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
Holographic interferometry: principle

1. Holographic Recording

2. Holographic Reading

3. Object deformation and Holographic reading

INTERFEROGRAM
Holographic interferometry

- Technique for measuring displacements

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

- Optical Phase Difference
- Average Intensity
- Contrast
- Displacement map

\[ \Delta\phi(x, y) = S \cdot L \]
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
4. Modulation of refractive index $\Delta n = HOLOGRAM$
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
    - $\Delta t$ can be as small as nanoseconds
    - Such technique is limited by the laser source
PHIFE - FP5 “Growth”

- **Pulsed Holographic Interferometer for the analysis of Fast Events**
  - Objective: Develop Holographic Interferometer with Photorefractives
    - 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

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PHIFE - Developments

硄 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 : \( I = I_{02} (1+m \cos \Delta \phi) \)
PHIFE - Developments

♦ 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
PHIFE - Prototyping

- Industrial prototype = Holographic Head + Laser
PHIFE - tests

♦ Vibrations: Electronic board on shaker
  - total amplitude of vibration can be millimeters
  - $\lambda = 1064$ nm / AsGa crystal
PHIFE - tests

- Shock: Metallic plate with hammer
  - laser: double pulse sequence (25 Hz rep. Rate, 120 µs delay)
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 $\lambda=1064$ 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