STSM REPORT

STSM Application number: COST-STSM-ECOST-STSM-BM1205-190514-044689

STSM Grantee: Carlos Yáñez

STSM title: Novel techniques for velocimetry measurements in fluids using Self-Mixing Interferometry.

Home Institution: Centre for Sensors, Instruments and Systems Development - CD6-UPC Barcelona Tech (Terrassa, ES)

Host Institution: École Nationale Supérieure d'Électronique, d'Électrotechnique, d'Informatique, d'Hydraulique, et des Télécommunications - ENSEEIHT (Toulouse, FR)

STSM period: 19 May 2014 - 23 May 2014

STSM purpose: Collaboration in novel SMI techniques for velocity measurements in fluids.

DESCRIPTION OF THE WORK CARRIED OUT DURING THE STSM:

During the week this STSM was carried on, diverse topics about Self Mixing Interferometry (SMI) were discussed. The first day I saw the setup that is mounted in the SMI laboratory of ENSEEIHT, where a liquid solution of water and variable quantities of milk are mixed together and pumped out to a micrometric flowchannel. The light beam emitted by a Laser Diode (LD) is guided through an optical system (composed basically of a lens) into the flowchannel, and the position of the beam over the flowchannel is set in a very precise way using a motorized linear stage. Fig. 1.

The photons backscattered by the milk particles embedded in water reenter the LD cavity and disturb the LD's junction voltage, this voltage is then acquired, amplified and converted to a digital signal known as Self Mixing Signal.

The SMI signal and its frequency domain is plotted in real time using Labview and the velocity is obtained solving the following equation for V_{flow}:

$$f_{Doppler} = \frac{2nV_{flow}\cos(\theta)}{\lambda}$$

Where:

$f_{Doppler}$ = Frequency Peak Value.

n = Refractive Index of the surrounding medium.

θ = The angle the target velocity vector makes with respect to the propagation axis of the laser beam.

λ = The laser wavelength in free-space.

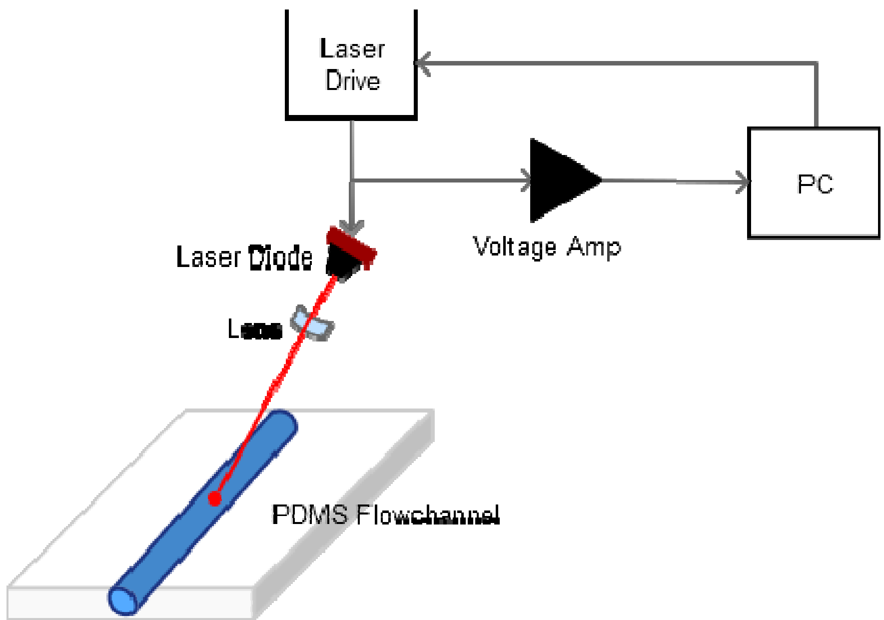

Fig. 1 Blocks diagram of the system

The following days were dedicated to simulate the system described above using Matlab.

A series of Matlab files were given by professor Julien Perchoux from ENSEEIHT to show me how the SMI signal can be treated digitally and how to obtain the frequency domain information from it. Taking those files into account, I performed a series of simulations for velocity measurements in fluids. The results will be discussed later on this report.

The challenge of simulating the SMI signal is based on how the Matlab program is capable to solve the well known Lang-Kobayashi equations. They presented a theoretical model that describes the dynamical changes in the carrier density of a semiconductor laser induced by a signal of feedback. In the specific case of my work, this feedback is produced when the laser beam is focused against a target in motion (a flowing liquid, a spinning disk, etc.).

The equation that describe the emission frequency of the laser diode under feedback (ν_F) is:

$$\nu_F = \nu_0 - \frac{C}{2\pi\tau_d} \sin\left(\omega_D t + \Phi_D + \arctan\alpha\right)$$

Where:

ν_0 = Emission frequency in the free running state.

C = Feedback parameter.

τ_d =External laser diode cavity round-trip time (time of fly of the light from the external facet of the laser diode to the target and way back).

ω_D = The Doppler angular frequency.

t = Time.

ϕ_D = Phase Doppler.

α = Linewidth enhancement factor.

The expression of the laser diode optical output power under feedback (P_F) is:

$$P_F = P_0[1 + m\cos\left(\omega_D t + \Phi_D\right)$$

Where *m* represents the modulation index.

RESULTS:

Using the files and explanations I received from professor Perchoux during this STSM, I was able to simulate the SMI signal produced for a target in movement. This knowledge will be exceptionally important in my future work at CD6-UPC in Barcelona, Spain, due to the fact that one of my main objectives as Ph.D. student is to be able to measure precisely the blood flowing in to the human vessels.

The simulation conducted consider a rotating target (i.e. a CD) with a fixed angular velocity, the laser beam is then focused over the target surface with a known angle θ with respect to the propagation axis of the laser. Fig. 2.

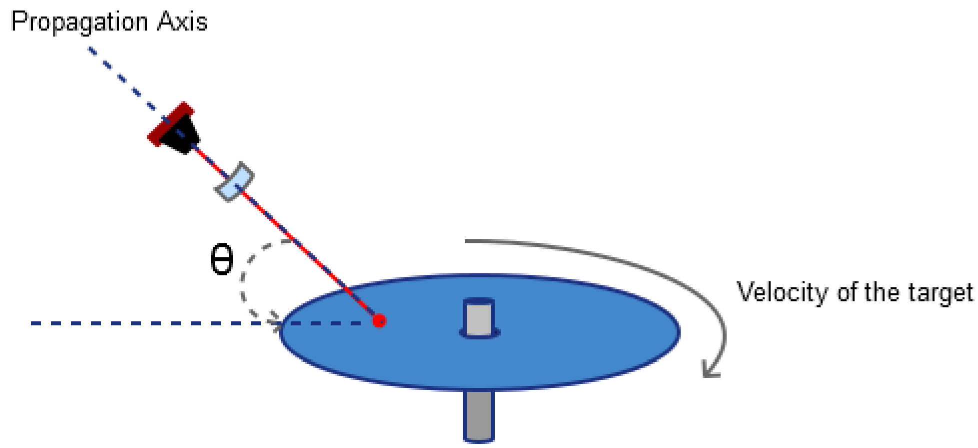

Fig. 2. Diagram of the system that was simulated on Matlab.

The results from this simulation are the following graphics (Fig. 3, Fig. 4 and Fig. 5):

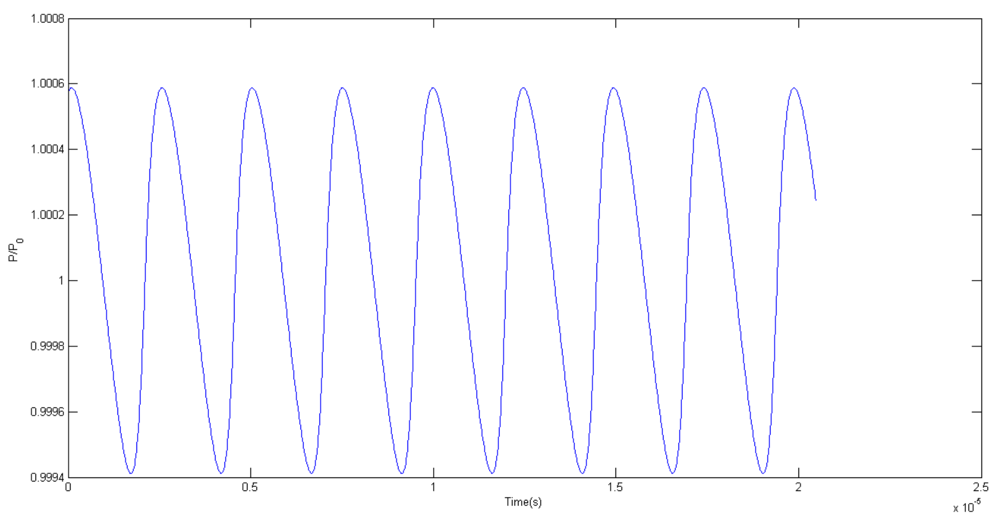

Fig. 3. SMI Signal

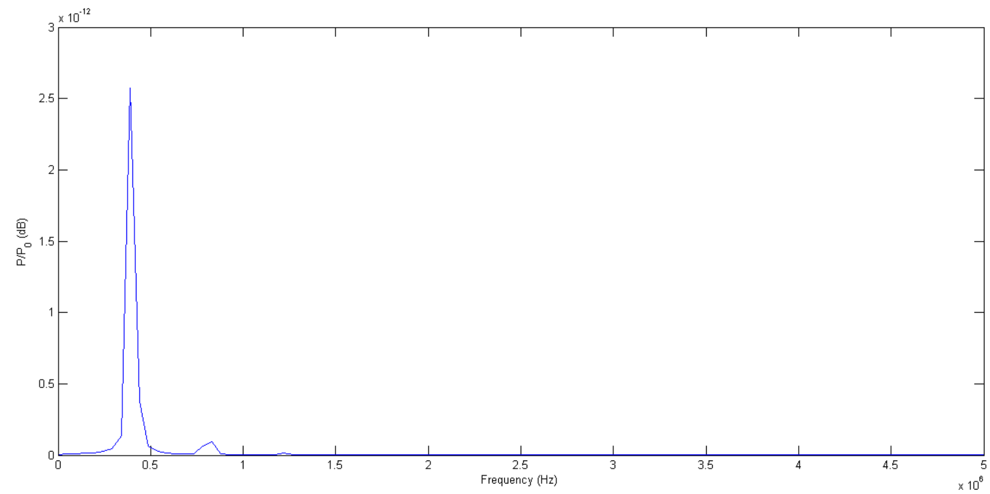

Fig. 4. Frequency domain of the SMI signal.

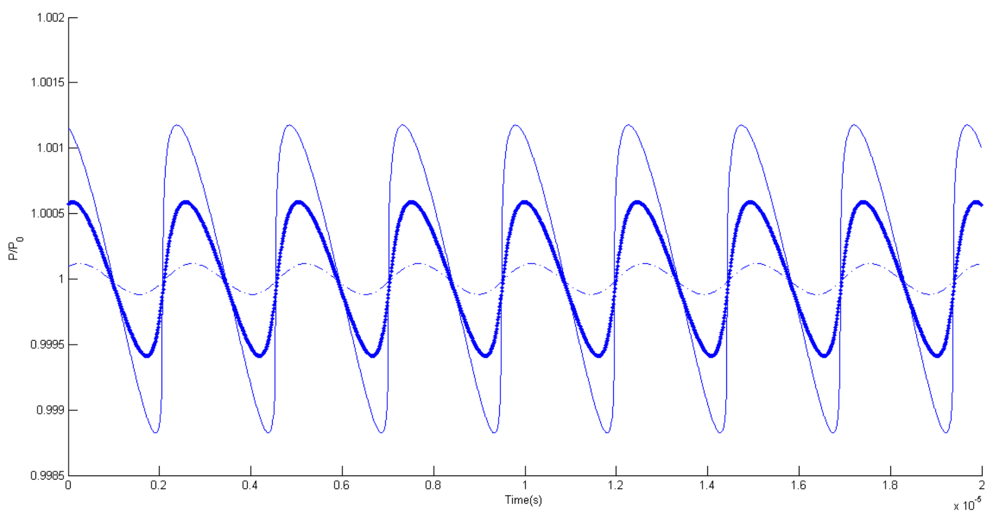

Fig. 5. SMI signals for values of C = 0.1 (dotted line), C = 0.5 (wide line)and C = 1 (regular solid line).

The obtained results have good concordance with the theoretical velocities in all the simulations that were performed. In conclusion, we are now capable of compare those results with real life situations and furthermore, we can use those simulations to predict some values we may expect in fluidic systems.

FUTURE COLLABORATION WITH THE HOST INSTITUTION:

We hope that the close collaboration between CD6-UPC and ENSEEIHT may continue in future STSM, specially in the field of Optics where both institutions have been doing enormous contributions. We can accomplish a lot by working together in this area.

STSM OUTCOME FORM

STSM application number	Home institution & country	Host institution & country	BM1205 WG	Objective of the collaboration	Results of the collaboration
COST-STSM-ECOST-STSM-BM1205-190514-044689	Centre for Sensors, Instruments and Systems Development - CD6-UPC Barcelona Tech (Terrassa, ES)	École Nationale Supérieure d'Électronique, d'Électrotechnique, d'Informatique, d'Hydraulique, et des Télécommunications - ENSEEIHT-LAAS (Toulouse, FR)	WG4	Collaboration in Novel techniques for velocimetry measurements in fluids using Self-Mixing Interferometry.	We were able to effectively simulate SMI velocimetry systems.

I acknowledge that the described short term scientific mission was successfully carried out in the conditions here specified, and prospects for potential collaborations are expected in the coming months out of the agreements reached.

Toulouse, France. 03 June 2014

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