Cophasing activities at Onera

Kamel Houairi

Frédéric Cassaing

Cophasing at Onera

I/ Pupil-plane fringe sensing

- Persee
- Gravity

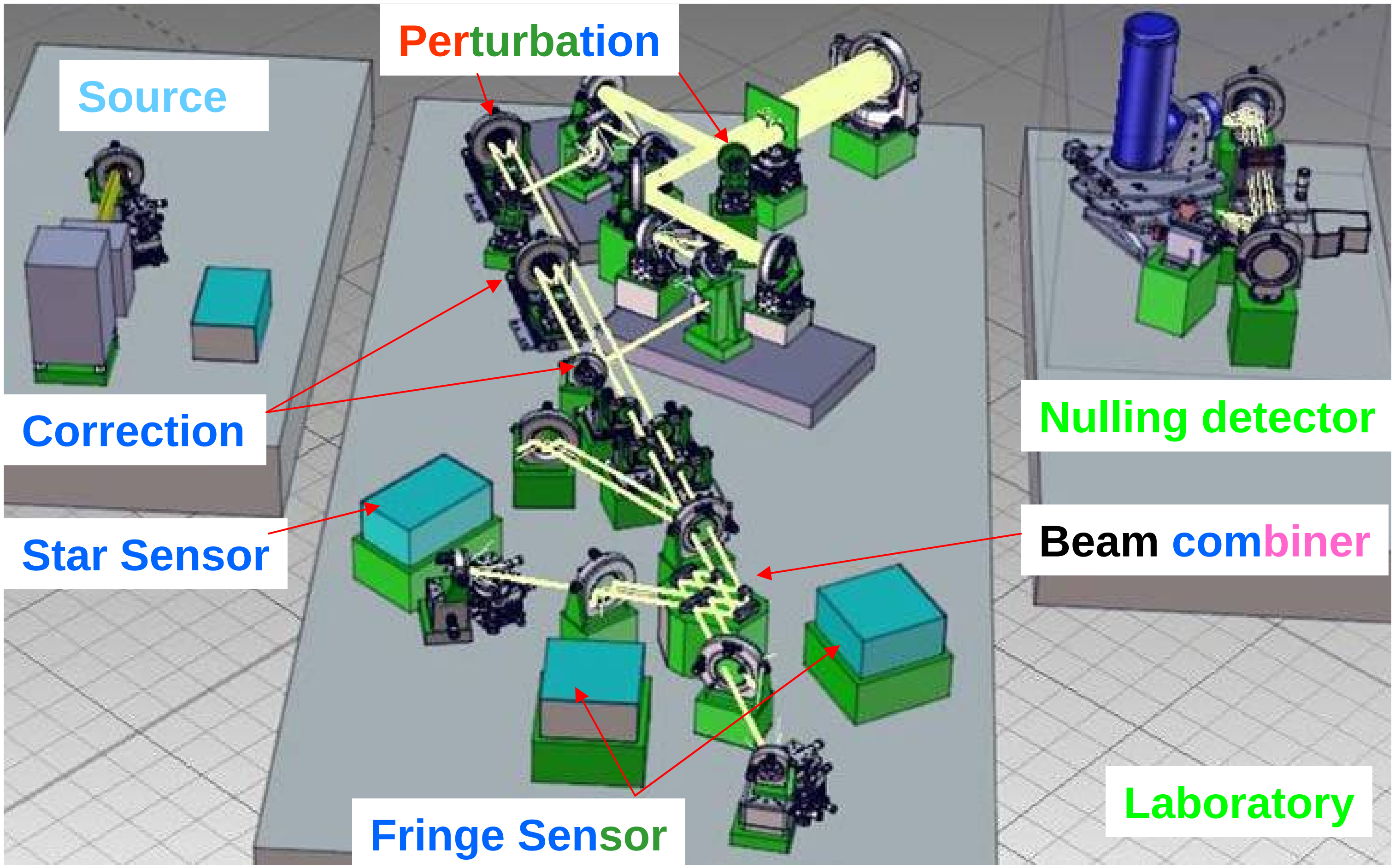
II/ Focal-plane fringe sensing

- Phase retrieval/diversity
- New algorithms under study (F. Cassaing)

PERSEE

- Context
  - Nulling demonstrator for formation-flying missions (Darwin/TPF-I, Pegase, FKSI, …)
- Main objectives
  - $10^{-4} \pm 10^{-5}$ achromatic nulling
    - In the [1.6-3.2] µm spectral band
    - In presence of realistic disturbances
    - For several hours
  - Validate the full operation (star/fringe acquisition, tracking, calibration, unloading of fine correctors)

Consortium and sub-systems



CNES

GEPI

IAS

LESIA

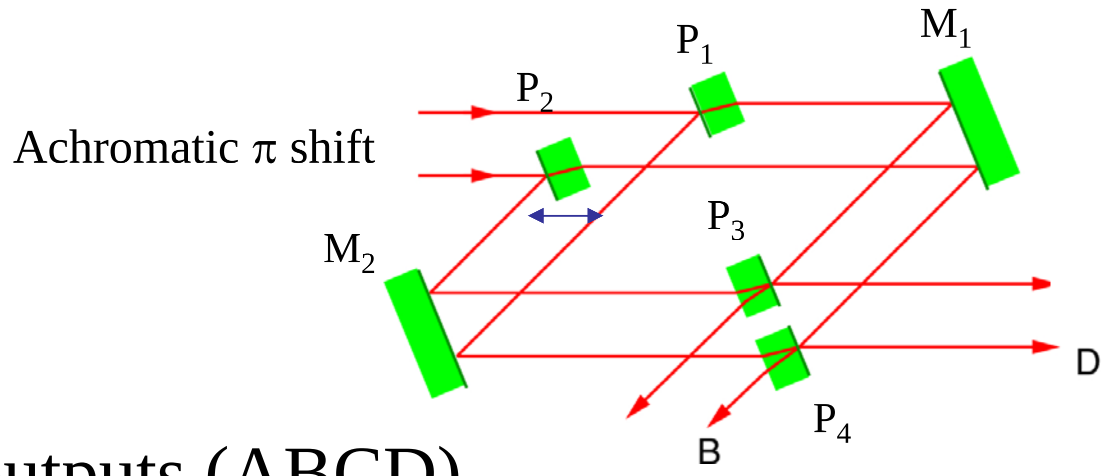
OCA

ONERA

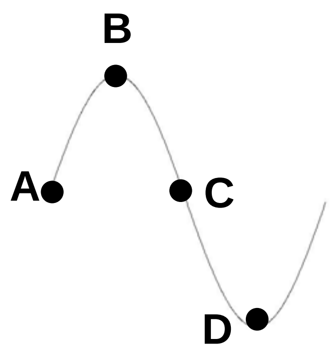
TAS

Beam combination

- Wide-band null ➔ Modified Mach-Zehnder



- 4 outputs (ABCD)
  - Spectral separation after combination
  - Common fringe sensor / science instrument



Nulling [1.6-3.2] µm

Fringe tracking [0.8-1.5] µm

Fringe sensor setup

- Spatial modulation
  - Allow high measurement frequency (fringe acquision)
  - D measured by fringe sensor
    ➔ Real Time null depth monitoring
- Central fringe identification
  - Dispersion is the simplest way
  - Minimize detector noise
    ➔ **2 spectral channels are enough**

Simultaneous ABCD in I & J
➔ 2 phases, 2 visibilities

Operating modes and free parameter optimization

Mode	Measurement	Estimator	Parameters
Detection	Visibility	$\widehat{V^2} = qV_I^2 + (1-q)V_J^2$	λ_s, q
Acquisition	Goup delay	QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.	λ_s
Tracking	Phase delay	QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.	λ_s, p

Estimator noises depend on λ_s

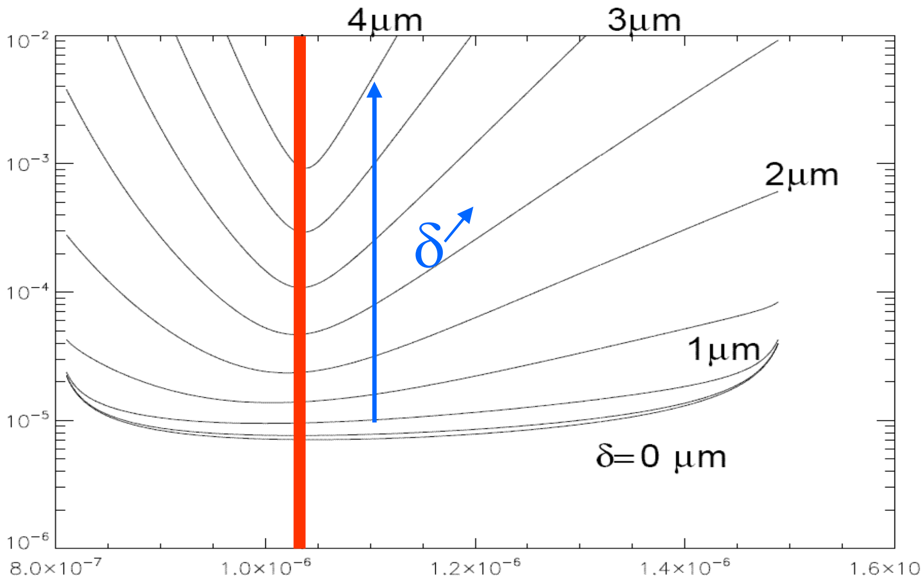
Dispersion: I = [0.8-λ_s]µm -- J = [λ_s-1.5]µm ➔ Optimal λ_s ?

Separation wavelength optimization

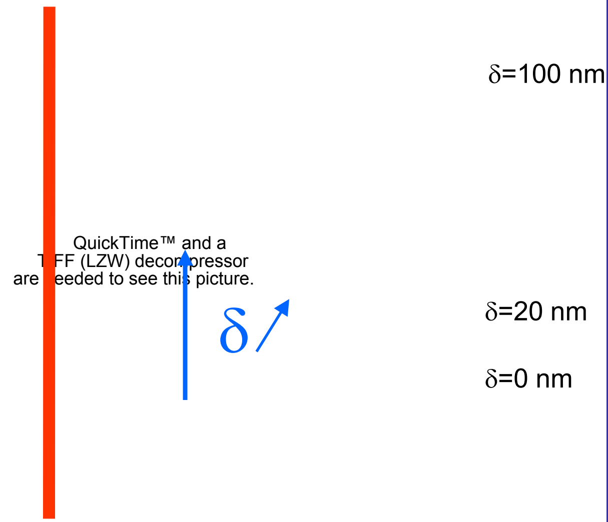
Wide spectral band ➔ Measurement noise = f(δ)

Estimated OPD measurement noise vs λ_s (photon noise)

Group delay



Phase delay

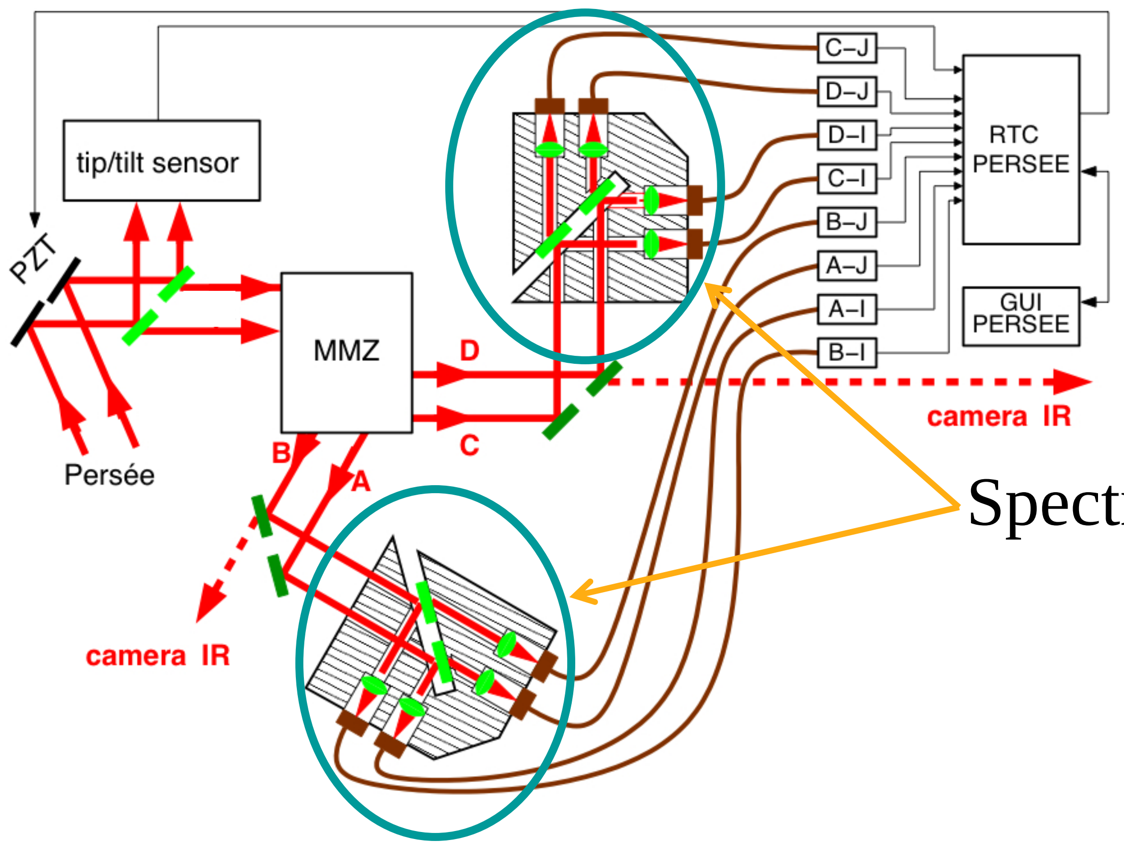


λ_s = 1 µm, sensitive

λ_s = 1 µm, p=0.5, not sensitive

Final cophasing (piston/tip/tilt) design

Correction

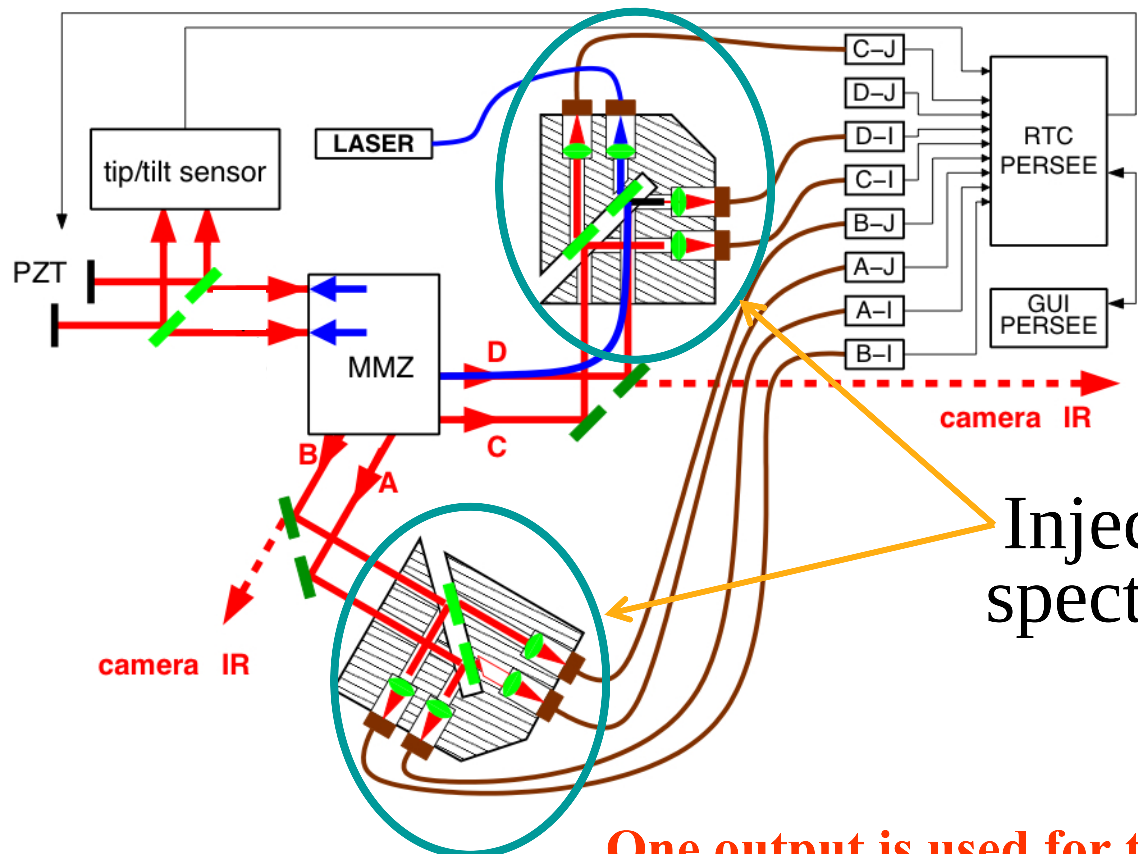


- RT computer
- 8 monopixel detectors

Spectral dispersion

Cophasing design at Onera (autocollimation)

Correction + Perturbation



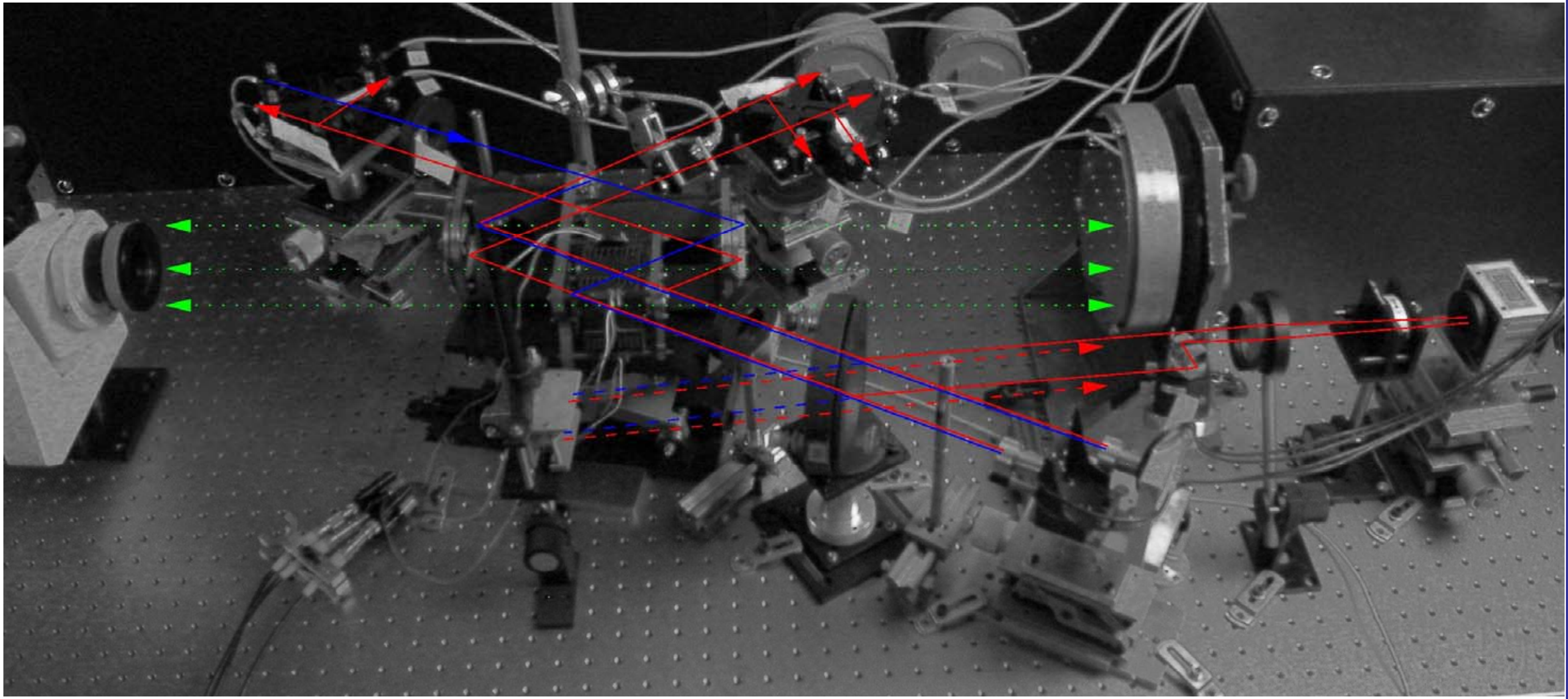
- RT computer
- 8 monopixel detectors

Injection bloc: spectral dispersion

One output is used for the light injection

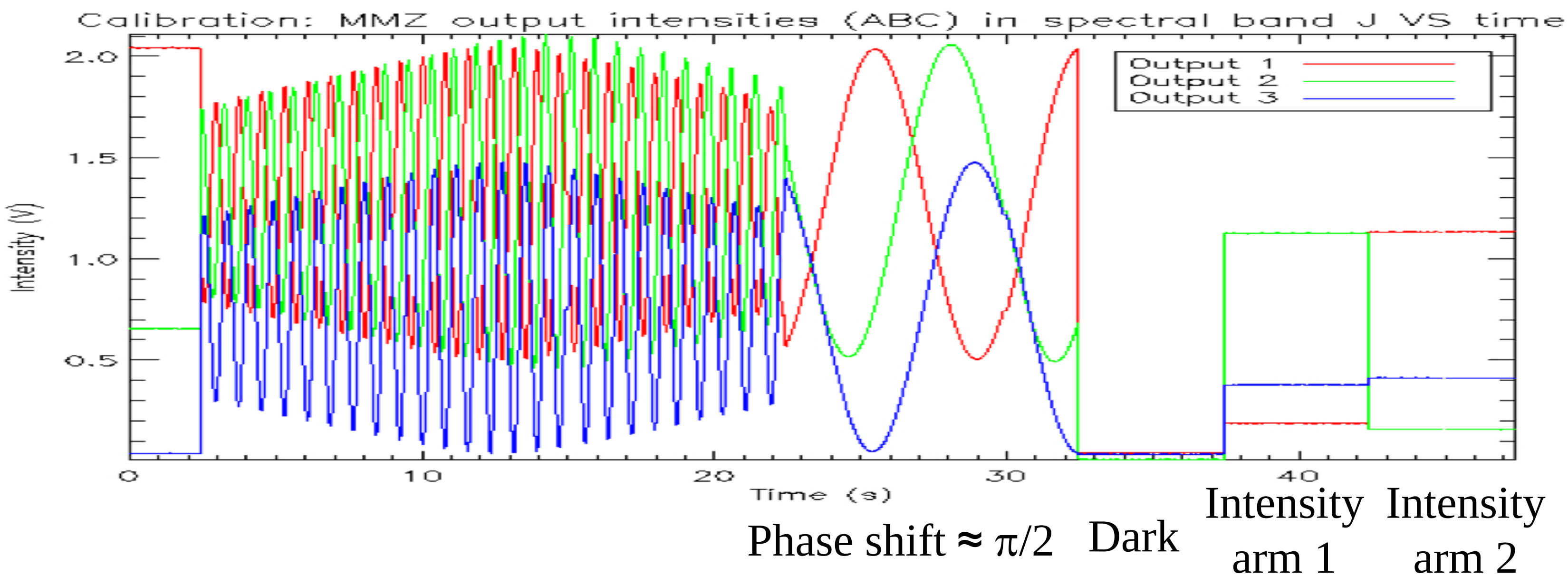
Preliminary cophasing implementation at Onera

Backwards light injection   Detection   Alignment



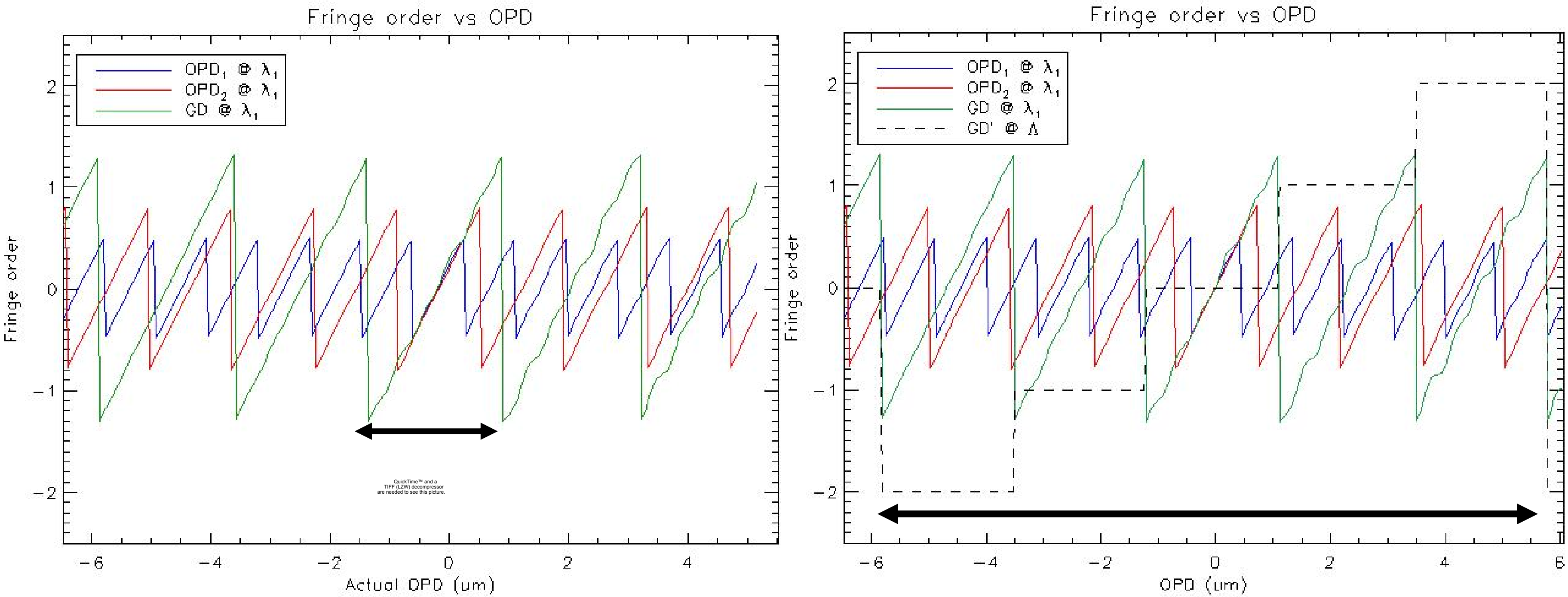
Calibration

- Analytical equations of the spatial interferometer
  - – Linear system ➔ OPD = f^{-1}(measurement)
- Need a calibration process



New extended coherencing algorithm (experimental results)

- Estimated OPD is λ-periodic ➔ two lambda analysis to extend the unambiguous range
- Classical algorithms are Λ periodic
- Estimation of the synthetic wavelength fringe order by a new (real time) agorithm

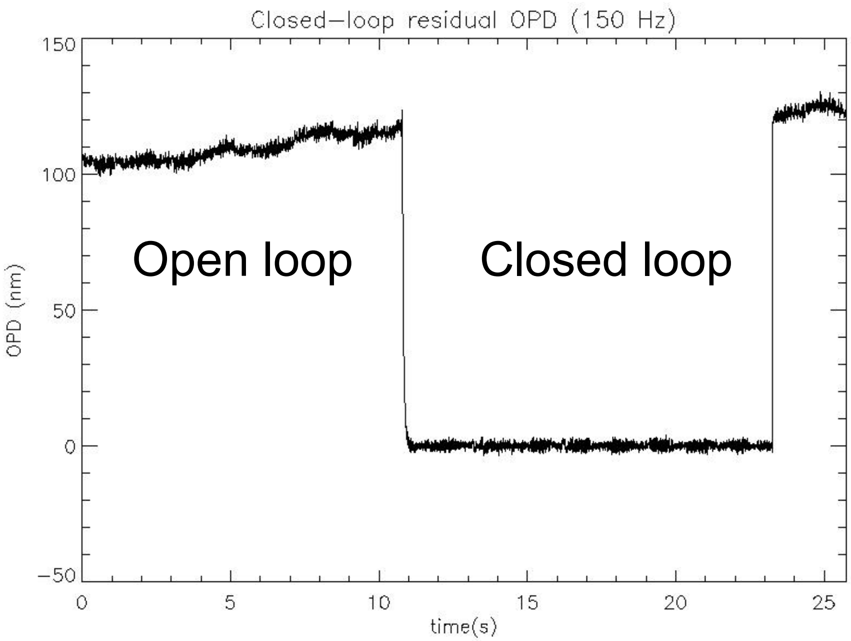


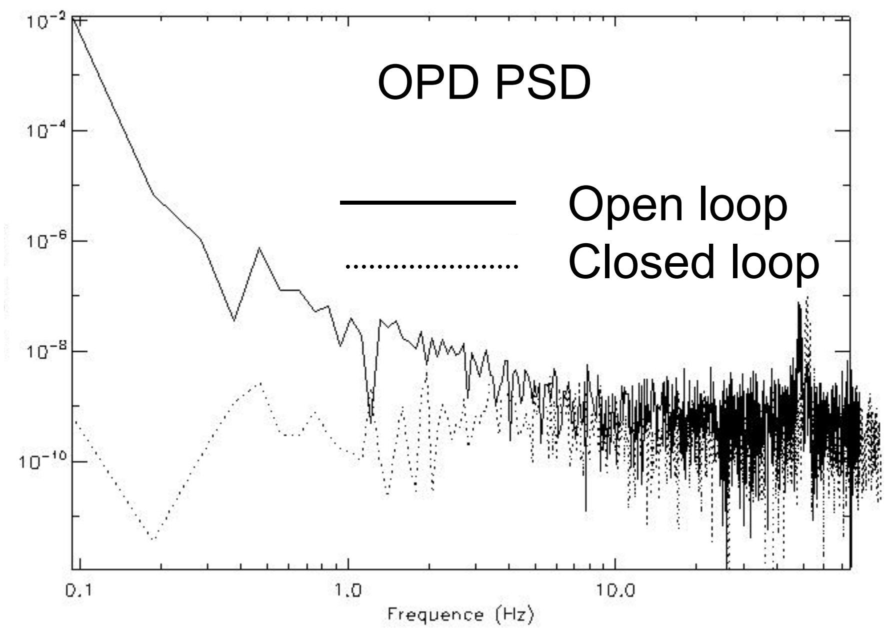
Extension of the OPD estimation range by a factor of 5

To do: Extension for N>2 spectral channels (PRIMA DATA)

Results of the fringe tracking

- Only laboratory disturbances, sampling = 150Hz





  - Open loop: σ_{opd} = 4.5 nm rms
  - Closed loop: σ_{opd} = 1.3 nm rms

➔ **nanometric residual reached**

Gravity

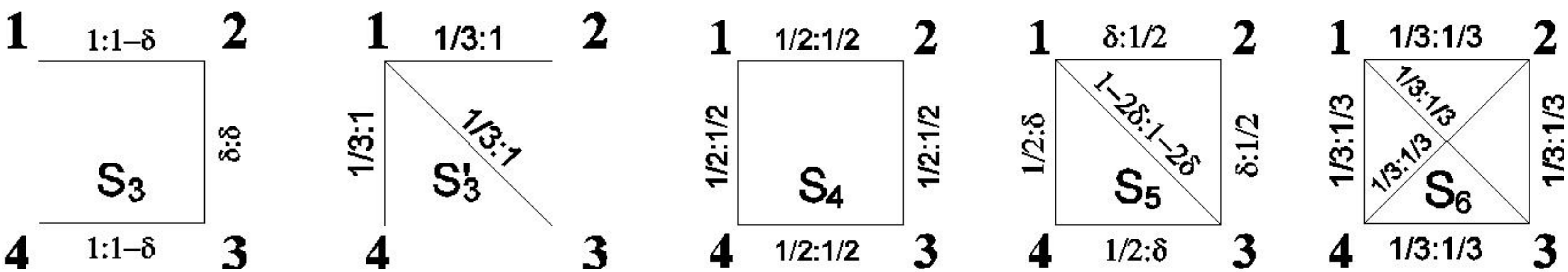
- 2nd generation VLTI instrument

- Instrument design:
  - 4 UTs
  - AO correction
  - **Fringe tracking**

Fringe tracking residual OPD < $\lambda/10$

GRAVITY: 4 beam combination

- 4 telescopes to combine
  - 3 independent OPDs to control
  - Hyp.: pairwise based combination → 6 baselines
- Several possibilities to combine the beams



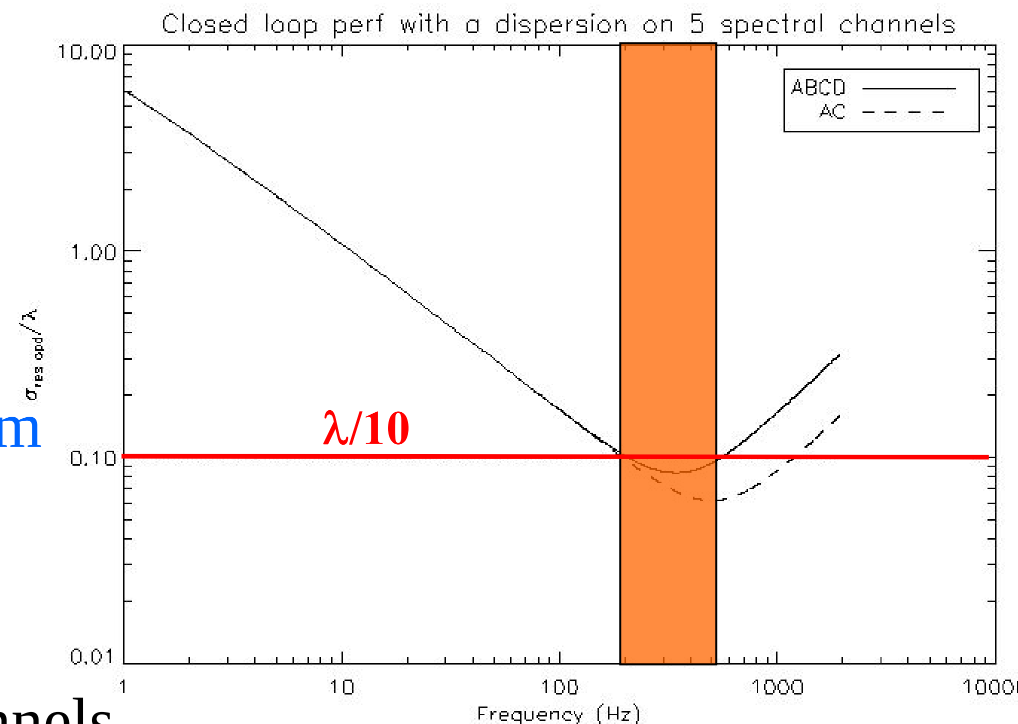
——— One OPD measurement   1/3:1 Splitting ratio

What is the best combination ?   How to choose ?

Systematic □□□□□procedure derived, based on noise propagation minimization

Gravity FS simulation

- Selected Fringe Sensor:
  - S_6 $\boxtimes$
- Control law:
  - Integrator model based
- Atmospheric OPD spectrum
  - R_0=0.95m @ 2.2µm
  - t_0=47ms @ 2.2µm
  - Total variance: 23 µm rms



- Dispersion: 5 spectral channels (coherencing + science measurements with fringe sensor)

Specification (λ/10) reached with loop frequency f_s = 400 Hz

Onera's Perspectives for pupil-plane FS

- Persée :
  - Complete Persee installation and qualification
  - Operate cophasing and nulling systems in parallel
  - New PhD student for advanced control techniques
- Gravity
  - Refined simulation underway (Phase B)
  - New PhD student fall 2009 (Lesia-Onera)