On-sky ability of ALOHA/CHARA at 1.55 µm to detect astronomical sources in H band

P. Darré, R. Baudoin, L. Grossard, L. Delage, F. Reynaud
XLIM, UMR CNRS 7252, France

With the collaboration of the CHARA team

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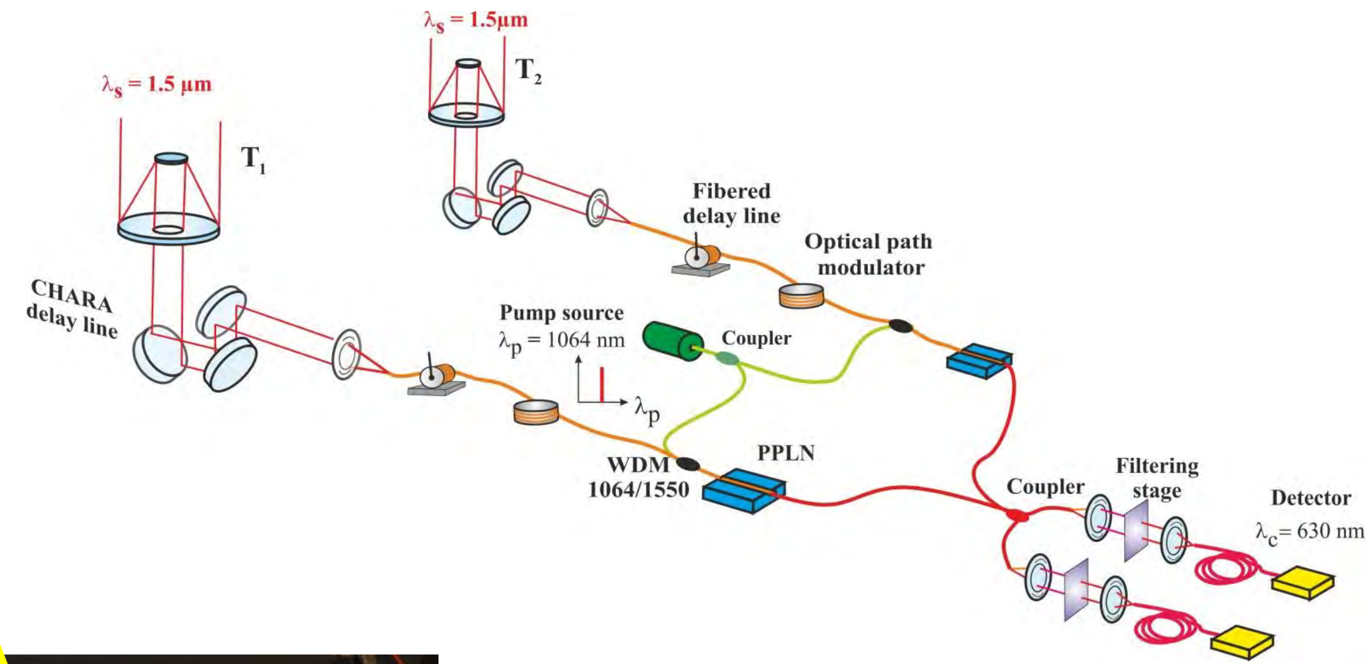
Introduction

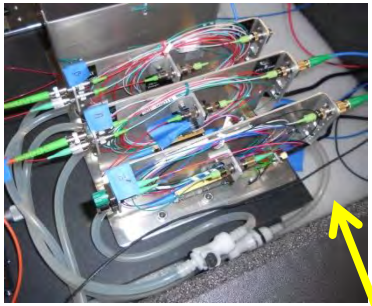
- Implementation of a prototype operating at 1.55 µm and converting the light in the visible domain (630 nm)
- Validation of the ALOHA concept in laboratory (cf. introduction by François Reynaud) :
  - Conservation of fringe constrast and phase closure after SFG process (Brustlein & al., 2008 / Ceus & al., 2011)
  - Detection ability in photon counting regime (Ceus & al., 2013)
  - Achievement of spatial coherence analysis of a blackbody source through SFG process (Gomes & al., 2013)
- Current investigations : concept validation on-sky
  - Photometric configuration (2014)
  - Interferometric configuration (2015)

Presentation of the ALOHA setup

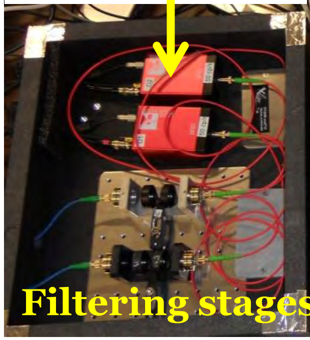
Experimental setup

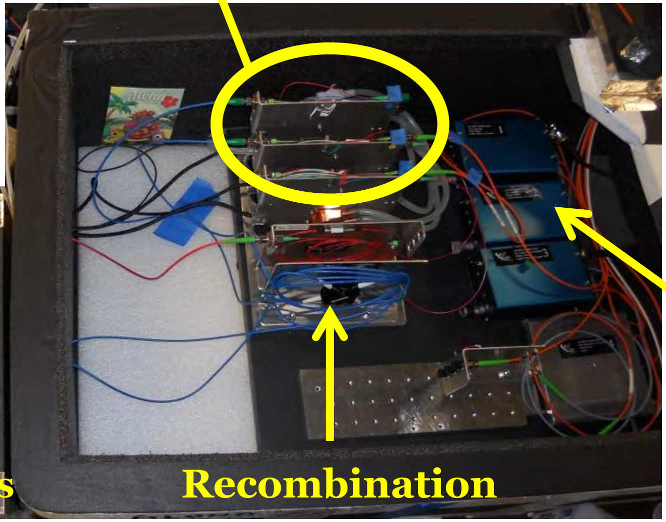


PPLN waveguides



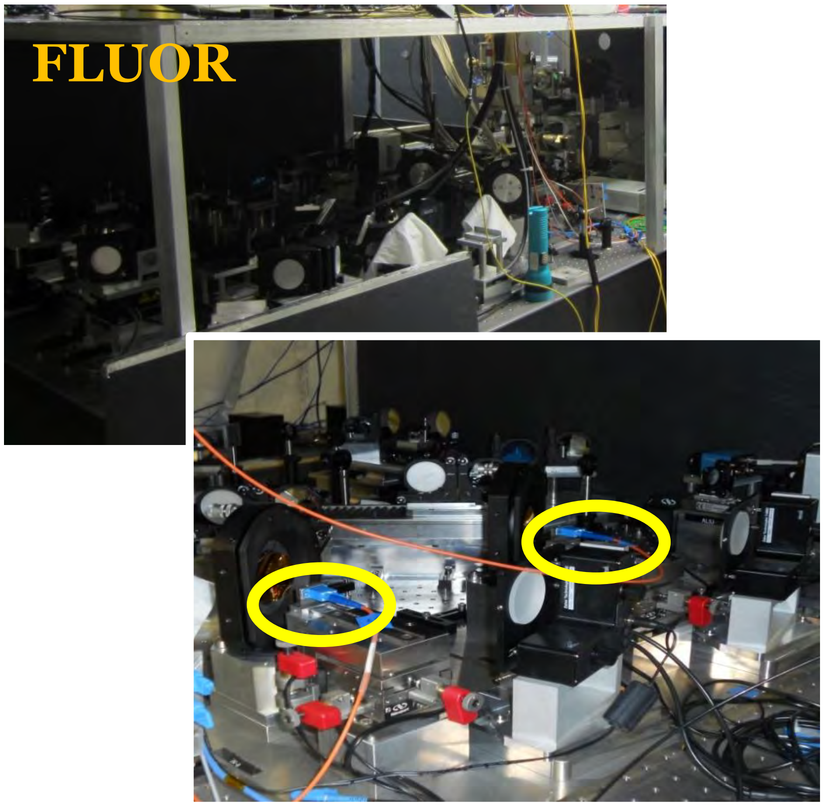
Detectors





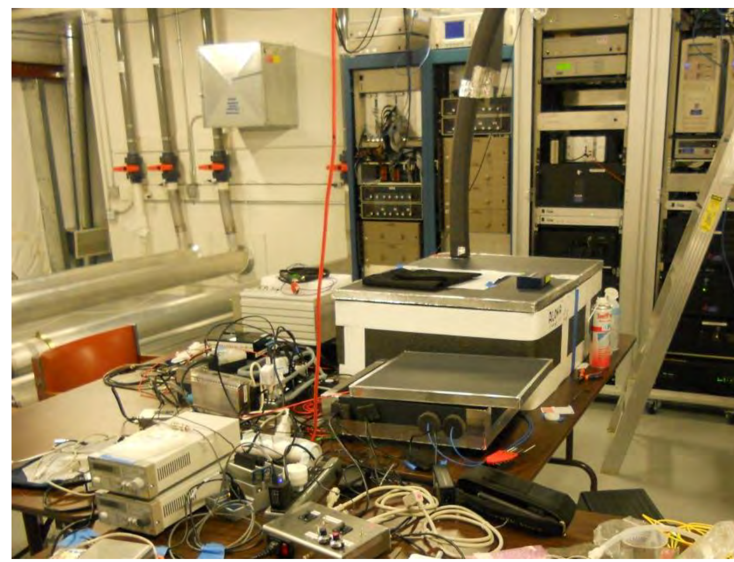
Delay lines
+ OPM

Implementation on CHARA focal lab



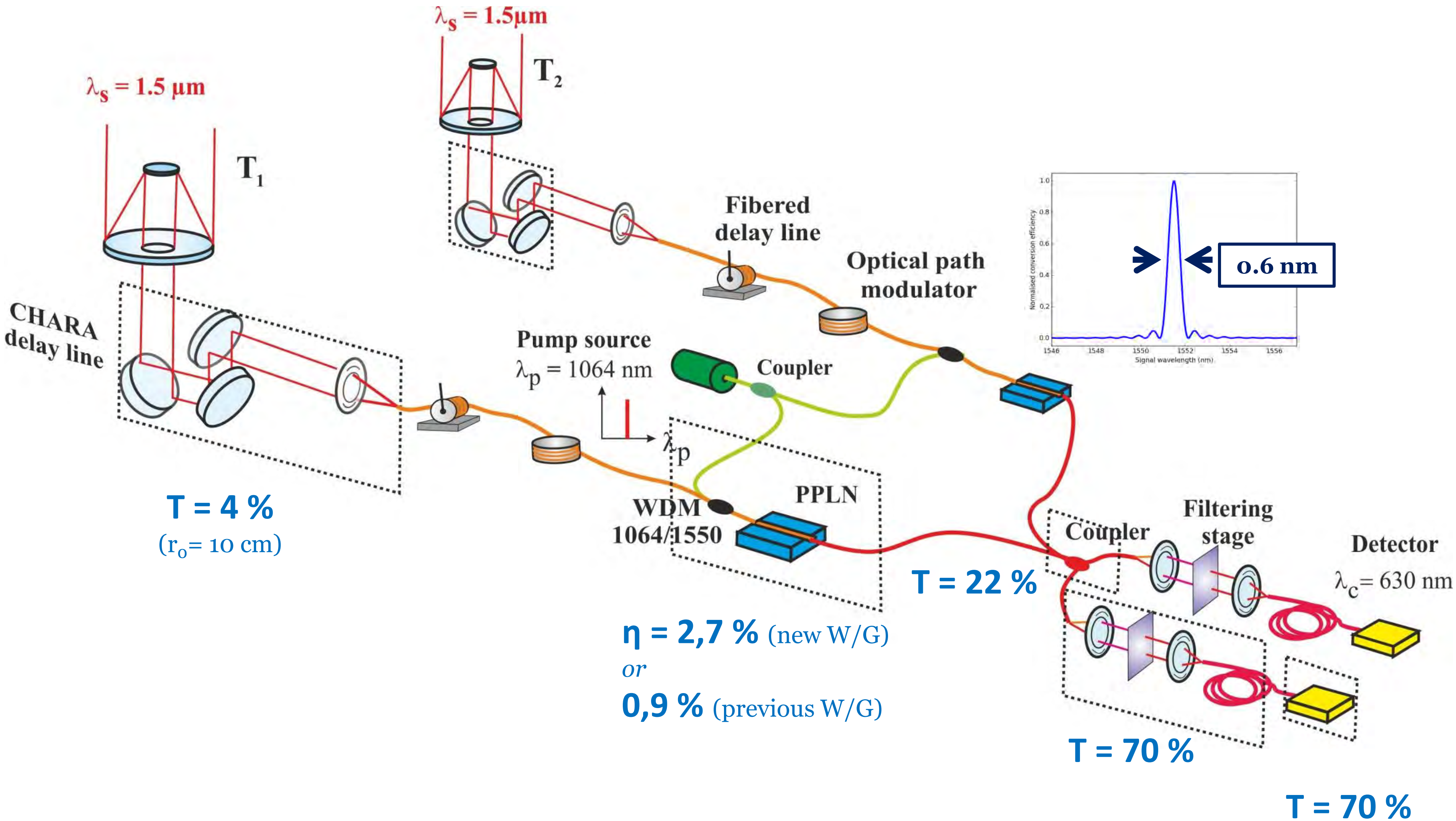
Connection of the ALOHA fibers into the FLUOR injection module

Fibres routing through the wall ---> **vibrations !!**



Implementation of the setup in the room next to the focal lab

Transmission of ALOHA

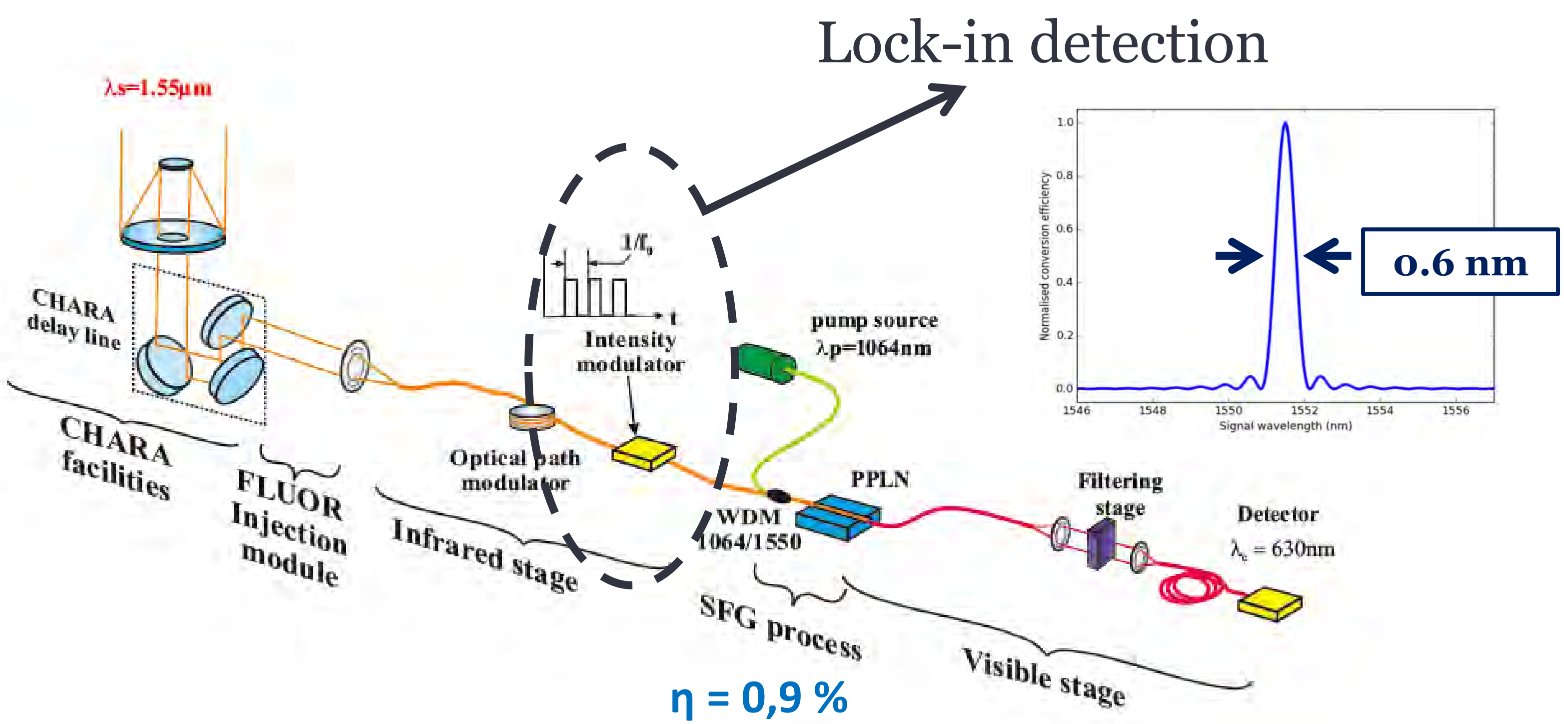


Global transmission of ALOHA : 0.3 %

Photometric testing (2014)

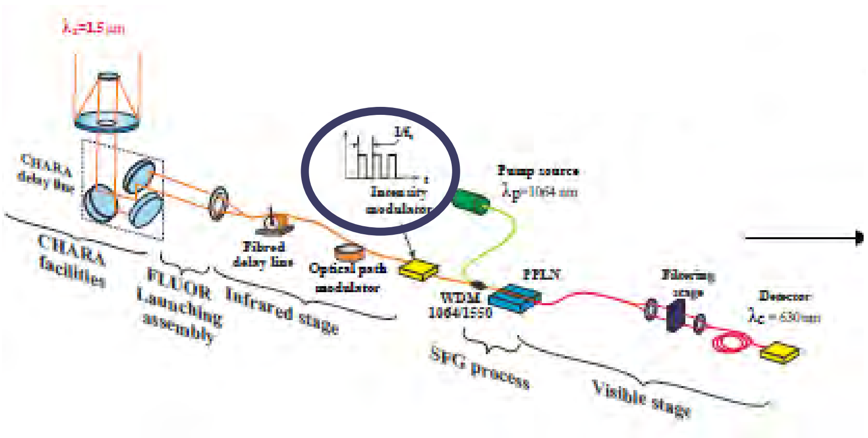
Photometric testing

Goal: Demonstration of the instrument ability to detect a low flux using a conversion stage



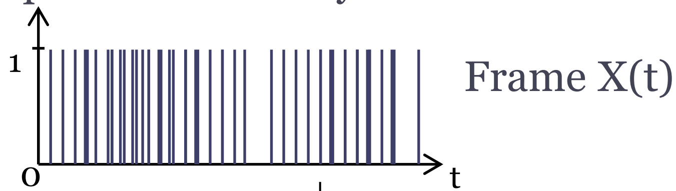
- Photometric investigation in H band (at 1.55 µm) using a single arm of the interferometer.
- Addition of an intensity modulator (-6 dB flux loss) to recover the signal at the output.

Signal processing



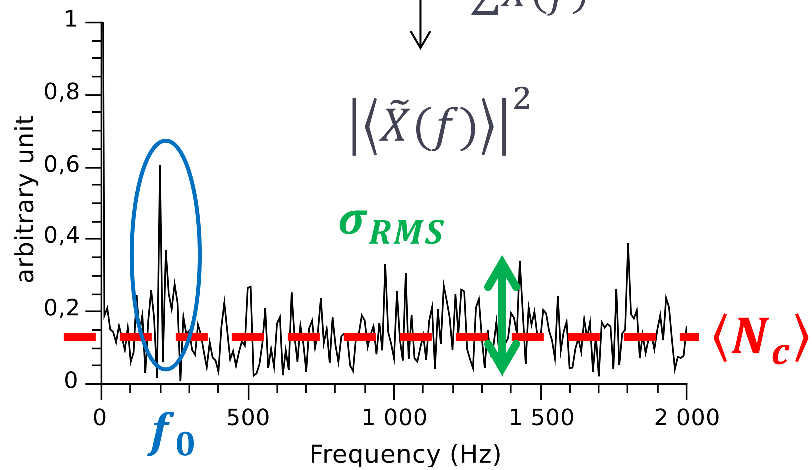
Modulation with a squared waveform at f = 200 Hz

Detection in photon counting regime : acquisition of binary data



$$\tilde{X}(f) = FFT\ (X(t))$$

$$\Sigma \tilde{X}(f)$$

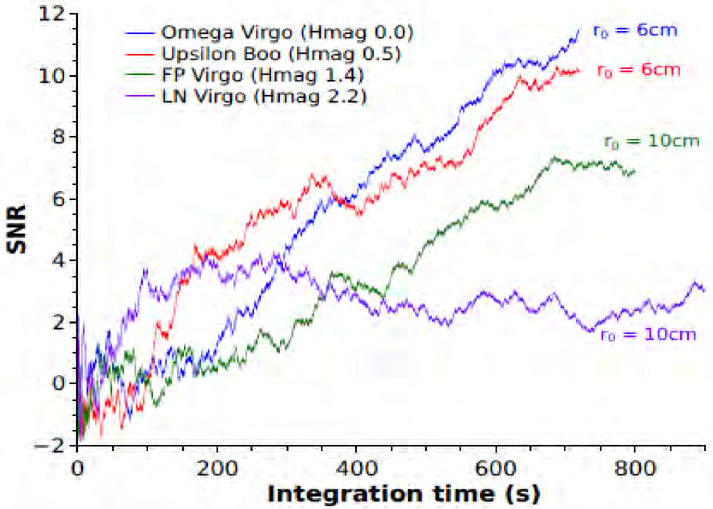


$$SNR = \frac{\left|\langle \tilde{X}(f_0) \rangle\right|^2 - \langle N_c \rangle}{\sigma_{RMS}}$$

Synchronisation between the intensity modulation and the detection

Photometric testing: results

- **Coherent** integration of the frame $\tilde{X}(f)$ over N frames
- Instrumental limiting magnitude: SNR > 3 criterion
- LN Virgo (**2.2 mag** in H band): faintest source detected



Stellar source	H_{mag}	date	atmospheric coherence length r_0 (cm)[a]	Seeing (arcsec)	integration time ΔT (sec)	SNR
Alpha Boo	-2.8	2014 May 11	4	2.8	350	34.1
R Leo	-1.9	2014 May 12	7	1.6	350	32.7
Gamma Her	-1.8	2014 May 13	3.5	3.2	350	18.8
Omega Virgo	0.0	2014 May 12	6	1.9	720	11.5
Upsilon Boo	0.5	2014 May 12	6	1.9	720	10.1
FP Virgo	1.4	2014 May 14	10	1.1	800	6.4
LN Virgo	2.2	2014 May 14	10	1.1	900	3.0

η = 0,9 % $\Delta\lambda$ = 0.6 nm

(Baudoin & al., 2016)

Interferometric testing (2015)

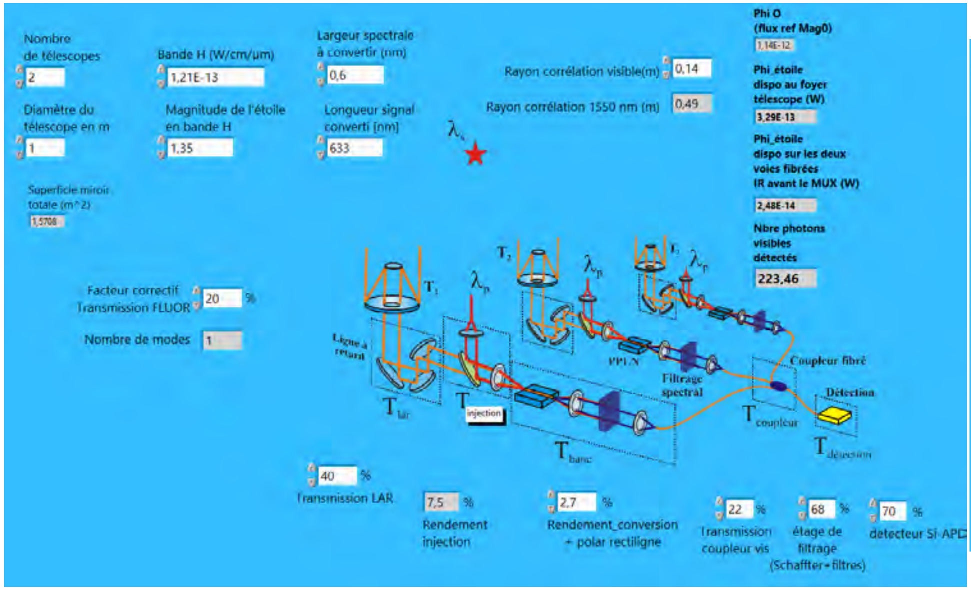
Performance estimation (1)

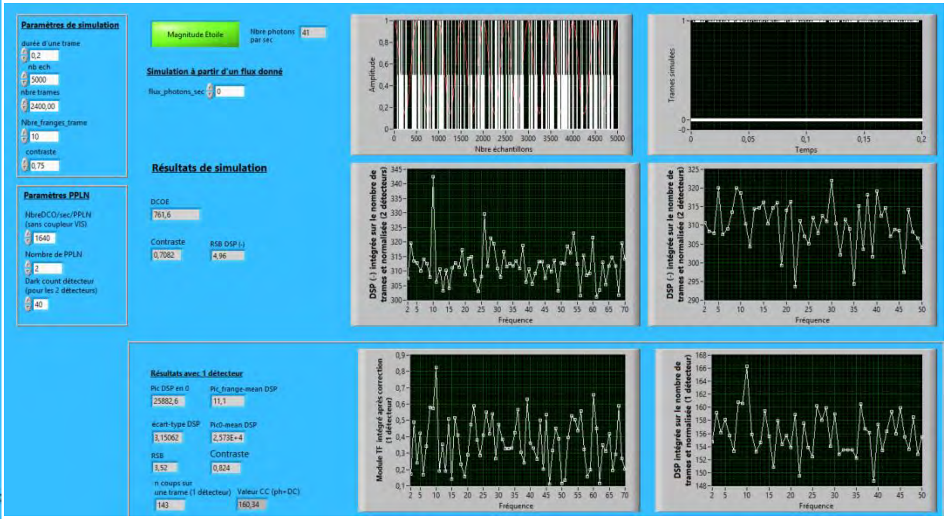
Next step: Evalutation of the limiting magnitude in interferometric mode

- Integration on the squared modulus of the spectrum $\left\langle \left|\tilde{X}(f)\right|^{2} \right\rangle$ (piston effect : **incoherent** detection)

- Signal-to-noise ratio $$\mathrm{S/N} = \frac{\langle|\widetilde{X}(f_{mod})|^2\rangle - \langle N_c\rangle}{RMS(\langle|\widetilde{X}(f)|^2\rangle)}$$

- Simulation





Performance estimation (2)

- Simulated performance of the interferometric configuration at CHARA (piston effect over the frame not simulated)

Simulated SNR for a **1.5 mag** source for different atmospheric coherence length r_o (Integration time over **20 min)**

	$r_0 = 6$ cm	$r_0 = 10$ cm	$r_0 = 14$ cm
Seeing (arcsec)	1.9	1.1	0.8
$\tau = 100$ ms	2.6	25	82
$\tau = 200$ ms	5.0	35	117
$\tau = 400$ ms	6.5	47	163

Integration time over **20 min** (individual frames of 200 ms)

	$r_0 = 3$ cm	$r_0 = 6$ cm	$r_0 = 10$ cm	$r_0 = 14$ cm
Seeing (arcsec)	3.8	1.9	1.1	0.8
$\mathrm{H}_{\mathrm{mag}}^{\mathrm{limit}}$	0.1	1.6	2.8	3.7

Improvement and Future prospects

- Calibration of the constrast : Addition of photometric channels and detection with the FLUOR camera
- Study the relation between the coherence time of atmospheric turbulence and the frame duration
- Integration of ALOHA in the focal lab ? (limitation of perturbation sources)
- N.A. FLUOR = 0,23 ; N.A. ALOHA = 0,12 ---> injection flux losses in fibers
- Fusion splicing of fibers: improvement of the SNR
- Increase of the analysed infrared bandwidth with simultaneous frequency conversion processes (Darré & al., 2015)