DE LA RECHERCHE À L'INDUSTRIE

POLARIZED PDV: A DUAL ANALYSIS OF PARTICLE CLOUD EJECTED FROM SHOCK LOADED METALLIC PLATE

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OVERVIEW

- **Goal of the study**

  → **underline the role of polarization in PDV**

- **Proposed polarized PDV setup**

  → **optimizing the interference contrast**

- **Depolarization (= modification of polarization) from non spherical particles**

  → **aggregated and ellipsoidal particles**

- **First results (shock-loaded tin plate)**

- **Future improvements**

GOAL OF THIS STUDY

- **How can we retrieve more information of particles ejected from shock loaded metallic plate ?**

  - The role of polarization was underestimated in PDV until it was pointed out in 2012 (PDV workshop, Ke-Xun Sun talk, UNLV, NSTech)
  - Non spherical / aggregated particles depolarize incident light (→ loss of contrast in PDV signal)
  - Degree of depolarization by particles depends on the nature of the incident polarization (linear ? circular ?)

- **We propose a PDV system based on a dual analysis:**

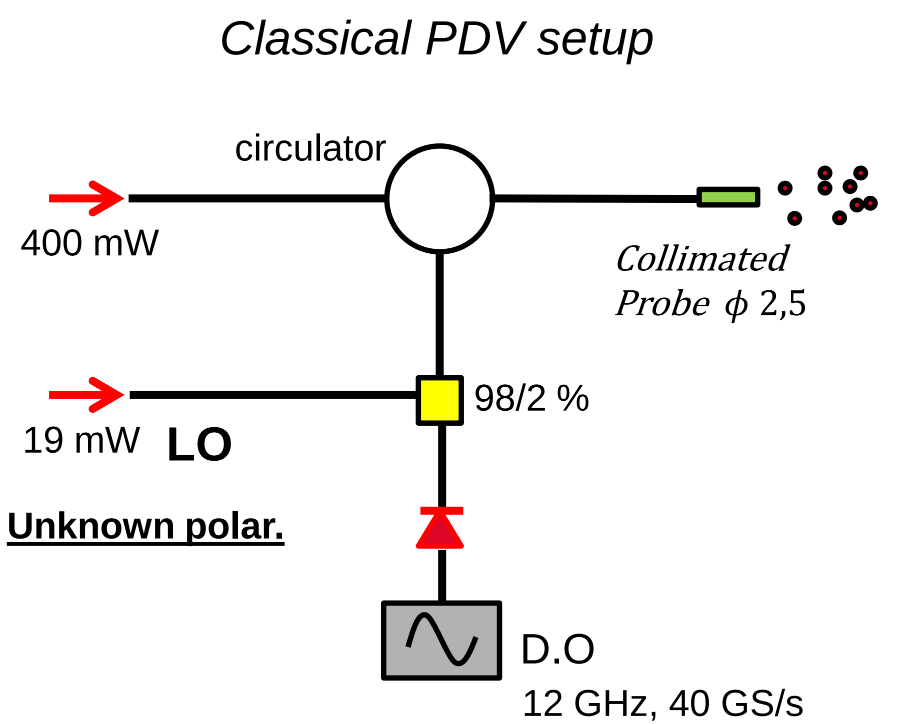
  - Back-scattered polarization split on a H / V basis
  - Local Oscillator (LO) split on a H / V basis

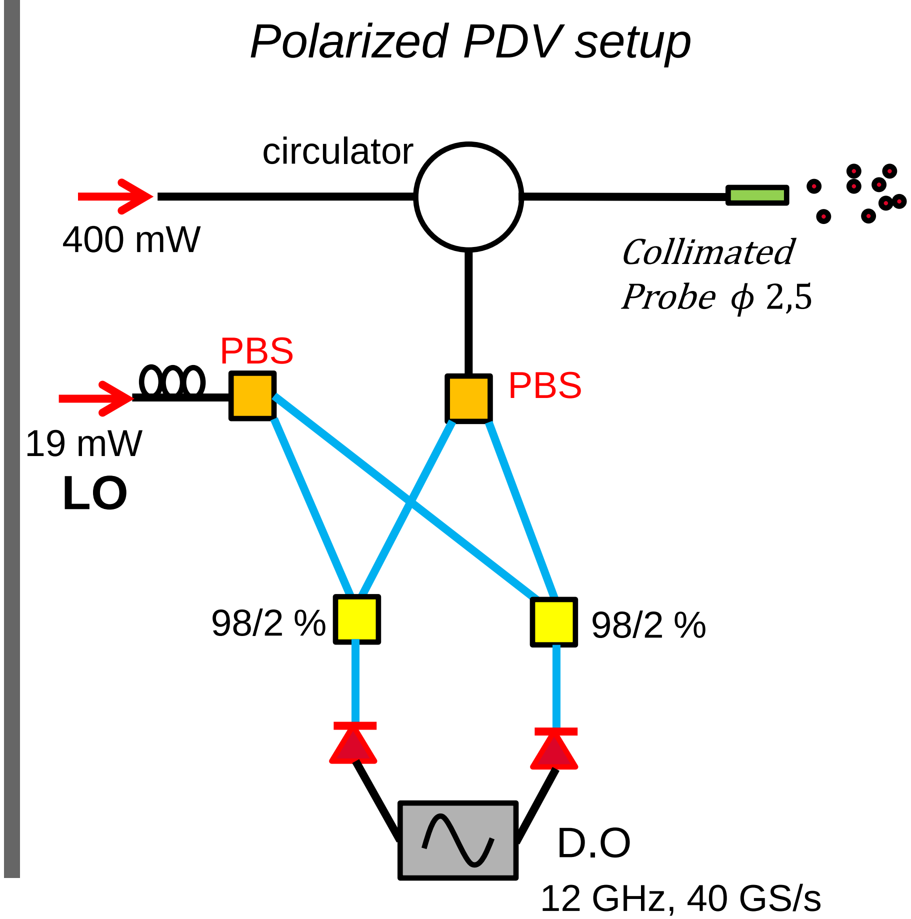
  } → Optimizing contrast

  → 2 signals from one probe = 2 different views of the same scene

- **Results are presented**

A COMPARISON BETWEEN 2 PDV SYSTEMS





$\lambda = 1{,}55\ \mu m$

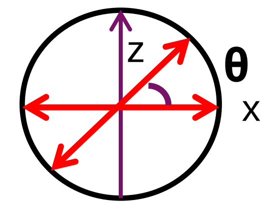
- Polarization maintining optical fibers
- SM fiber

The aim of this polarized PDV setup is to show how we can recover more Information (and more optical power) by optimizing the interference contrast

POLARIZED LIGHT AND OPTIMIZING CONTRAST

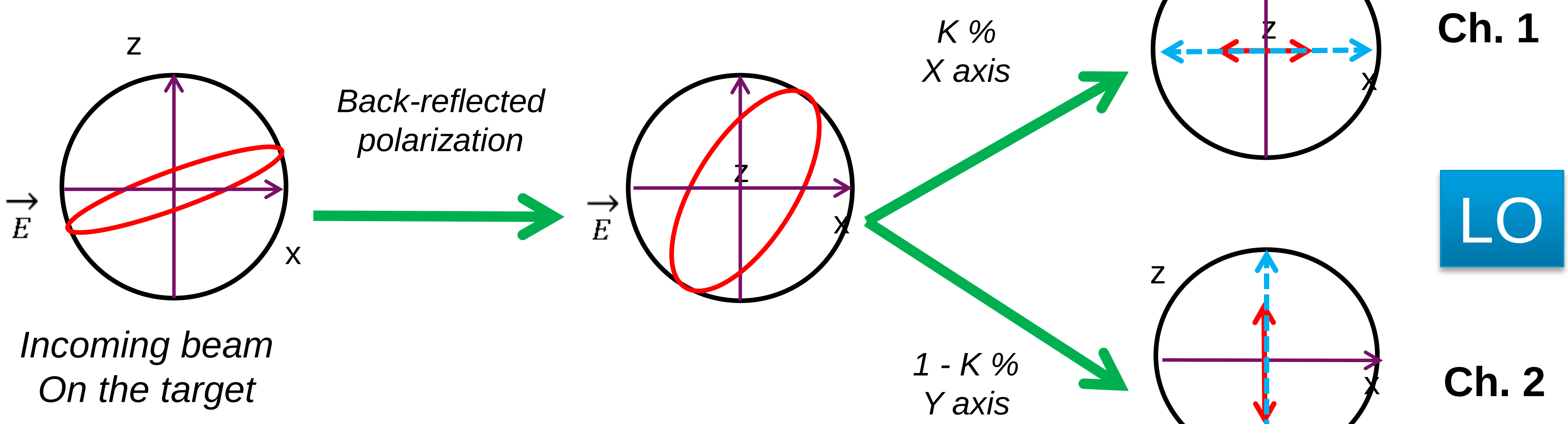
PDV effeciency :

$$I = I_0 + I_r + 2\sqrt{I_0 I_r}\cos(2kx(t))\,\mathbf{\cos(\theta)}$$



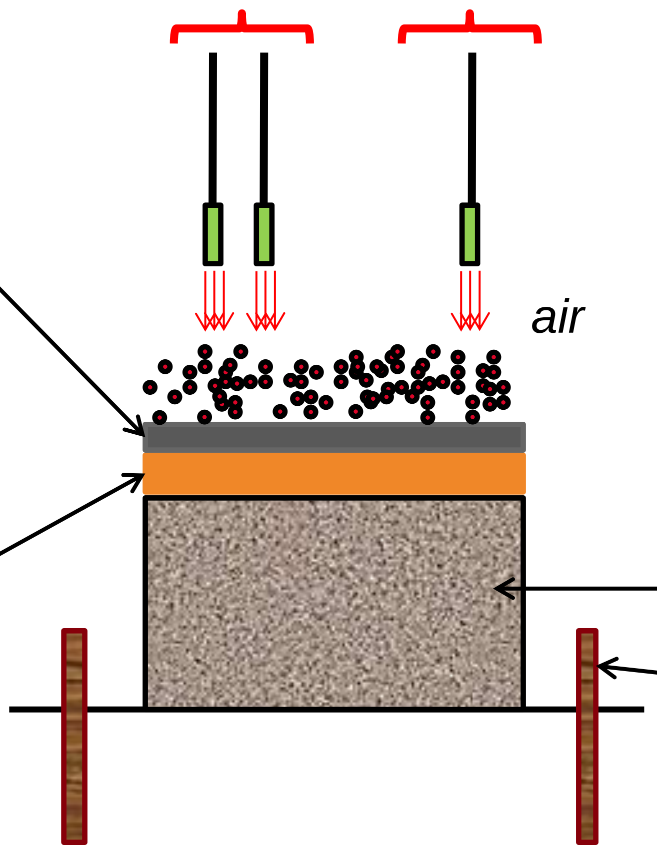
- No signal for orthogonal polarization
- Optimized contrast for parallel polarization

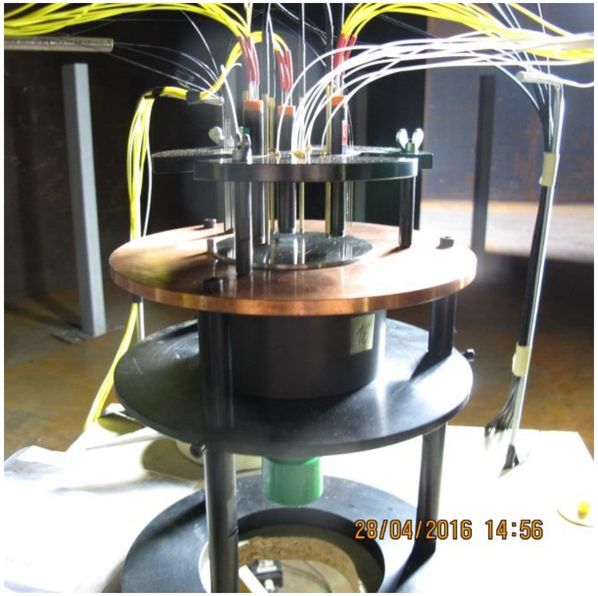
Optimized contrast :



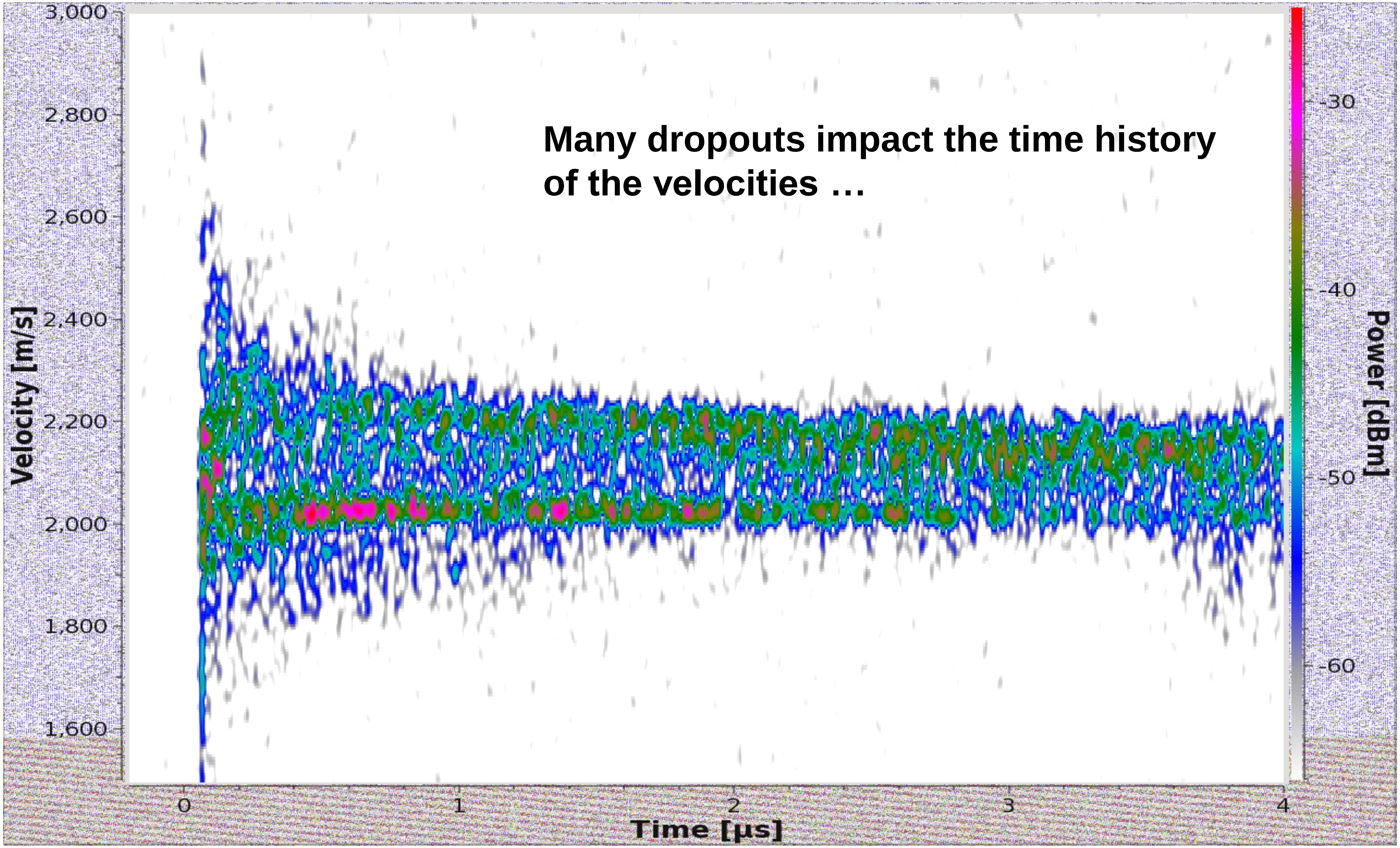
EXPERIMENTAL SETUP

- A Plane Wave Generator is used to shock a tin plate which free surface is patterned (triangles). The transmitter is a Copper plate :



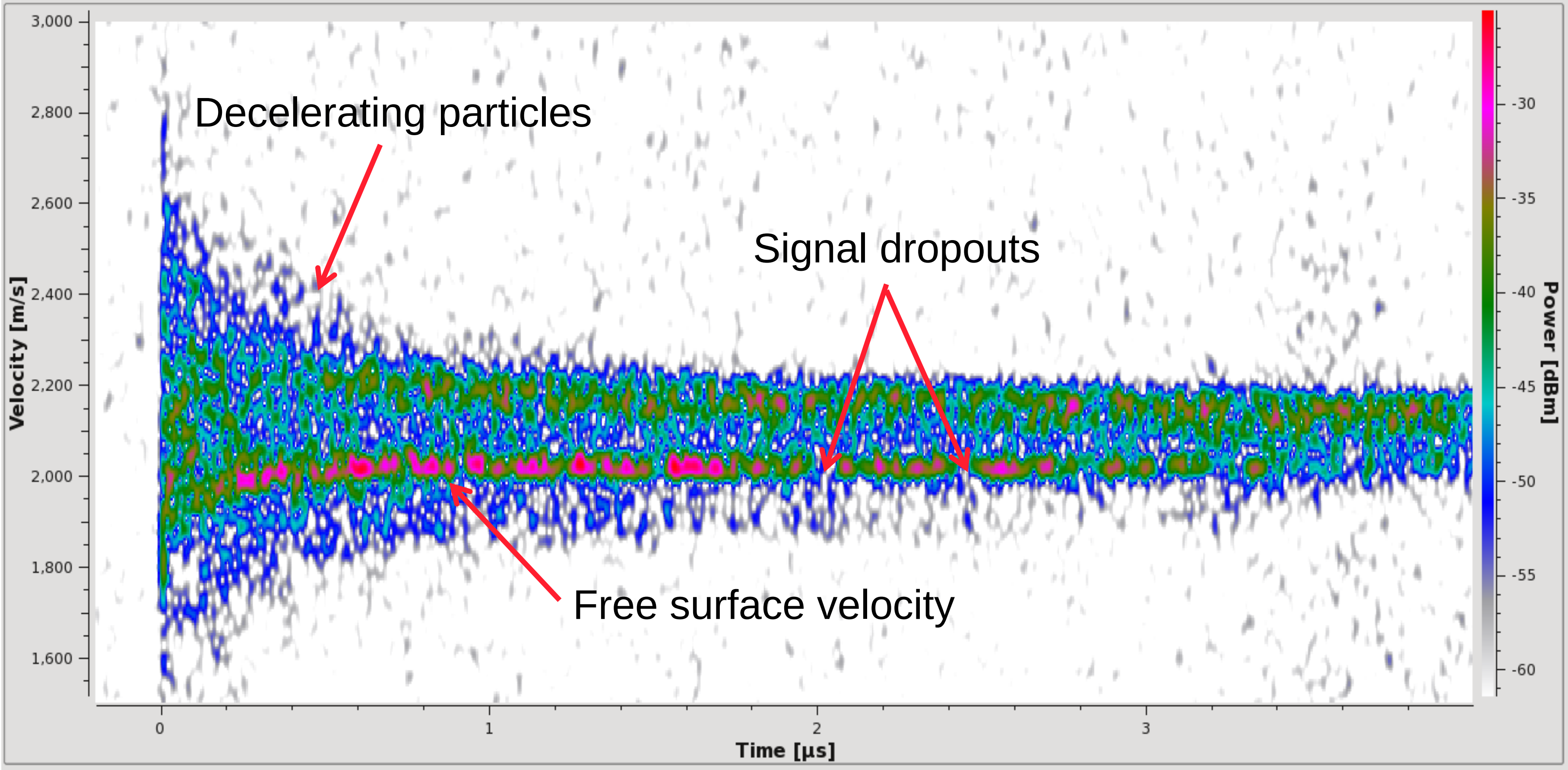


A CLASSICAL PDV ANALYSIS



SPECTROGRAM CHANNEL 1

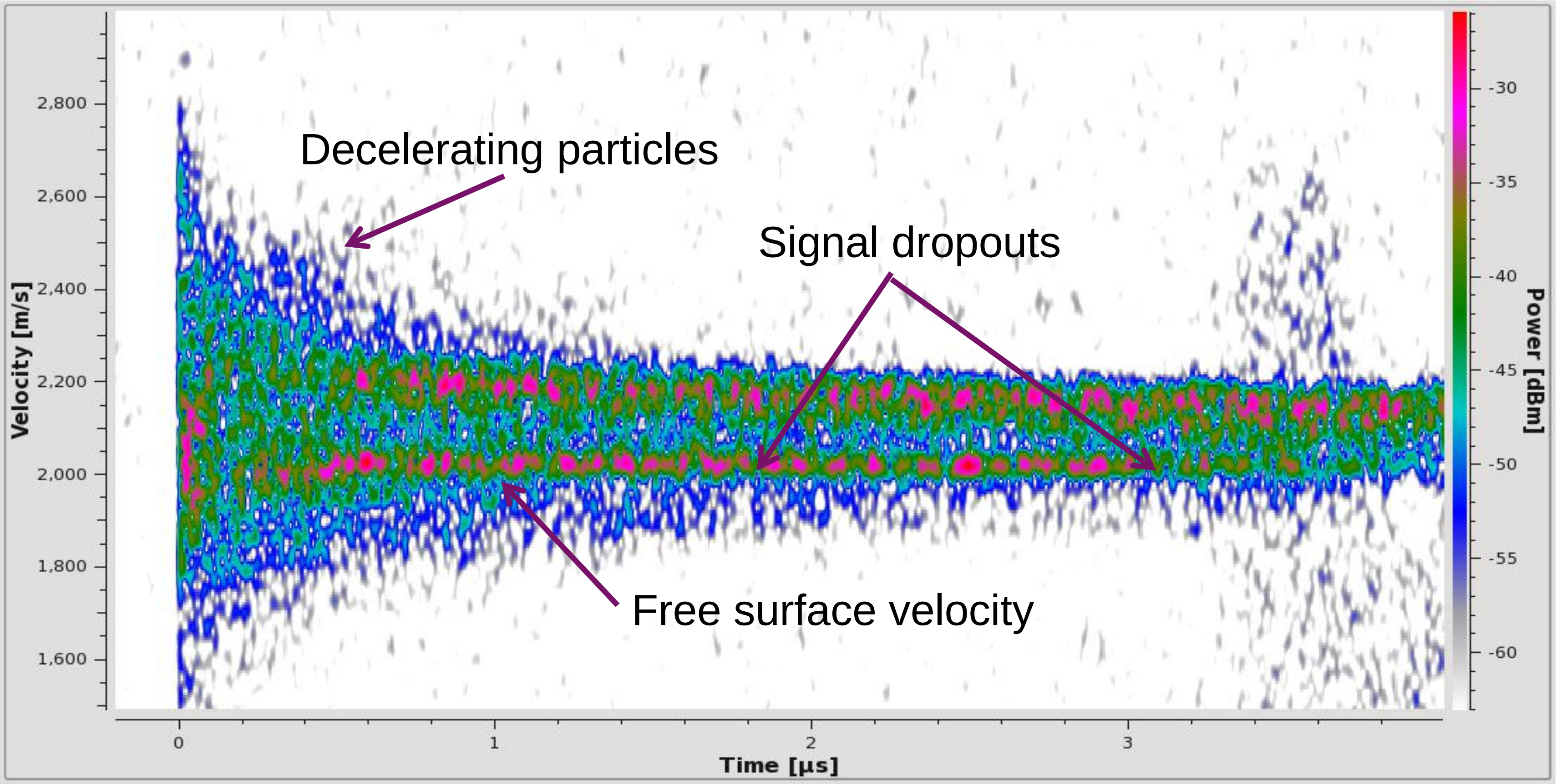
PDV spectrogram (first Channel) H Polarization



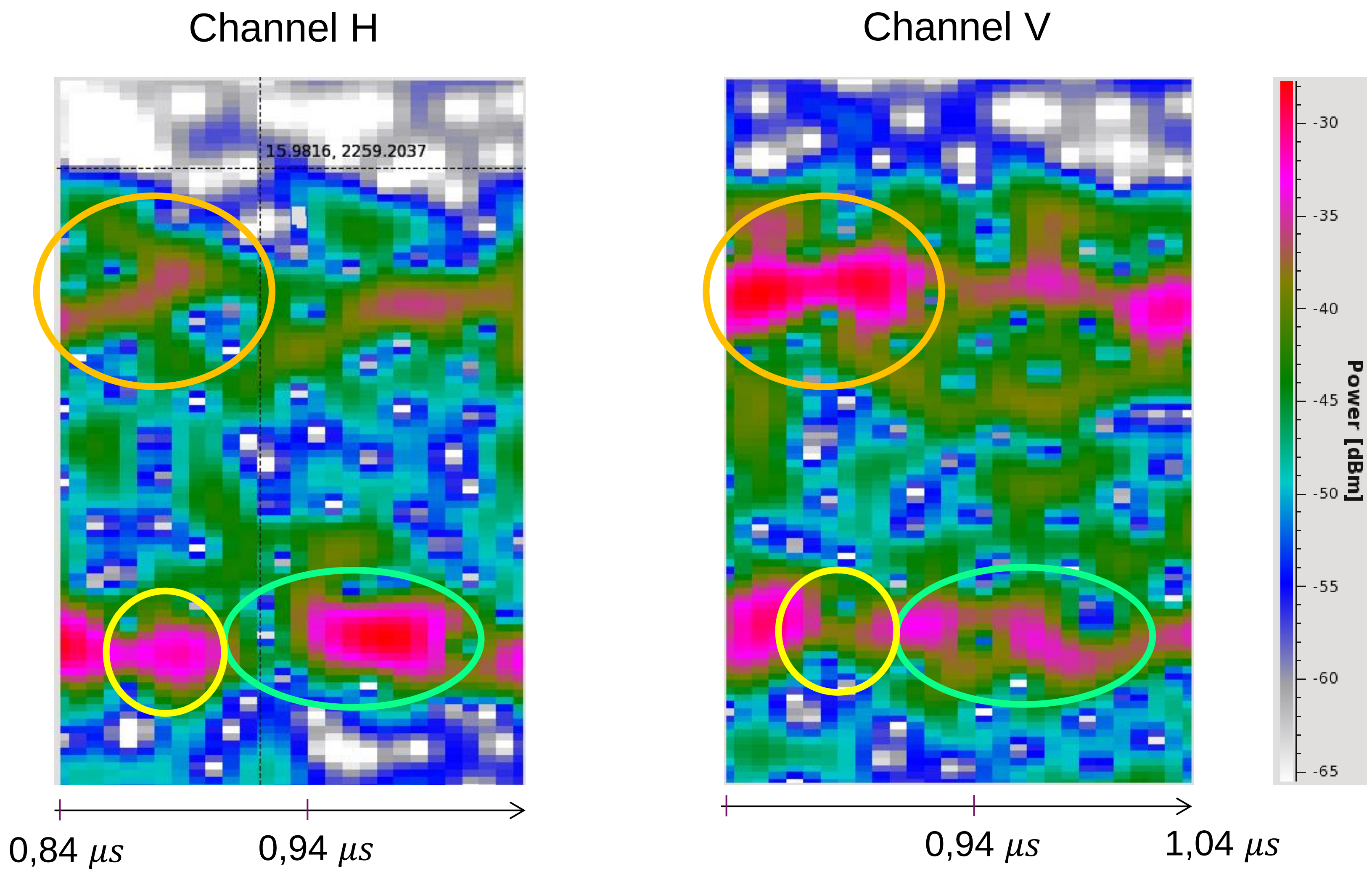
(STFT analysis. T = 50ns. dT = 10%. Zero-padding: 3)

SPECTROGRAM CHANNEL 2

PDV spectrogram (second Channel) V polarization

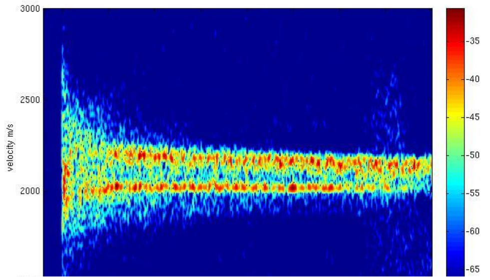


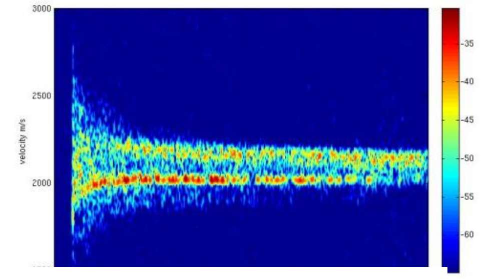
A COMPARISON IN A SPECIFIC REGION

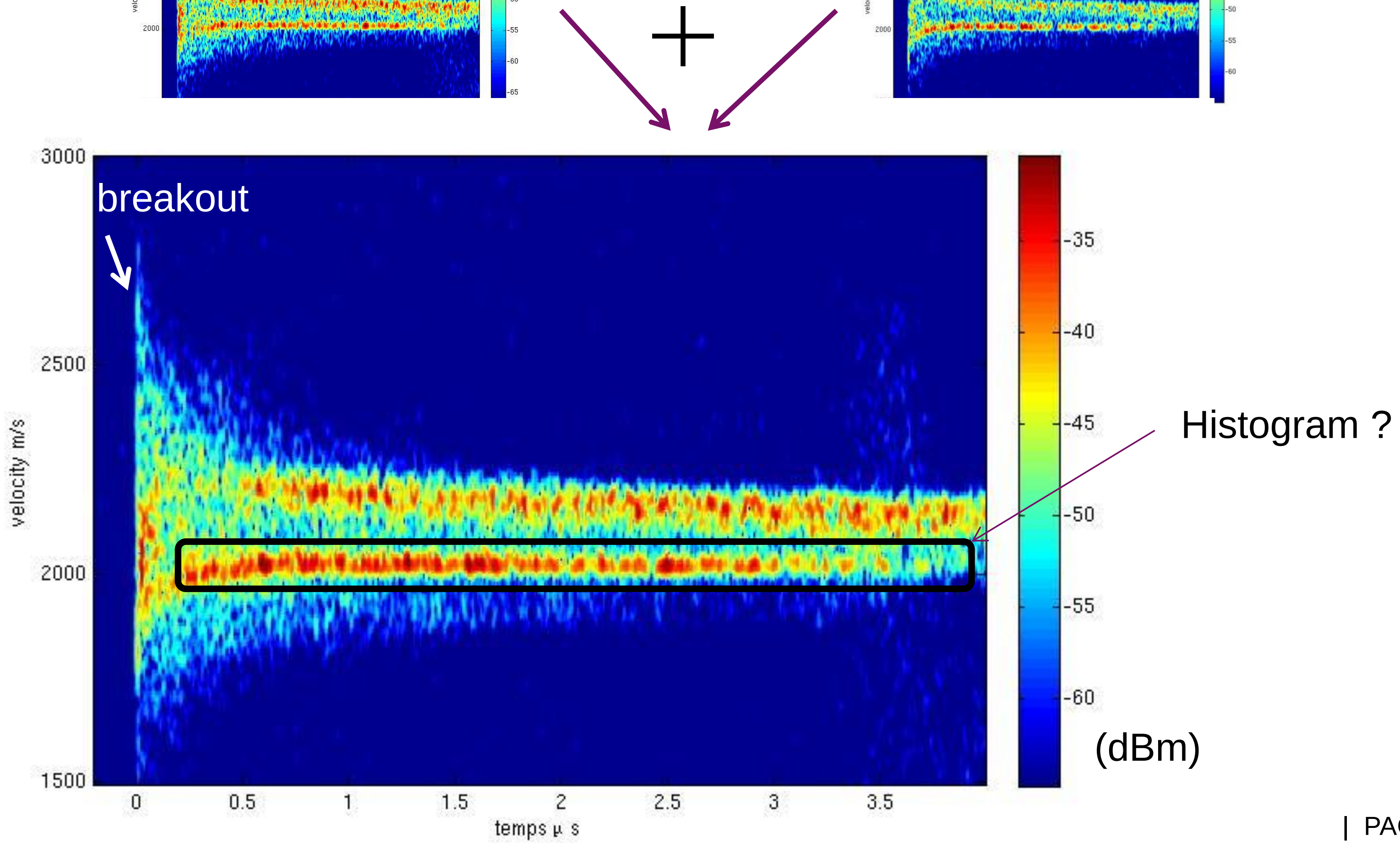


Signal dropouts are better suppressed compared to a classical analysis

WE CAN MERGE THE 2 SPECTROGRAMS

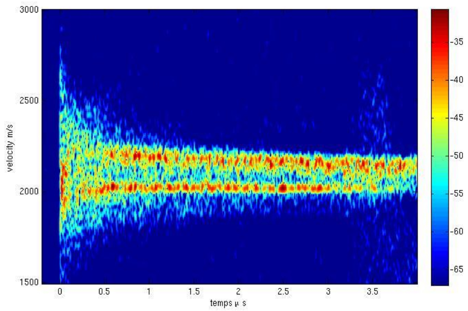




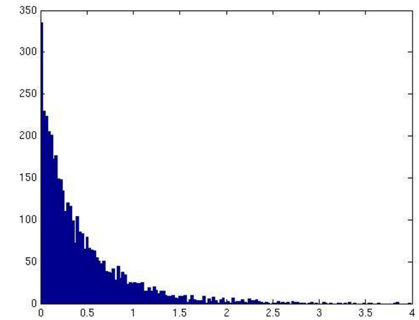


STATISTICS OF THE POWER: HISTOGRAMS FROM FREE SURFACE VELOCITY PROFILES

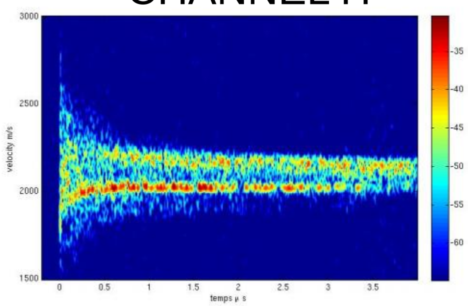
CHANNEL V

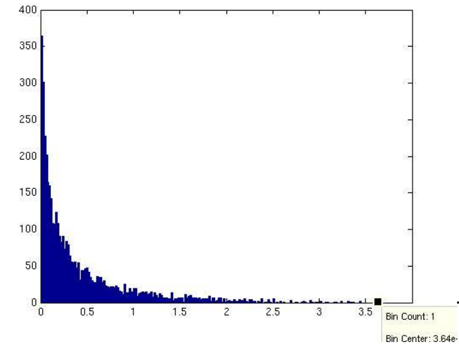


Histogram (surface Velocity over time)



CHANNEL H



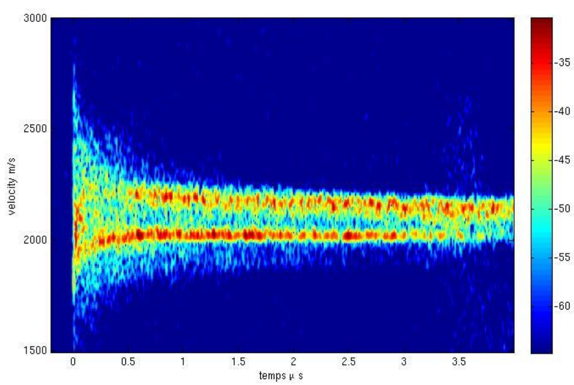


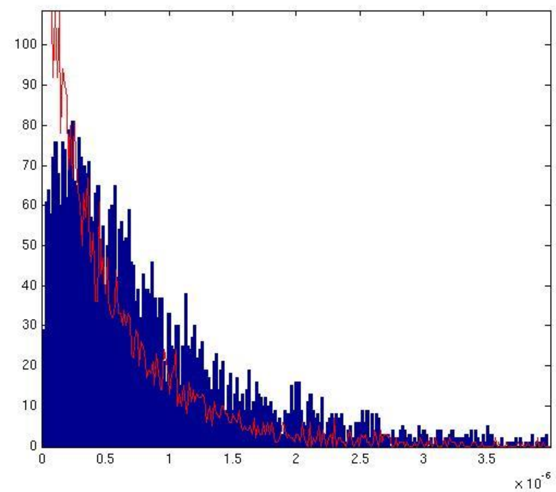
$$\overline{I_1} = 4{,}69.10^{-7} W$$
$$\sigma_1 = 5{,}59.10^{-7}\, W$$

<u>For each channel (H & V)</u>
<u>We get a negative</u>
<u>Exponential distributions</u>

$$\overline{I_2} = 4{,}29.10^{-7} W$$
$$\sigma_2 = 5{,}42.10^{-7}\, W$$

H+V



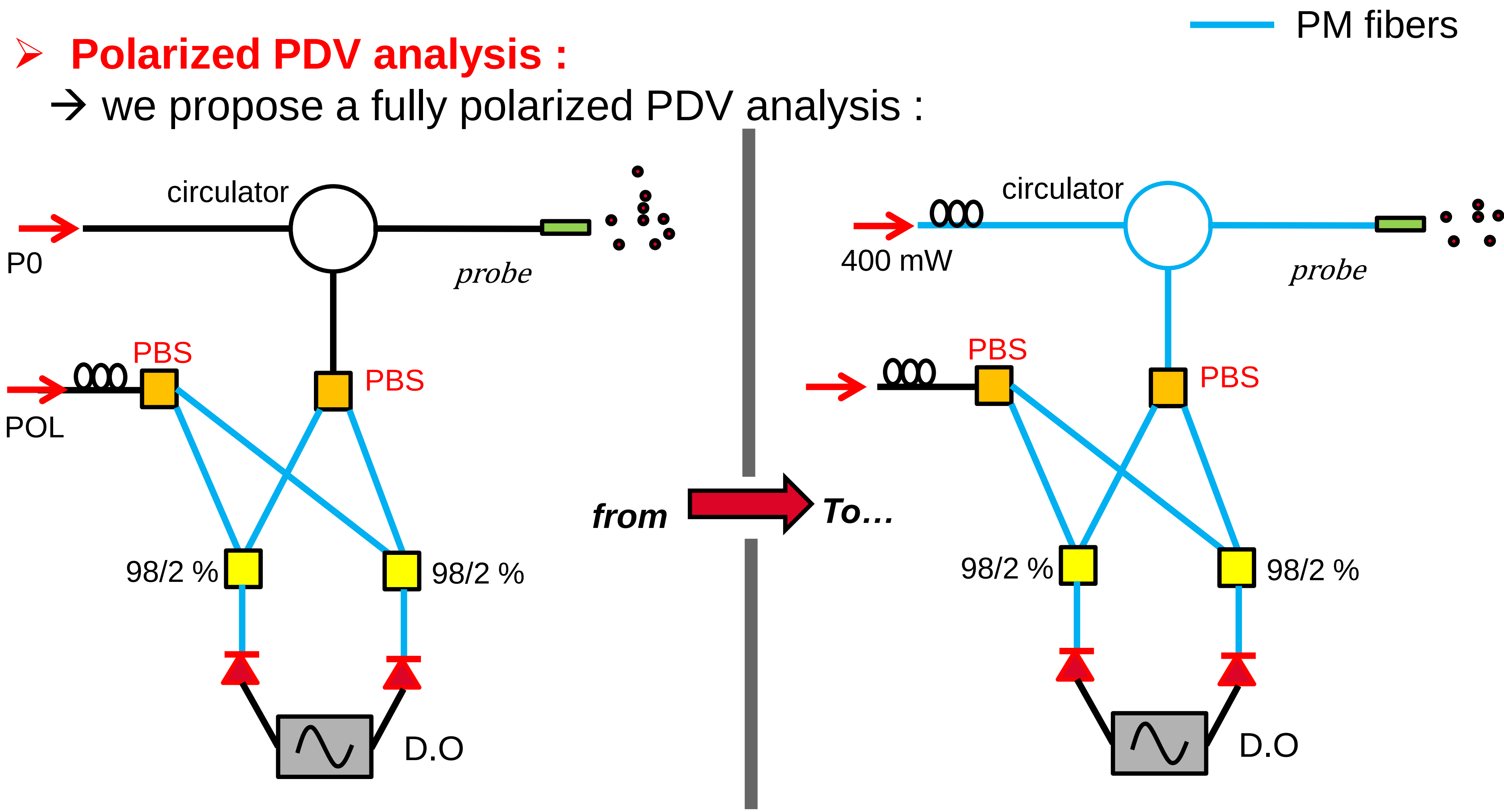


<u>Reduction of the « temporal speckle » contrast :</u>

$$C = \frac{\sigma_S}{\overline{I_S}} = \frac{\sqrt{\overline{I_1}^2 + \overline{I_2}^2}}{\overline{I_1} + \overline{I_2}} = 0{,}70$$

Instead of C = 1

- **Polarized PDV analysis :**
  → we propose a fully polarized PDV analysis :



→ Aligning both LO and input polarizations to optimize the contrast on 1 channel
→ Observe effects of depolarization

SPHERICAL PARTICLES DO NOT DEPOLARIZE LIGHT

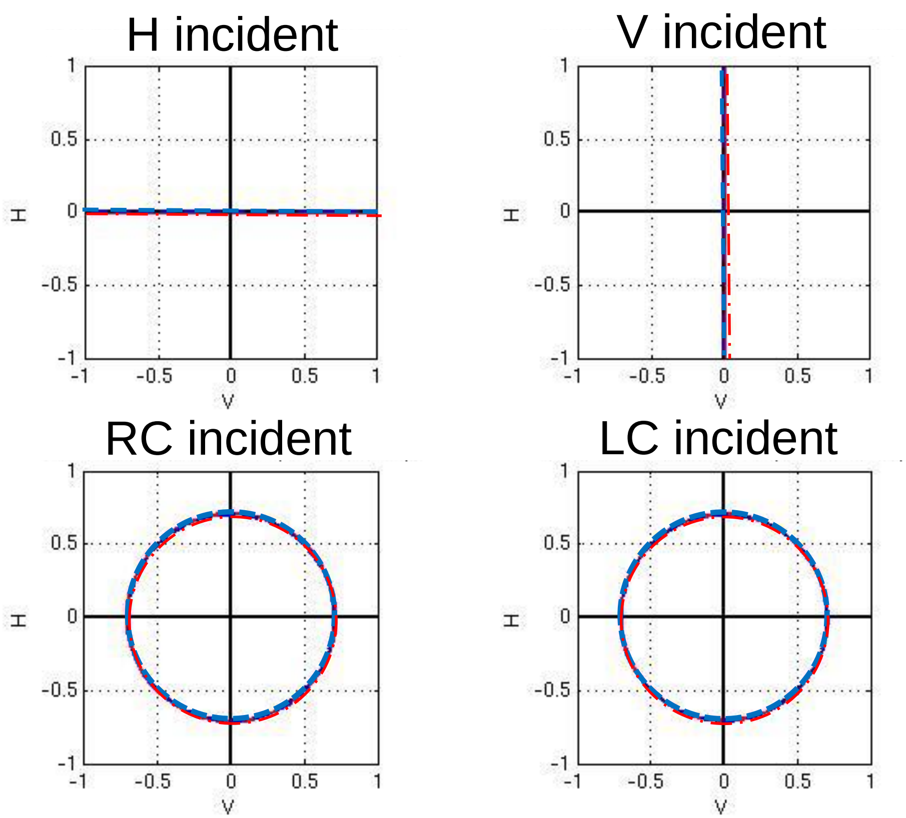
The backscattered power can be calculated either using:

- **Backscattered Mie efficiency**
- **Exact Electromagnetic simulation calculations**

For a perfect sphere, the backscattered polarization is unchanged

Incident Polarization

Backscattered Polarization



Left-handed Circular Illumination (LC)

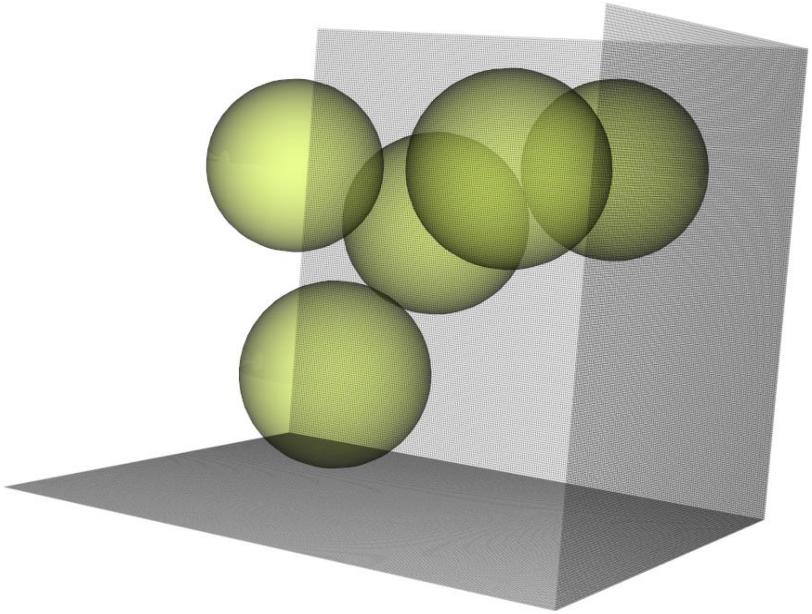
→ Right-handed Circular backscattered light (RC)

BACKSCATTER POLARIZATION OF AN AGGREGATE

For non spherical particle, backscattered power and polarization fully depend on:

- **The orientation of the particle with respect to the beam**
- **The incoming light polarization**

Example: 5 gold sphere aggregate. $\lambda = 1{,}55\ \mu m$. Optical refractive index :
n = 0,55 + 11,5i



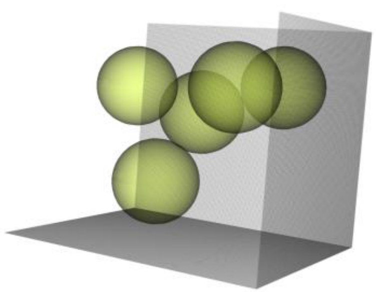
→ Loss of symetry compared to a perfect Sphere

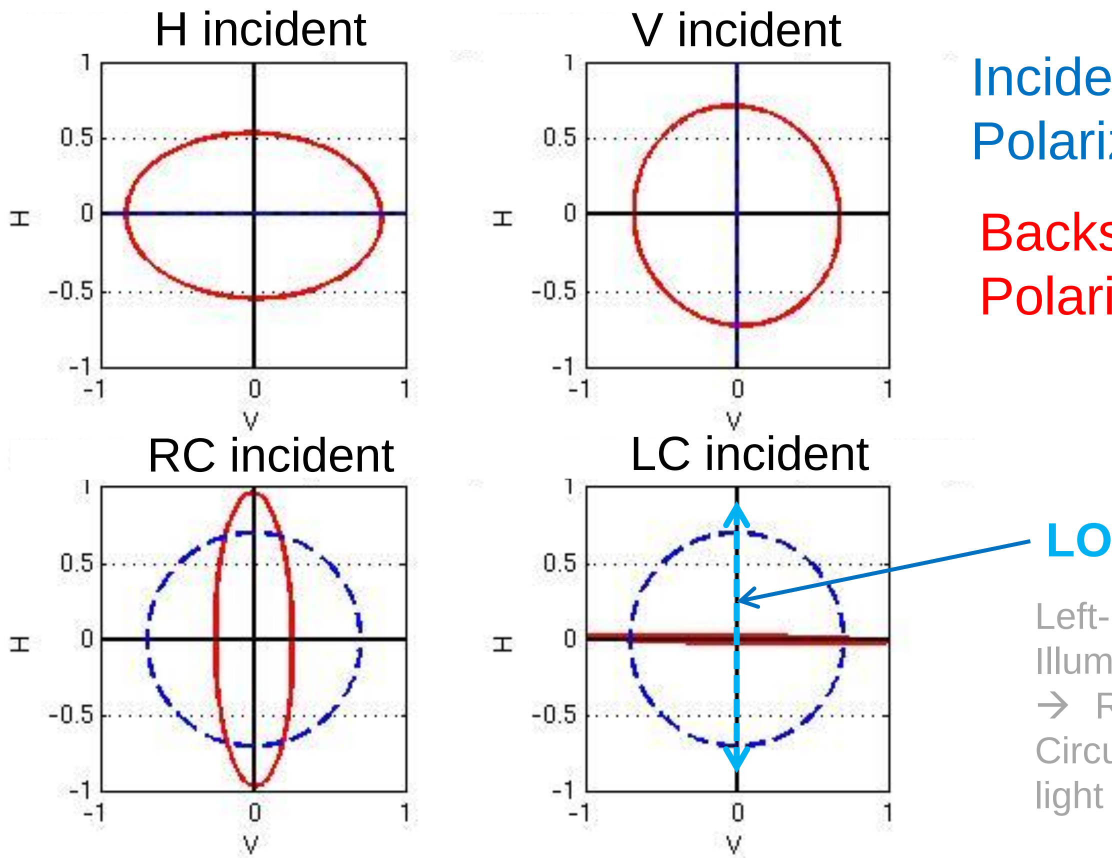
→ No way to retrieve backscattered power and polarization properties without an exact EM simulation

NON SPHERICAL PARTICLE AND BACKSCATTERED DEPOLARIZATION

Example: 5 gold sphere aggregate. The backscatter polarization is obtained from the calculated Stokes Vector in the far field region of the scatterer

The repartition of the optical power is 49 / 51 %





Incident Polarization

Backscattered Polarization

Left-handed Circular Illumination
→ Right-handed Circular backscattered light

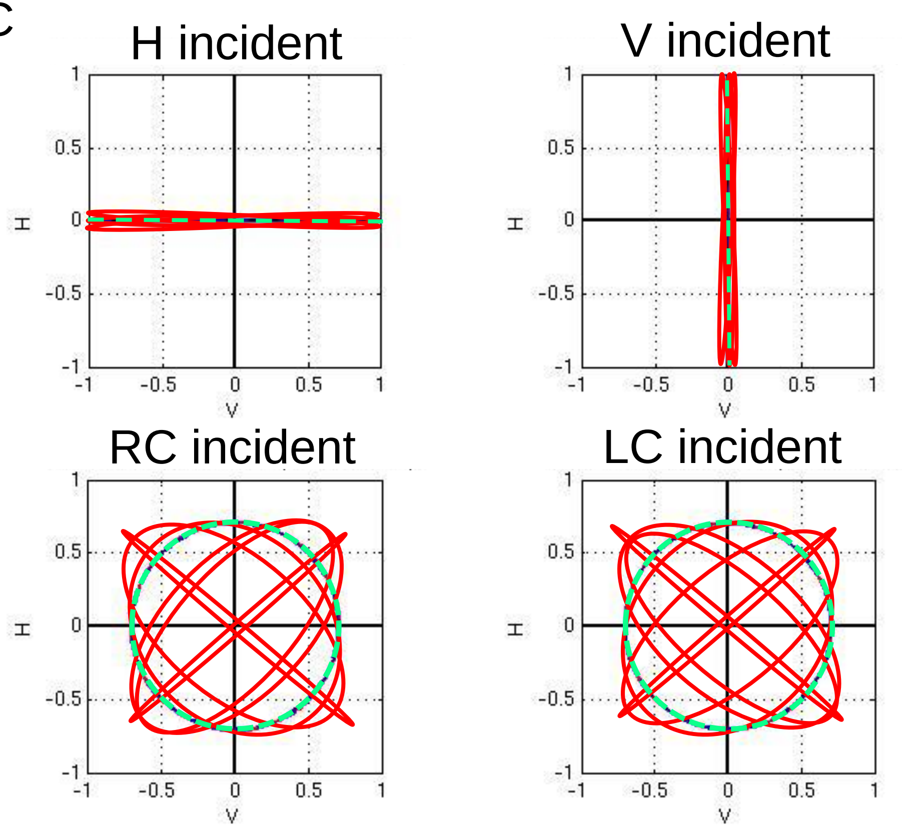
For complex geometries, polarization must be introduced in terms of detectivity. In this example, a Left-handed Circular incident polarization destroys the interference in case of a vertically polarized LO

WHAT ABOUT ELLIPSOIDAL PARTICLES?

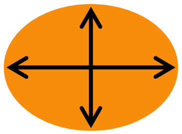
Example: random orientation of a gold ellipsoidal particle. The backscatter polarization is obtained from the calculated Stokes Vector in the far field region of the scatterer

→ Interest to use a linearly incident polarization because the changes of polarization are negligible. Interfere with a linearly LO will then optimize the contrast.

(but not with an LC or RC incident polarization)



Incident polarization



a/b = 1,2 $(1,2\mu m/1\mu m)$

CONCLUSION

➢ **Polarization and PDV developments in shock physics experiments :**

→ Improved PDV contrast (reduction of a « temporal speckle » contrast:
Can we improve the optical simulation of cloud particle ejected under shock ?

→ Merge two spectrograms : fill some signal dropouts.

→ Improve the detectivity of complex-shaped objects.

→ Perspectives : align both LO and input polarizations to maximize only one channel.

→ We will quantify more precisely the depolarization
→ Choose a linearly incident field
→ Link depolarization ratio to particle density … (?)
→ Validate the speckle contrast reduction using polarization diversity

Thank you for your attention !

Commissariat à l'énergie atomique et aux énergies alternatives
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