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Double-pulsed holographic interferometry with photorefractive crystals

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Summary

- Holographic interferometry
- Photorefractive effect
- The PHIFE project (EU funded - FP5)
  - Objectives
  - Main Work Packages
- Development Phase
- Industrial prototyping
- Industrial test
- Conclusion - Future prospects

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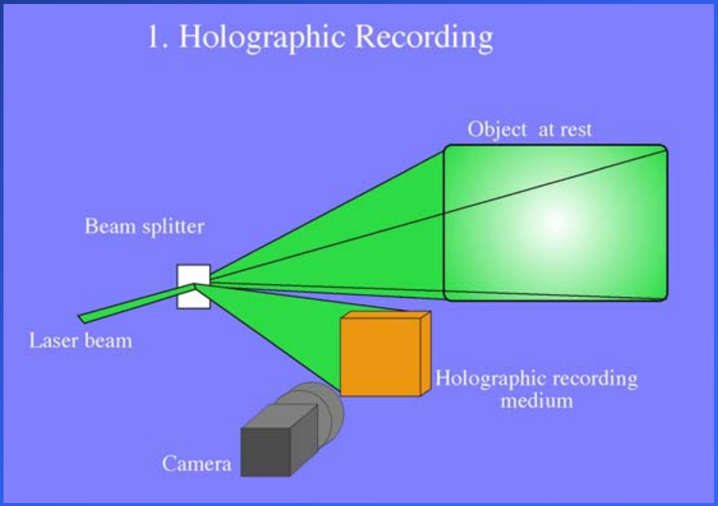
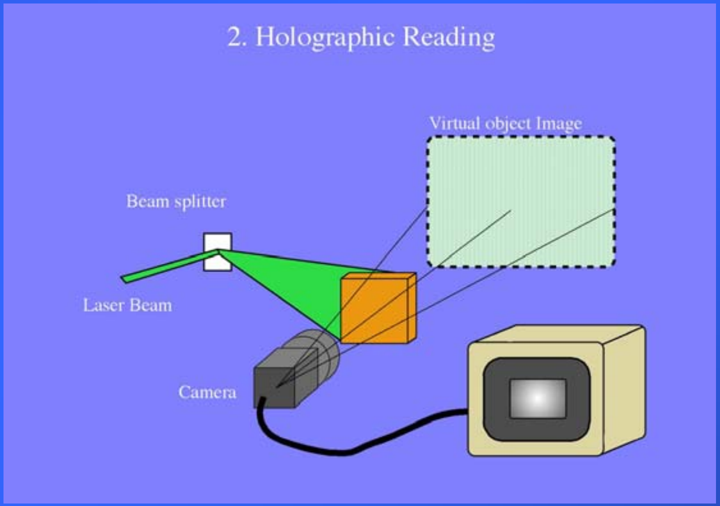
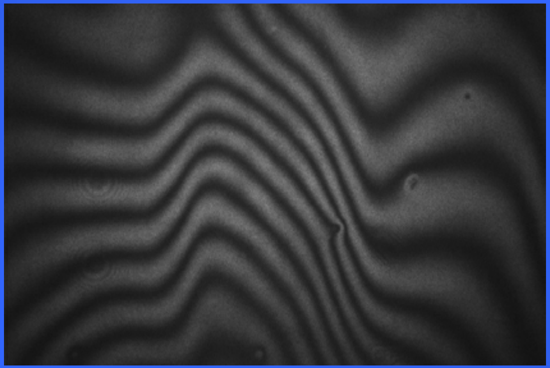
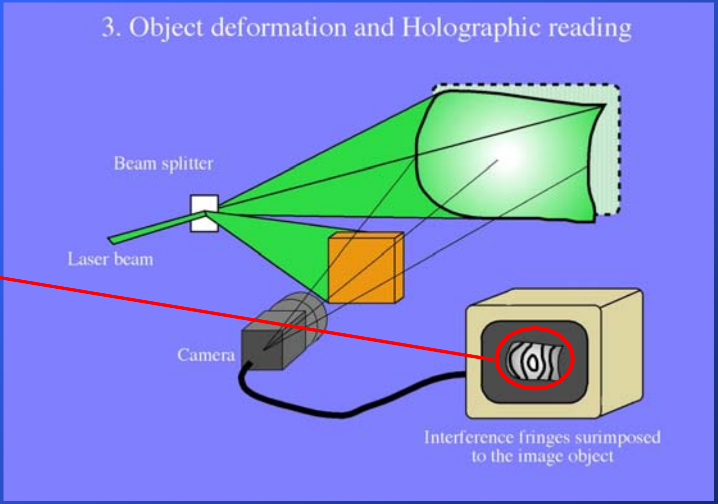
Holographic interferometry : principle







INTERFEROGRAM



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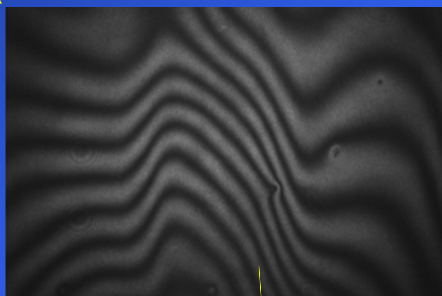
Holographic interferometry

- Technique for measuring displacements

y



x

Average Intensity

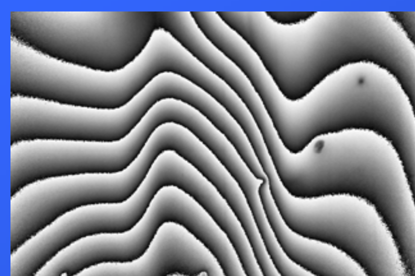
Optical Phase Difference

$$I(x,y)=I_0(x,y)\,[1+m(x,y)\,\cos(\Delta\phi(x,y))]$$

Contrast

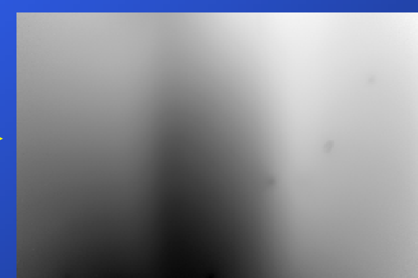
Phase computation technique (phase-shifting, FFT,..)

Optical Phase Difference



(modulo 2π)

Displacement map

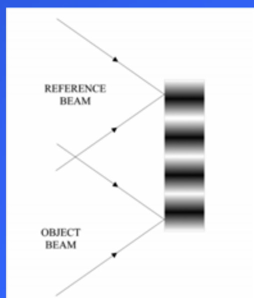


$$\Delta\phi(x,y) = \boldsymbol{S.L}$$

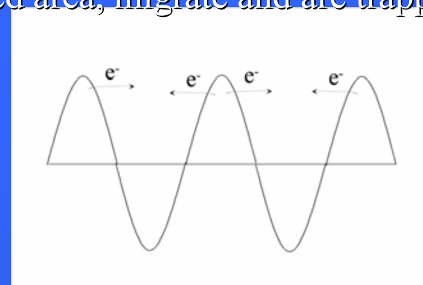
Photorefractive Effect

- Holographic Interferometry
  - Key element of applicability : holographic medium
  - Userfriendliness = Self-processable and reusable medium
- Photorefractive effect

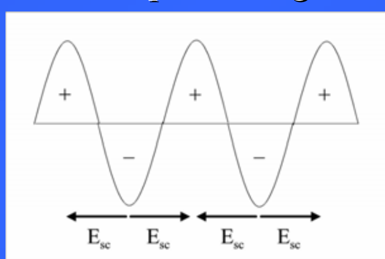
1. Fringe pattern created by interference between 2 waves



2. Charges generated by photo-excitation in illuminated area, migrate and are trapped in dark area



3. Local space charge field



Pockels effect

4. Modulation of refractive index Δn

= ***HOLOGRAM***

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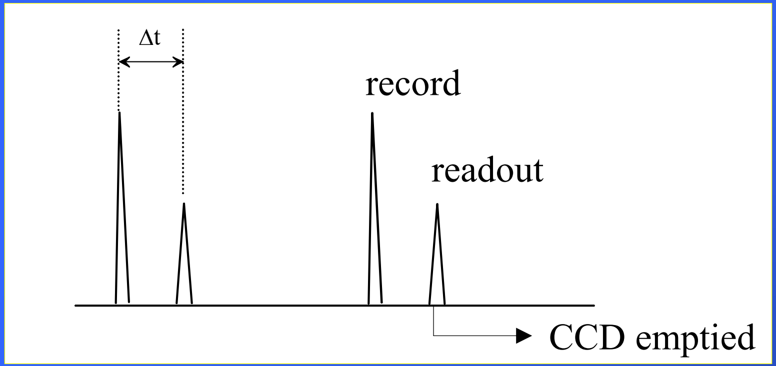
Pulsed illumination

- Application to pulsed holographic interferometry

  - First pulse :
    - Hologram recording
    - object state 0
  - Second pulse :
    - Hologram readout
    - object state 1
    - Interferogram showing (state 1 - state 0)



  - Photorefractive crystals respond at nanosecond scale
    - Δt can be as small as nanoseconds
    - Such technique is limited by the laser source

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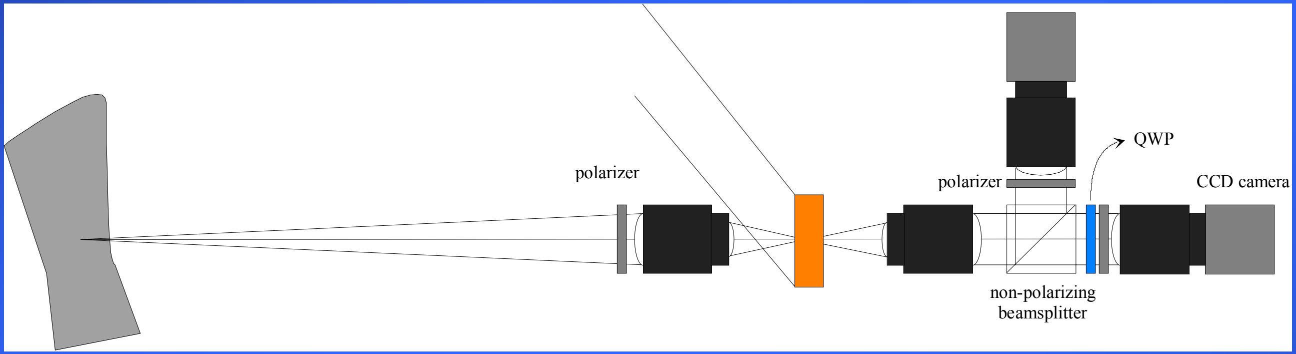
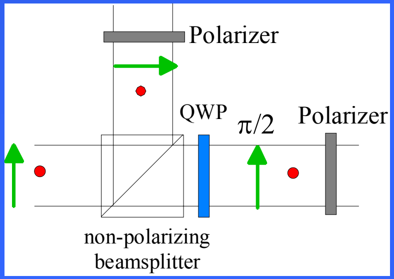
PHIFE - FP5 “Growth”

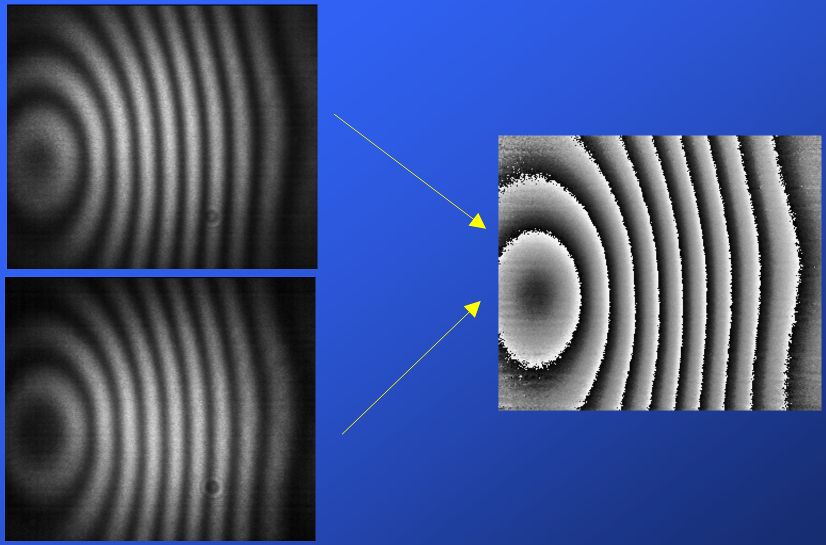
- Pulsed Holographic Interferometer for the analysis of Fast Events
- Objective : Develop Holographic Interferometer with Photorefractive
  - high resolution (no speckle noise) quantified results
  - high temporal bandwidth (from 1 - 200 µs)
  - high repetition rate (25 Hz)
  - applied to vibrations, shocks, aerodynamic studies
- WorkPackages
  - Development of holographic heads
    - wavelengths 532 (BSO) and 1064 nm (AsGA or CdTe : novelty)
    - new phase quantification techniques
  - Development of new double-pulse laser/single cavity YAG Q-switch
    - 25 Hz, High energy, variable delay between pulses
  - Industrial prototyping
  - Industrial tests

PHIFE - Developments

- Novel phase quantification technique # 1
  - Fully passive simultaneous phase-shifting with 2-cameras







- Cam 1 : $I = I_{01} (1+m \sin \Delta\phi)$
- Cam 2 : $I = I_{02} (1+m \cos \Delta\phi)$

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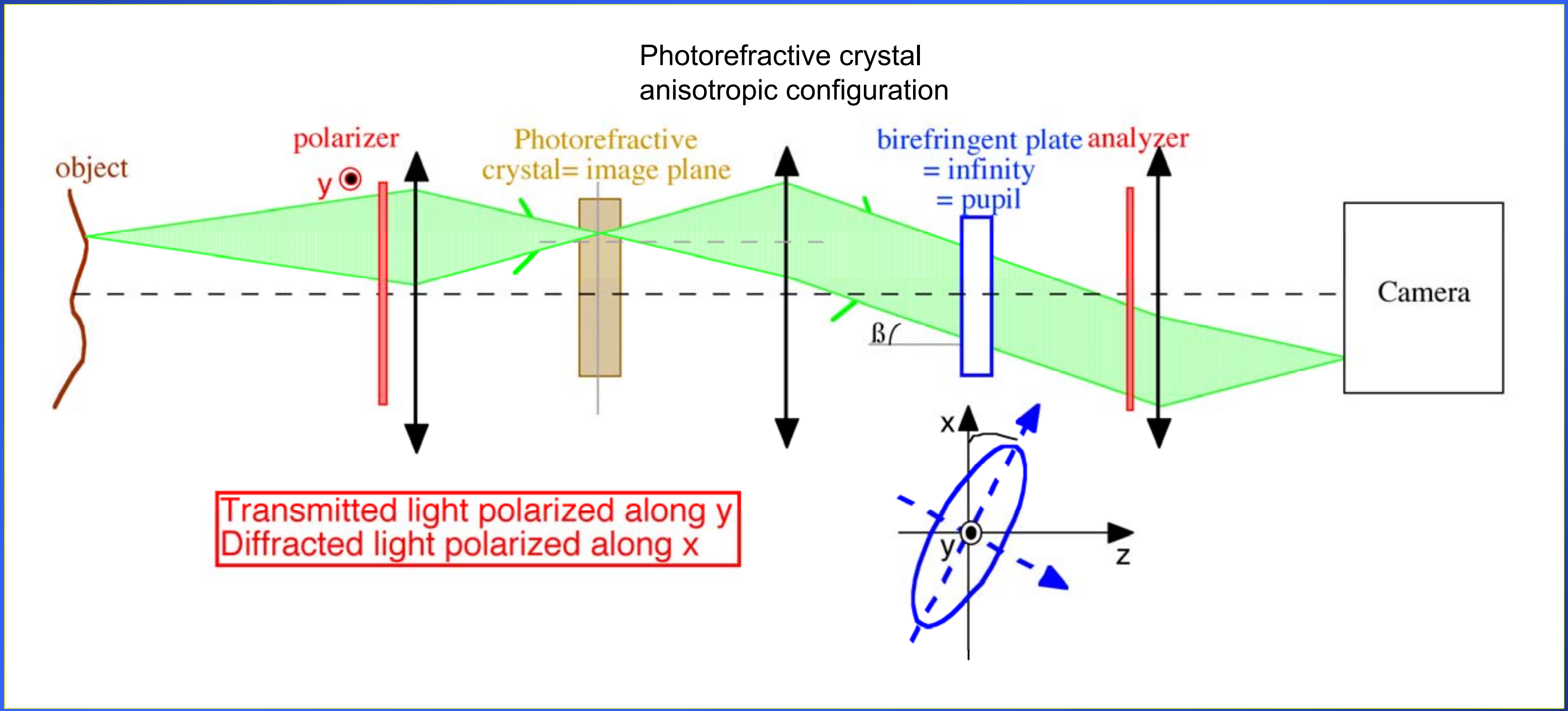
PHIFE - Developments

Laboratoire Charles Fab
de l'Institut d'Optique

- Novel phase quantification technique # 2
  - Passive introduction of carrier fringe pattern prior to use of Fourier filtering

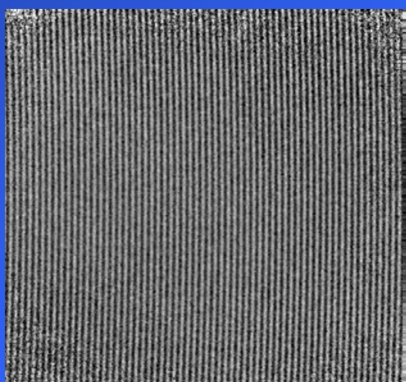


CNRS patent: "*Dispositif pour la génération d'une porteuse dans un interférogramme*" 13/03/2003; n° 0303010, France; PCT (2003).

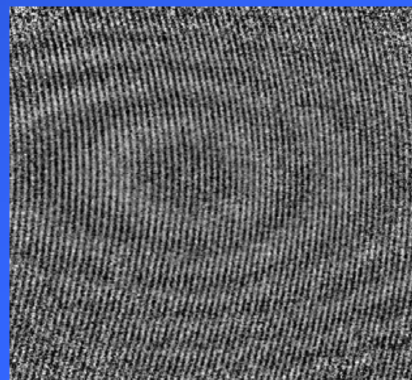
PHIFE - Developments

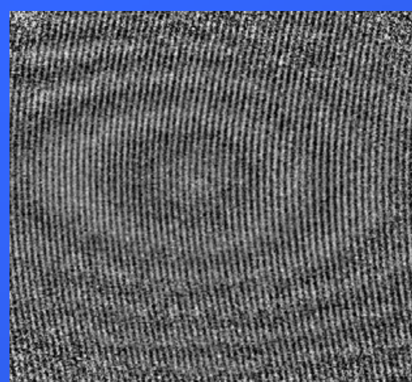
- FFT single frame processing with carrier fringes

CARRIER

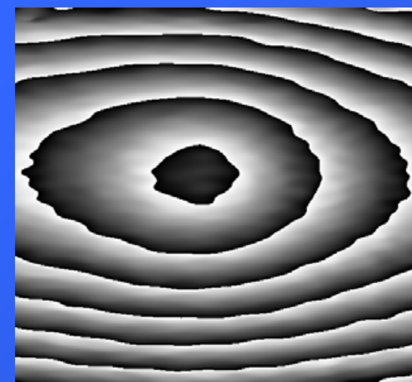


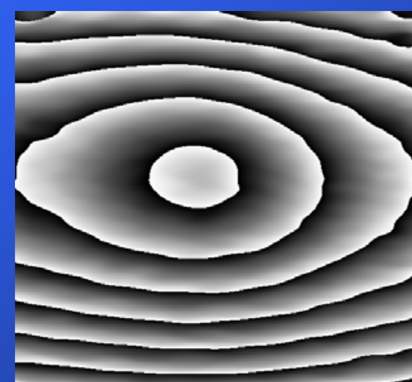
CARRIER + OBJECT DISPLACEMENT





PHASE AFTER FFT PROCESSING





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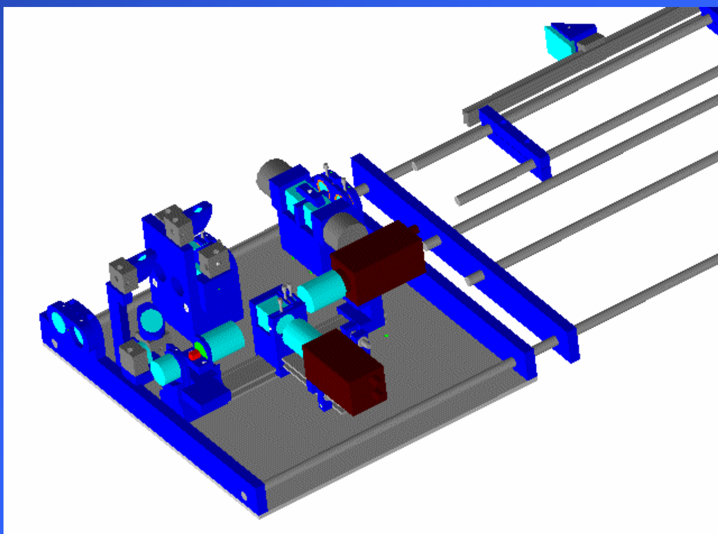
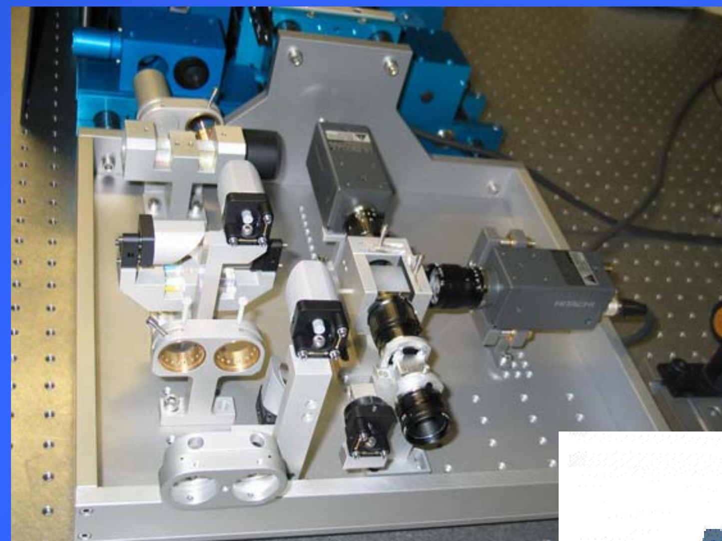
PHIFE - Prototyping

- Industrial prototype = Holographic Head + Laser

OPTRION
OPTICS & METROLOGY





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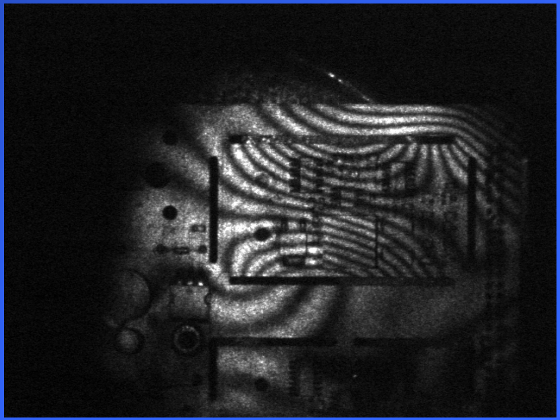
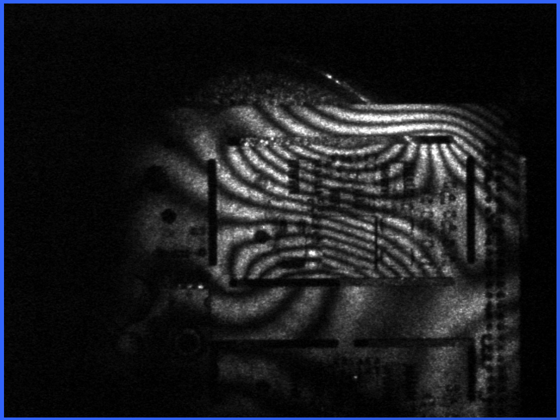
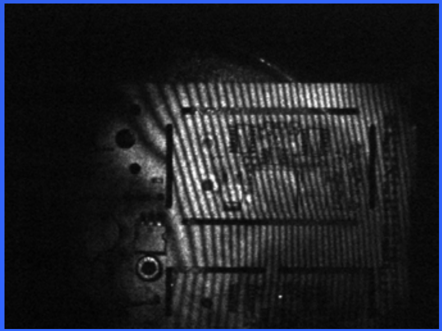
PHIFE - tests

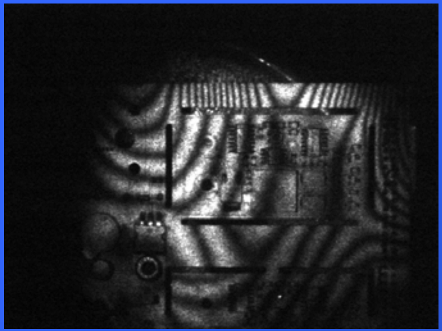
AMITRONICS
Angewandte Mikromechatronik GmbH

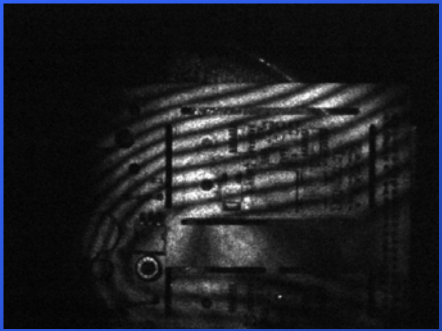
- Vibrations : Electronic board on shaker
  - total amplitude of vibration can be millimeters
  - λ = 1064 nm / AsGa crystal











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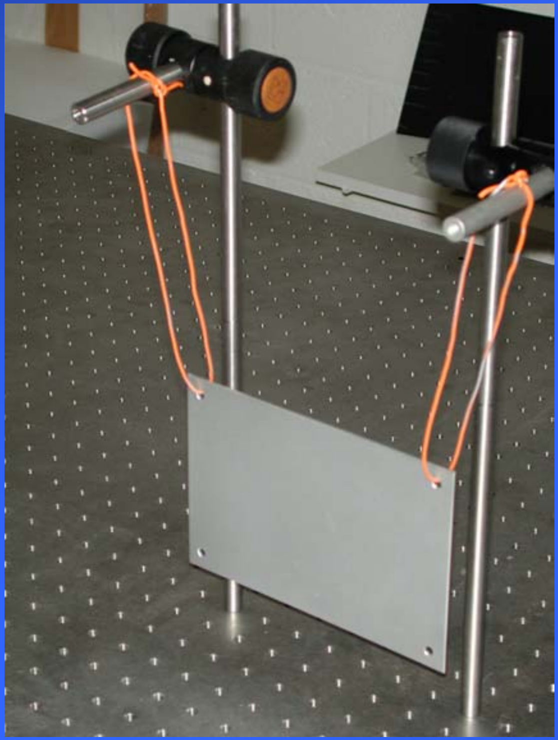
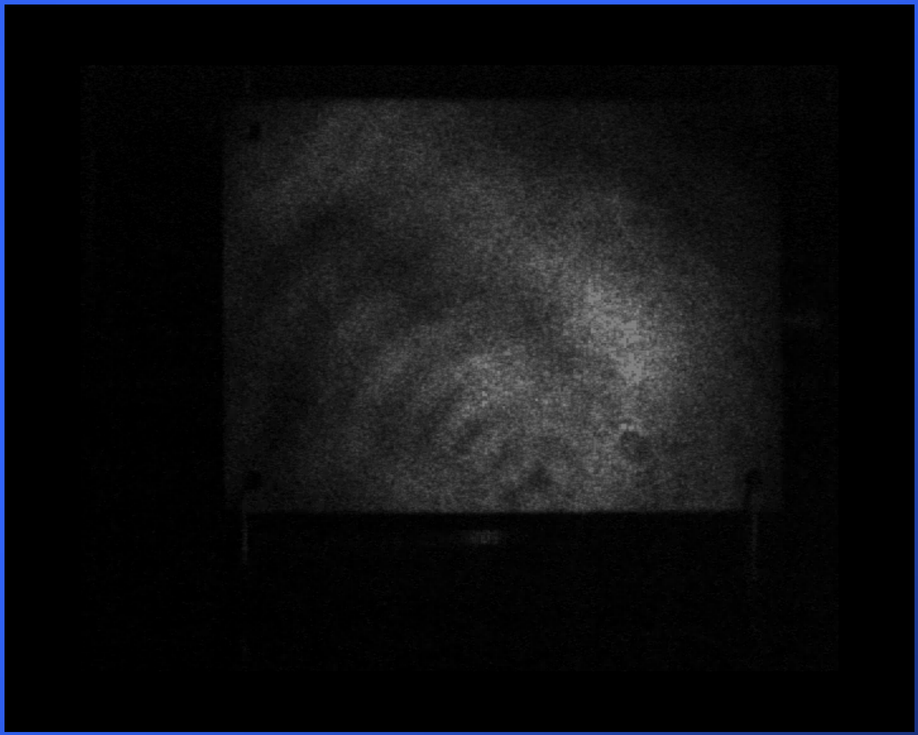
PHIFE - tests

Amitronics Angewandte Mikromechatronik GmbH

- Shock : Metallic plate with hammer
  - laser : double pulse sequence (25 Hz rep. Rate, 120 µs delay)





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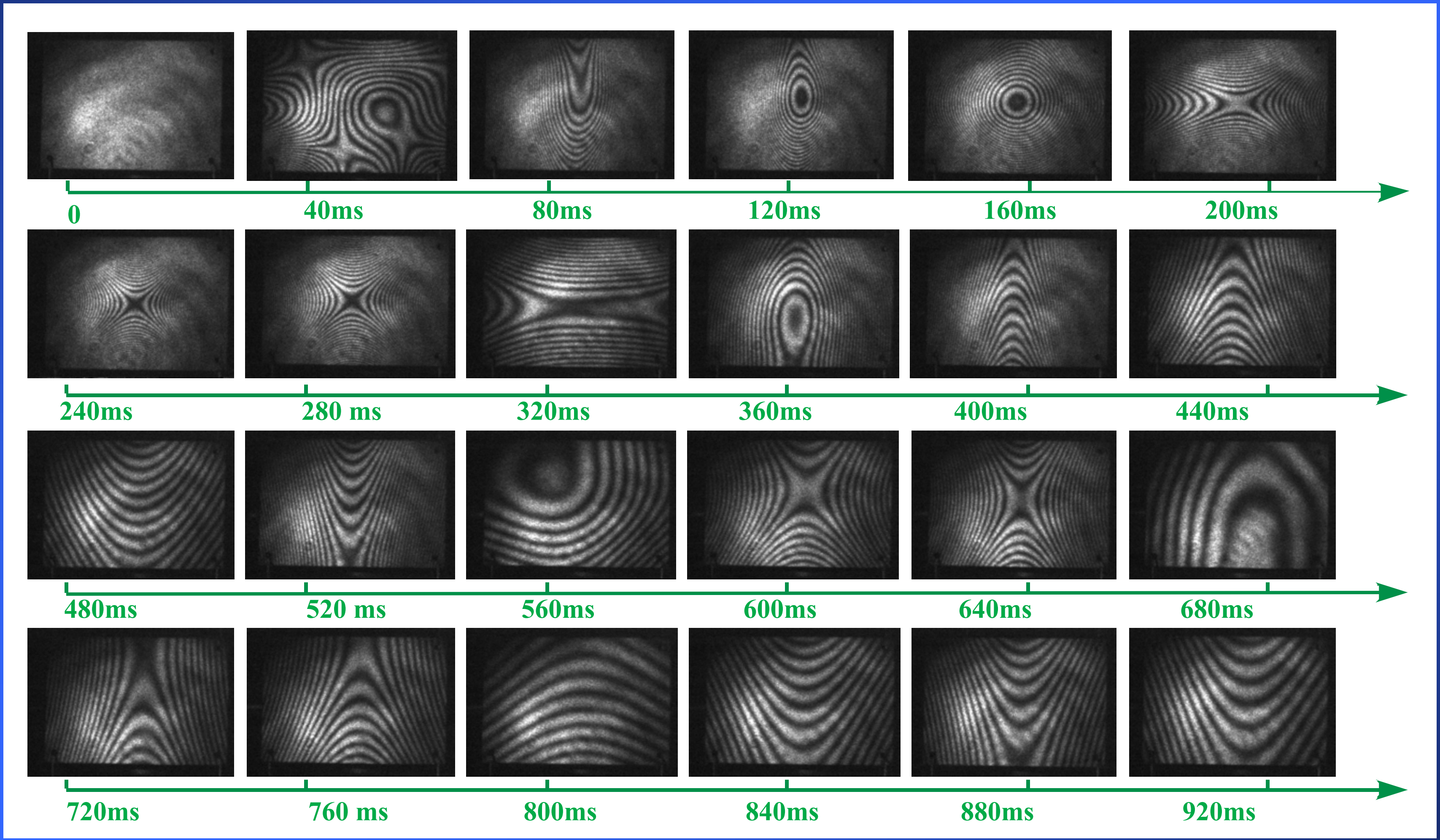

Conclusion - Future prospects

- Achievements :
  - New double-pulse YAG Q-switch laser has been developed
  - Novel phase quantification techniques were demonstrated
  - First demonstration of dynamic holography at λ=1064 nm with AsGa crystals
  - Demonstration in vibration and shock analysis
  - Demonstration in transonic flow visualisation (not presented)
- Future prospects :
  - Possibility of demonstrations of PHIFE after project terminated (search of partners for tests)
  - Amplitude and phase of vibration measurements
  - Shock analysis (“ping test”)
  - main sectors investigated : aeronautical/automotive