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NEW OPTICAL MICROBAROMETER

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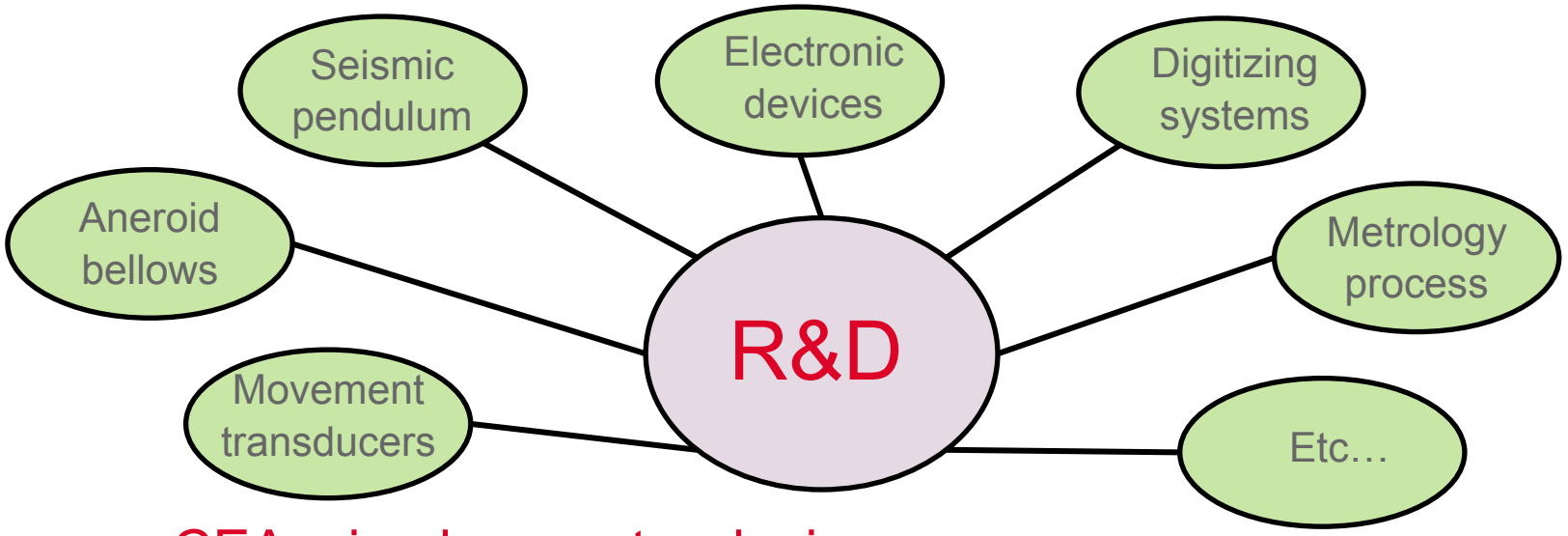
SUMMARY

- INTRODUCTION
- MICROBAROMETER PRINCIPLES
- OPTICAL TRANSDUCER PRINCIPLES
- OPTICAL MICROBAROMETER
- THE FIRST DESIGN
- THE SECOND DESIGN
- CONCLUSION

INTRODUCTION



CEA microbarometer designs:

… 2000 2005 2015 Today -> Tomorrow

MB2000 MB2005 MB3

R&D : OptoGeo new optical microbarometer
French Patent 1262878

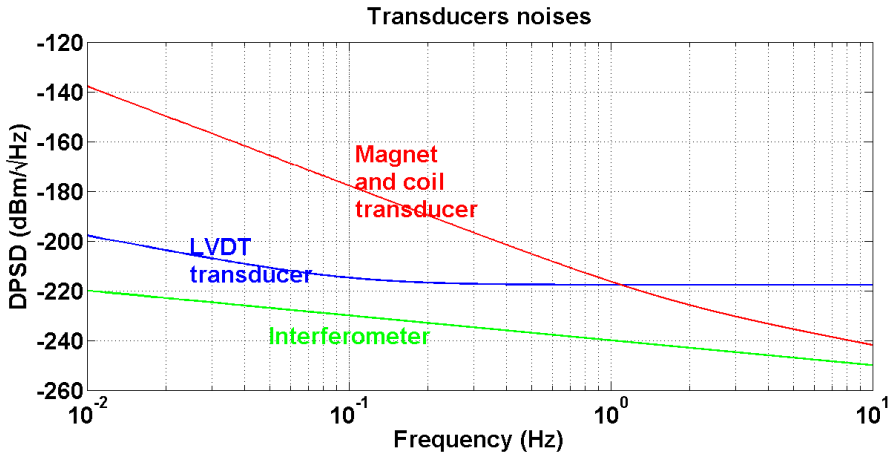
LVDT transducer

Magnet & coil transducer

Interferometer

Principles

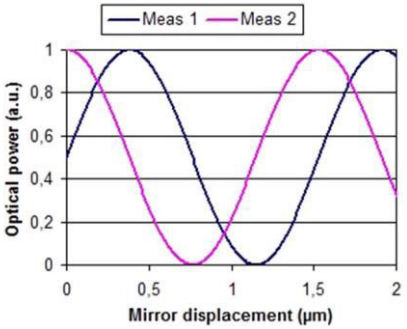
- Interferometer compared to LVDT and Magnet and Coil transducers:
  - lower noise



  - Larger operational range

    - Two quadrature fringes

    - No limit on phase fringes measurement

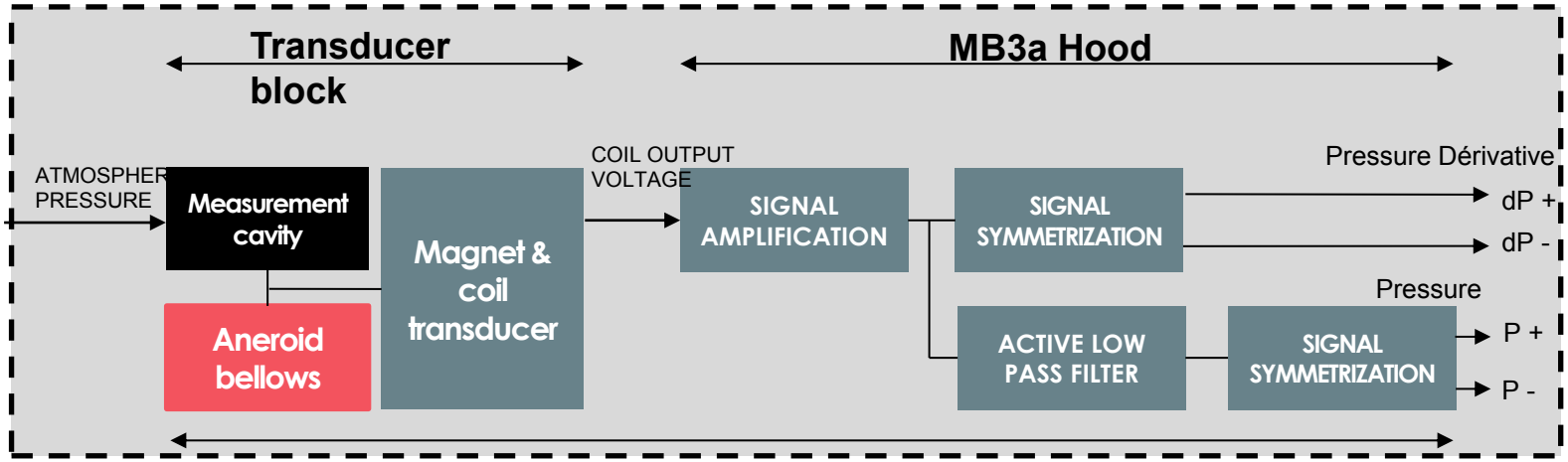


Objectives

- **increase performances (noise and operational range) of the sensor**
- **No more electrical mass difficulty**

MICROBAROMETER PRINCIPLES

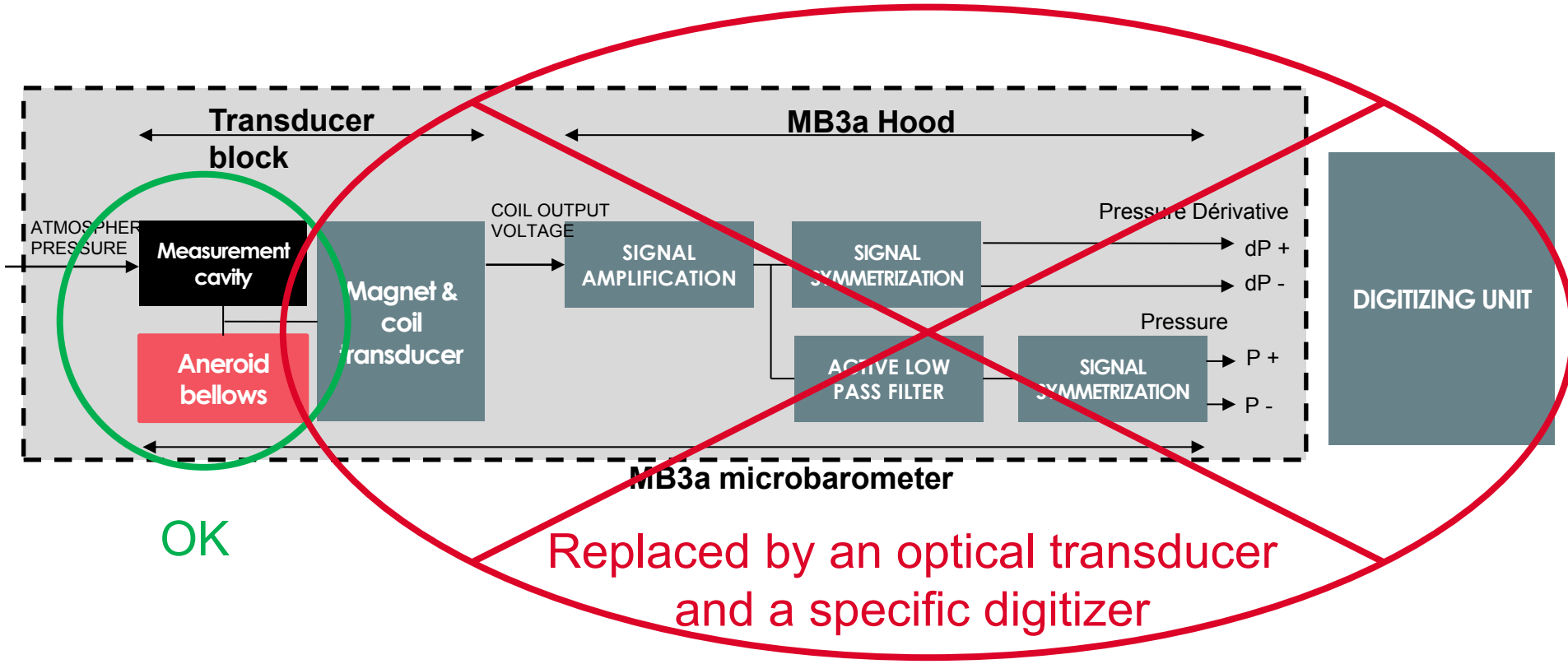
Current microbarometer principle



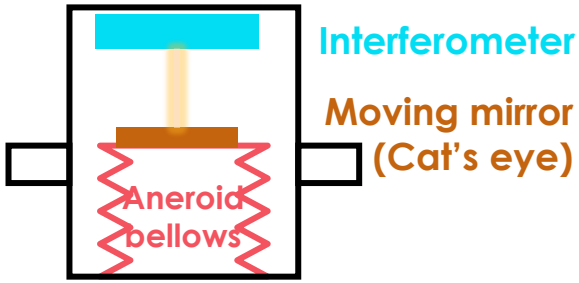
DIGITIZING UNIT

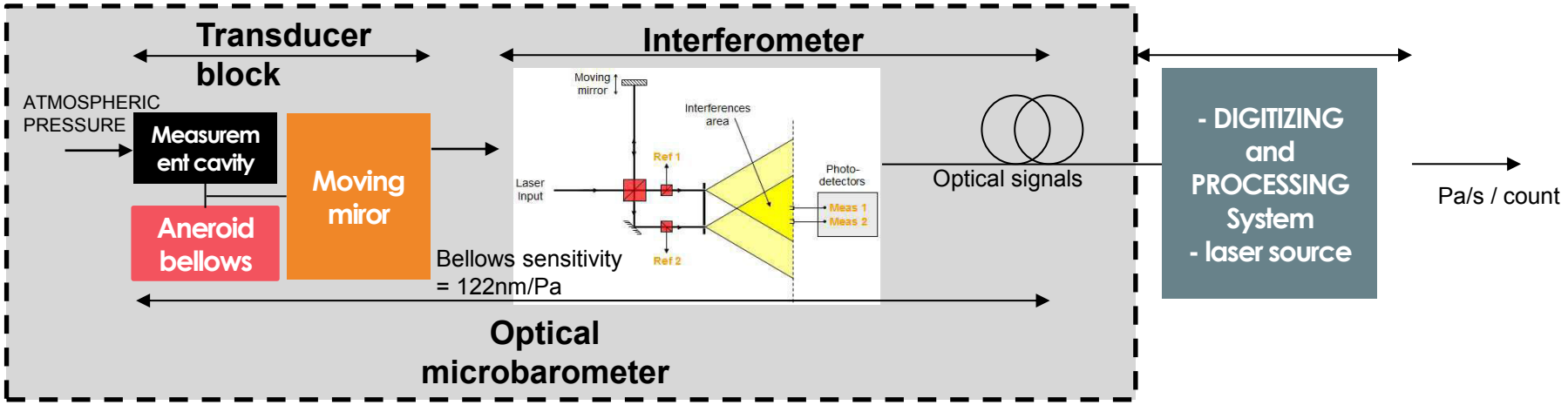
MICROBAROMETER PRINCIPLES

Magnet and coil transducers principle



OPTICAL MICROBAROMETER

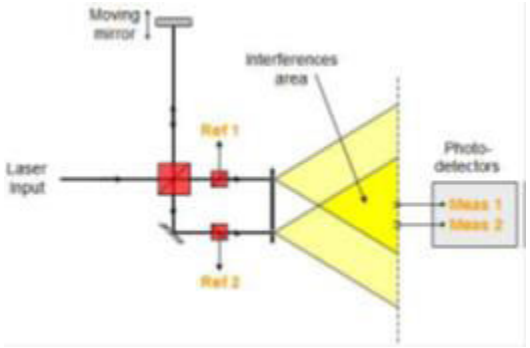




INTERFEROMETRIC TRANSDUCER

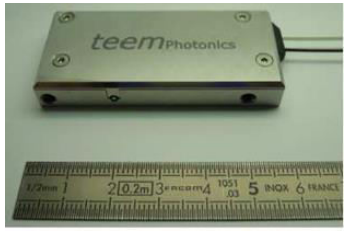
Interferometer principle

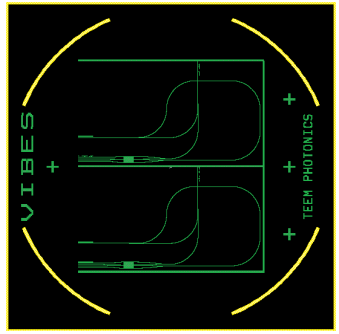
- « Mic-Mac » interferometer: One Michelson arm and one Mach-Zehnder arm
- 2 quadrature fringes to compute the phase:
  - Meas1 & Meas2
- 2 photometric signals to control photometric variations
  - Ref1 & Ref2



Interferometer technology: integrated optics

- Interferometer is designed with optical waveguide obtained by ion-exchange process into a glass wafer
- Less adjustment than standard interferometer
- Interferometer is included into a compact package



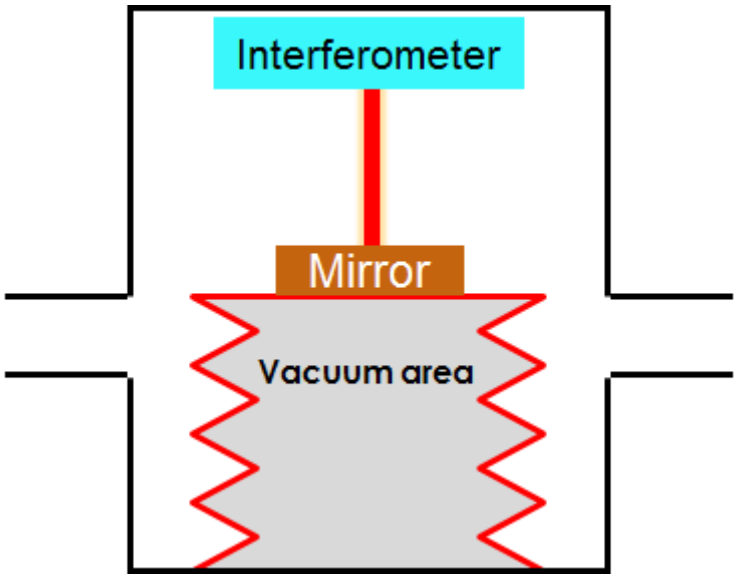


OPTICAL MICROBAROMETER

2 steps to design the optical microbarometer

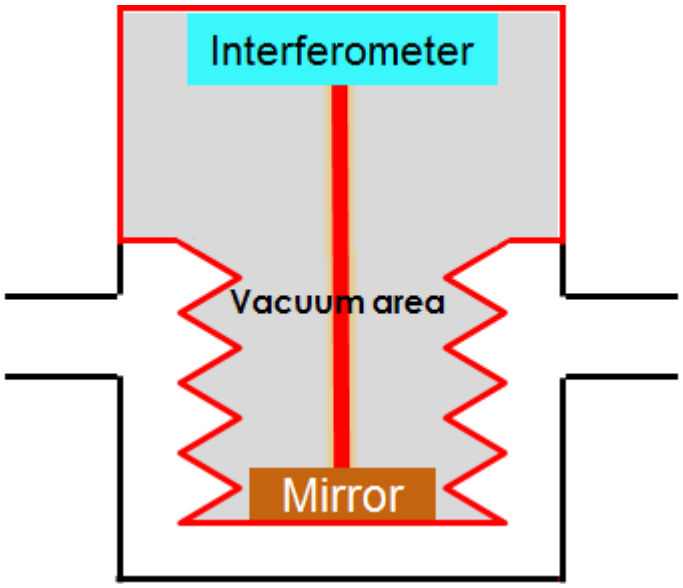
- Step 1: Concept validation

  Interferometer outside the aneroid bellows



- Step 2: Fully integrated prototype

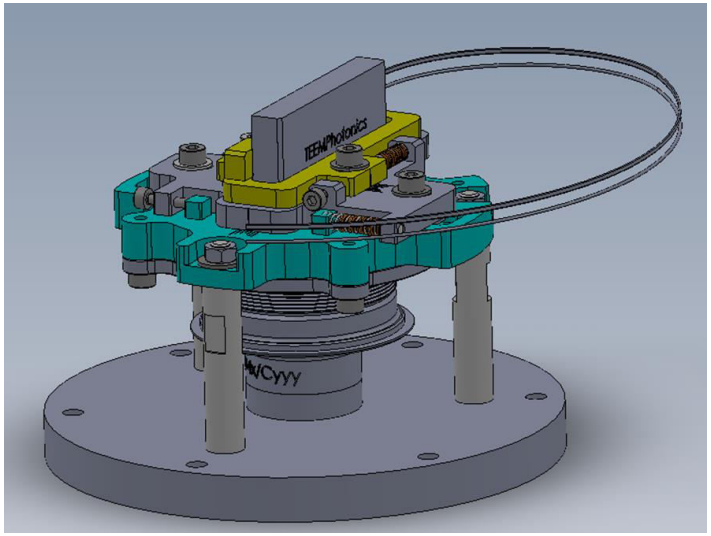
  Interferometer inside the aneroid bellows



FIRST DESIGN

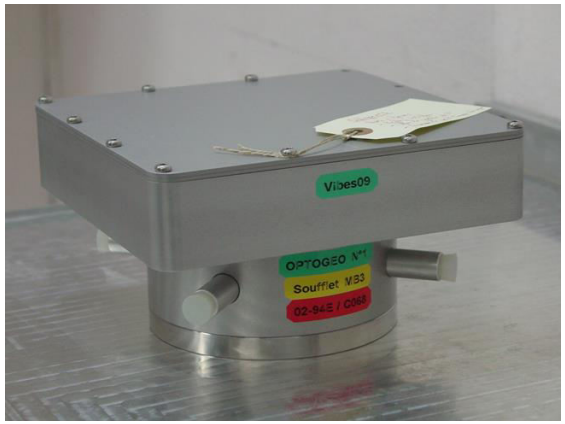
Objectives:

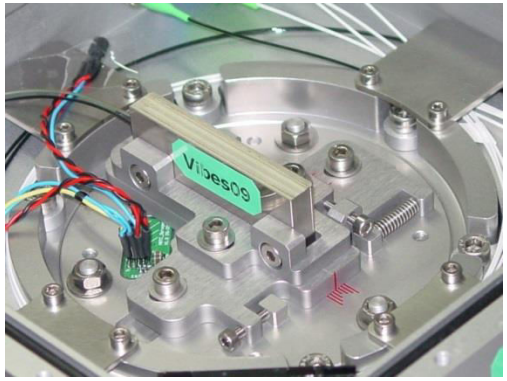
- to characterize the main components (aneroid bellows, interferometer)



6 prototypes

- 3 with a MB3a bellows (OptoGeo 1,2,3)
- 3 with a MB2005 aneroid bellows (OptoGeo 4,5,6)

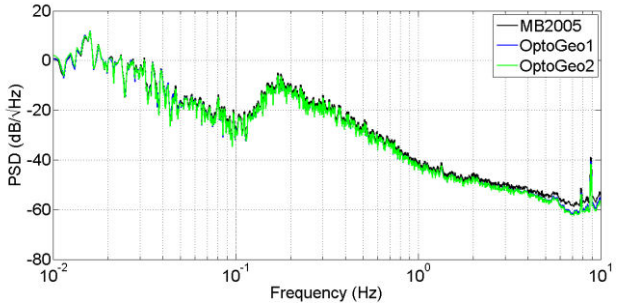


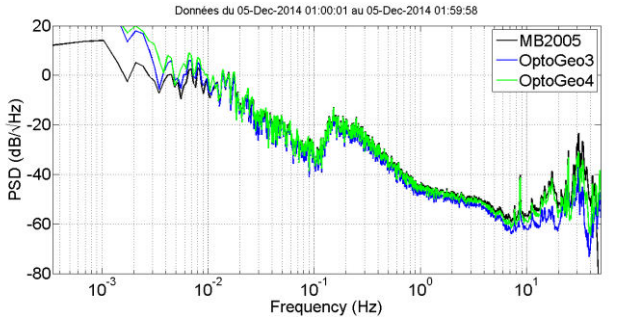


FIRST DESIGN MEASUREMENTS

Experiment:

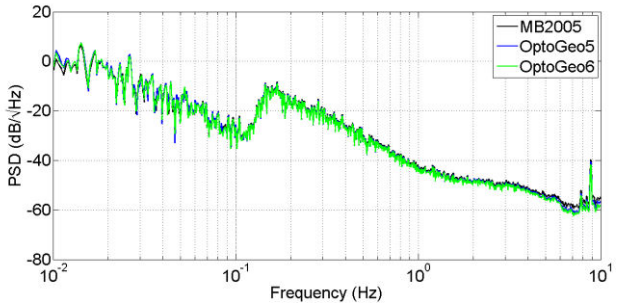
- 6 OptoGeo + 1 MB2005 (reference sensor)
- Observations of the same signal
- Comparison between each sensor measurement to validate the OptoGeo measurement



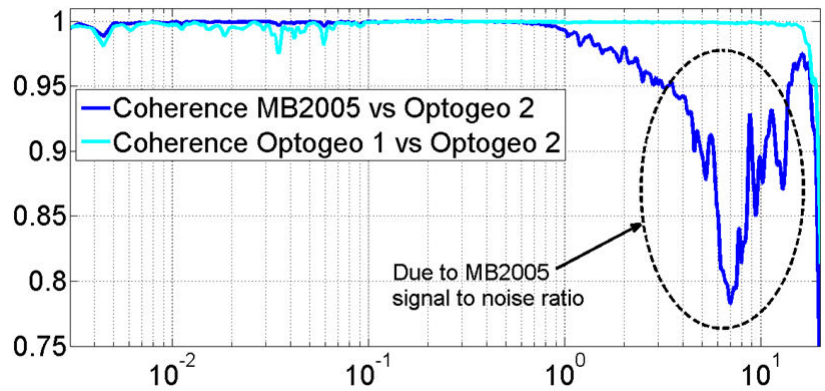


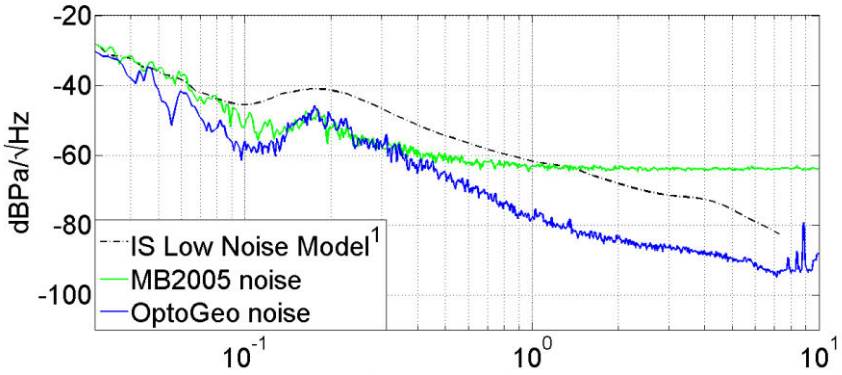
Results:

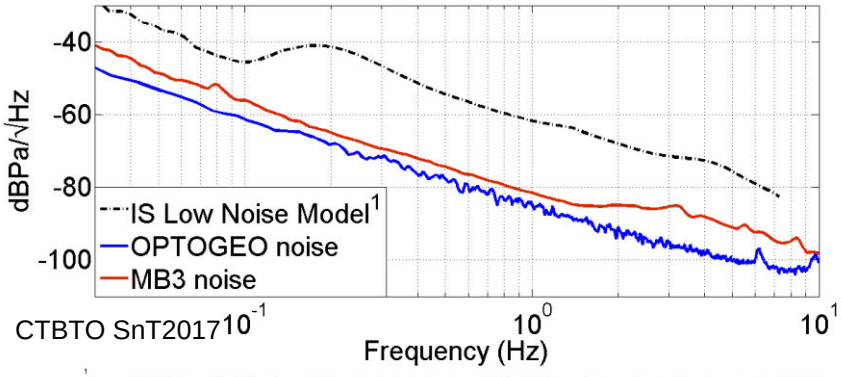
- Signal PSD is similar for all sensors in a wide bandwidth
- High frequency: seismic sensitivity



FIRST DESIGN MEASUREMENTS







[1] Bowman, J. R, G. Shields and M S. O'Brien, *Infrasound station ambient noise estimates and models: 2003-2006*, Infrasound Technology Workshop, Tokyo, Japan, November 13-16, 2007.

Coherence:

- Between MB2005 and each OptoGeo:
  - > 0,98 on a large bandwidth
  - f > 1 Hz: noise level of MB2005
- Between 2 OptoGeo:
  - > 0,98 on all the bandwidth

Noise evaluation:

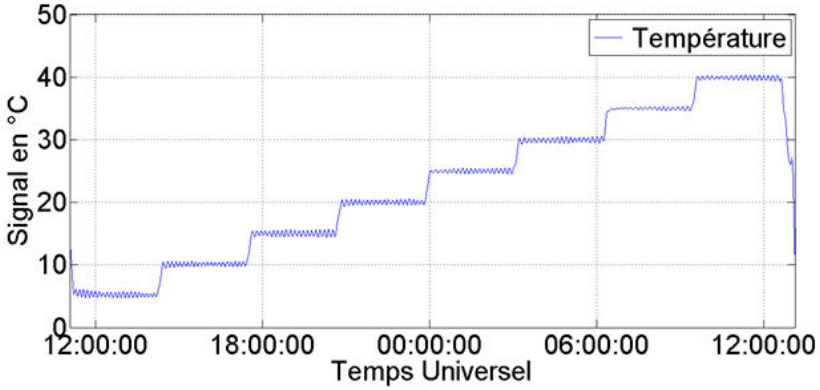
- 2 sensors method (Holcomb, L.G., 1989)
- Better noise for OptoGeo than MB2005
- Between 0,1 and 0,3 Hz: due to evaluation method

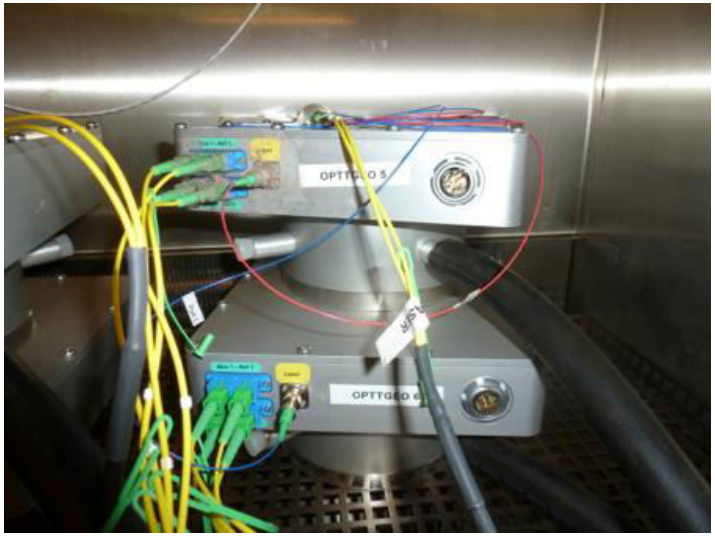
- Optimization of measurement cavity
- Noise measurement
- Better noise than MB2005 and MB3

FIRST DESIGN MEASUREMENTS

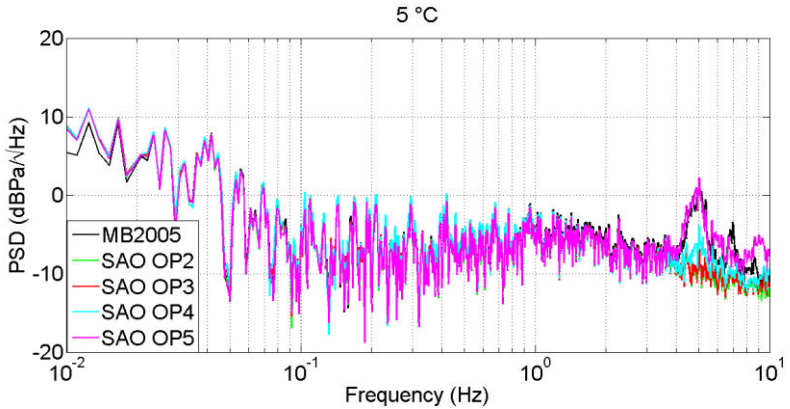
Thermal test:

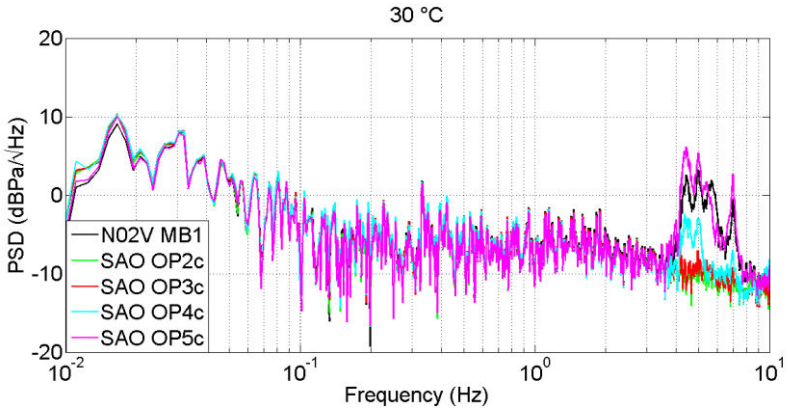
- Temperature from 5 to 40 °C
- Steps = 5 °C

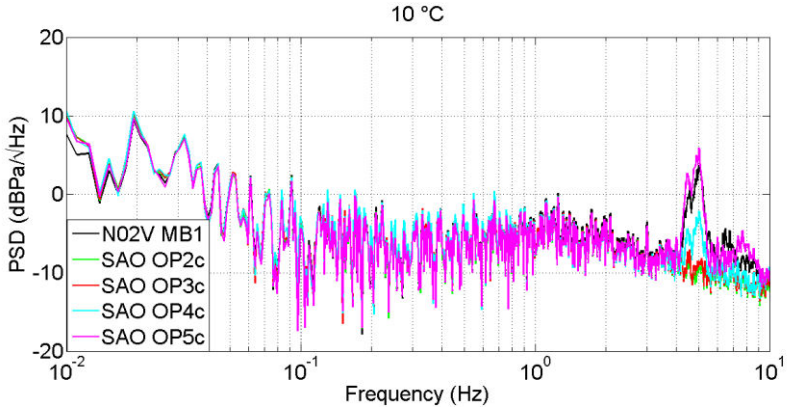


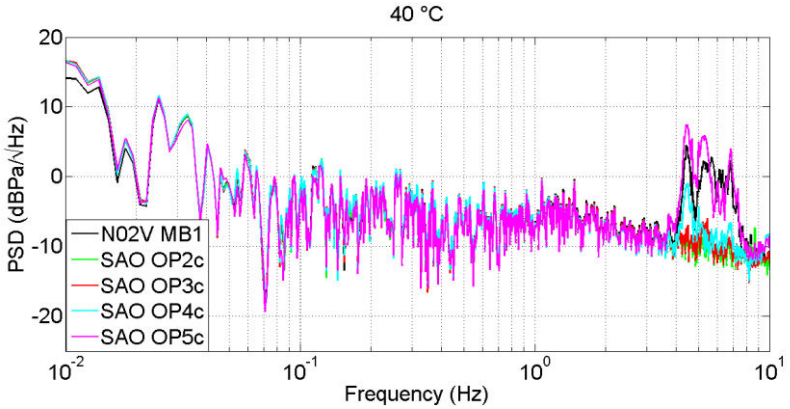


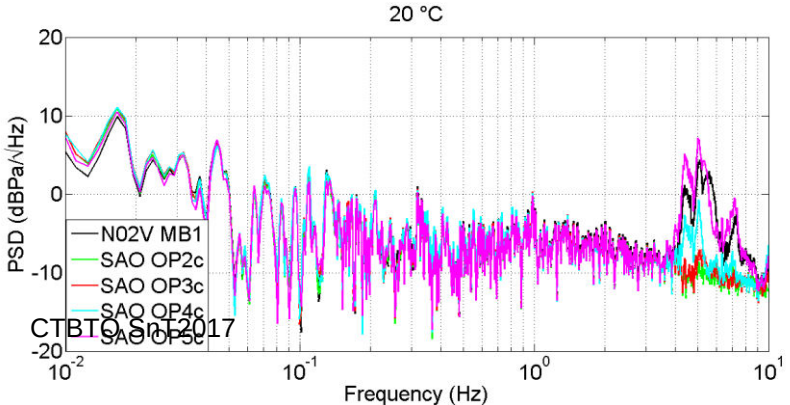
FIRST DESIGN MEASUREMENTS











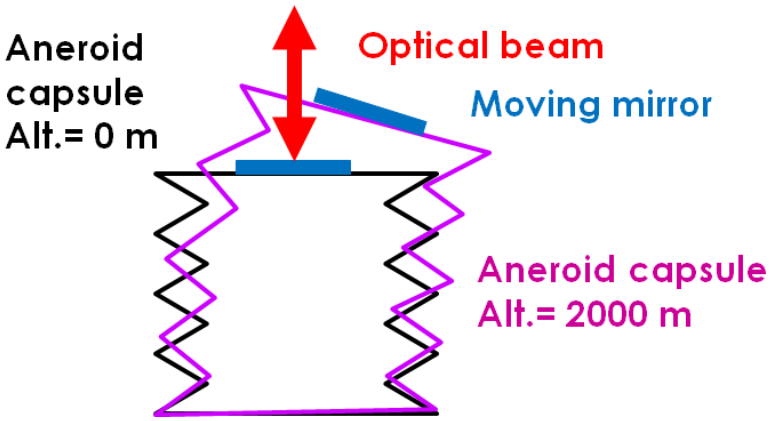
Results:

- Thermal effects on sensitivity comparable to MB2005

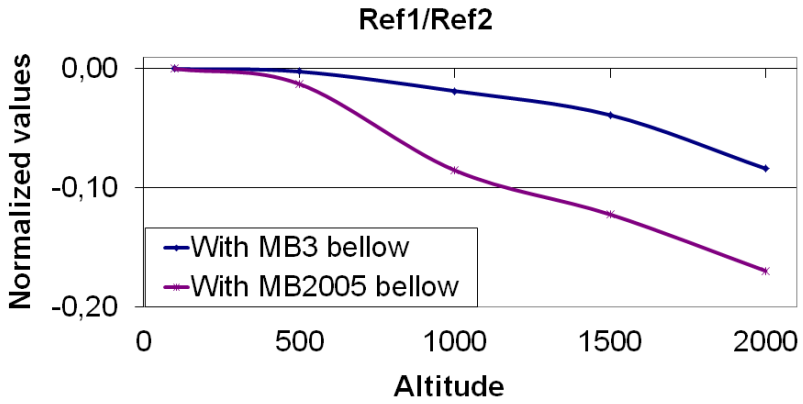
FIRST DESIGN MEASUREMENTS

Effects of altitude:

- Expected: no effect due to interferometric measurement principle
- Transversal deformation due to symmetrical errors during manufacturing



- Measurement: The 2 photometric signals at 5 different altitudes



Results:

- No complete loss of reflected optical beam: OptoGeo always gives reliable measurements
- Lower effects for OptoGeo with MB3 aneroid bellows
- Larger operational range than MB3&MB2005

- **Optogeo will be usable in all CTBTO stations without any adjustment**

FIRST DESIGN

Sum up:

- Significantly lower noise than MB2005 and slightly lower than MB3 
- Temperature effects on sensitivity: similar to MB2005/MB3 microbarometers 
- Altitude effects:
  - Larger operational range than MB3&MB2005 
  - No adjustment

Conclusion:

- Encouraging results for the following design
- Choice of MB3 aneroid bellows
- Following design: interferometer inside the aneroid bellows
  - optical components protection (humidity, dust, …)

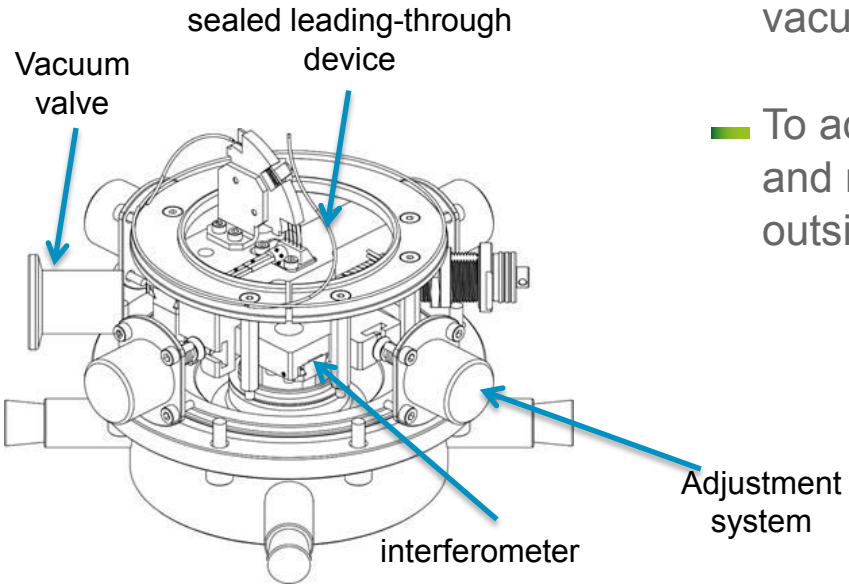
SECOND DESIGN

Goal:

- Insert the interferometer inside the aneroid bellows, under vacuum
  to avoid environmental perturbations (humidity, dust, …)

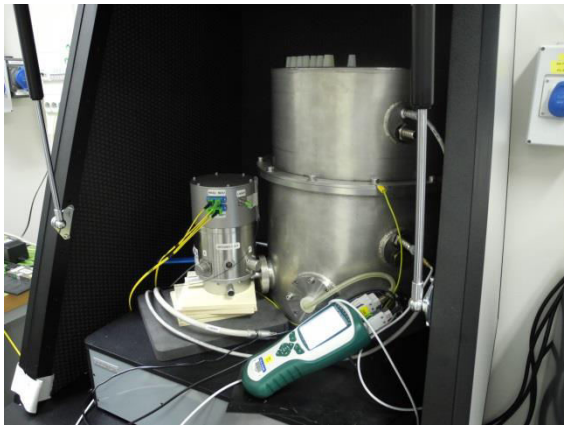
4 prototypes

- With MB3 aneroid bellows
- Challenges:
  - Smaller interferometer under vacuum
  - To adjust the interferometer and mirror positions from the outside of aneroid bellows

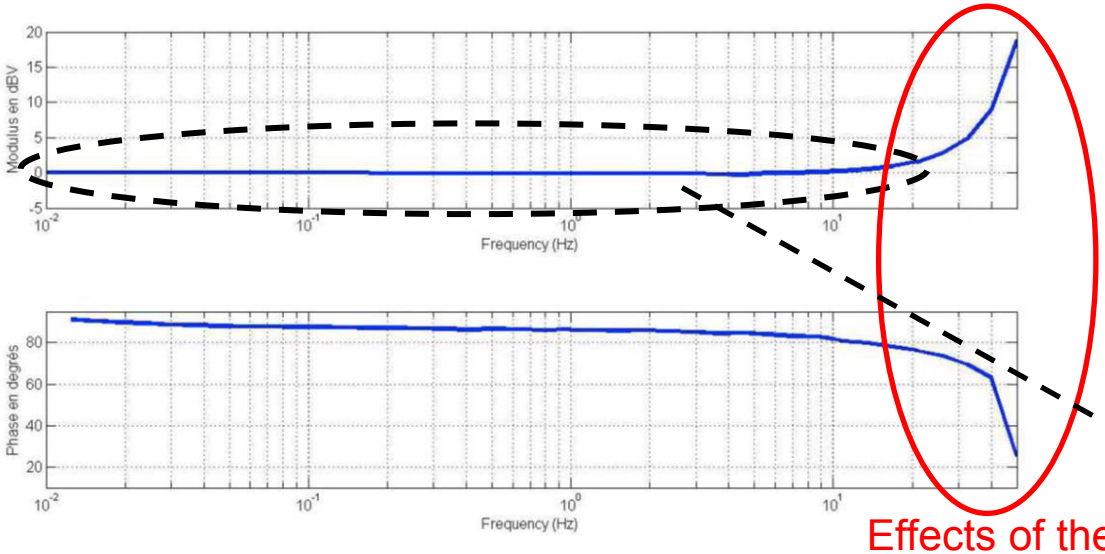


SECOND DESIGN EXPERIMENT

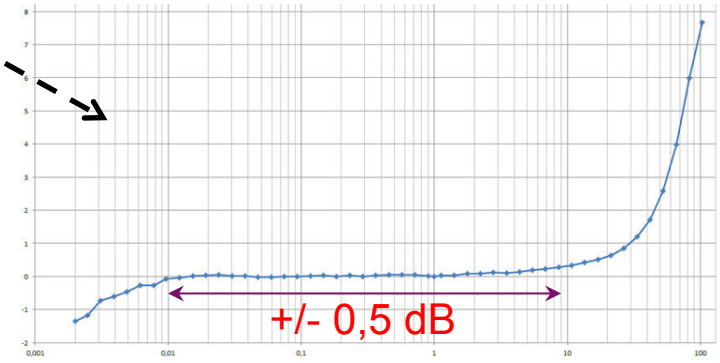
Transfer function measurement:



- Use of infrason metrology test bench (IS Calibrator)



Effects of the test bench



- Flat response on a large bandwidth

CONCLUSION

SUM UP

- Lower noise than MB2005 on all the bandwidth
- Temperature effects: similar to present microbarometers
- Altitude effects: no adjustment
  - Better static dynamic
- Flat instrumental response on all the bandwidth: interesting for metrology (possibility for secondary standard)
- Very interesting results
- Feasibility prouved

FUTURE WORKS

- Robustness of optical fiber connectors
- Mechanical design to improve (adjustment bellows, …)
- « Optical » digitizer: lower noise, lower consumption
- Quality of the laser source (lower phase noise)

Application for seismic VBB sensors: launching a new 3 years program of R&D (Project under contractualization with DGA)

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