25 µm)

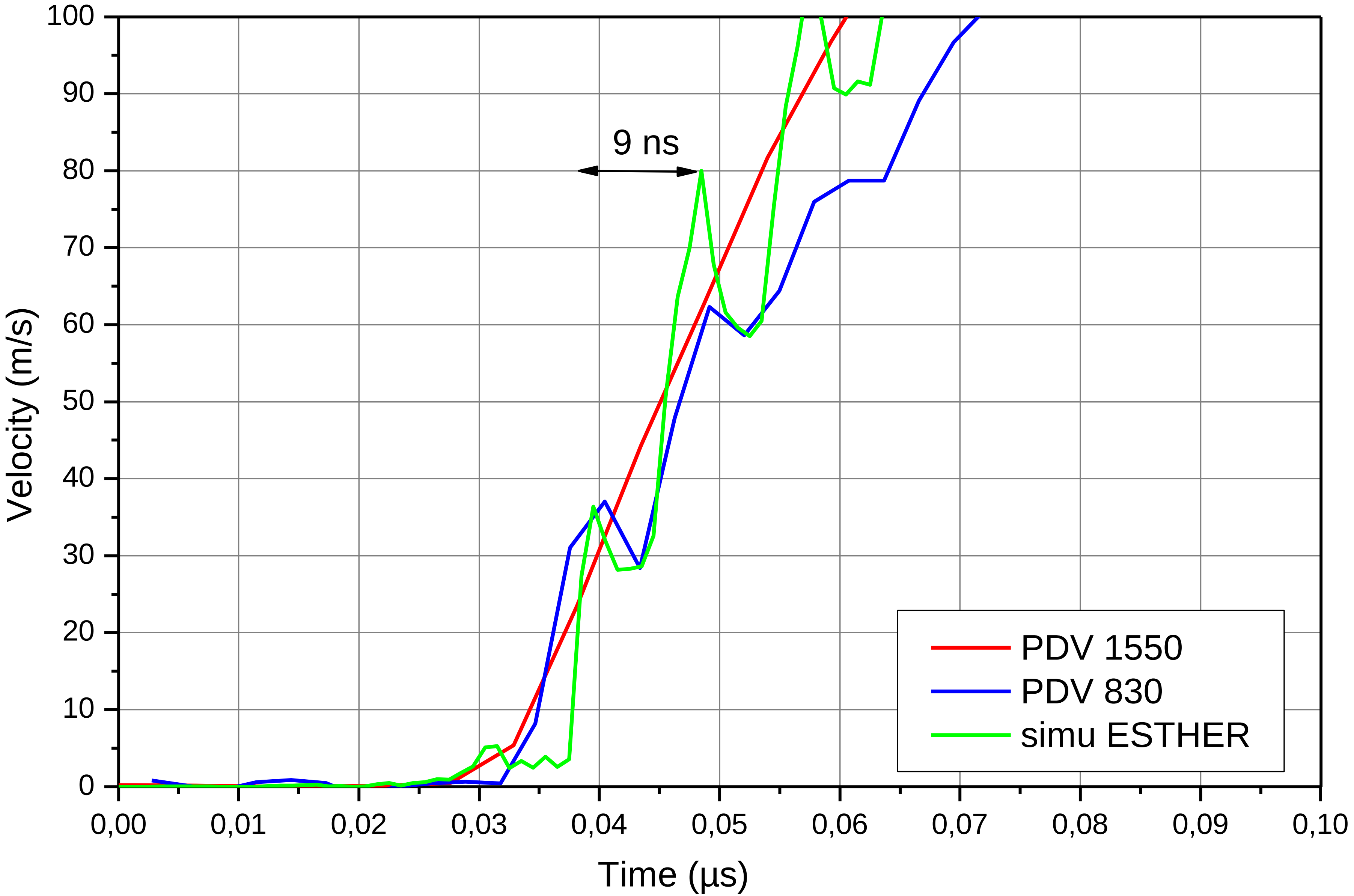
1550 nm (1452 J/cm²)



830 nm (1429 J/cm²)



PDV comparison with simulation (Fe 25 µm)



Conclusion and perspectives

- **Validation of PDV performances at 830 nm with laser shock experiments**

- **Signal analysis shows a significant gain on resolution in time and frequencies (or velocity) => x2 theorical / PDV 1550**

- **Good fit between simulation and experiment results**

- **Improvements :**

  - ➢ **add a 2nd laser (reference)**

  - ➢ **increase laser optical power (> 100 mW) to see the particles**

Acknowledgements at GCLT team: Emilien LESCOUTE, Arnaud SOLLIER and Benjamin JODAR

Thank you for your attention

Questions ?