RTprocessing

Traitement de l'information optique en temps réel pour l'imagerie interventionnelle

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Collaboration: N. Ducros, Creatis, Lyon

Technology for surgical guidance

1950s

2000s

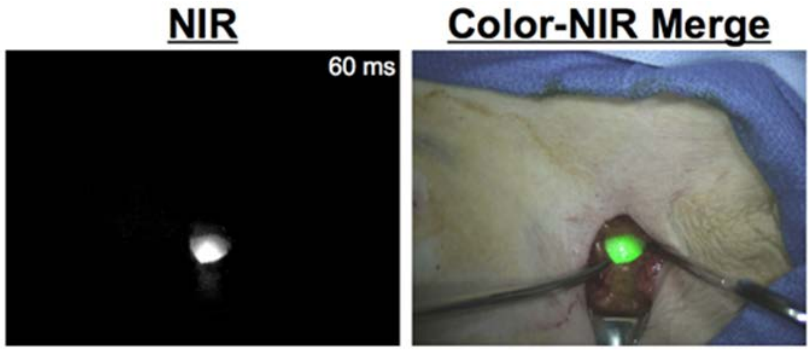
- Surgery is performed subjectively
- Variable outcome (recurrence, morbidity, mortality)
- Few guidance tools available

→ Investigate the benefit of optical imaging

Optical imaging for surgery

Molecular Imaging for Surgery

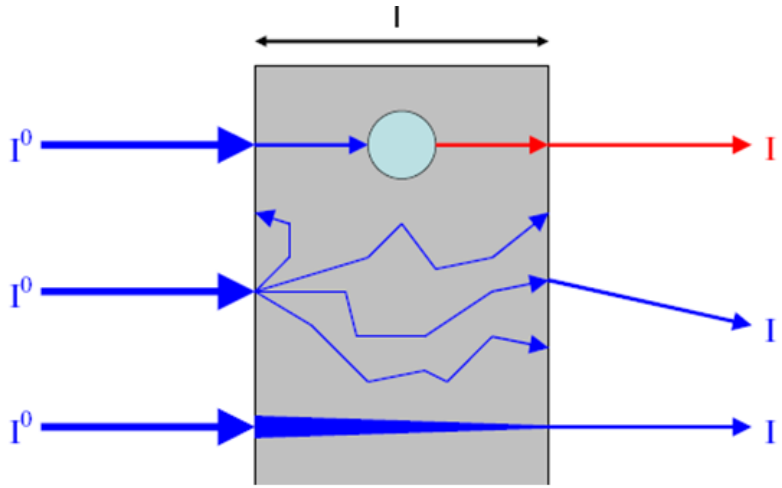
- Non contact
- Inexpensive
- Non ionizing
- Portable



Qualitative Contrast Agent Localization
Specific (i.e. targeted)
Non-Specific (i.e. passive)

→ Excellent candidate for surgical guidance

Photons interact within living tissues



Fluorescence

Scattering Blurring

Absorption Red color

Photons interact within living tissues

Absorption

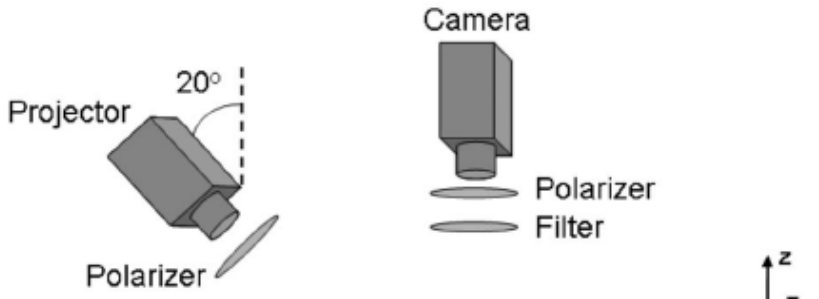
Hemoglobin ⇔ Oxygen saturation
Lipids ⇔ Metabolism
Water ⇔ Hydration

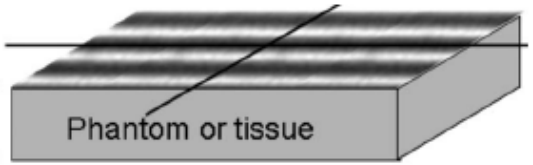
Scattering

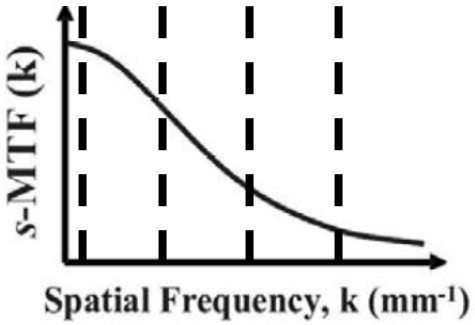
Scattering ⇔ Subcellular content

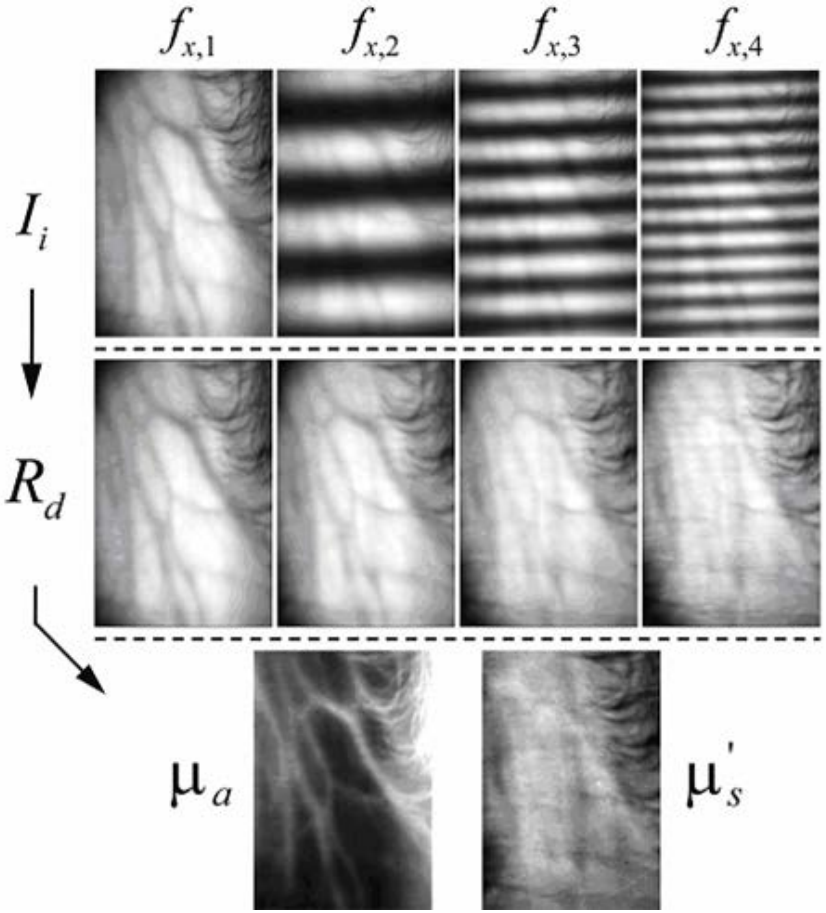
Endogenous molecular contrast
→ functional & structural contrast

Spatial Frequency Domain Imaging







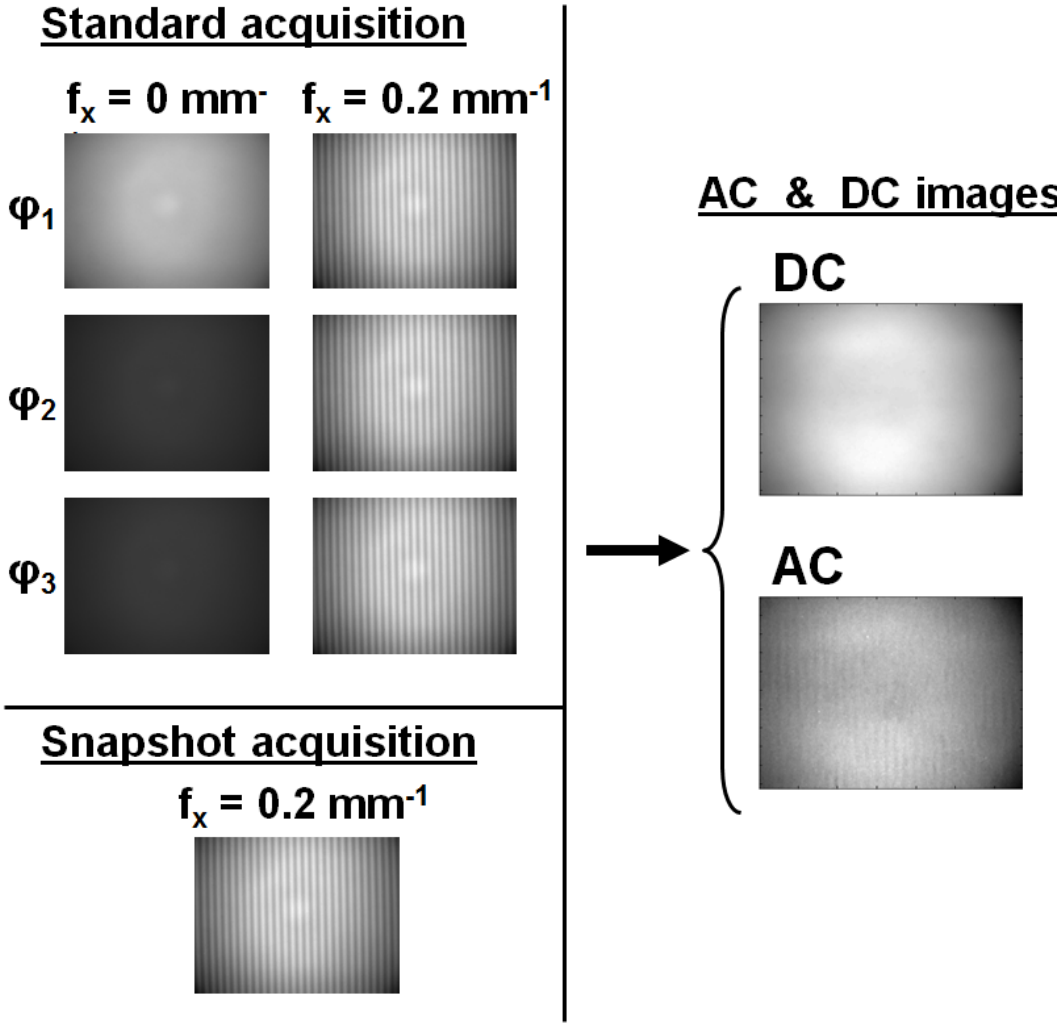


→ Real time ?

Cuccia *et al.*, J Biomed Opt., 2009;14(2):024012.

Towards real time acquisition

Single Snapshot OP Imaging

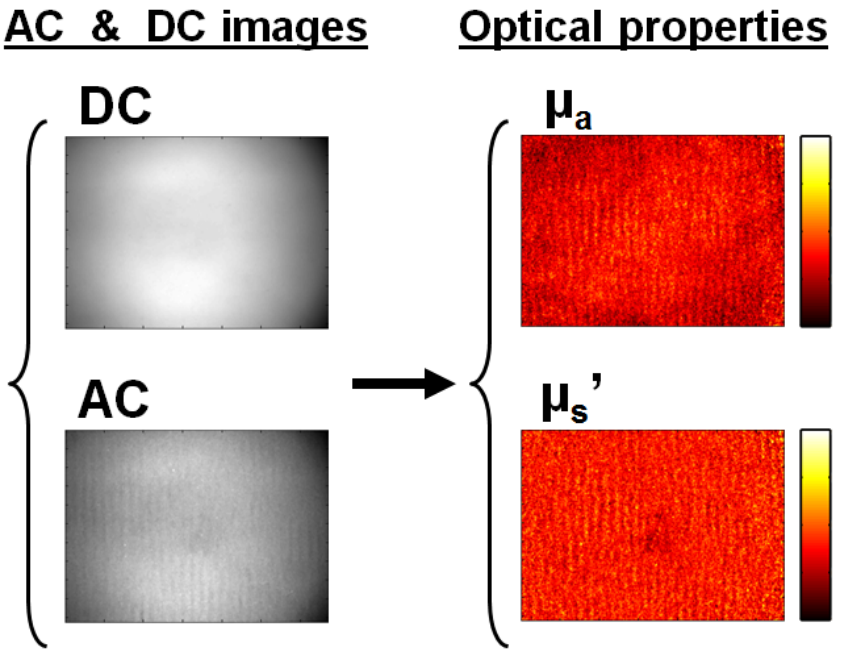


Vervandier *et al*., Biomedical Optics Express, 2013, *4(12):2938-44.*

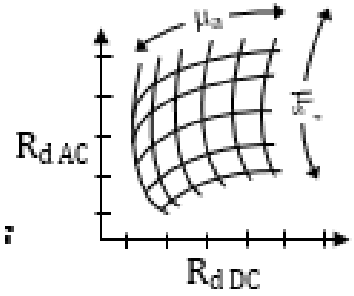
Optical properties recovery

- From reflectance to optical properties
- Rapid processing using lookup tables (~1 s)

→Not fast enough

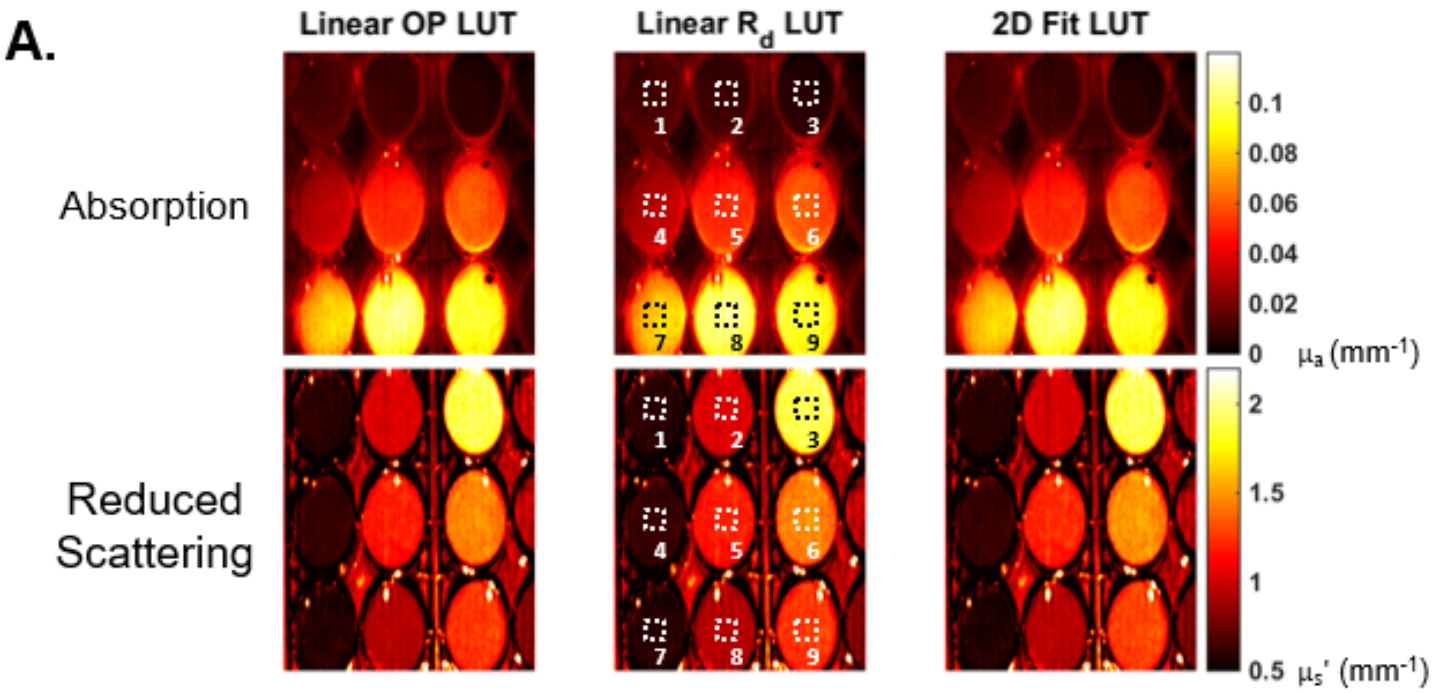


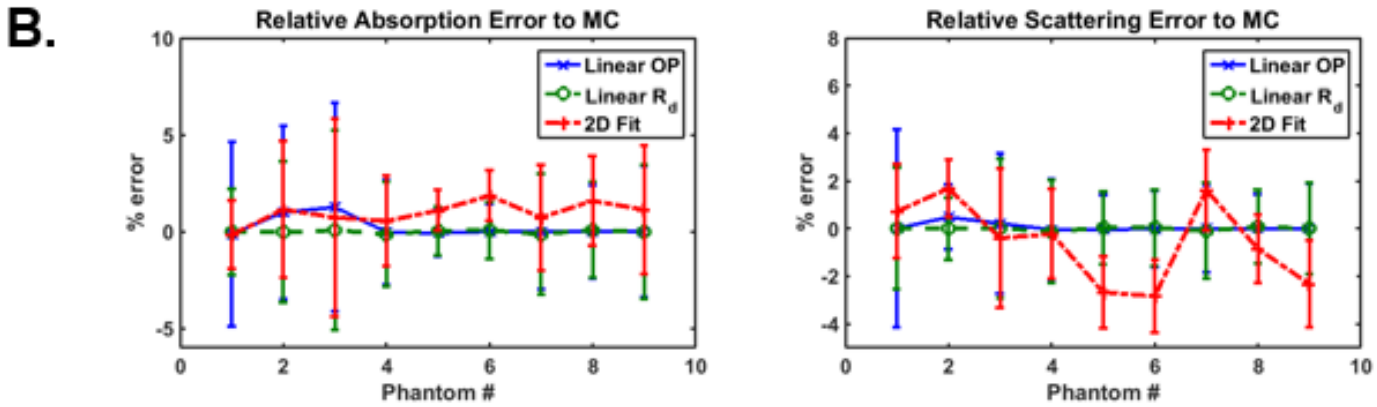
- Proposed solution :
  - Ultrafast lookup table
  - Analytical inverse model



Angelo *et al.*, JBO Letters, *Accepted*

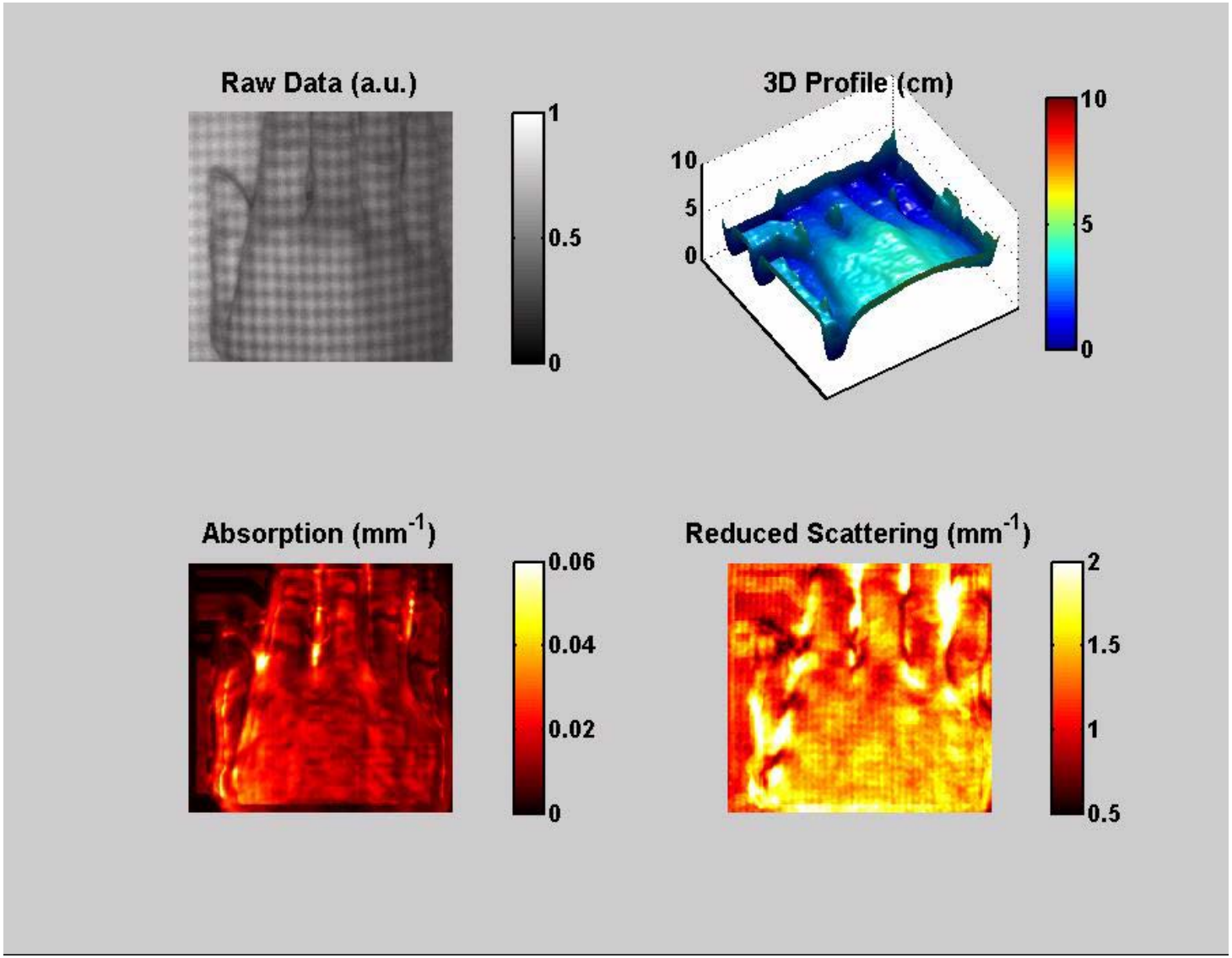
Phantom validation





Angelo *et al.*, JBO Letters, *Accepted*

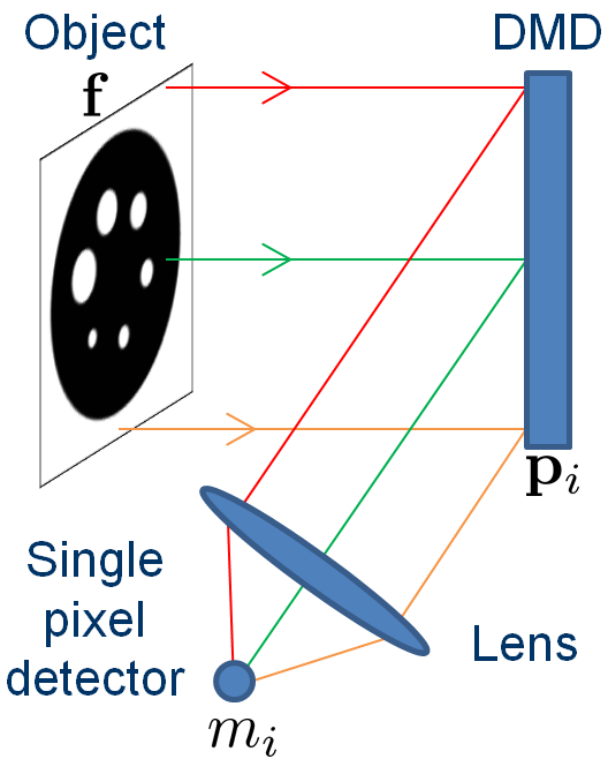
3D-SSOP



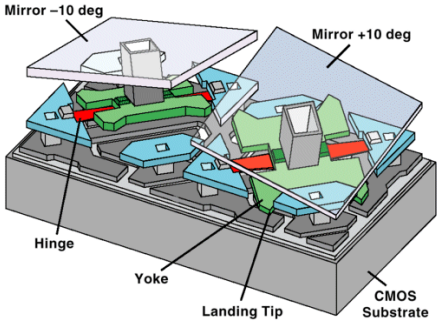
Van de Giessen *et al.*, Biomedical Optics Express, 2015*, 6(10):4051-62*

Compressive imaging

Single-Pixel Imaging



Digital Micro-mirror Device (DMD)



Two mirrors of 13.7 µm (Texas Instruments)

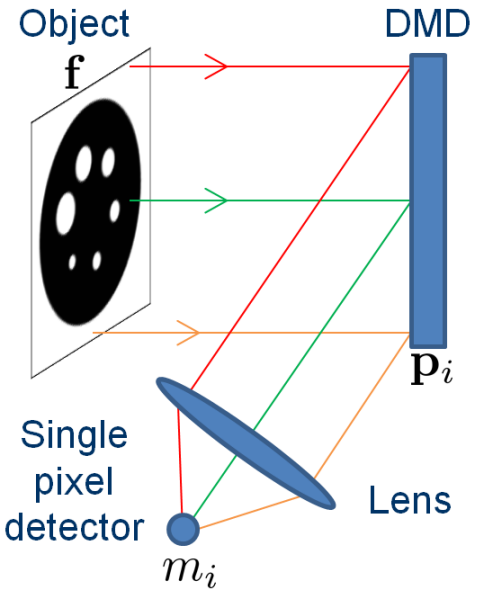
- High-quality low-cost:
  - **High quantum efficiency**: able to detect weak intensity light changes
  - **Multispectral** or **infrared** imaging
  - **Time-resolved** system

Compressed Sensing

- Single-pixel acquisition
  - 1 image
  - *I* patterns
  - *I* measurements

$$\mathbf{f} \in \mathbb{R}^{N \times N}$$
$$\{\mathbf{p}_i \in \mathbb{R}^{N \times N}, i = 1..I\}$$
$$m_i = \langle \mathbf{f}, \mathbf{p}_i \rangle$$

Problem : 1) Choose the patterns
2) Recover the image from the measurements



Single-pixel camera (SPC)

→ The compressed sensing theory tells how to solve 2) considering very few patterns for 1)

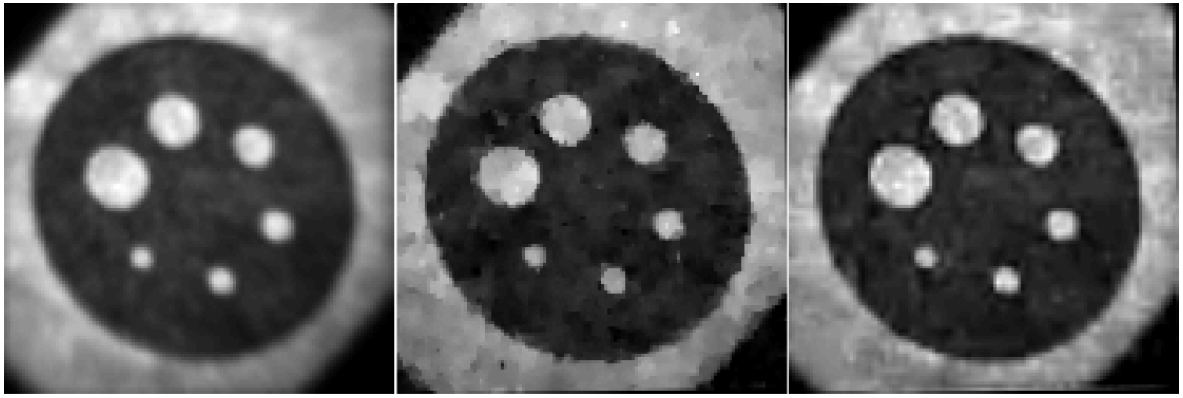
→ Information is compressed during acquisition ($I << N^2$)

Adaptive Basis Scan (ABS)

- CS-based image recovery is slow (ℓ_1 minimization)

- In [1], we propose to
  - Adapt the patterns to the image
  - Acquire the image in a multiresolution fashion

  → Fast image recovery with high compression rate can be achieved



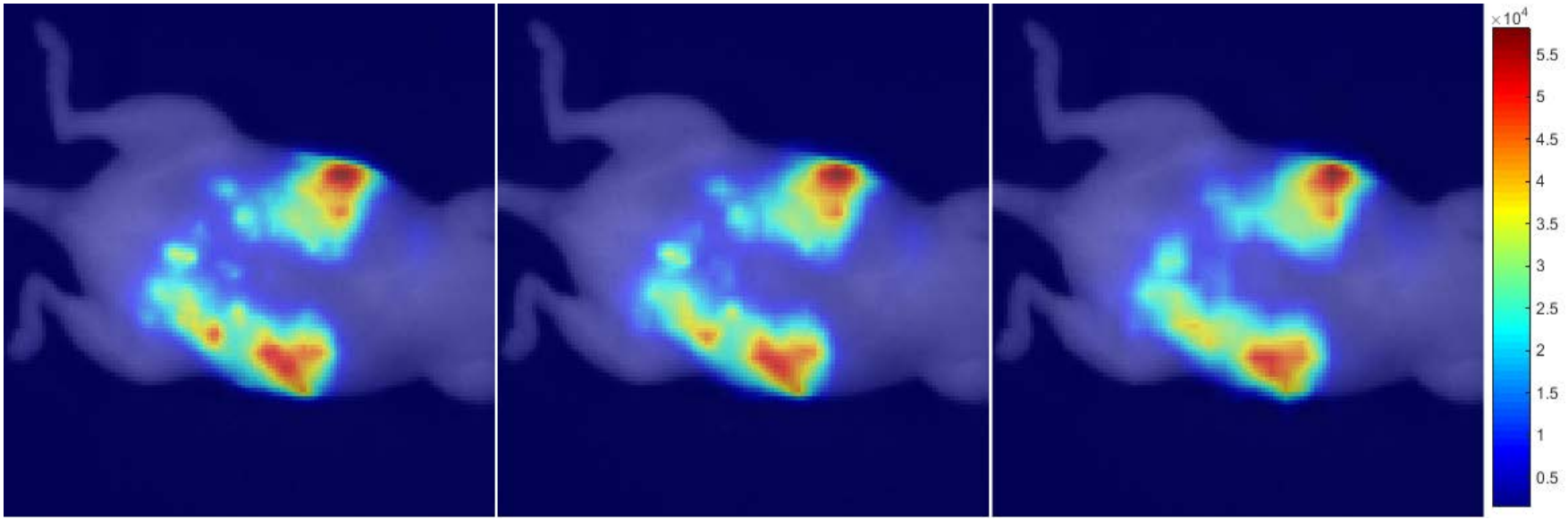
CCD	***CS***	***ABS***
128 x 128 *image*	**t = 14 s**	**t = 0.2 s**

[1] F. Rousset *et al.,* IEEE Trans. Comp. Imaging, 2016 (in press)
https://www.creatis.insa-lyon.fr/~ducros/single_pixel_imaging.html

Adaptive Basis Scan (ABS)

Simulations on real images

- Bioluminescence image over ambient light image*



Reference 128 x 128

CR = 95 %
PSNR = 41.2 dB

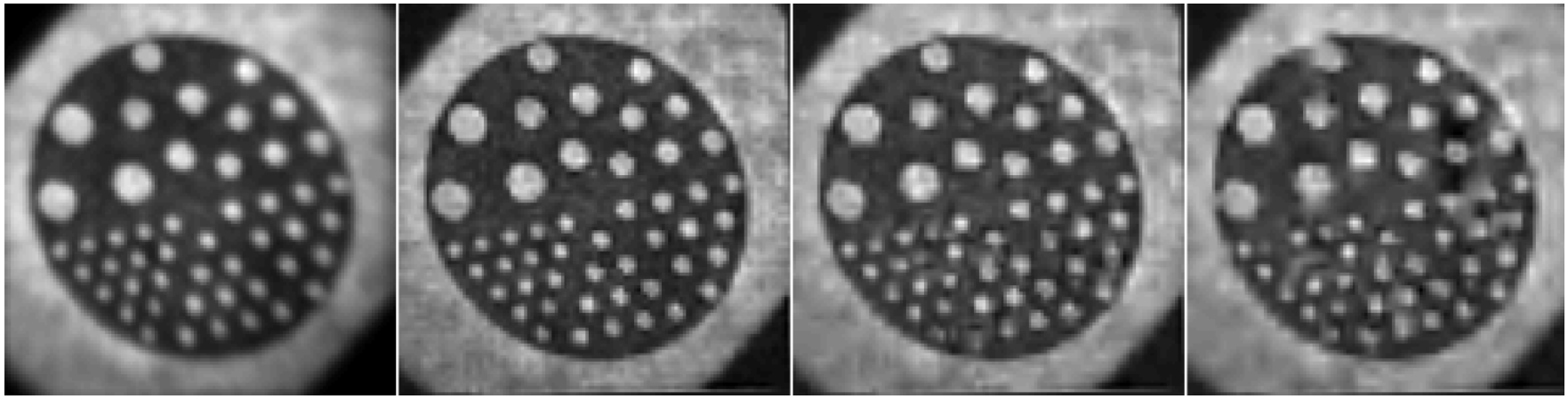
CR = 98 %
PSNR = 35.3 dB

- **High compression** rates for **smooth images**

* image courtesy of V. Josserand and J.L. Coll

Adaptive Basis Scan (ABS)

Experimental data



Experimental CCD
128 x 128 image

CR = 75 %
PSNR = 22.4 dB

CR = 85 %
PSNR = 21.5 dB

CR = 90 %
PSNR = 20.9 dB

- Measured pixel pitch of **210 µm,** $\varnothing = [1;3]$ mm

Future Work

- Real-time spectroscopic imaging using compressive imaging and SSOP

- Pre-clinical validation onto rat dorsal flap model (venous occlusion) at the Imagines platform (ICube, Strasbourg)

Thank you
for your attention