Multi-wavelengths crosstalk-free PDV and uncertainties evaluation

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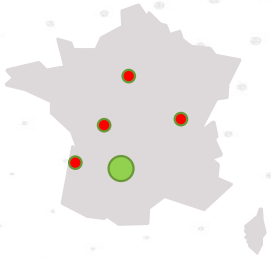
CEA DAM Gramat

Alternative Energies and Atomic Energy Commission



Military Applications Division (DAM)

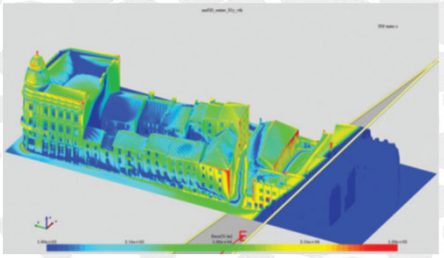
3 **Missions**

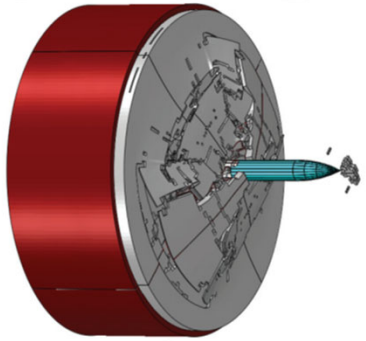
- Nuclear deterrence
- Conventional defense
- Homeland security

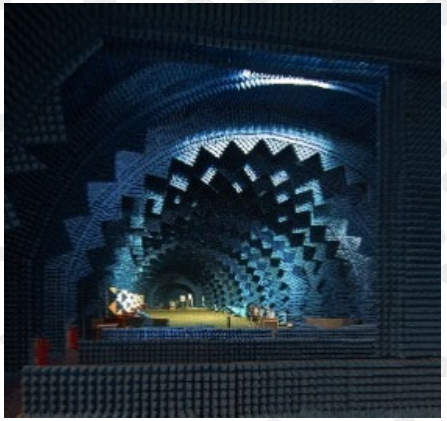
Gramat

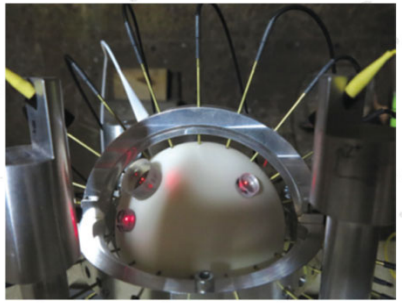
2 **Research areas**

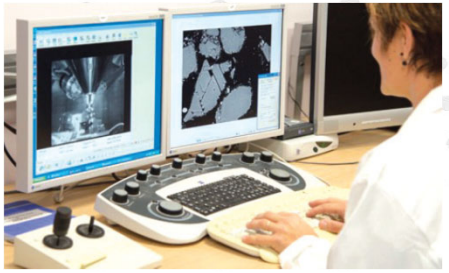
- Electromagnetism threats
- High energy material physics











Introduction

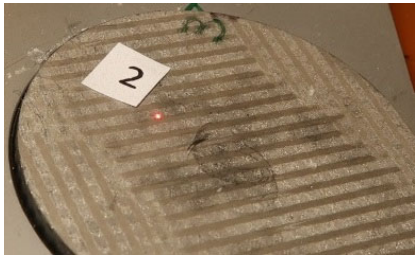
- More and more measurements channels
- Very close measurements for instance in on 3D carbon materials

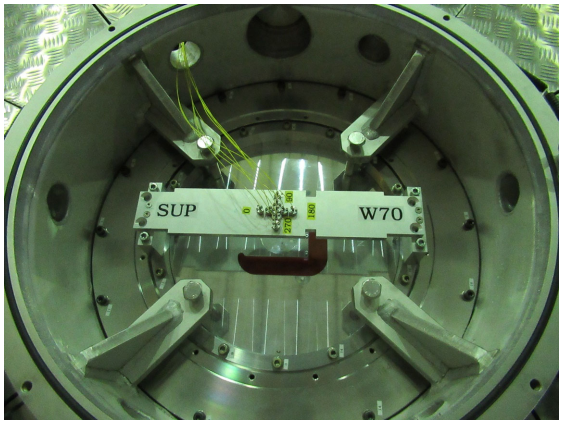
Any X-Talk issue ?

Solution tested and validated:

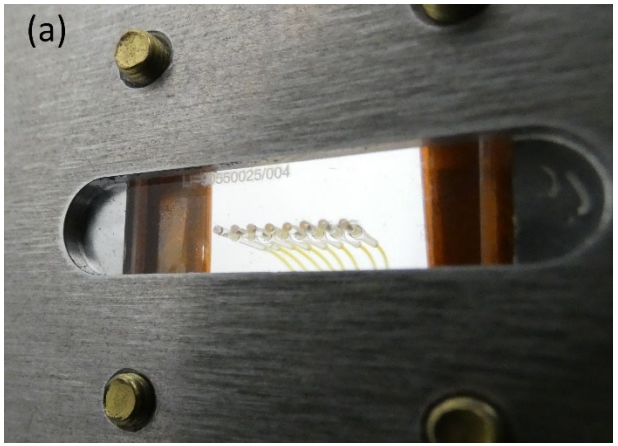
- 1 telecom wavelength per channel

=> Wavelength multiplexing at the same time





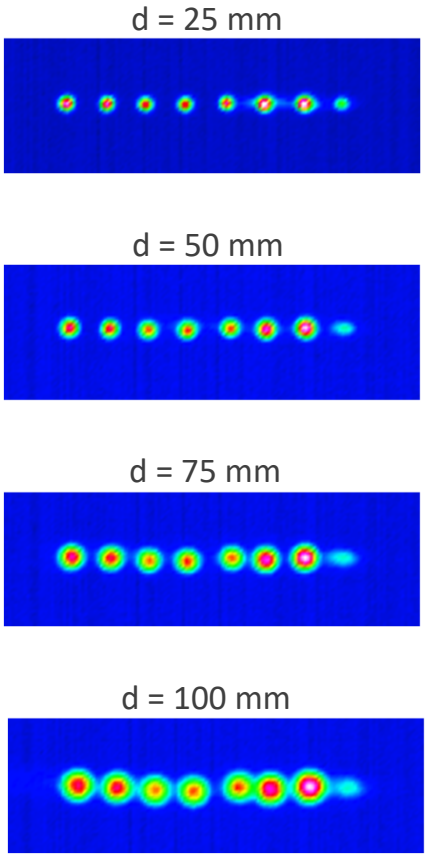
Cross-talk illustration



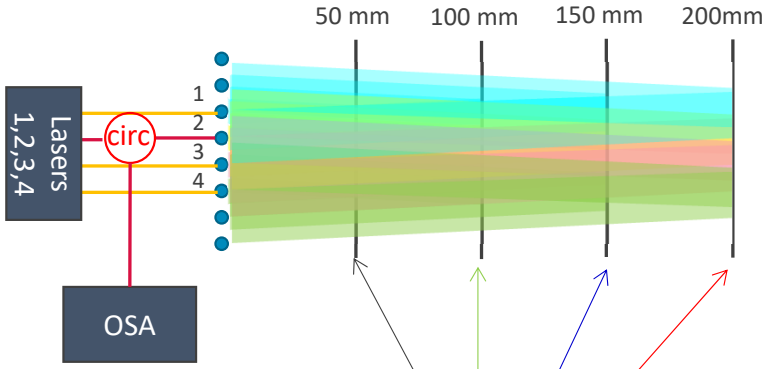
Line of 8 collimators

- Diameter : 0.5 mm
- Pitch : 1 mm
- Beam waist at the output 0.18 mm

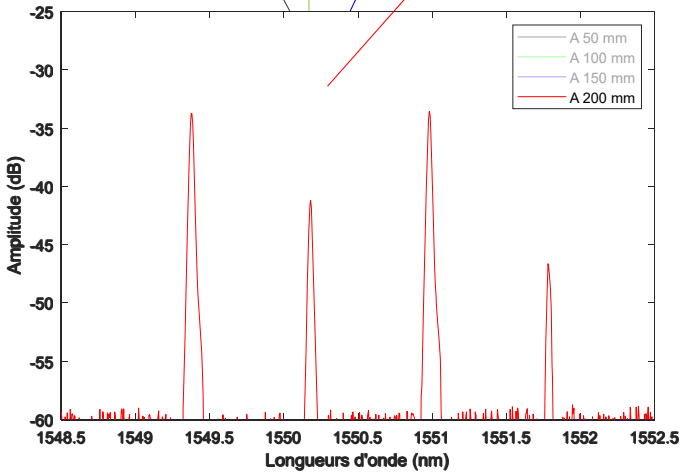
Output beams



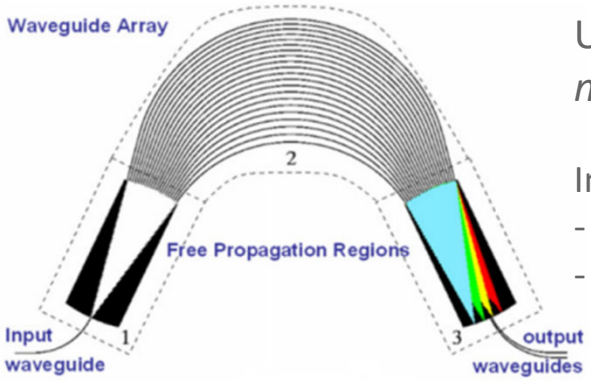
Crosstalk Measurement



Channel 2 reflected optical spectrum



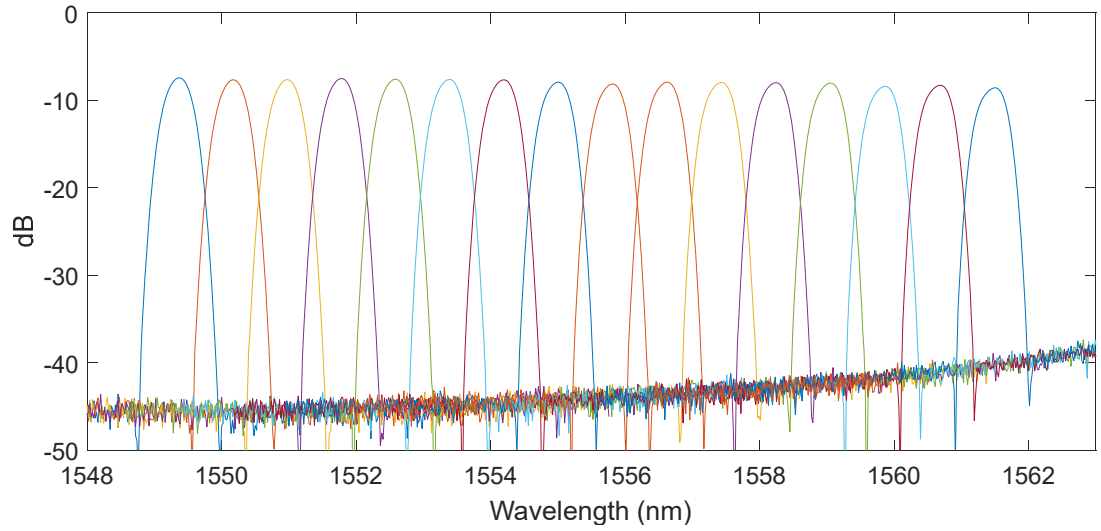
Wavelength multiplexing



Use of a photonic integrated circuit => AWG: *Arrayed Waveguide Grating, normally used in Wavelength-Division Multiplexing (WDM) optical networks*

In our case:

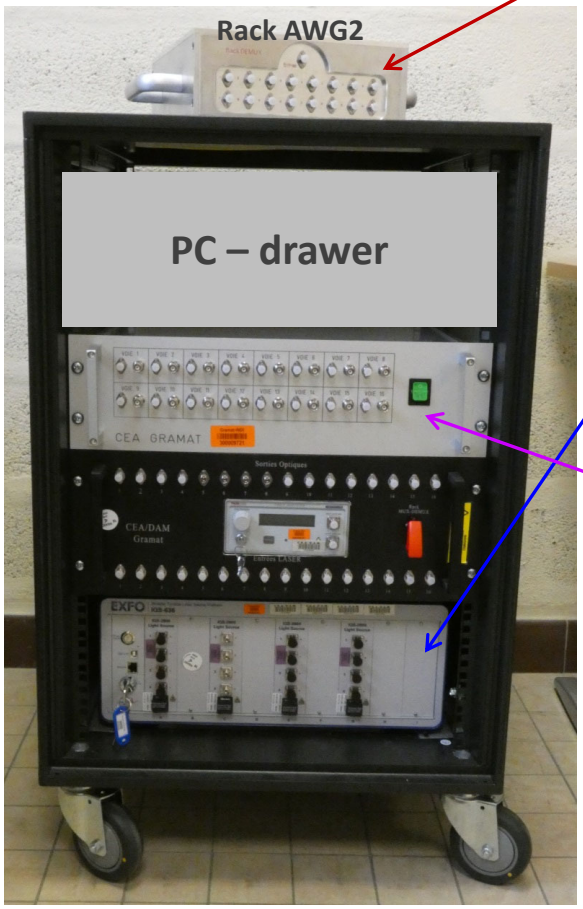
- 16 wavelengths from the ITU grid spaced by 100 GHz (~0.8 nm)
- "Flat-top design"

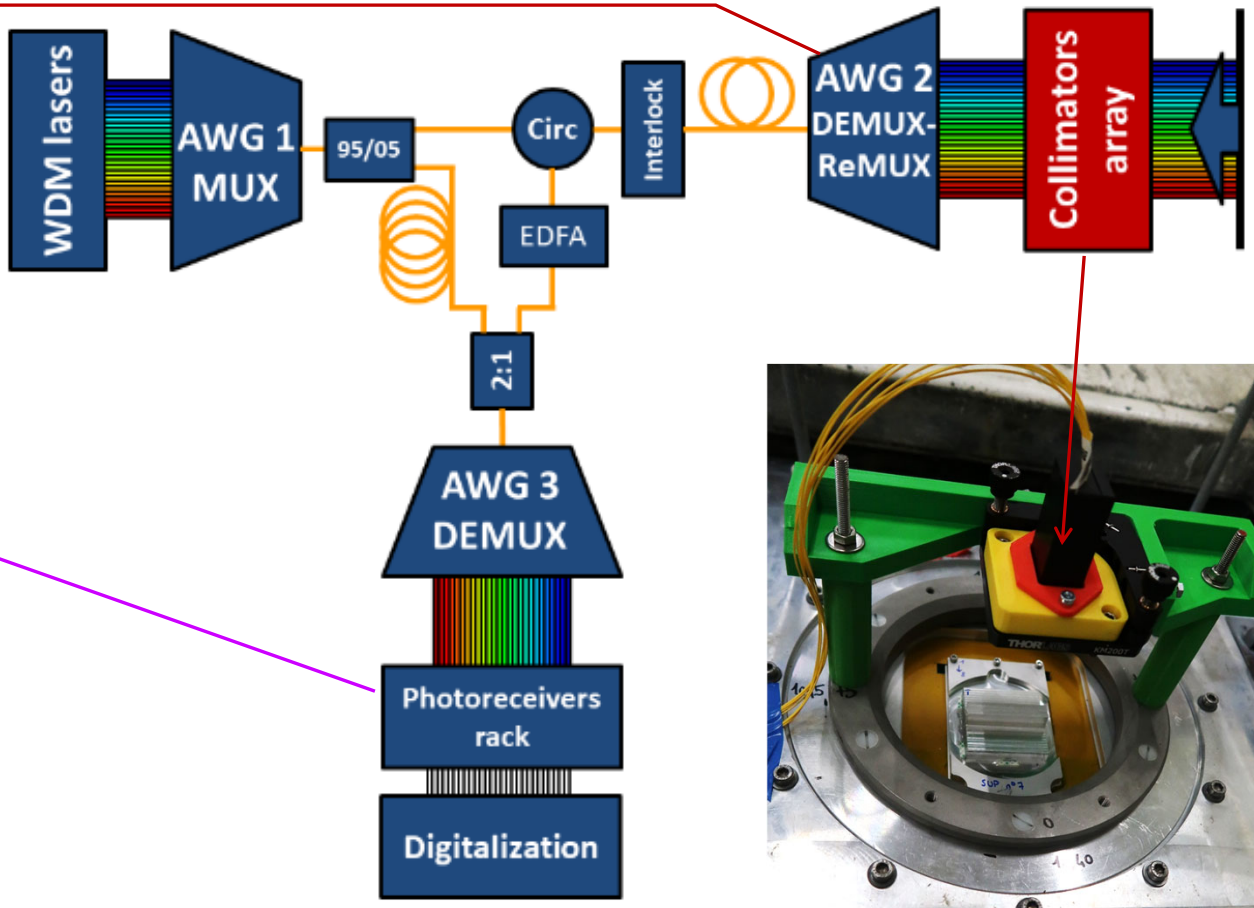


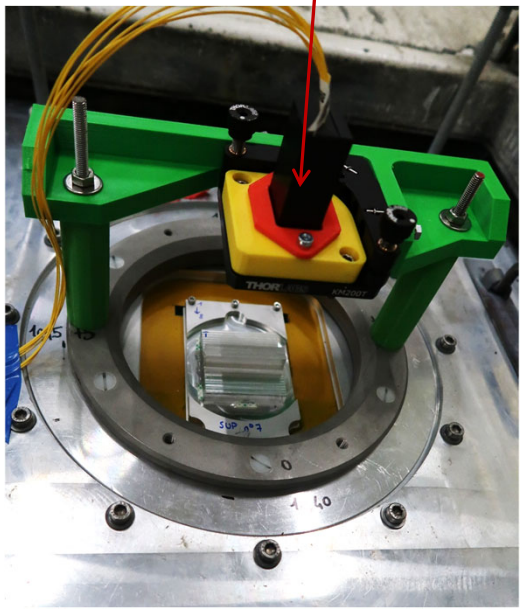
Channel	λ (nm)
1	1549.31
2	1550.11
3	1550.92
4	1551.72
5	1552.51
6	1553.33
7	1554.13
8	1554.94
9	1555.74
10	1556.55
11	1557.36
12	1558.17
13	1558.98
14	1559.79
15	1560.60
16	1561.41

Y. Barbarin et al. "*Extremely small AWG demultiplexer fabricated on InP by using a double-etch process*", IEEE Photonics Technology Letters, 16(11), 2478 – 2480 (2004)

Multi-Wavelength PDV System

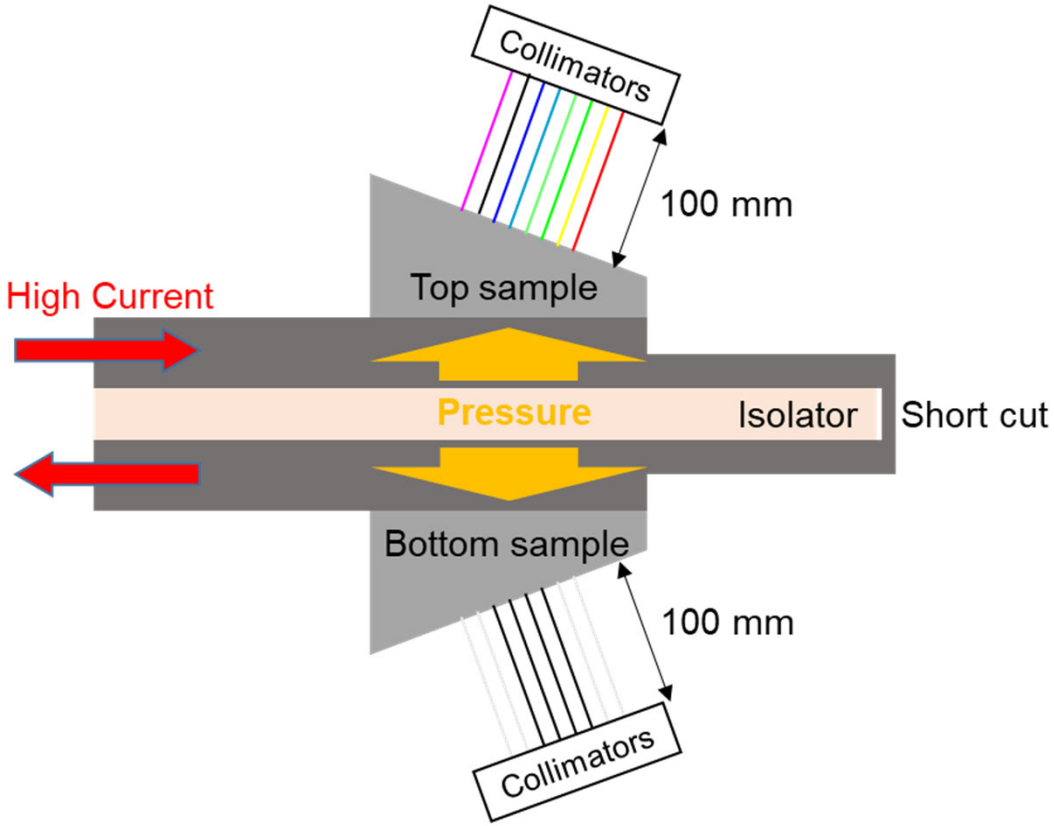






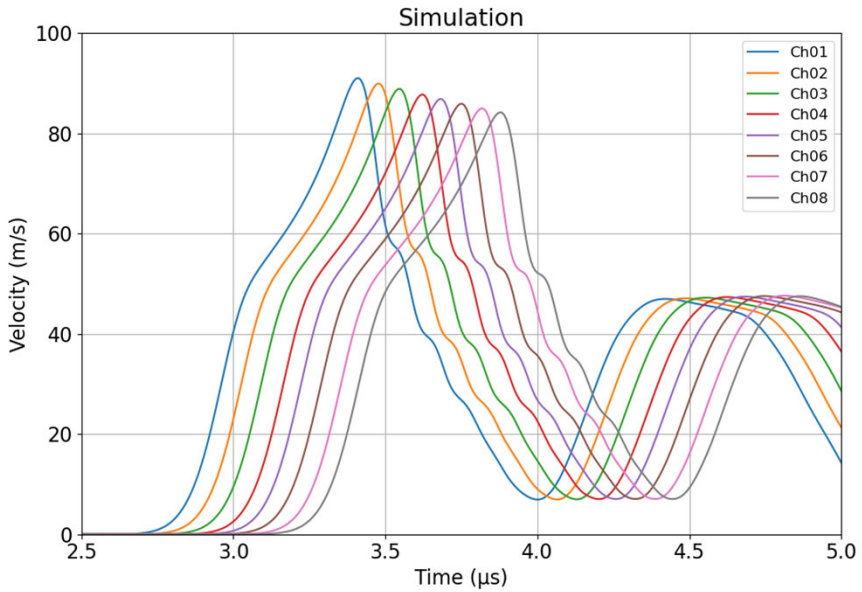
Y. Barbarin et al., « Multi-wavelength crosstalk-free photonic Doppler velocimetry », Rev. Sci. Instrum. 91, 123105 (2020)

HPP experiment with crosstalk



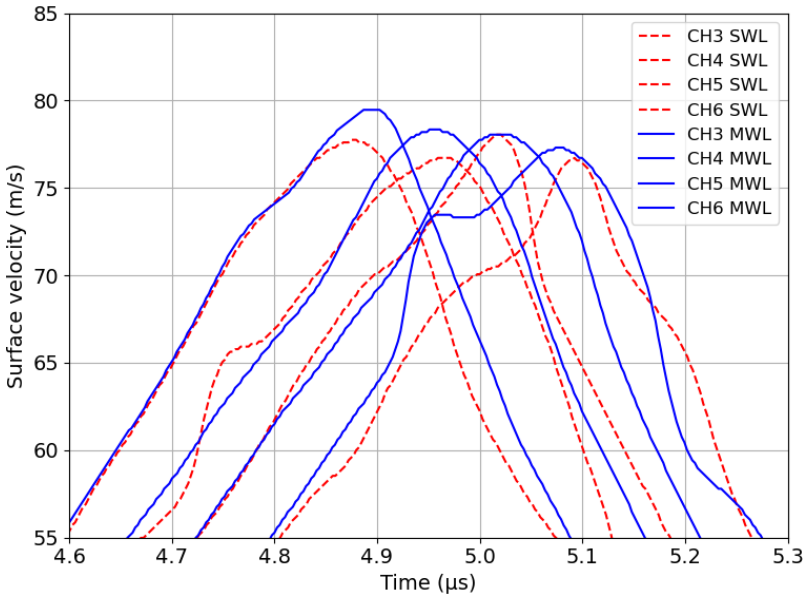
Samples with a triangle shape

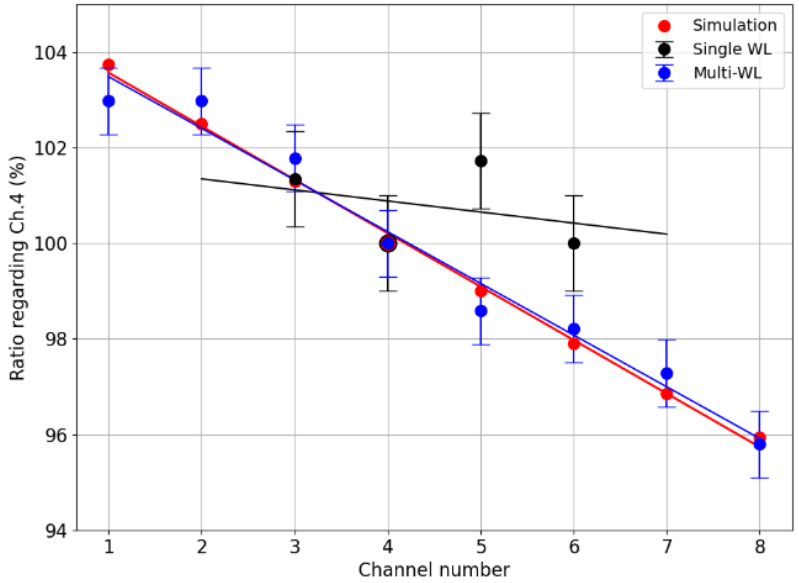
- Velocity profiles shifted in time
- The peak velocities decrease with the thickness of the target



Y. Barbarin et al., « Multi-Wavelengths Crosstalk-Free Velocimetry Demonstration and Uncertainties », Review of Scientific Instruments, 93, 083904, (2022)

HPP experiment with crosstalk - Results





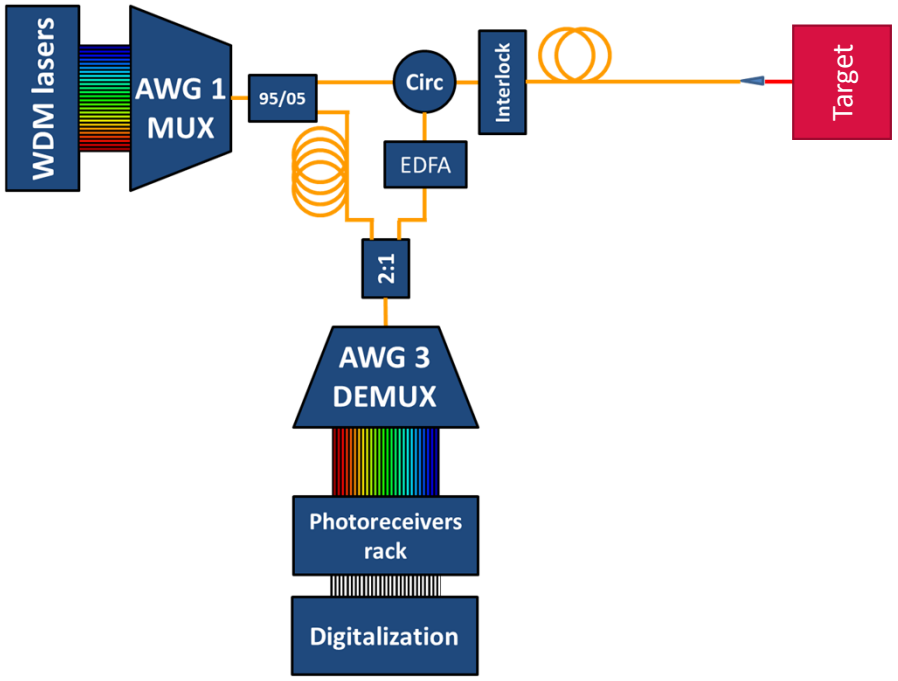
Single λ => No clear decrease from channel to channel
=> Crosstalk identified

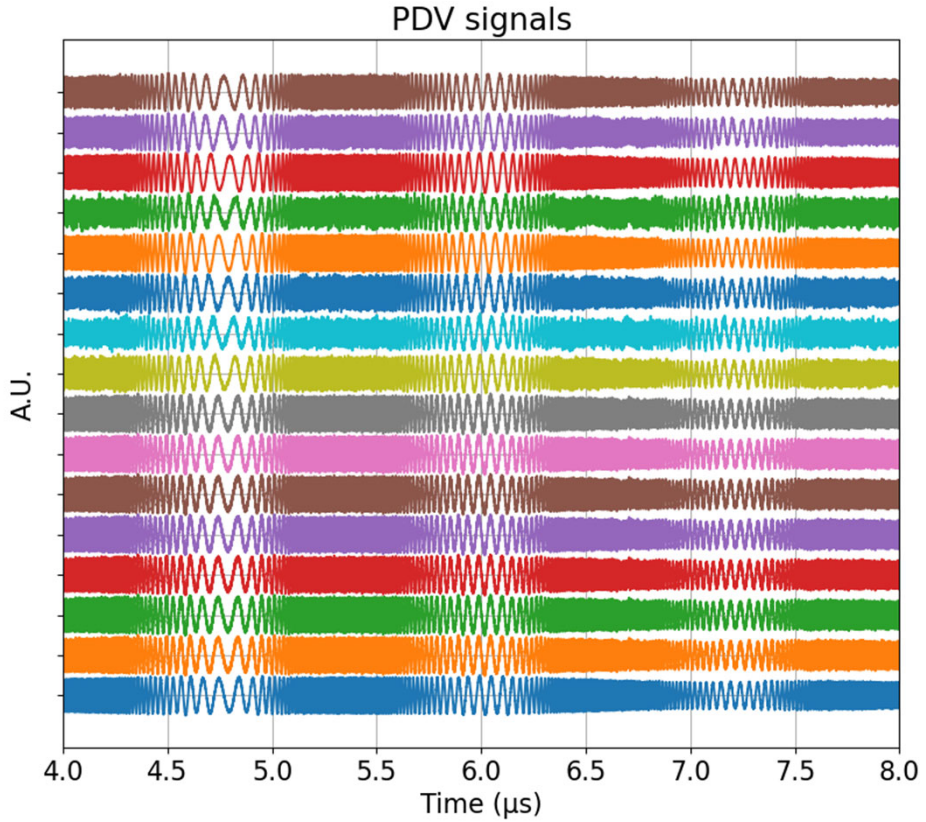
MWL => Decrease from channel to channel
=> NO crosstalk

Y. Barbarin et al., « Multi-Wavelengths Crosstalk-Free Velocimetry Demonstration and Uncertainties », Review of Scientific Instruments, 93, 083904, (2022)

Using all the wavelengths in the same probe

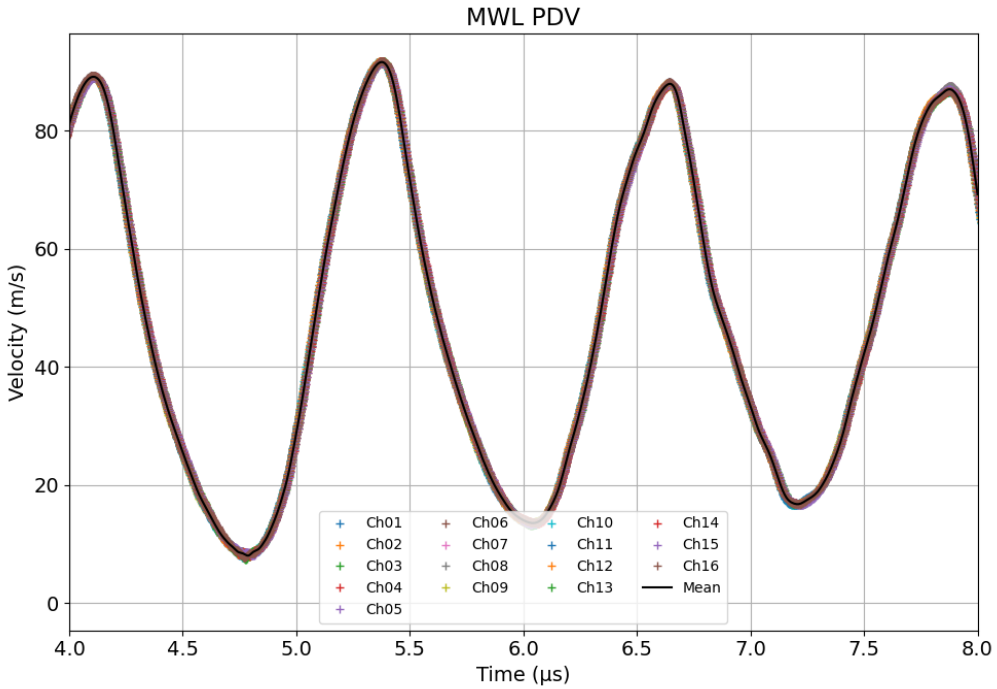
- 16 measurements with 16 slightly different wavelengths

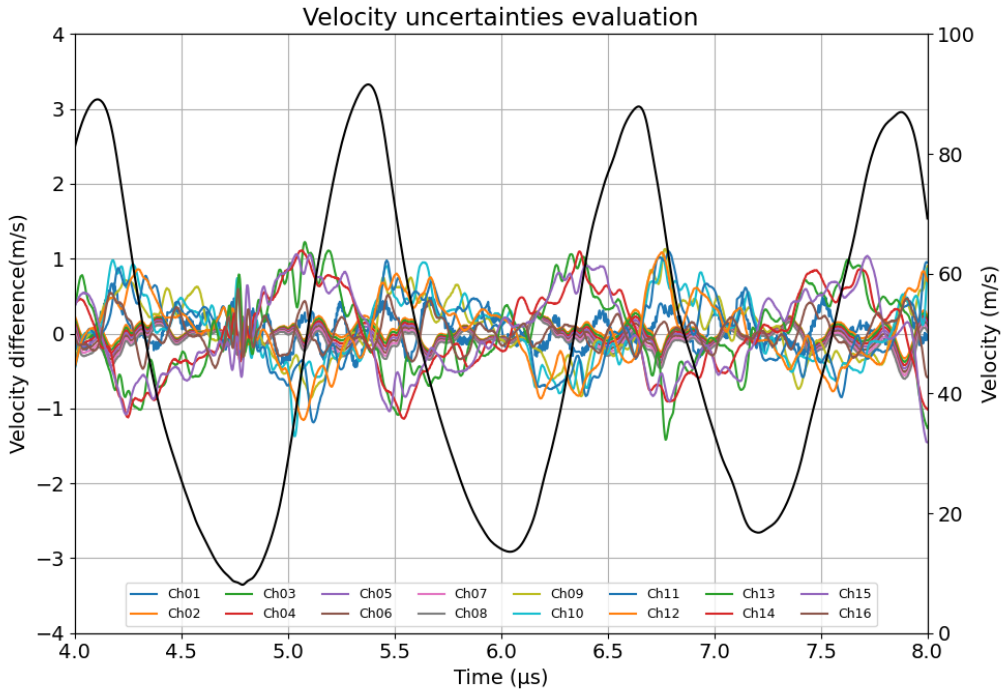




➔ Statistical studies with experimental data

Uncertainties on the velocity profile



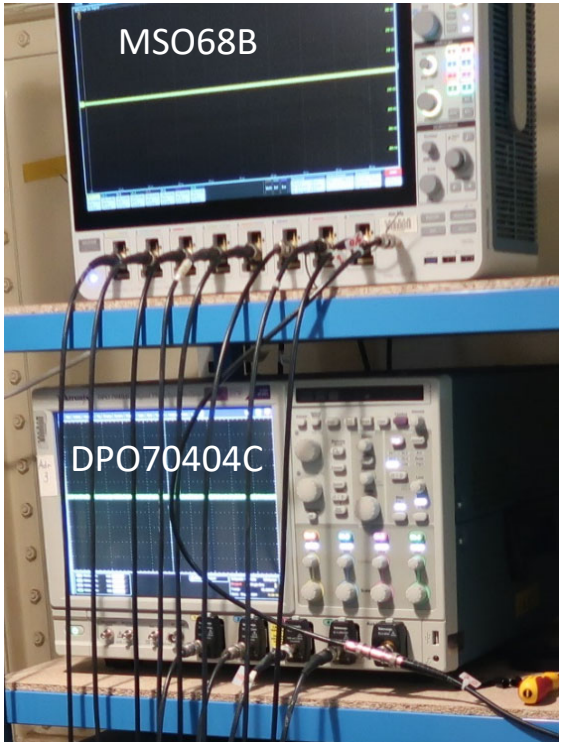


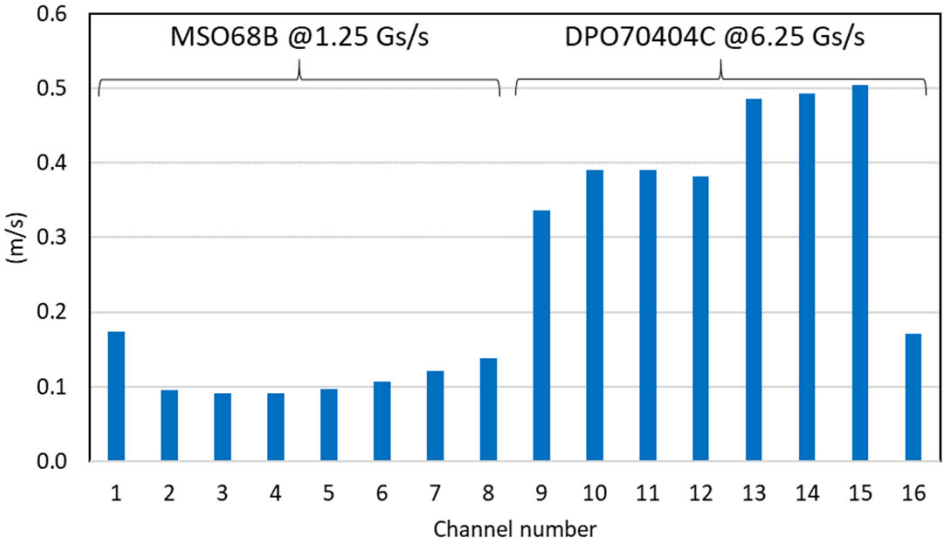
- Velocities between ~8 and ~92 m/s
- Data processed with the same STFT parameters (Δt = 50ns)
- Hypothesis : the mean curve is the reference (in black)

- Velocity differences vary from ± 0.5 m/s up to ± 1.3 m/s
- A tiny correlation with the acceleration phases
- Mean uncertainties : 0.254 m/s (0.68%)

More closely

Two types of digitizers





Theoretical uncertainties [ref]

$$\sigma_v \geq \frac{\lambda}{2 \cdot \pi} \cdot \sqrt{\frac{6}{\tau^3 \cdot f_s}} \cdot \frac{\sigma_S}{A}$$

σ_S/A : «noise fraction »
fs : Frequency sampling
τ : Window width

Gen 2020 :
± 0,11 m/s
ENOB = 8,65

Gen 2012 :
± 0,40 m/s
ENOB = 5,8

Theory :
± 0,15 m/s

ENOB : Effective Number Of Bits

[ref] D.H. Dolan, “Extreme measurements with Photonic Doppler Velocimetry (PDV)” Rev. Sci. Instrum. 91, 051501, (2020)

Conclusions and outlook

- Demonstration of 16 wavelengths crosstalk-free PDV near 1550 nm
- A comparison with a single wavelength system showed that cross-talk can deteriorate the measurements
- First uncertainties study with an experimental approach

  ➔ the uncertainties values obtained with the most recent digitizers are close to the theoretical ones

Outlook

- Optimization of the laser powers (amplifiers)
- Addition of a common AOM into the system => heterodyne scheme => better time resolution
- More uncertainties studies

Thank you for your attention
Merci de votre attention

Contact: yohan.barbarin@cea.fr