# An innovative approach to Diffuse Optical Tomography using Code Division Multiplexing

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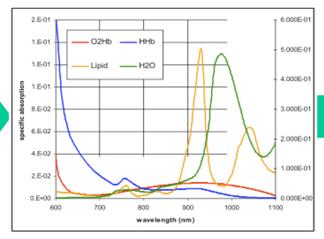
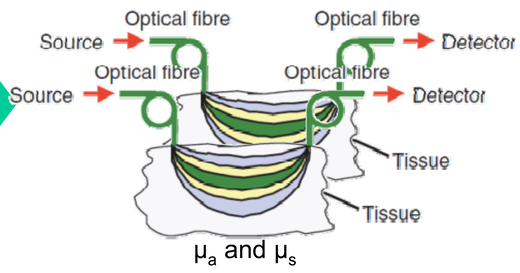
Abstract: This work introduces a novel approach to perform Diffuse Optical Tomography that aim to overcome the limitations and high costs of Time Domain conventional methods. The use of a multichannel double stage coding technique is investigated. A preliminary numerical validation of the model and first experimental activities are presented.

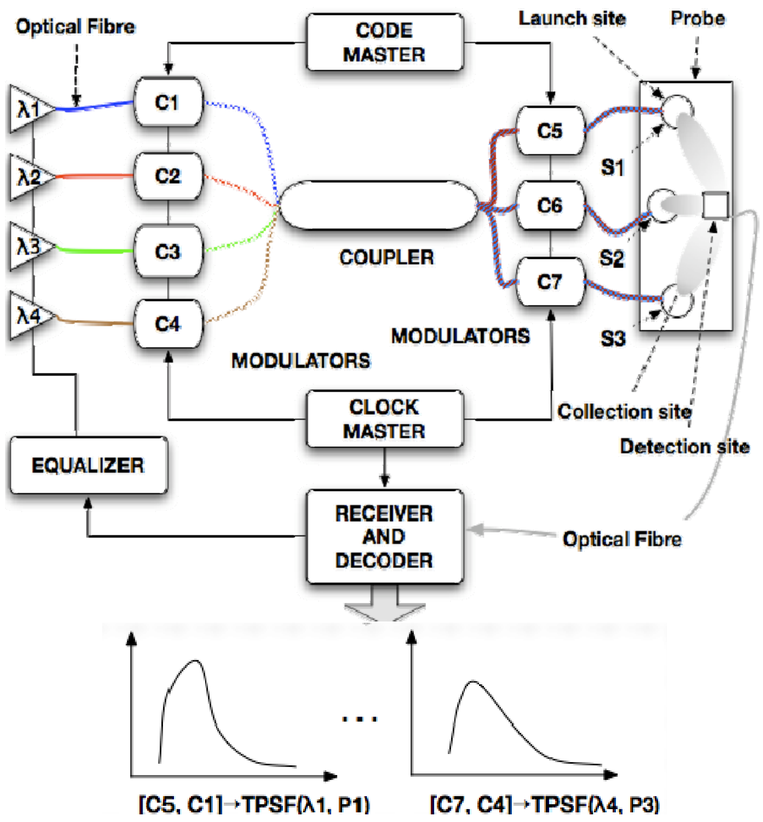
## NIR-DOS: Near Infrared Diffusive Optical Spectroscopy

Functional Imaging:
hemodynamics
(topography/tomography)



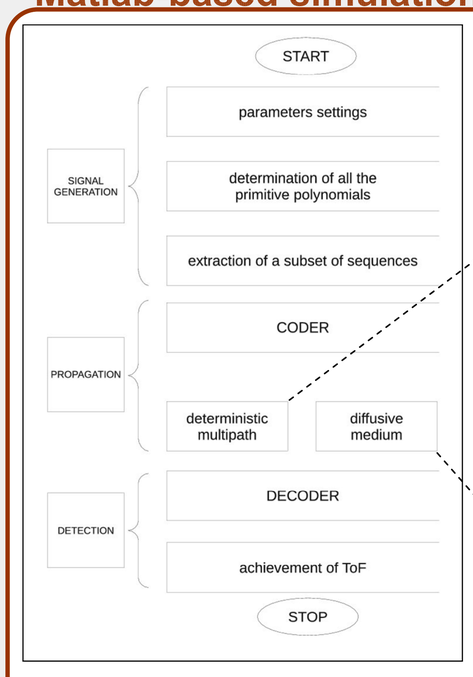




## Wavelength - Space CDM Time Resolved

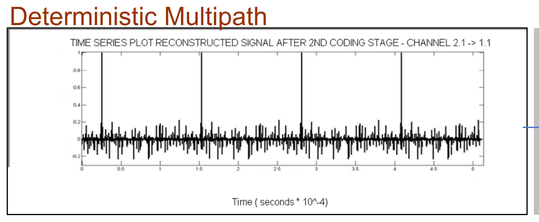



- Evolution of recent methodology (from 1 channel to multichannel)
- Two-step coding for λ and position
- Parallel emission and detection
- Shorter acquisition time
- Higher SNR
- Immunity to ambient light
- No limitations on emission due to TC-SPC limitations
- Cheaper CW equipment

## Matlab-based simulations

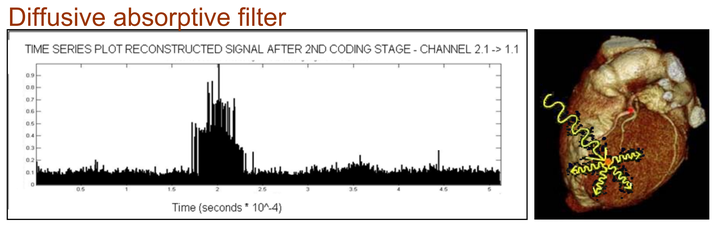



### Deterministic Multipath




- TOF is relative to signals passing through the first branch of each coding stage
- Four peaks corresponding to the four delay values of each path

### Diffusive absorptive filter




- Delays extracted from a Gaussian distribution. Variable attenuation A(t) according to the conventional Lambert-Beer Law

$$A = \varepsilon C v \qquad A(t) = \log_{10}\frac{I_0}{I_t} = \varepsilon C v t$$

## Conclusions

- *WS-CDM Time Resolved approach* for NI-DOS is investigated
- *Multichannel acquisition* and *double-stage coding* approach allows *speed* and *SNR improvement*
- Validation of the principle using standard fibre based TLC components *(@1550 nm)* has been carried out
- Simulations and experimental results are *perfectly consistent* when the number of light paths is small
- The appearance of *interchannel interference* is observed

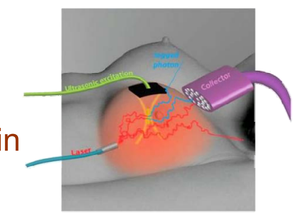
## Work in progress…

- Experimental activity *@690-900 nm* on phantom and biological tissue (waiting technology improvement)
- Investigation of more complex *coding families*
- Implementation of more *advanced detection* architecture
  - Interchannel interference reduction
  - SNR improvement
- Investigation of WS-CDM in *coherent optical methods*, in order to expand the advantages introduced by the proposal approach to optical coherent tomography (*OCT)*

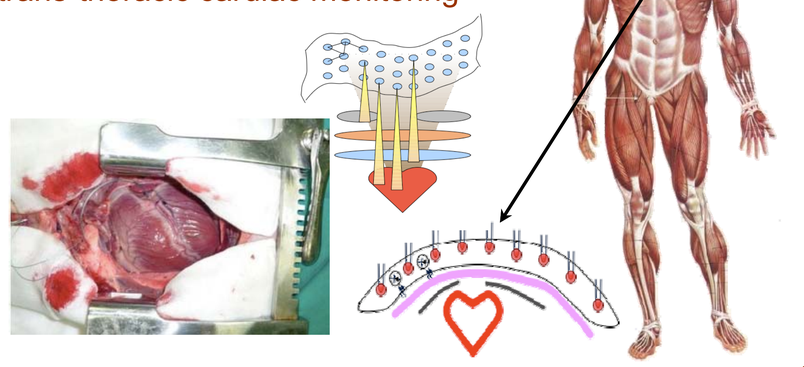
## DOT applications

Current applications:
- breast
- newborn infant brain

limited by SNR, speed, complexity

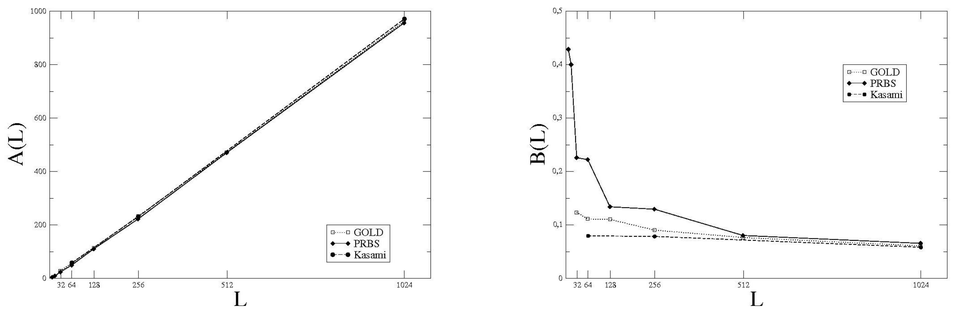



New targeted applications:
- open chest cardiac surgery
- trans-thoracic cardiac monitoring



## Approach to Coding

- Coding families considered: PRBS, GOLD and KASAMI
- Auto-correlation and cross-correlation properties have been evaluated
- Sequence length L in the range 32 – 1024
- Condidered quality factors :
  - Process gain A: difference between the maximum values of auto-correlation and cross-correlation
  - Ratio B: ratio between the peak magnitude of the cross-correlation and the peak magnitude of the auto-correlation



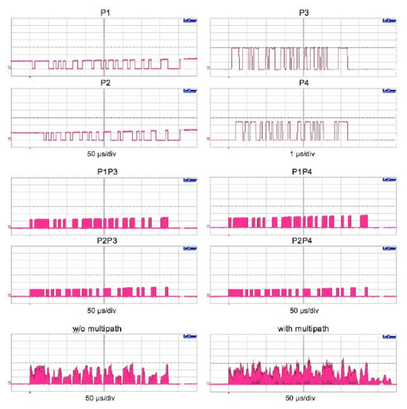

High values of A and low values of B assure better performances in CDM codes

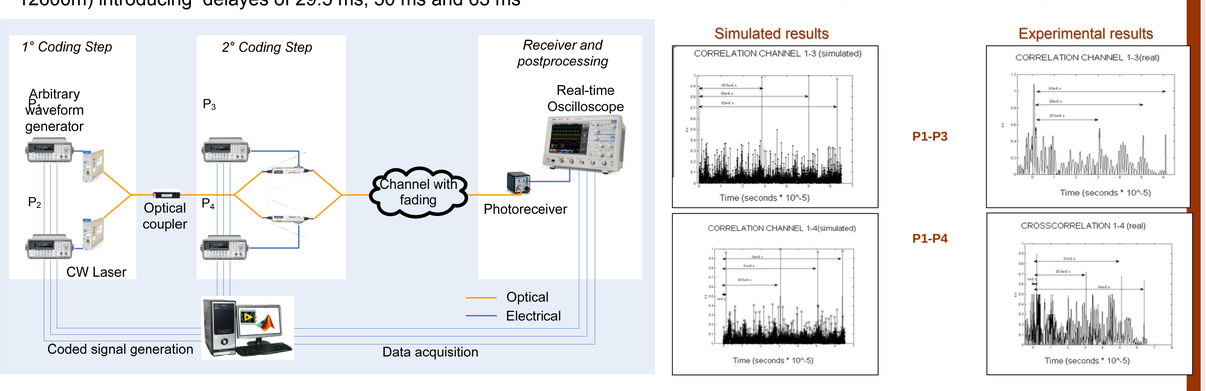
## Experimental activity

Double stage double coded-signal discrimination

Features:
- $P_1(t)$, $P_2(t)$ : $2^6$-1 PRBS (0,1) at 156.160 KHz generated by different seed
- $P_3(t)$, $P_4(t)$ : $2^6$-1 PRBS (0,1) at 9.99424 MHz generated by different seed
- Channel with detrerministic multipath

Multipath generated by fiber spool with different length (5900m, 10000m and 12600m) introducing delayes of 29.5 ms, 50 ms and 63 ms




- Timing agreement among simulations and experimental results is almost perfect
- SNR in real data is slightly lower than in simulations

## References

[1] L. Ascari, G. Berrettini, M. Giacalone, and L. Potì. "Wavelength and space code division multiplexing in optical tomography". In AIT 2010, Engelberg, Switzerland 29 June - 2 July, 2010.
[2] L. Ascari, G. Berrettini, S. Iannaccone, M. Giacalone, D. Contini, L. Spinelli, M. G. Trivella, A. L'Abbate, and L. Potì. "Wavelength and code division multiplexing in diffuse optical imaging". In SPIE Photonics West 2011, S. Francisco, USA 22-27 January, 2011.
[3] D. Contini, A. L'Abbate, et al. "Monitoring myocardial tissue hemodynamics during open chest surgery in pig by time-resolved NIRS". In BIOMED2009, Cyprus, 2009.