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DETAILED CHARACTERIZATION OF A CFRP LIGHTNING IMPACTED SPECIMEN BY COMPLEMENTARY PHASE IMAGING TECHNIQUES ON SYNCHROTRON AND IN THE LABORATORY

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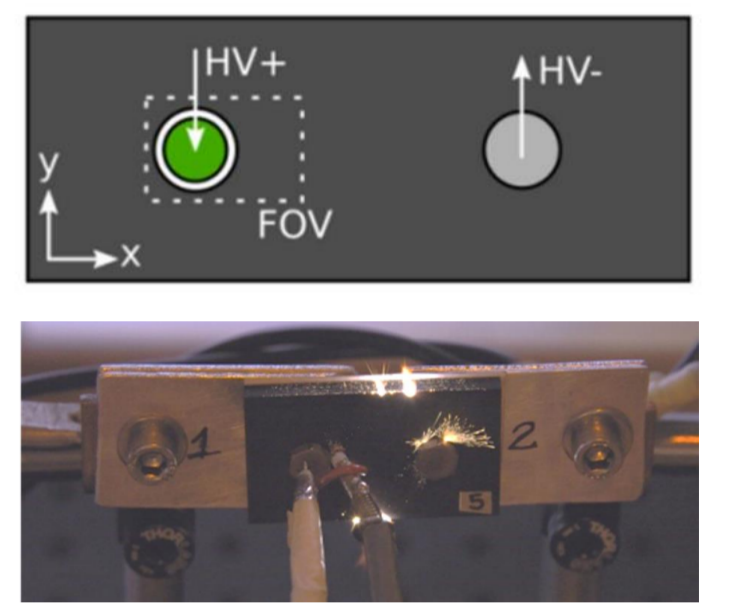
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Introduction

Today, we use more and more carbon fiber reinforced polymers (CFRP) in the aerospace industry. When they are damaged by lightning, defects can be formed in their structures. To understand these defects, an approach is to couple laboratory controlled induced lightning with non-destructive evaluation (NDE). Many NDE methods are used to study CFRP [1], among which X-ray imaging allows volume inspection with high spatial resolution. However, low attenuation carbon materials bring low contrast on the image. To improve it, the contribution of the phase signal of the X-ray wave front modified by the sample is considered in addition to the attenuation signal.

Sample

- ✓ Sample of CFRP ;
- ✓ Fibers orientation at +45°/-45°
- ✓ 3 times struck by lightning at 3kA
- ✓ Produced in controlled environment at the ONERA Department of Materials And Structures



Phase contrast methods

Synchrotron:

- Tomography measurement on ID19 with free propagation phase contrast method [2] ; Sample rotation 360° with an angular increment of 0.07° given 5000 images of 50ms of exposure time

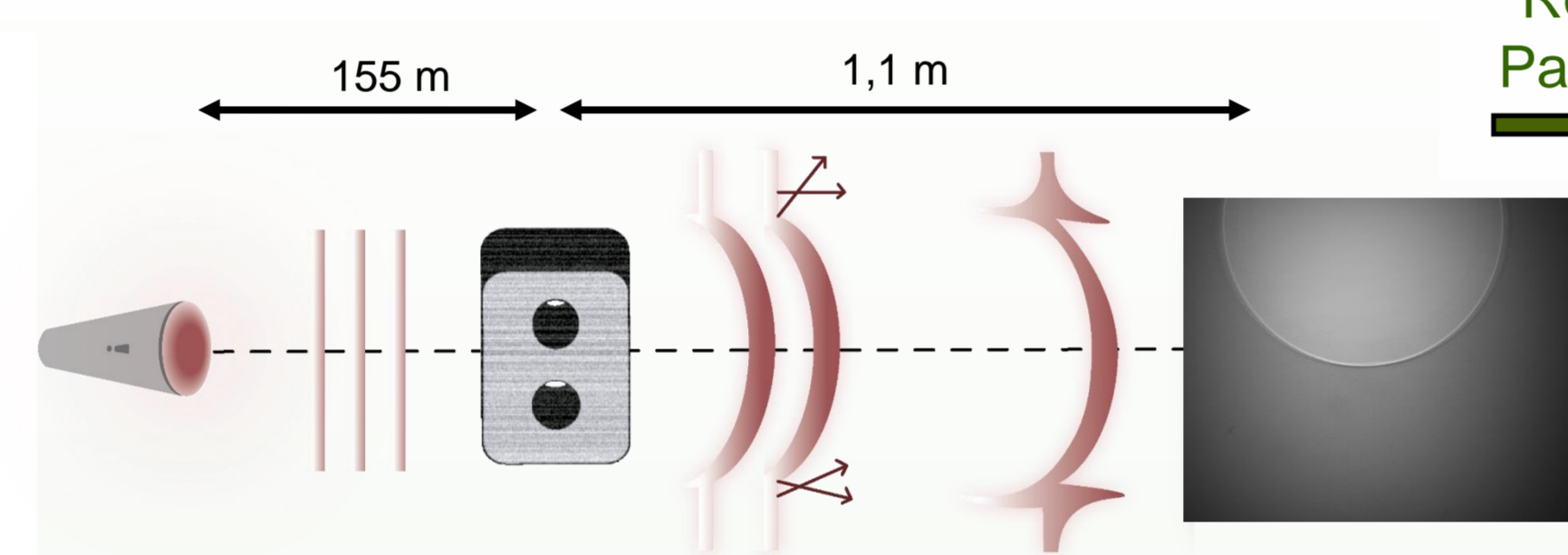
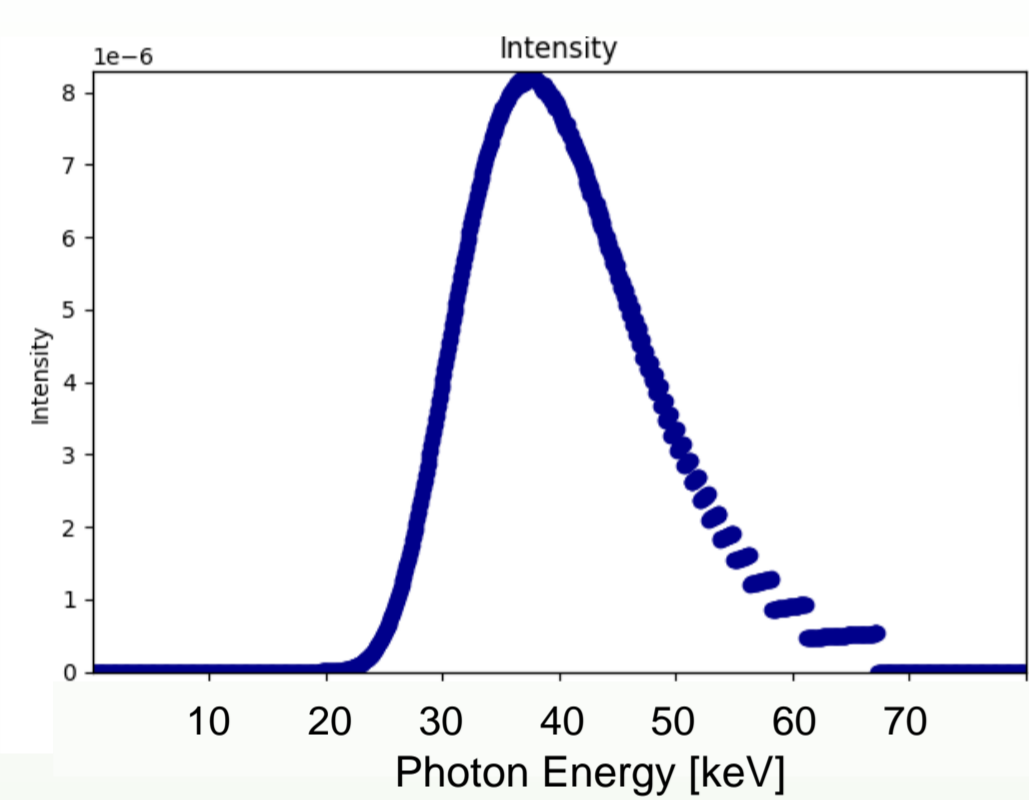


Fig 1: free propagation phase contrast method and source spectra

- Polychromatic source ; plane wave
- Detector pixel size = 6,5µm ; fov = 16.6 mm x 10.7 mm ; Magnification = 1 ; Effective pixel size = 6,5µm

Laboratory bench:

- Radiography measurement on microfocus X-ray tube with the Multi Lateral Shearing Interferometry (MLS) method [3,4],

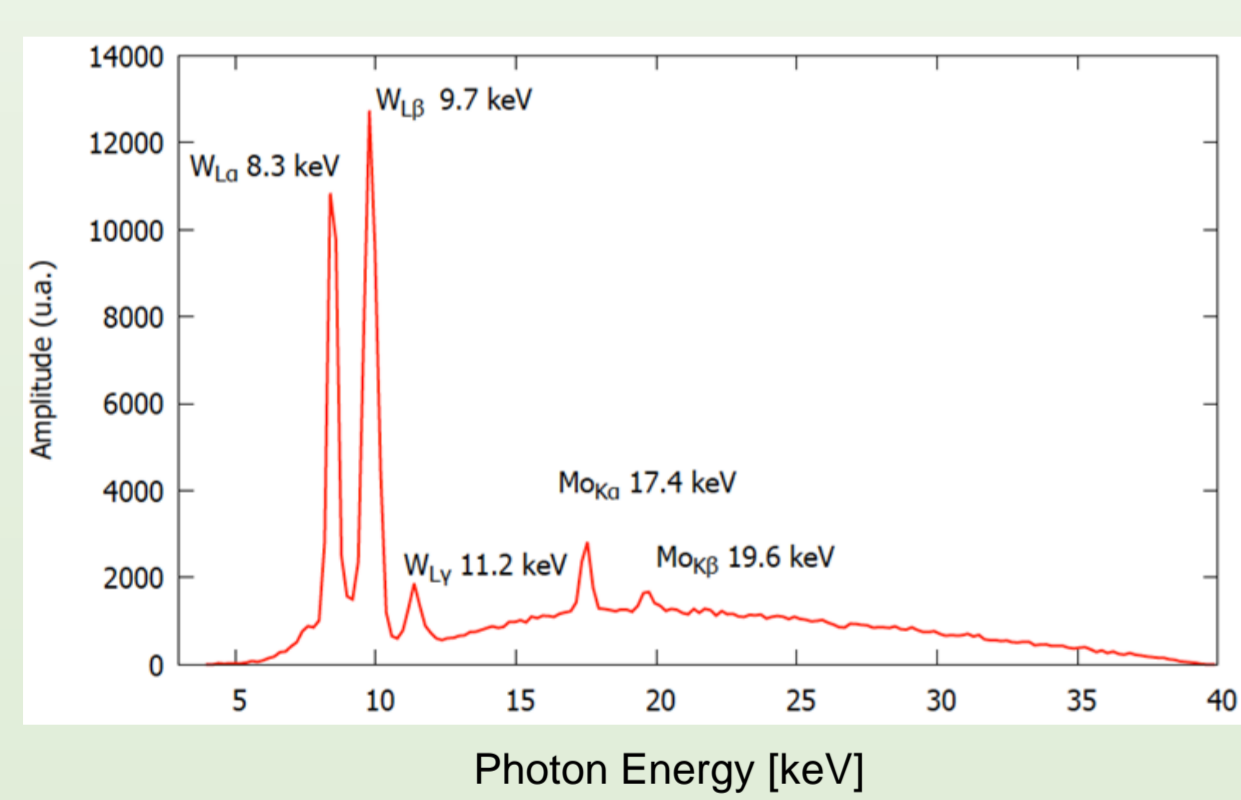
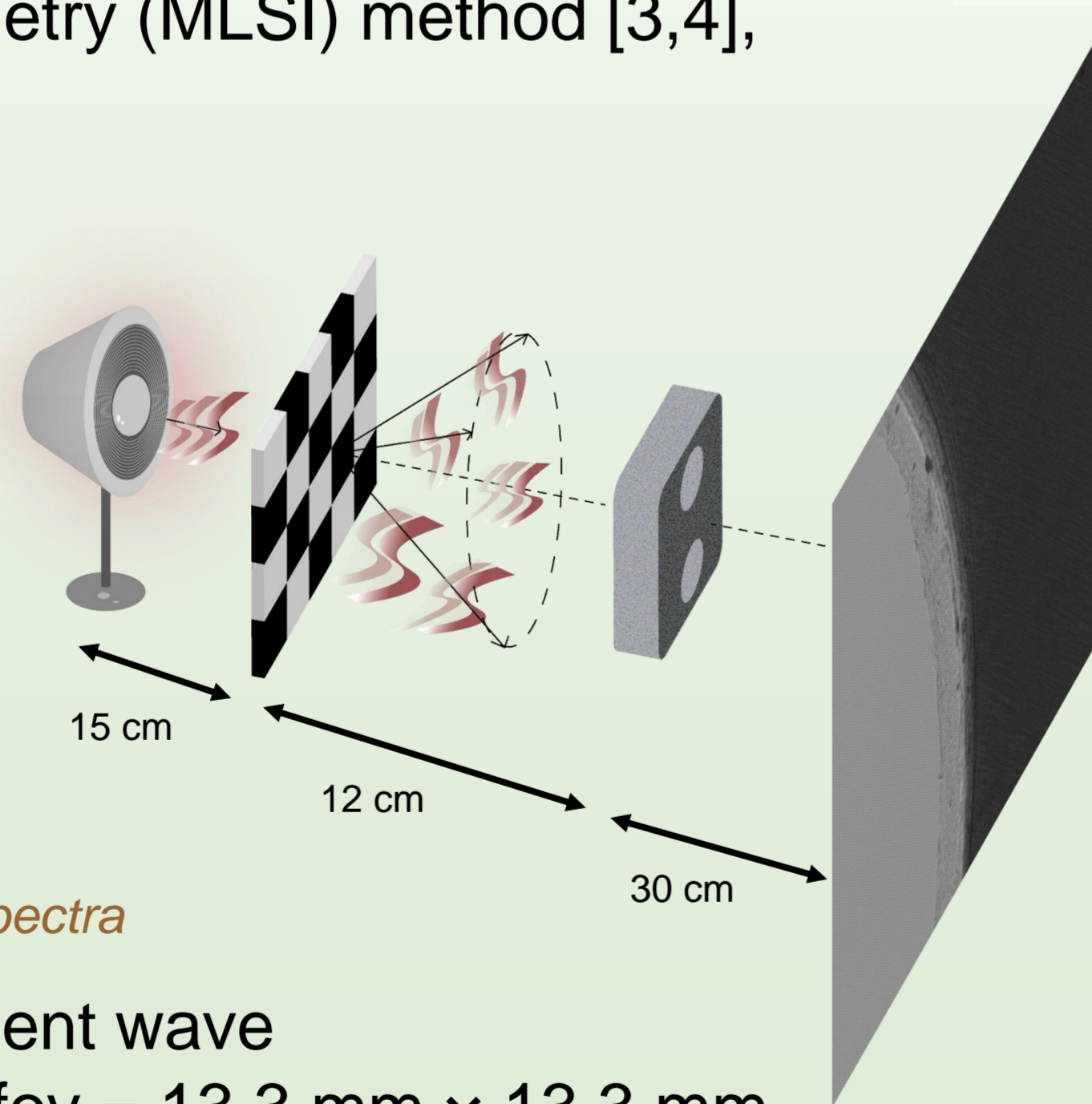


Fig 2: MLS method and source spectra



- Polychromatic source ; divergent wave
- Detector pixel size = 6,5µm ; fov = 13,3 mm x 13,3 mm Magnification = 3,2 ; Effective pixel size = 2,05 µm
- 2D Grating : orthogonal periodicity = 12 µm Phase shift [0;π] at 17,48 (Mo Kα)

Post-processing

Reconstruction with Paganin Algorithm [5]

Extraction by Fourier demodulation [6]

Results comparison

Synchrotron :

- The ID19 setup gives us a larger inspection area
- More sensitive to strong optical index variation

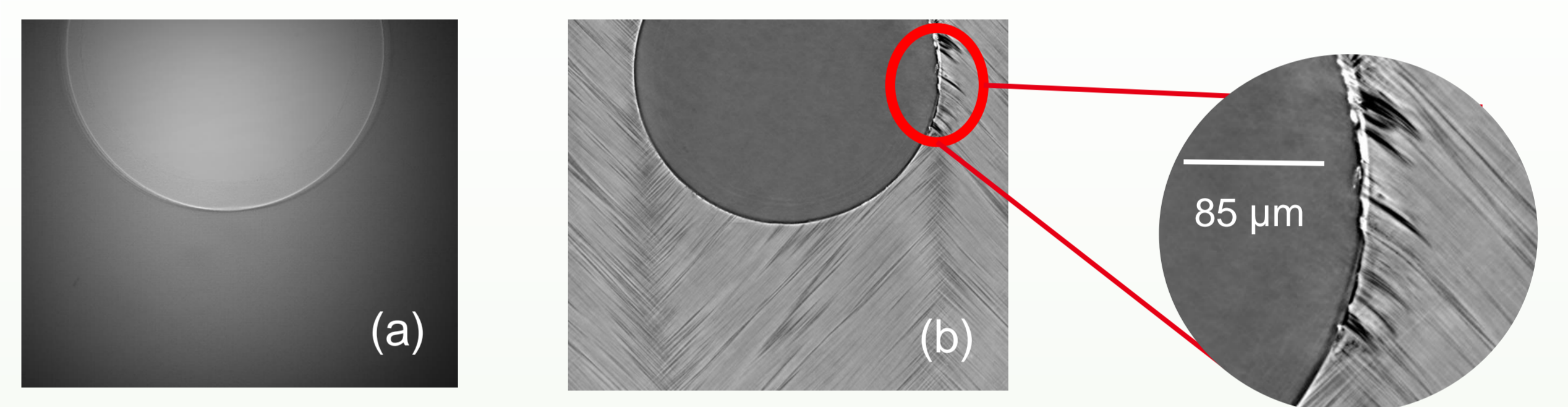


Fig 3: CFRP image with free propagation method : 2D projection (a) ; slice from the 3D reconstruction (b) [7]

Laboratory bench:

This phase contrast method offers complementary information between attenuation and phase image (Fig 4(a),(b)) and a better sensitivity to the fiber orientation (Fig 4(c),(d))

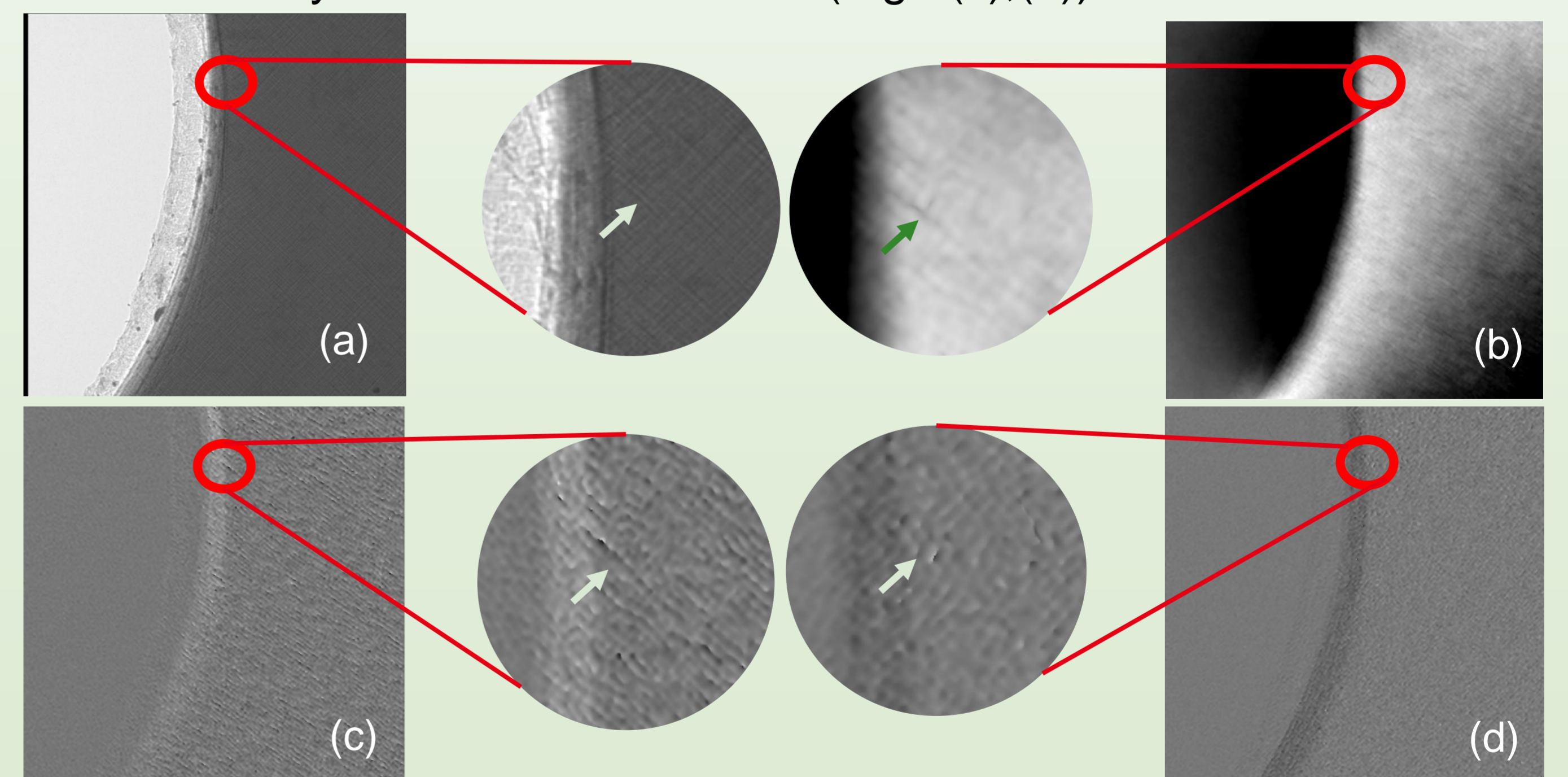


Fig 4: CFRP image with MLS method: Image of attenuation (a), phase image (b), phase gradient images in two axis directions (-x+y and x+y) (c)(d)

Conclusions et Perspectives

On the one hand , 2D and 3D synchrotron measurements offer a large inspection area, and sensitivity to strong optical index variation which is interesting to detect lightning damage especially at the interface screw/CFRP.

On the other hand, the laboratory bench, with MLS method, is more convenient to use. It allows to extract the phase, thus attenuation and phase image offer complementary information. As a result, 2D projection is able to evidence a lightning damage. Furthermore, the carbon fiber orientation appears clearly on 2D projection thanks to Fourier demodulation.

Thus, the future work will be to adapt the laboratory bench to tomography measurement, taking advantage of both higher sensitivity to fiber orientation and accessibility.

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