High-speed Lock-IN CMOS camera with pixel-level signal processing.

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Motivation

- Single photodiode: >1GHz

- Pixel array: 4096 pixel -> ~ 100'000 lines/s

- 2D Camera: 1Mpixel -> ~ 1000 frames/s

-> Data rate: ~1GB/s -> complex to transfer and process in real time
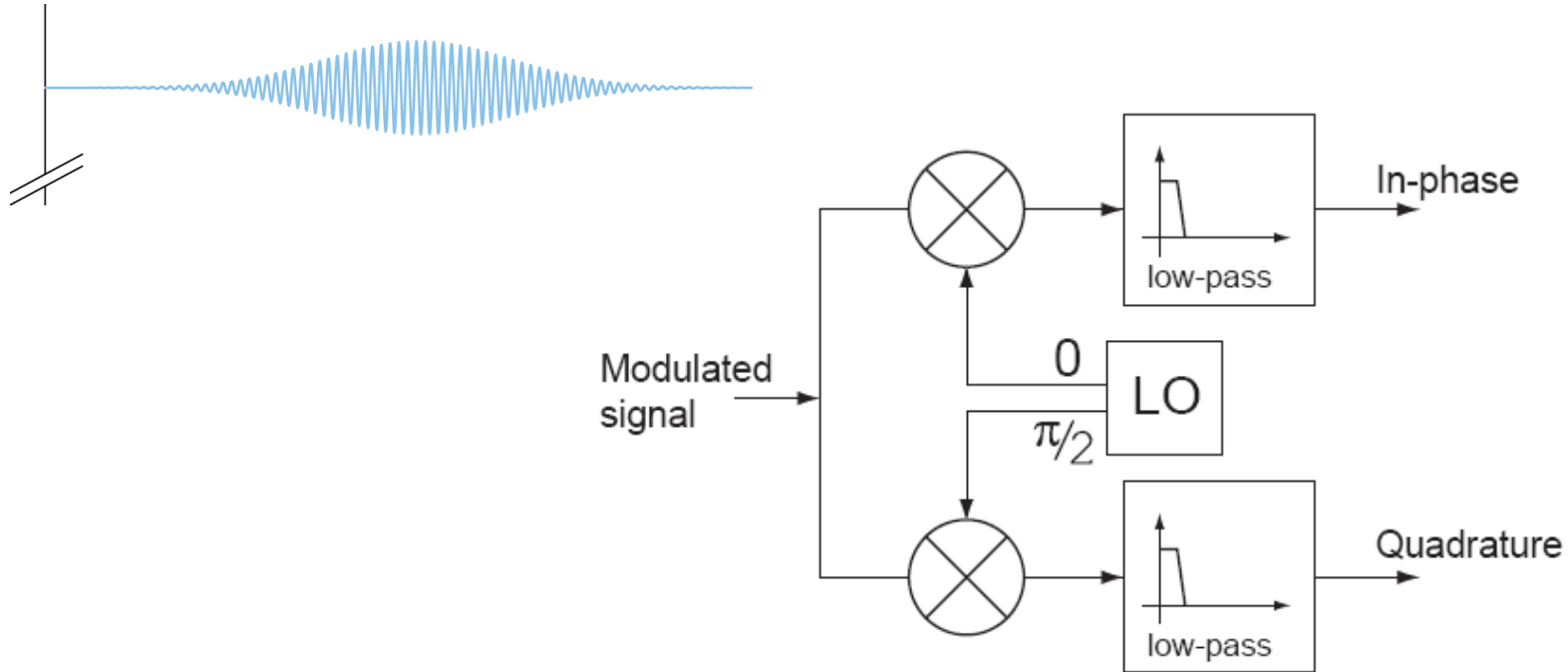
Modulated signal
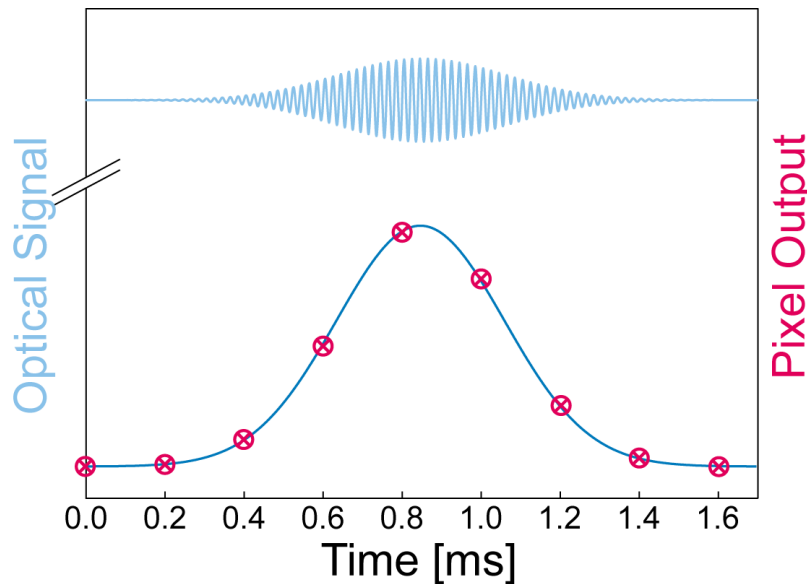
- Used in many fields:
  - Amplitude:
    - white light interferometry
    - Spectroscopy (pump-probe)
    - Lock-IN detection
  - Phase:
    - interferometry
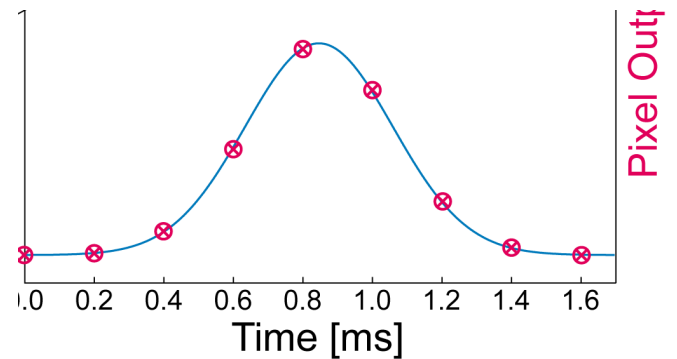   - 3D fringe projection
    - Doppler measurements.

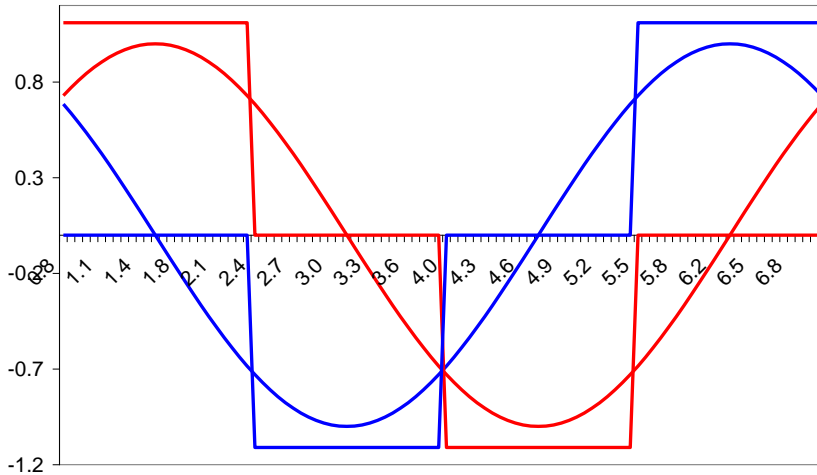- Max frequency limited for 2D sensors

Lock-In function

Modulated signal → In-phase (low-pass)

0 / $\pi/2$ — LO

Quadrature (low-pass)

$$A_m(T) = \frac{\omega}{n_c \pi} \sqrt{I(T)^2 + Q(T)^2}$$

$$\varphi(T) = a\tan\left(\frac{Q(T)}{I(T)}\right)$$

Pixel Output

Time [ms]

In pixel implementation

S. Beer (CSEM)
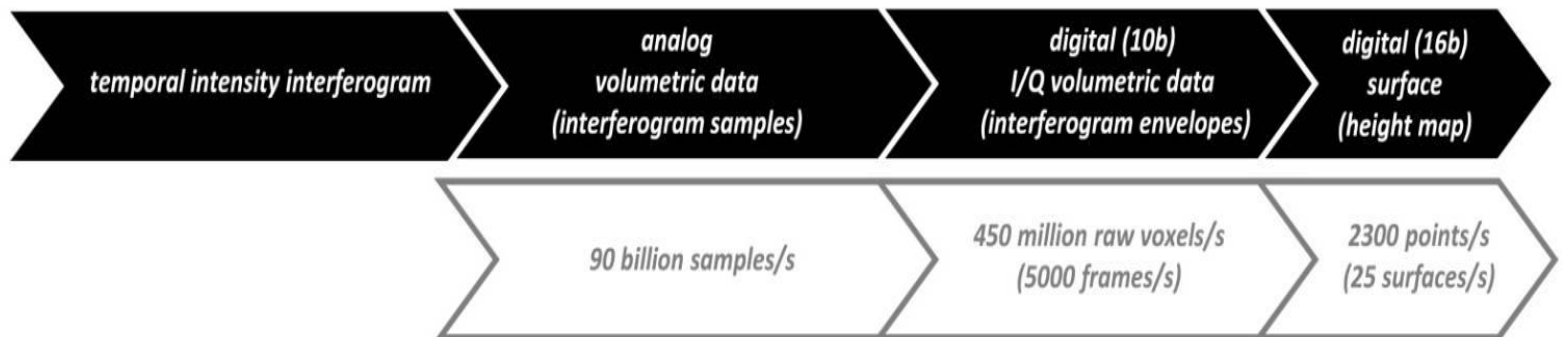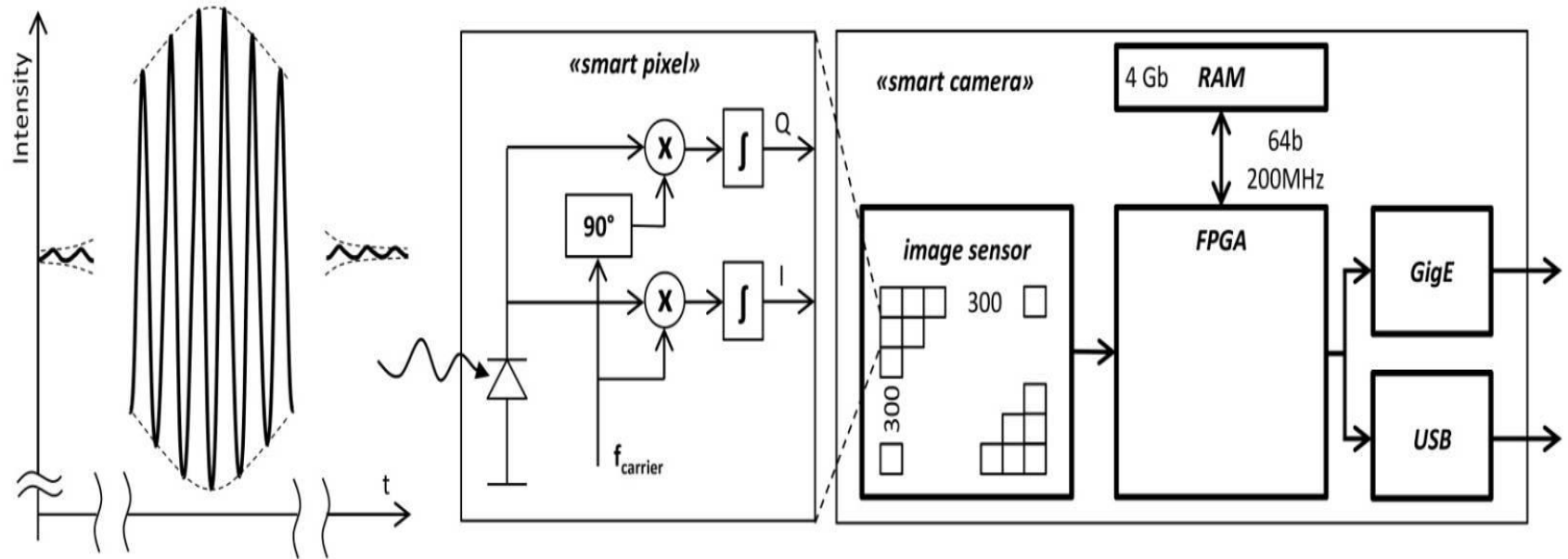

$$I(T + \frac{\pi}{4\omega}) \approx \sum_{i=nc(nF-1)+1}^{ncnF} \left(A_{4i} - A_{4i+2} \right)$$

$$Q(T + \frac{\pi}{4\omega}) \approx \sum_{i=nc(nF-1)+1}^{ncnF} \left(-A_{4i+1} + A_{4i+3} \right)$$
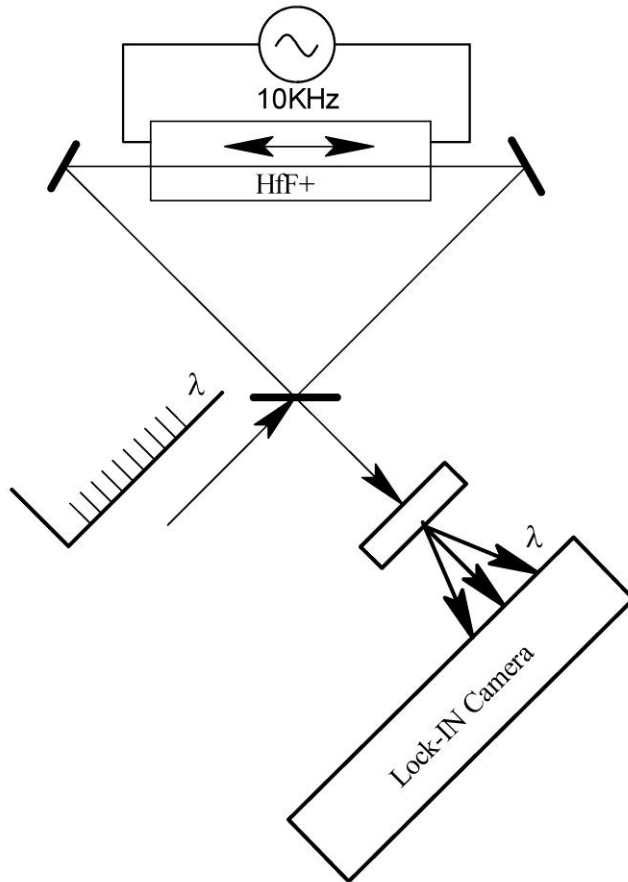
- Up to 1 Million analogue operations per second.
- Demodulation frequency: up to 250KHz.
- Up to 5000 I/Q frames per second for 300x300 pixel.
- Offset compensation circuit included in pixel.

Lock-IN camera

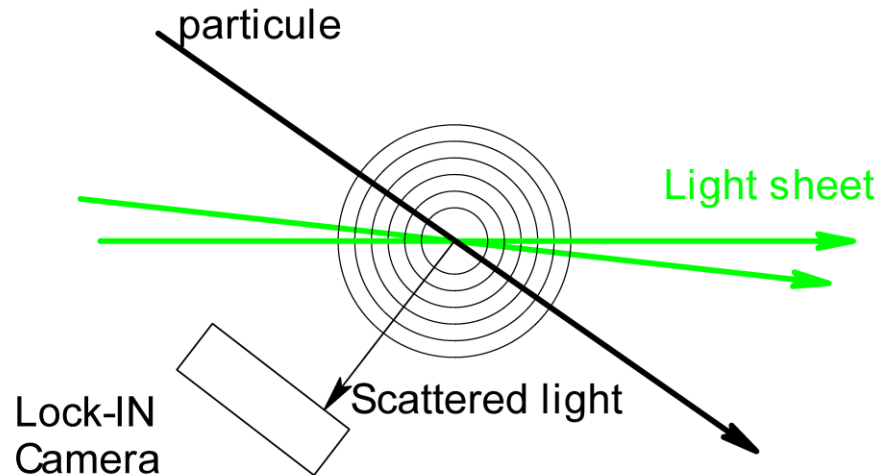# Frequency Comb Velocity-Modulation Spectroscopy.

- 1500 simultaneous channel over 150 cm^{-1}

- 30 images acquired for a full range scan (in 30 min.)

- Fractional absorption sensitivity: 3 x 10^{-7} (30 times better than previous DC experiments)
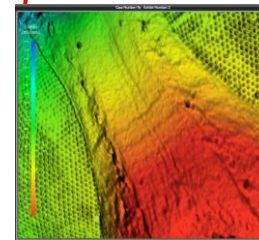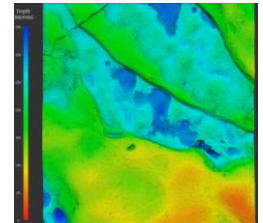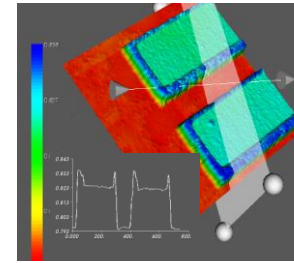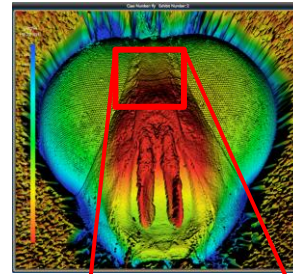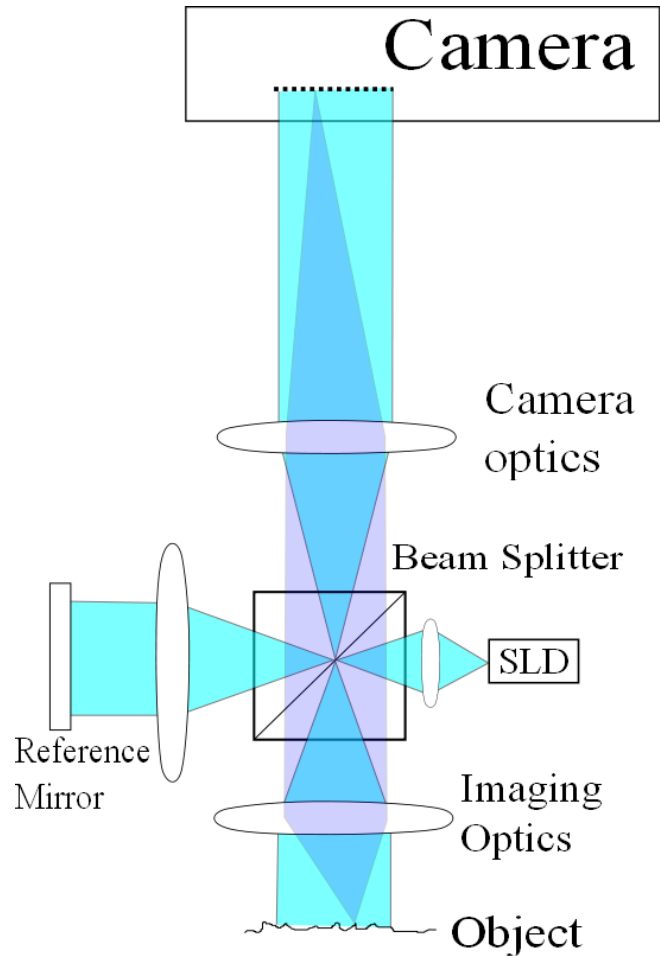
Imaging LASER Doppler velocimetry

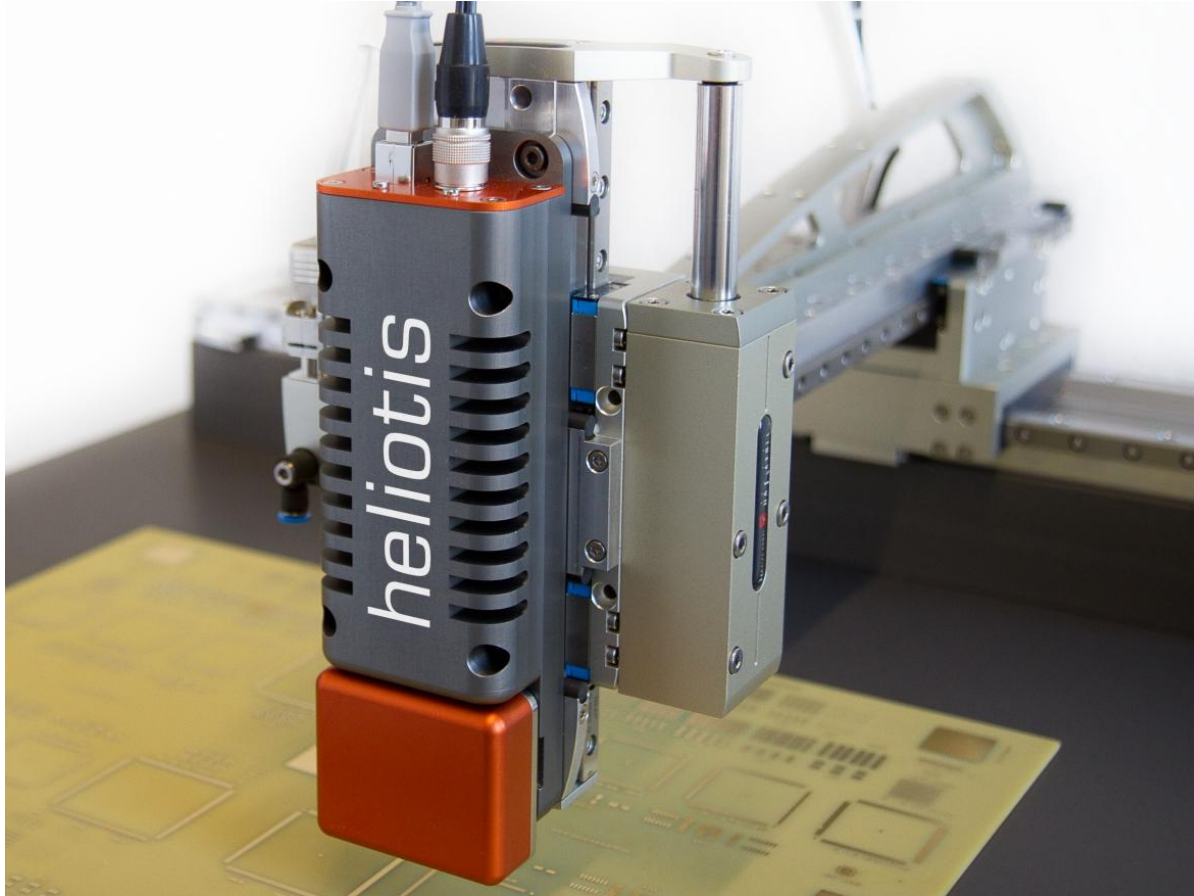A. Meier, T. Rösgen (ETHZ), 2010

- Phase difference between frames allow to measure the frequency of scattered light.
- An image with velocity distribution can be acquired at once.
- Velocities up to 3m/s have been measured.
- With higher power laser, up to 40m/s is feasible.

White light interferometry

PCB board

PCB solder mask
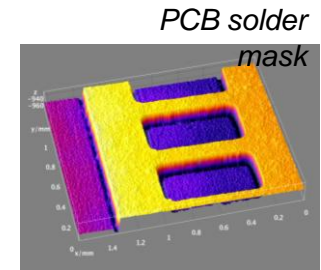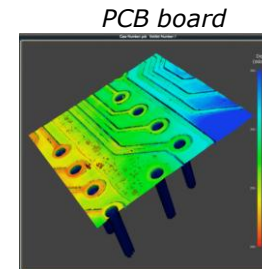
3D Vision Module H3

Applications

> in-line quality inspection
> lab automation
> surface roughness
> geometrical feature control
> OEM integration
> statistical process control

Features

> surface topography
> volume tomography
> robust and fast
> sub-um resolution
> measures any surface
> small form factor
> software modules for rapid integration (Windows, Mac, Linux)
> modular system of linear motors (portal robot)

Ballistics application

Pyramidal Technologies
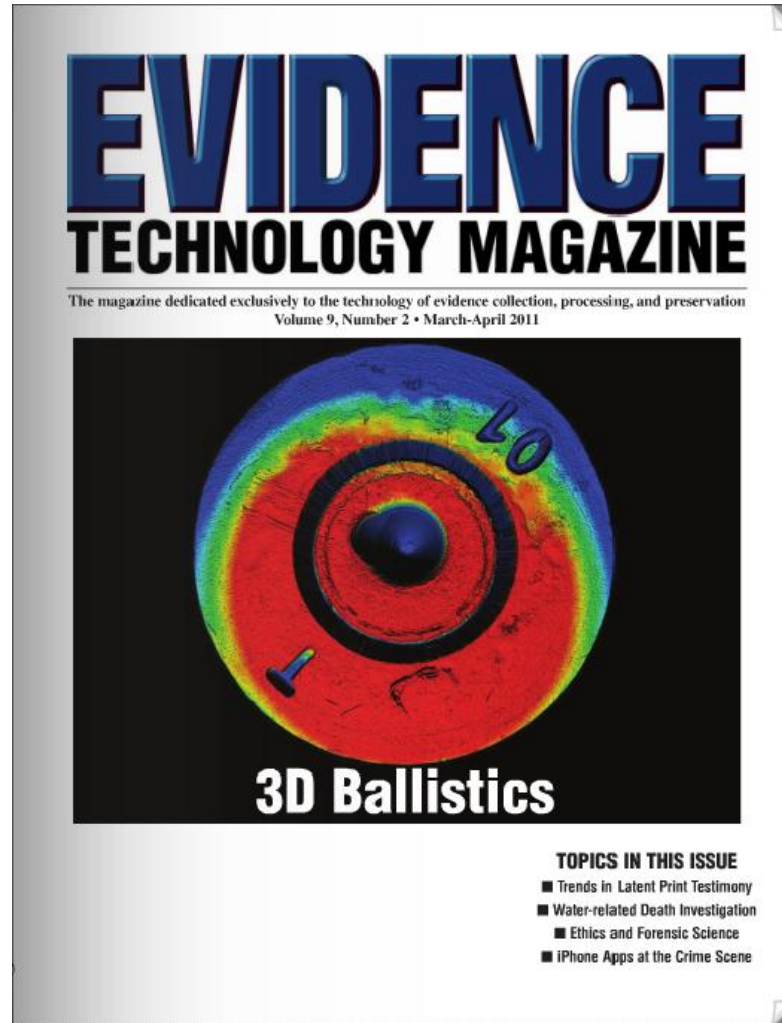
Parallel confocal 3D Imaging

3d-Intraoral Scanner

Traditional	Digital

Total:

Traditional	Digital
28 Steps	14 Steps
2 Traditional impression	1 Digital impression
2 Gypsum Model (+ analog)	1 Milling model & stumps
2 Shipping /Back	1 Shipping/Back
5 working hours	**-60% less working time**