Capteur sans contact pour la mesure de vibration et d'écoulement sanguin : Application à la cornée et au cancer de la peau

Adam QUOTB
Associate professor
ENSEEIHT-LAAS-CNRS

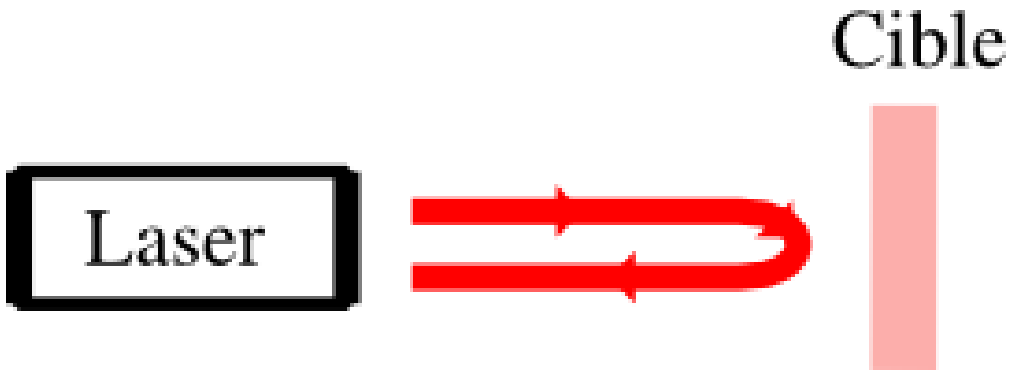
LAAS-OSE: Optoelectronics for Embedded Systems

> Team : 8 professors/ assistant professors – 4 engineers – 10PhD students – 2 Post-Doc

> Research domain : Design of optical sensors based on Optical Feedback Interferometry :

- Interferometry or time of fligth
- Integrated photodetectors

The principle: Optical Feedback Interferometry (OFI)



Interferences occur inside the laser cavity

→ Self-aligned system

→ Elimination of all optical device (appart from the lens... sometimes)

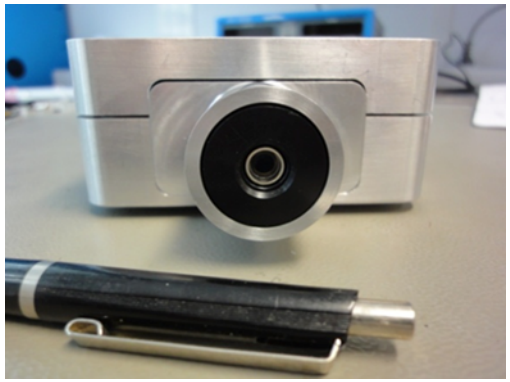
→ High integration density

→ Mechanical stability

We measure and analyze laser power variations

What we can do with OFI !!!!

> Vibrometry

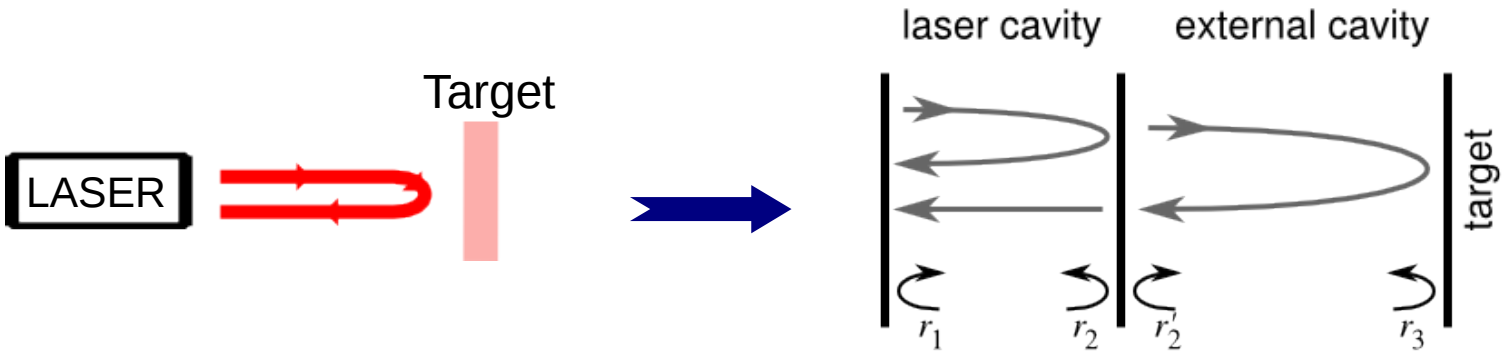


- > Mecatronic : Vibrations analysis
- > Acoustic : Laser microphone
- > Medical : Biomecanic analysis of auditory systems, ocular and cells

> Velocimetry

- > Mecatronic : Scrolling speed measurements
- > Micro-fluidic : Flow profile, particules detection and characterization
- > Medical : Blood flow analysis (vascularization ...)

OFI: Optical Feedback Interferometry



$$\tau = \frac{2n_{\text{ext}}L_{\text{ext}}}{c}$$ the external cavity round-trip time-of-flight

$$\begin{cases} P_F = P_0\left[1 + 2\frac{\tau_p}{\tau_c}\kappa\cos(\omega_F\tau)\right] \\ \omega_F = \omega_0 + \frac{C}{\tau}\sin\left[\omega_F\tau + \arctan(\alpha)\right] \end{cases}$$

$$\kappa = \frac{r_{\text{ext}}}{r_2}\left(1 - r_2^2\right)$$ the feedback strengh parameter

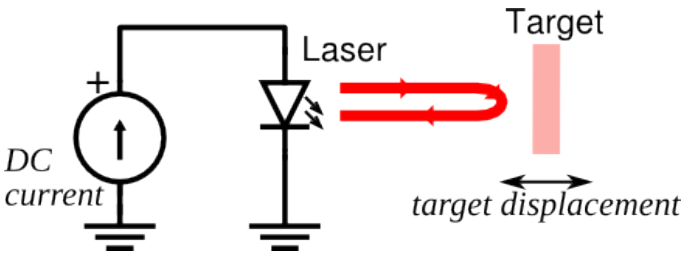
$$C = \kappa\frac{\tau}{\tau_c}\sqrt{1+\alpha^2}$$

The coupling coefficient

τ_c is the laser cavity round-trip time-of-flight,

α is the linewidth enhancement factor)

OFI: Vibrations measurements

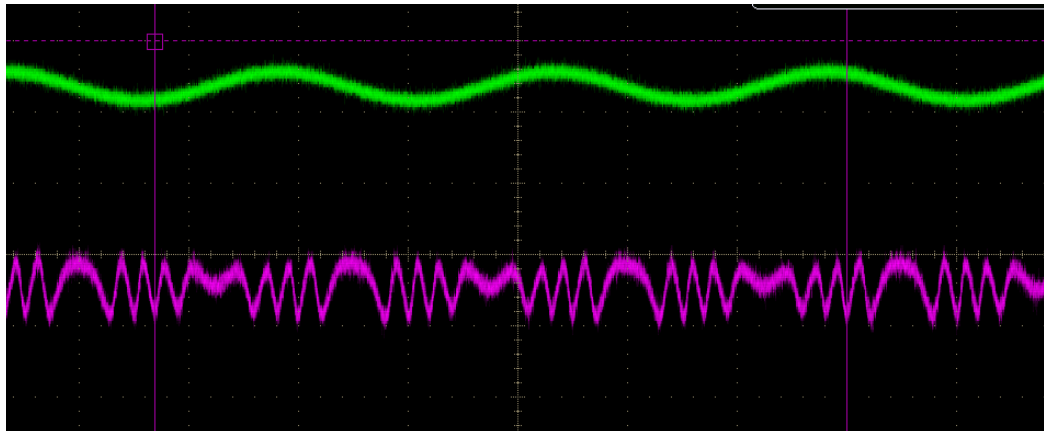


> Change in τ and in external cavity length

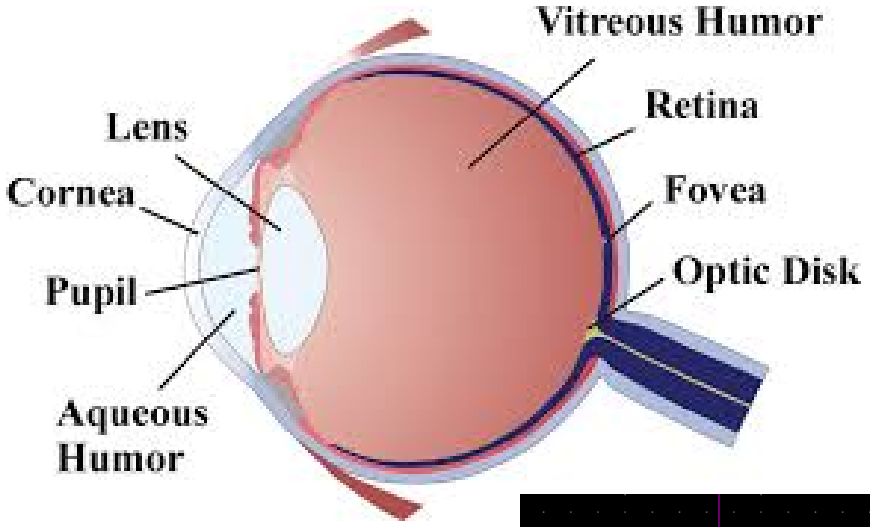
> The power variation is almost a nice periodic function of the distance. Each **fringe** represents a displacement of **λ/2**

Vibration command

OFI signal

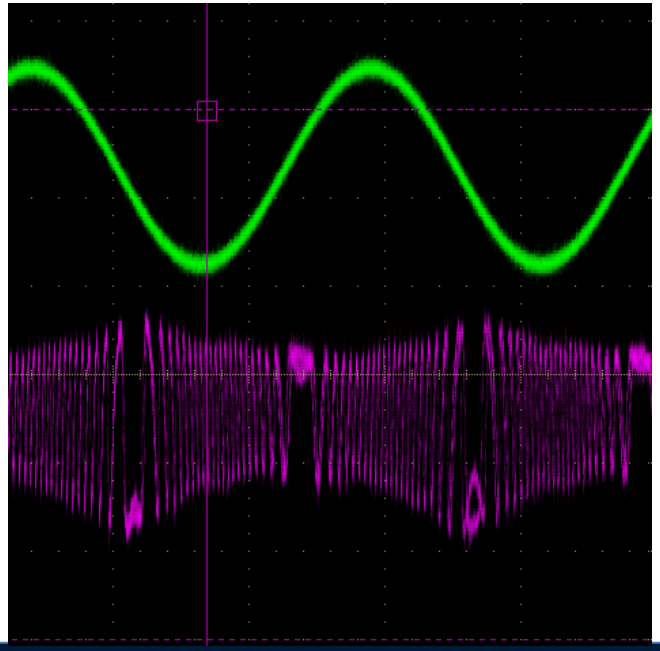


Ex vivo cornea vibration: Glaucoma detection



Vibration command

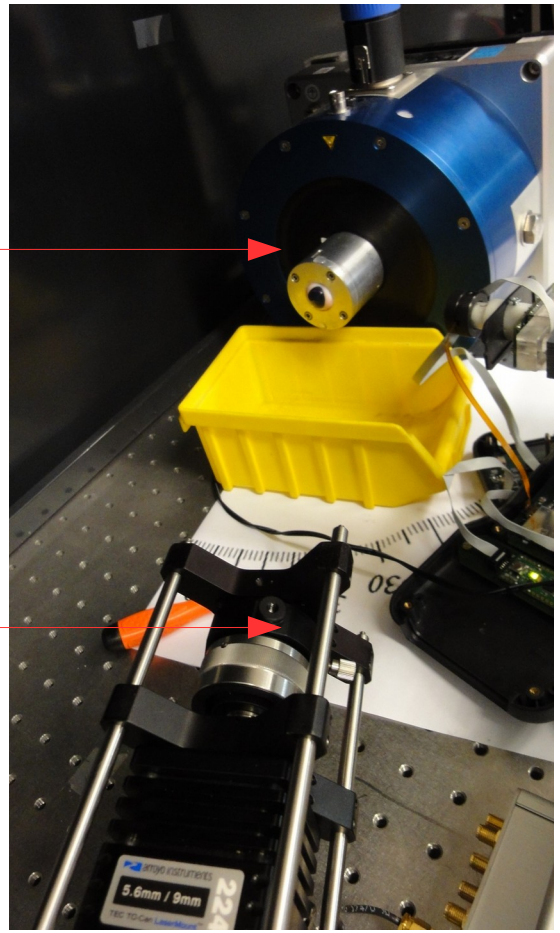
OFI signal



Ex-vivo set-up

Pig eye on a shaker

OFI

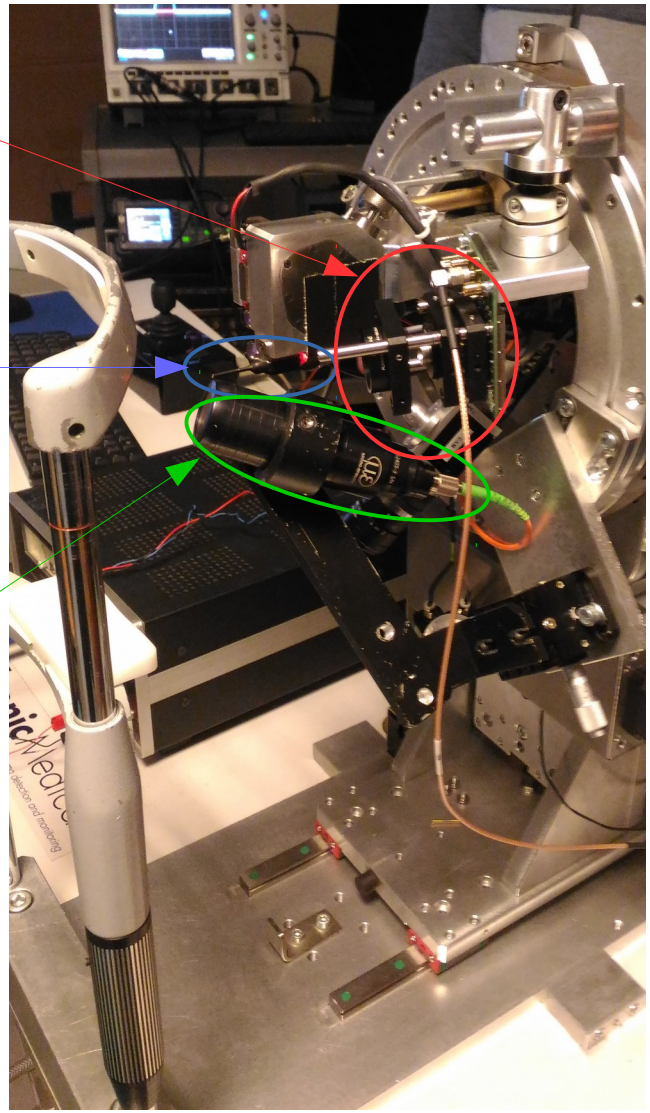


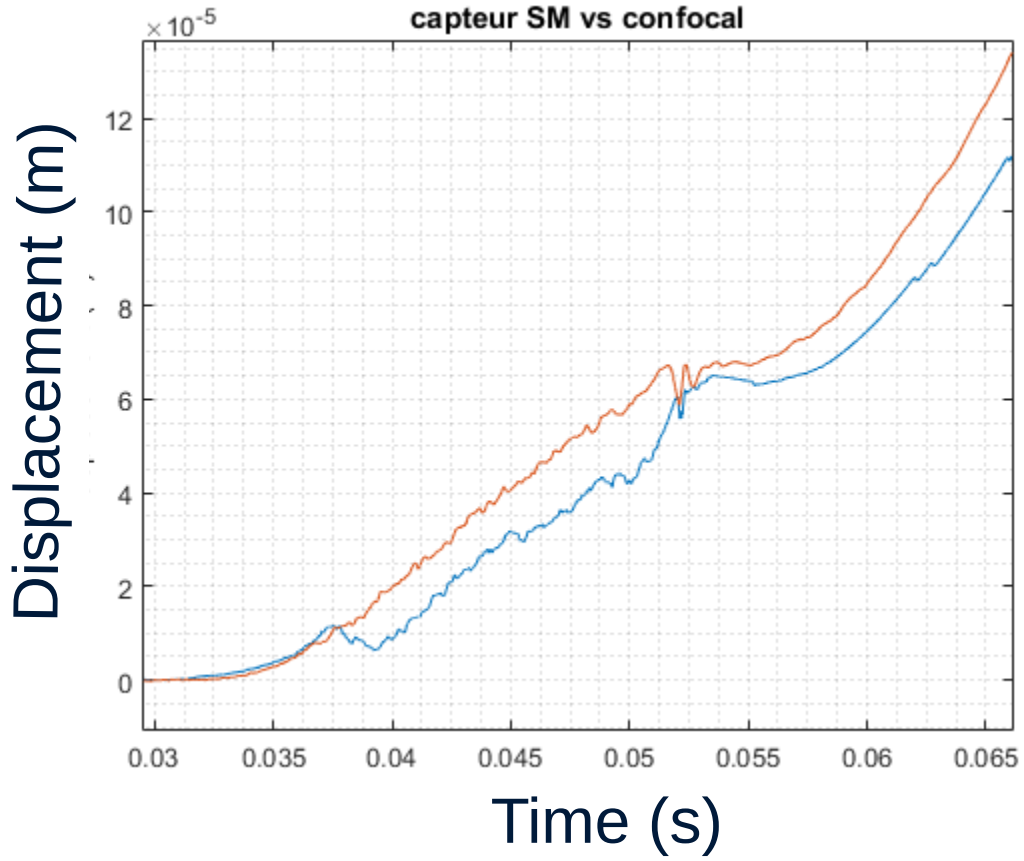
In vivo cornea vibration: Glaucoma detection

OFI

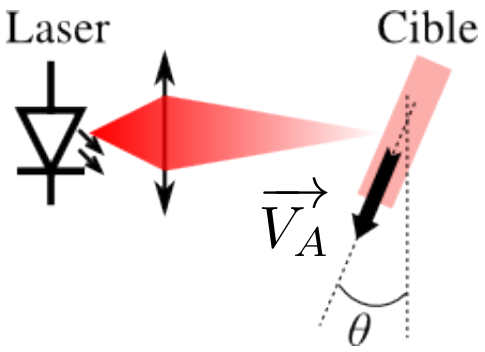
Air puff

Confocal (reference)





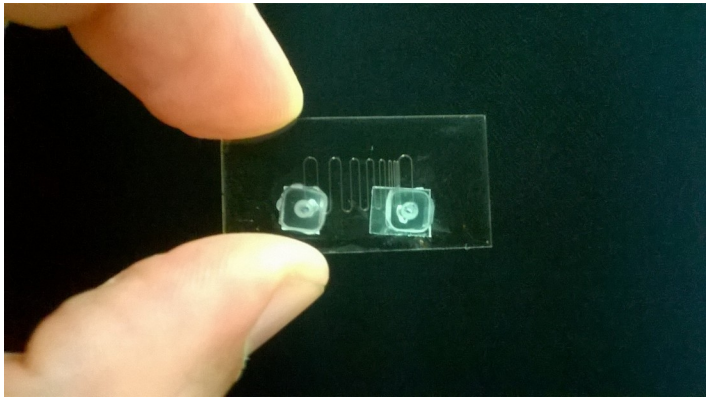
OFI: Velocity measurements



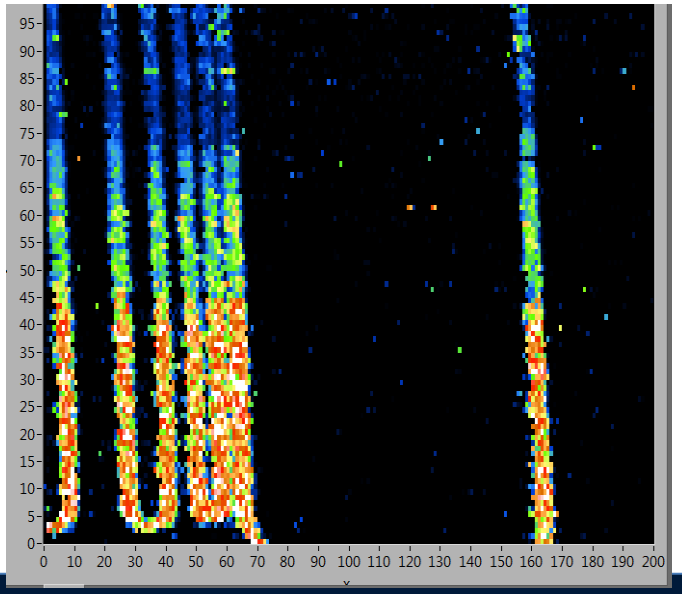
$$P_F = P_0 \left[1 + 2\frac{\tau_p}{\tau_c}\kappa\cos(\omega_D t + \Phi_D)\right]$$

$$\omega_D = 2\pi\nu_F \frac{-2V_A\cos\theta}{c + V_A\cos\theta} = 2\pi f_D$$

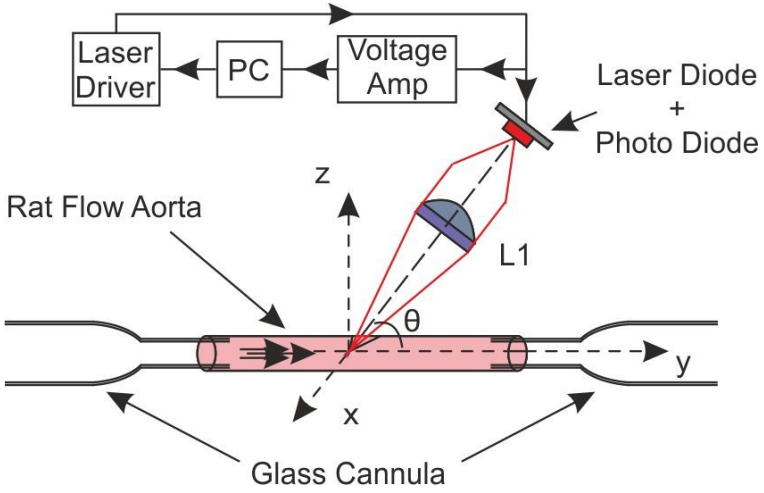
Microfluidic chip (serpentine)

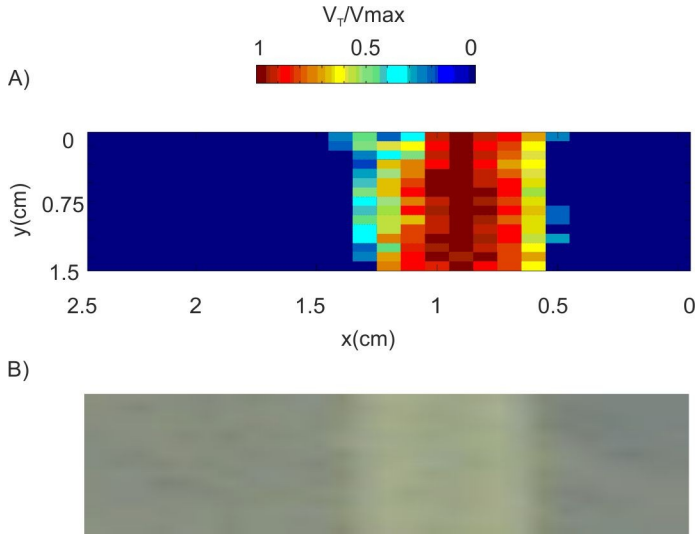


Flow velocity 2D imaging



OFI Myograph on ex-vivo rat aorta



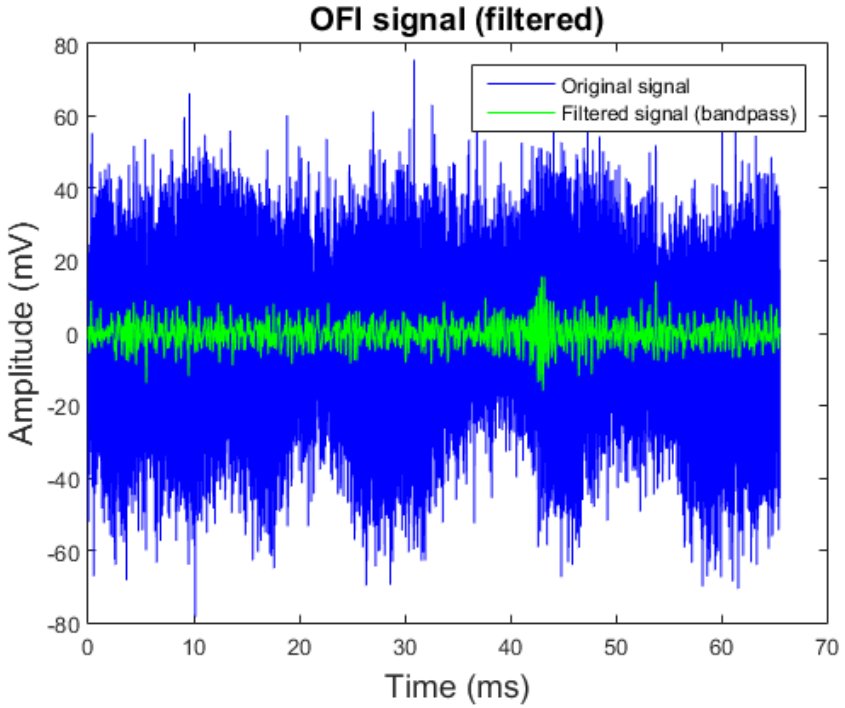


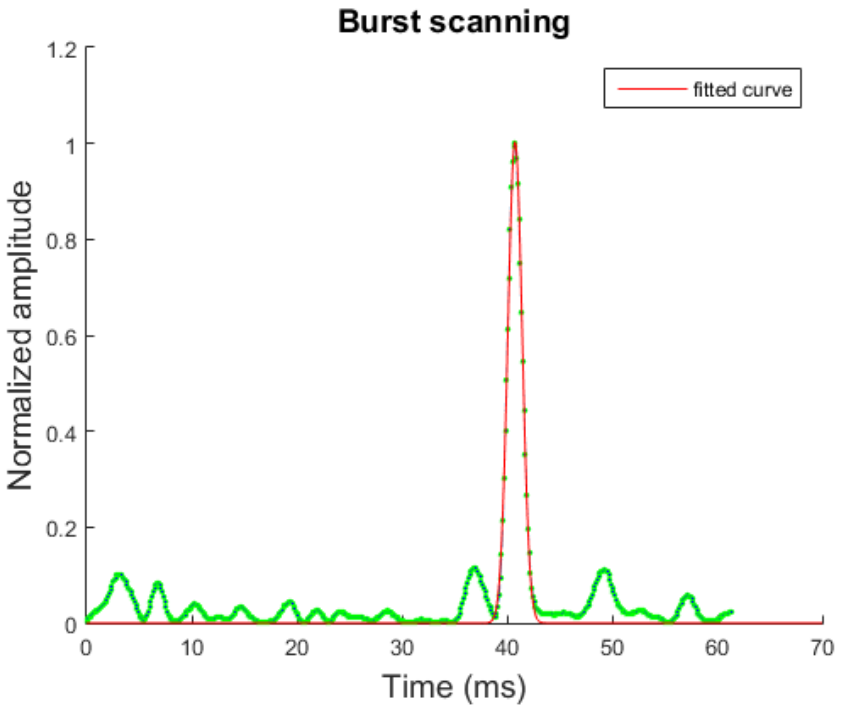
Microfluidics - Particle detection

Laser: 785nm @39.5mW - Doppler angle (normal): 8°
PDMS circular uChannel: 320 um (diameter) - Flow rate: 40 uL/min (Fdmax ≈ 5.9kHz)

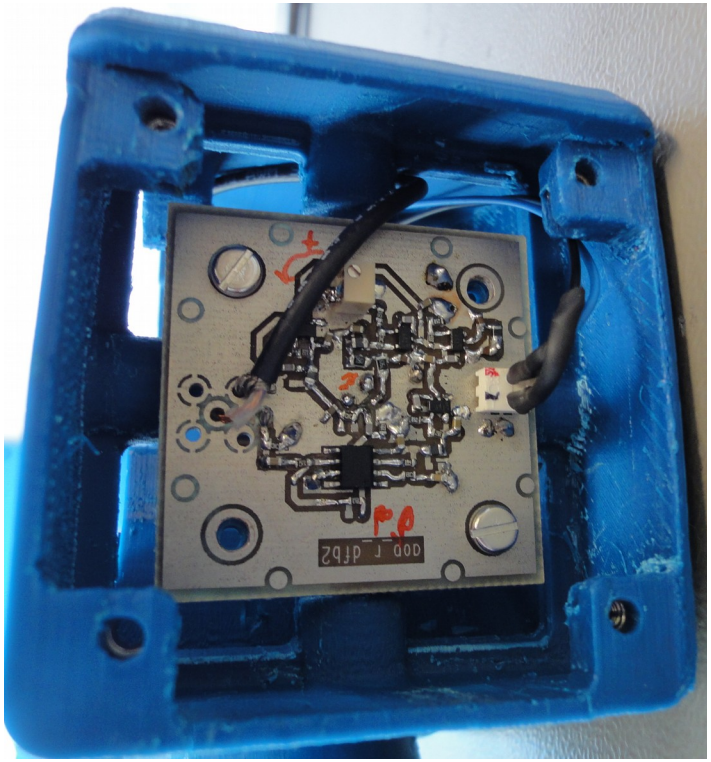
Particle: Polystyrene - TPD 1.05g/cm3 - Concentration:0.00005% - **Size: 552 nm @Fd=4.1kHz**

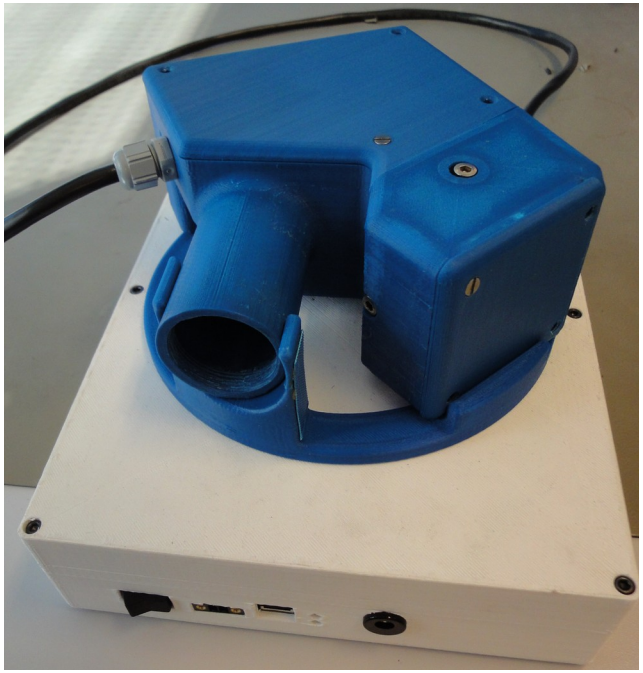
Bandpass: 1-8.5kHz



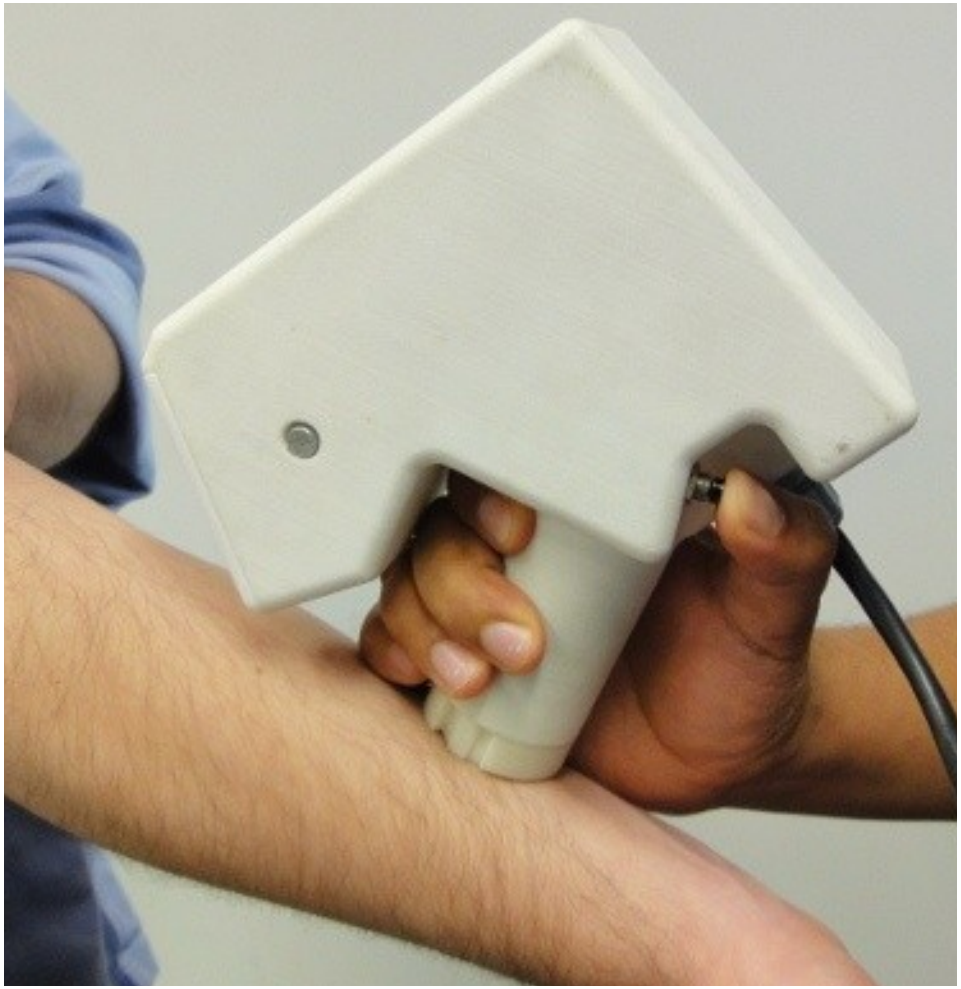


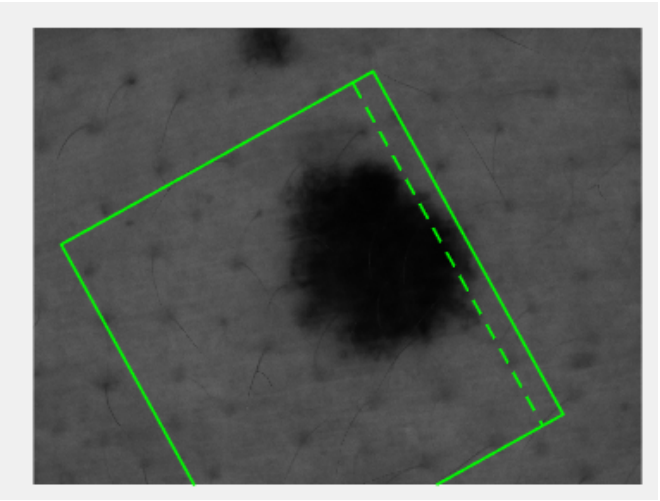
OFI: Skin blood flow scanning measurement setup for skin cancer detection





Suspicious area scanning





Conclusion and perspectives

- OFI can make vibrations and fluid flow profile analysis at the micro-scale level.
- OSE team objective is to find new partners for biomedical sensors development
    - OFI microscope
    - 3D OFI vascularization analysis
    - Fluid particle composition etc...

THANK YOU