# Design and development of an interferometric readout for planetary seismometers

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Journée des doctorants APC

# Outline

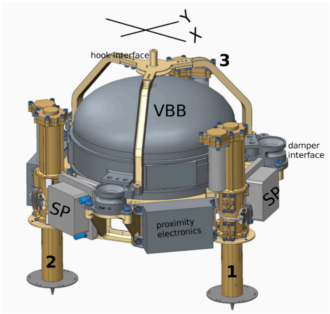
- Introduction
- Context
- General principle
- PDH technique
- Work in progress
- Conclusion

# Introduction

- ***In**terior Exploration Using **S**eismic **I**nvestigation, **G**eodesy, and **H**eat **T**ransport* :

  - 2 instruments (1 designed by IPGP: SEIS (3 **VBB**s))
  - Composition & Structure of Earth-like planets + Formation & Evolution
  - Delayed mission (2018)

- Analytical model for mechanical transfer function of the SEIS levelling system

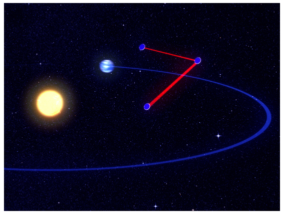



=> Comparison between 2 different sensors: InSight's VBBs & optical seismometer

# Context

- New generation of seismometers with improved performances :
    - Linearity
    - Noise level

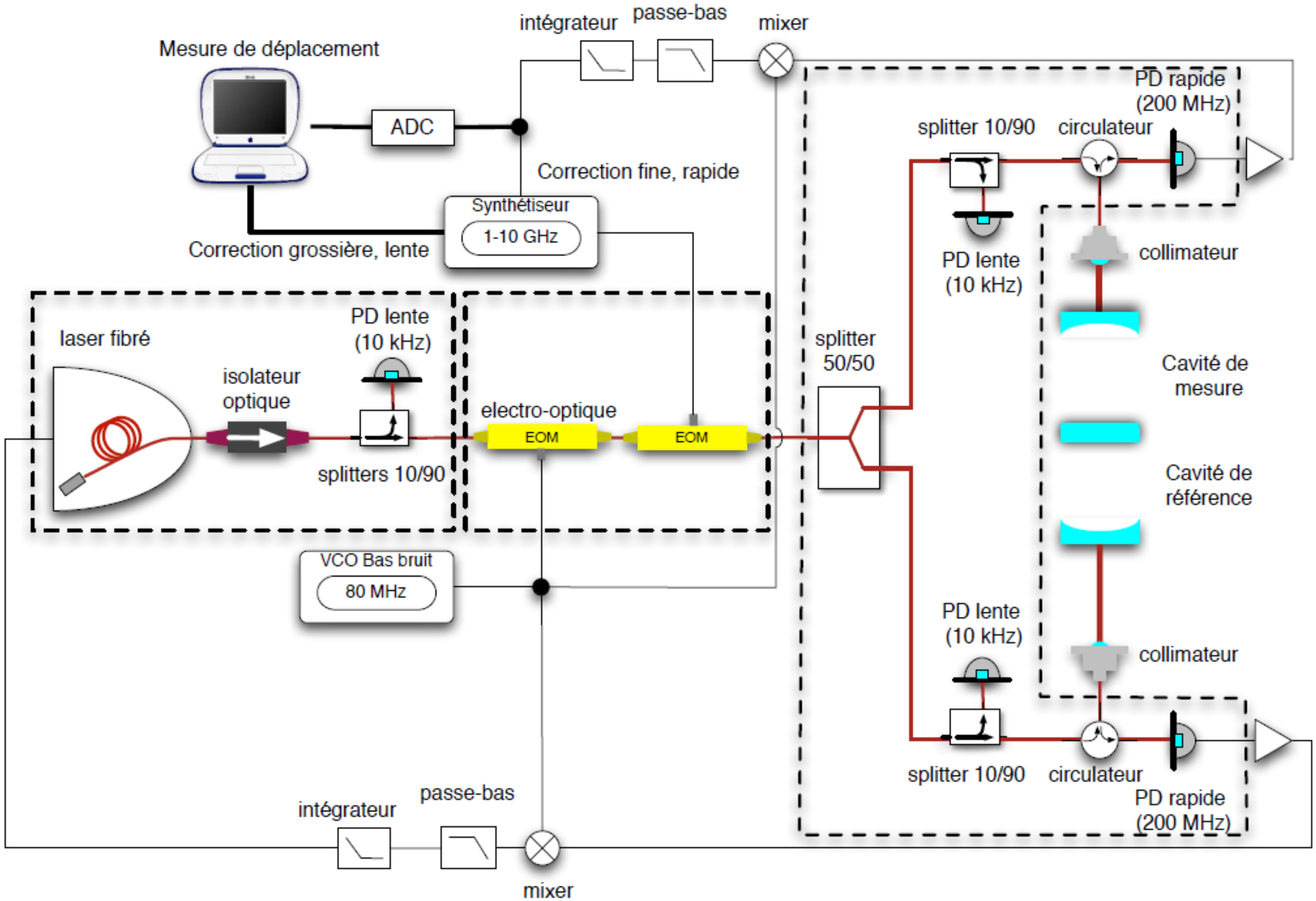
- Expertise in APC : interferometric measurements at low frequencies and very low noise levels



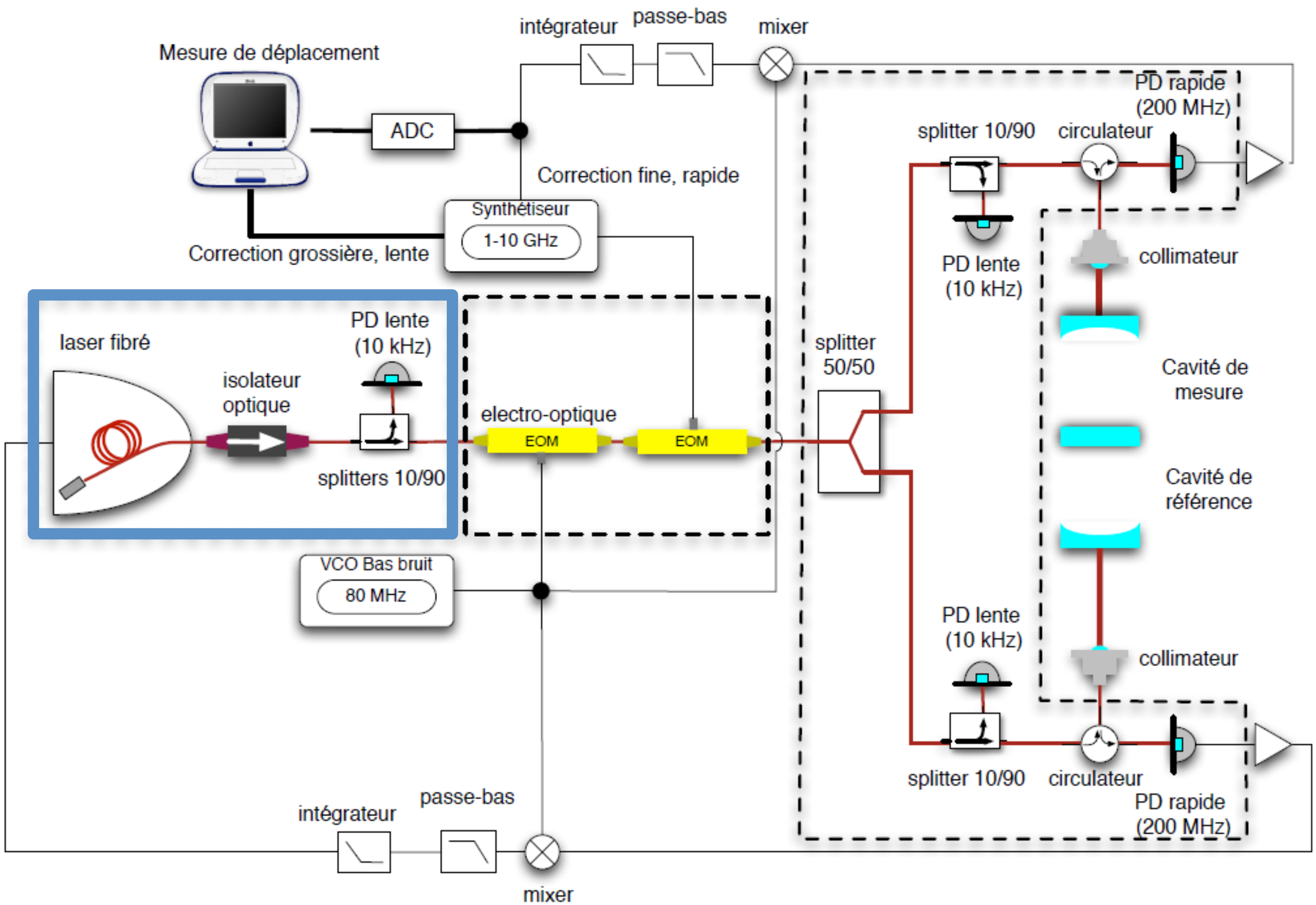
⇒ Objective : improve the sensibility by 2 orders of magnitude

Ex : InSight VBBs -> 4pm at 1 Hz

# General principle



# General principle



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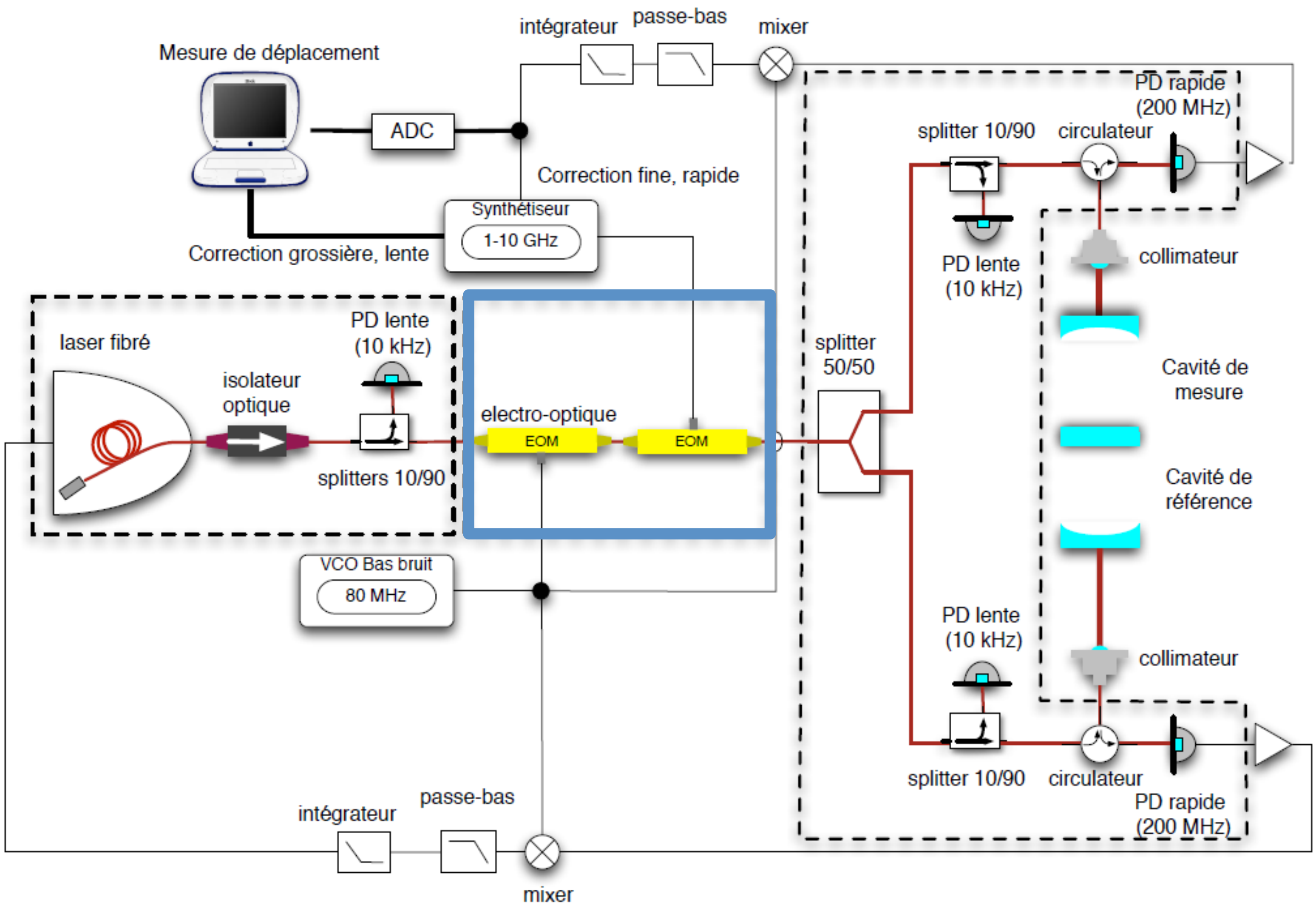

# PDH technique

- EOM : phase modulation $\beta.\sin(\omega_m.t)$

Signal (1st order): $V(t) = V_0.e^{i\omega t} + V_0.\frac{\beta}{2}.e^{i(\omega+\omega_m)t} + V_0.\frac{\beta}{2}.e^{i(\omega-\omega_m)t}$

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Carrier

Sidebands

# PDH technique

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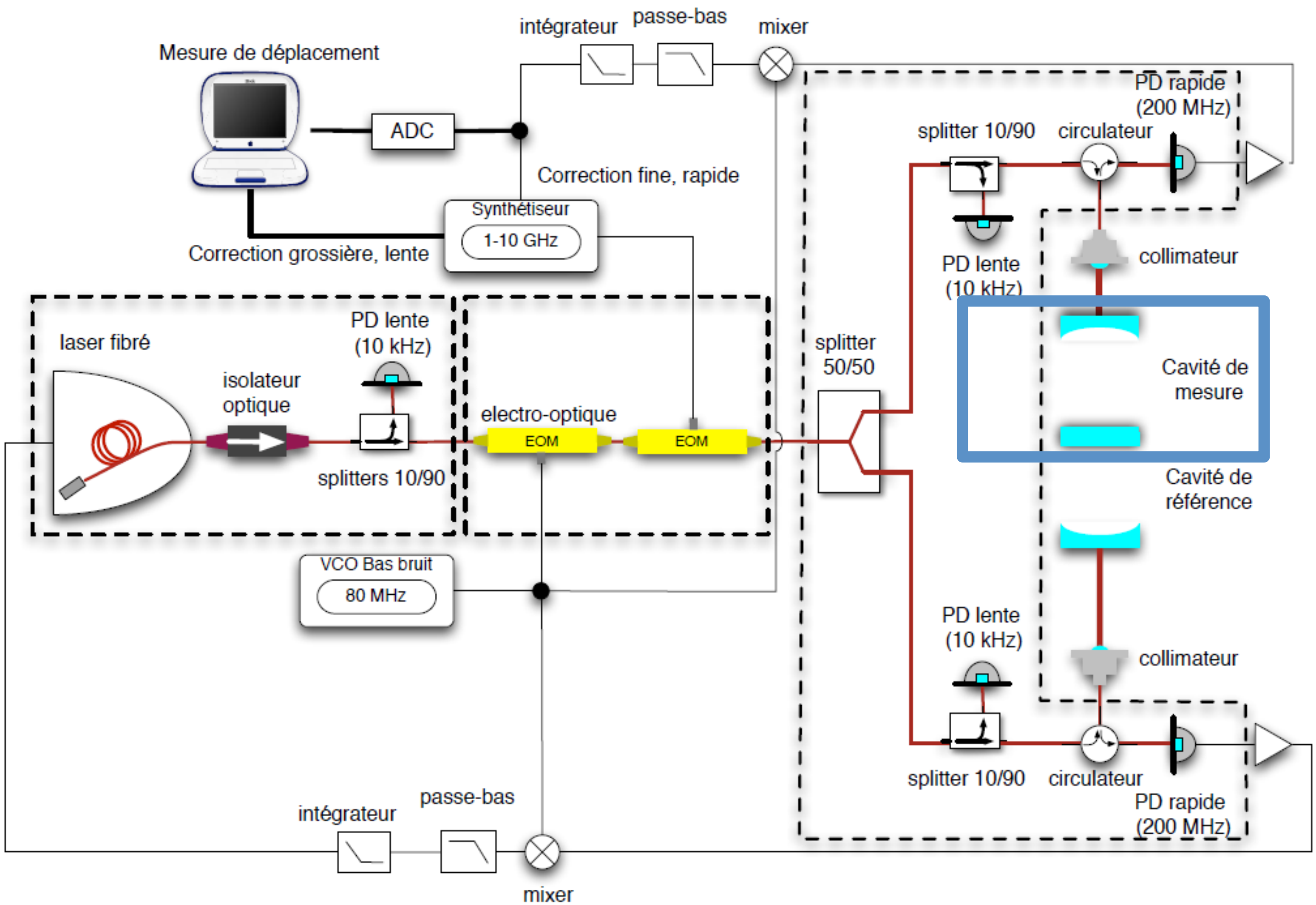
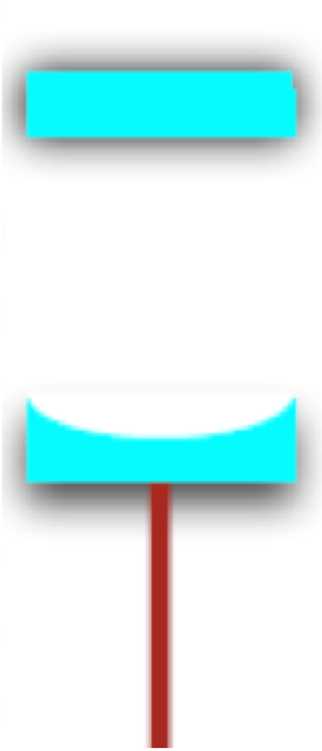
Carrier          Sidebands

⚠ Our case : 2 EOM => 8 sidebands

# General principle



# PDH technique



- $E_r$ = reflected light out of the FP cavity
- $E_{in}$ = incident light on the cavity

Transfer Function

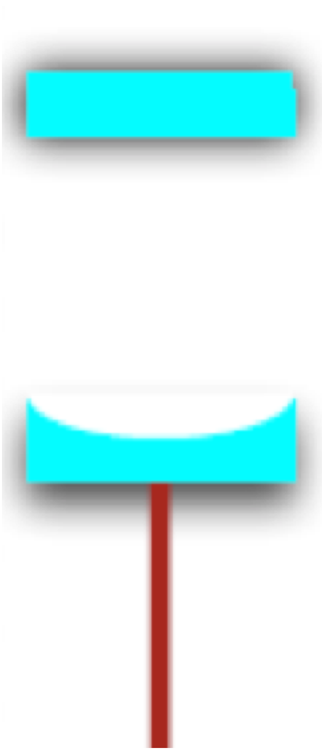
⇩

$$R(\omega) = \frac{E_r}{E_{in}} = \frac{-r_1 + (r_1^2 + t_1^2) r_2 e^{i2\alpha}}{1 - r_1 r_2 e^{i2\alpha}}$$

With :

- r : reflection coefficients of mirrors 1 and 2
- t1 : transmission coefficient of the mirror 1
- $\alpha = \omega L/c$

# PDH technique



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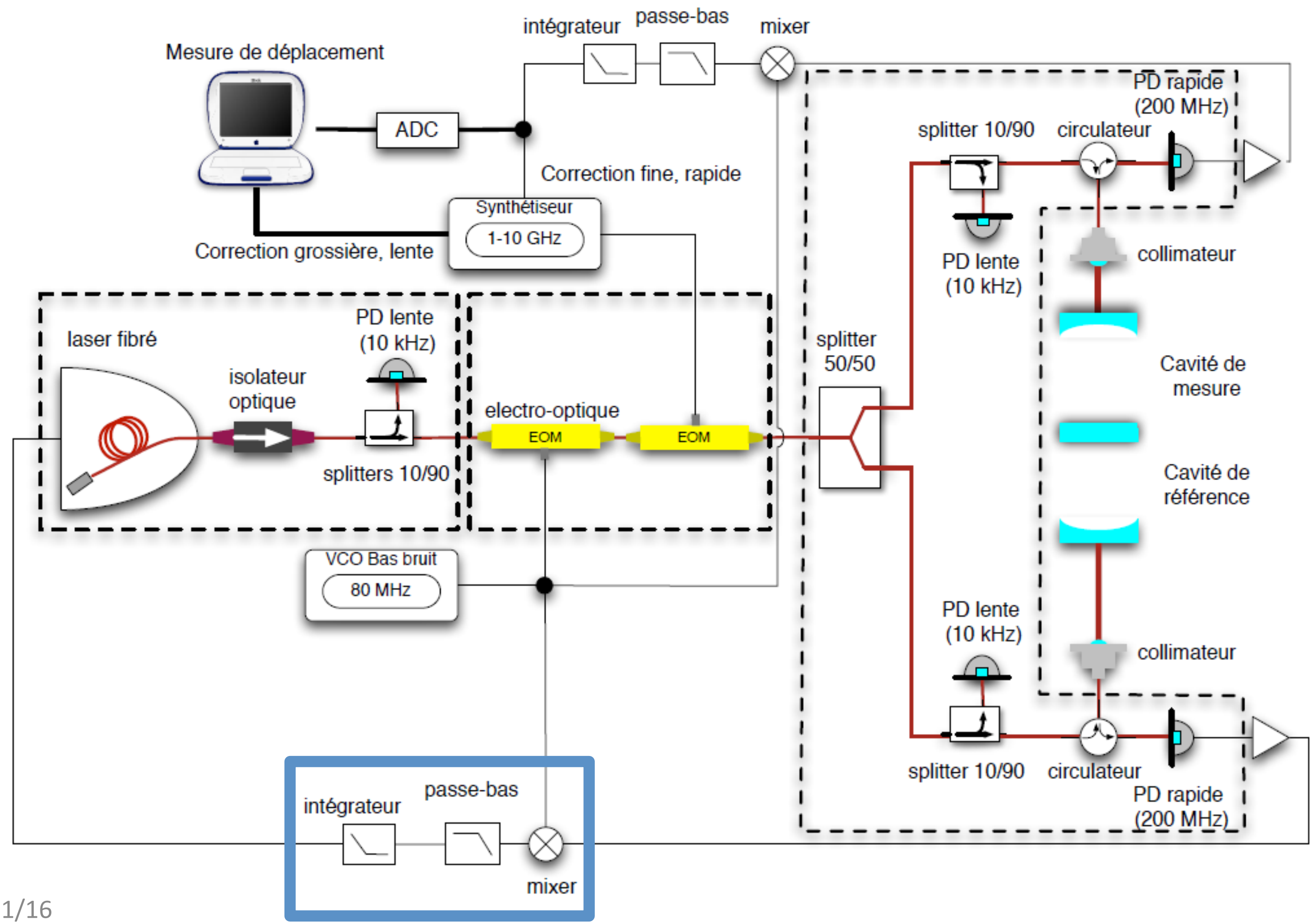
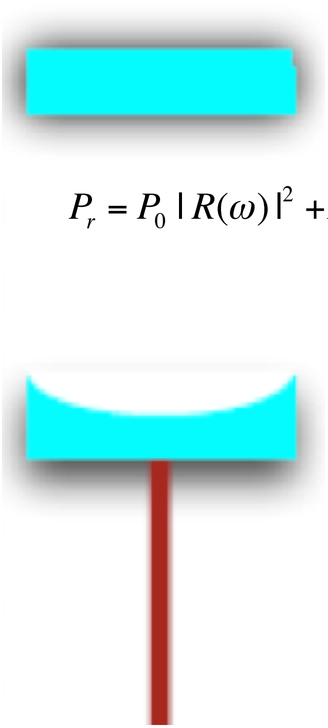
New signal : unaltered sidebands + phase shifted carrier

# General principle



# PDH technique

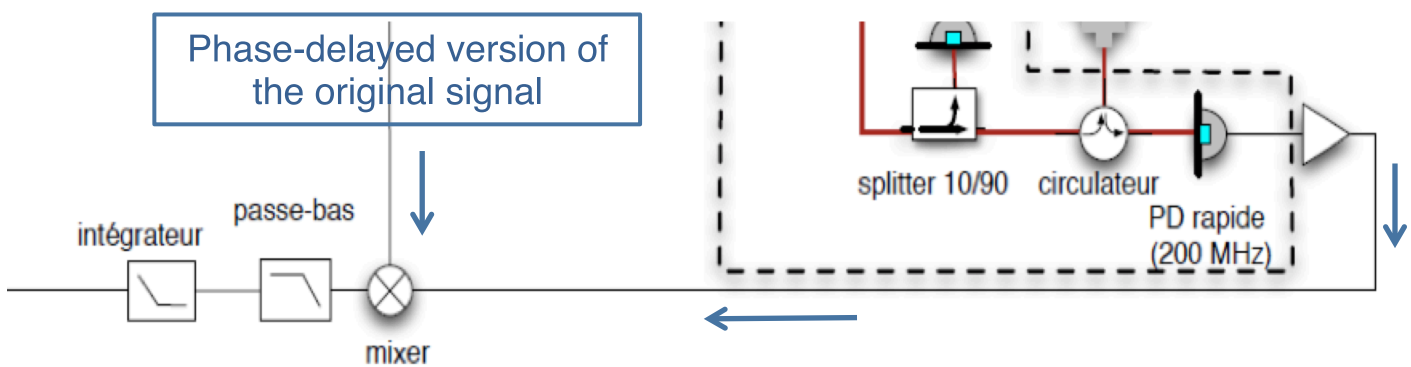


- Power :

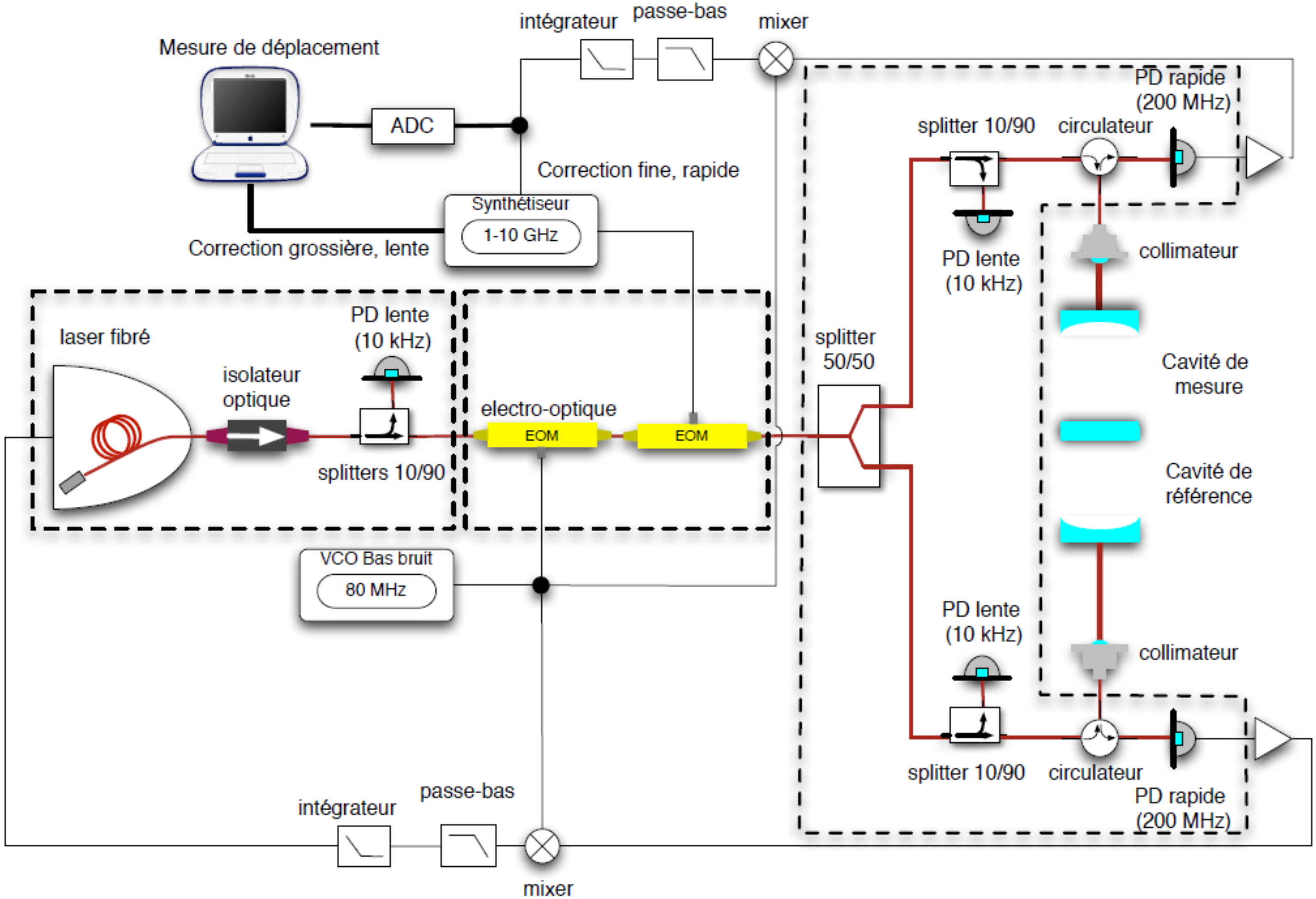
$$P_r = P_0 |R(\omega)|^2 + P_0 \frac{\beta^2}{4}\{|R(\omega+\omega_m)|^2 + |R(\omega+\omega_m)|^2\} + P_0\beta\{\mathrm{Re}[\chi(\omega)]\cos\omega_m t + \mathrm{Im}[\chi(\omega)]\sin\omega_m t\} + (2\omega_m terms)$$

$\chi$ is a function of $(\omega-\omega_{res})$

- Extraction :



# General principle



# Work in progress

- Mechanical prototype for cavity

| MAJOR CONSTRAINTS | |
|---|---|
| CONSTRAINT | SOLUTION |
| Vacuum resistance | Outgasing the material (under vacuum during a long period) before use |
| Minimization of cavity possible deformations under heat stress | Use of Invar material: good thermal properties, not expensive and possibility of complex shapes |
| Minimization of cavity possible deformations under vibratory stress (isolation in the range 10-2-1Hz) | Hopeless : no isolating materials at these frequencies!<br><br>For the moment: isolation guaranteed above 10Hz + cylinder design (to maximise dynamical properties) and massive cavity (to increase eigenfrequency) |

# Work in progress

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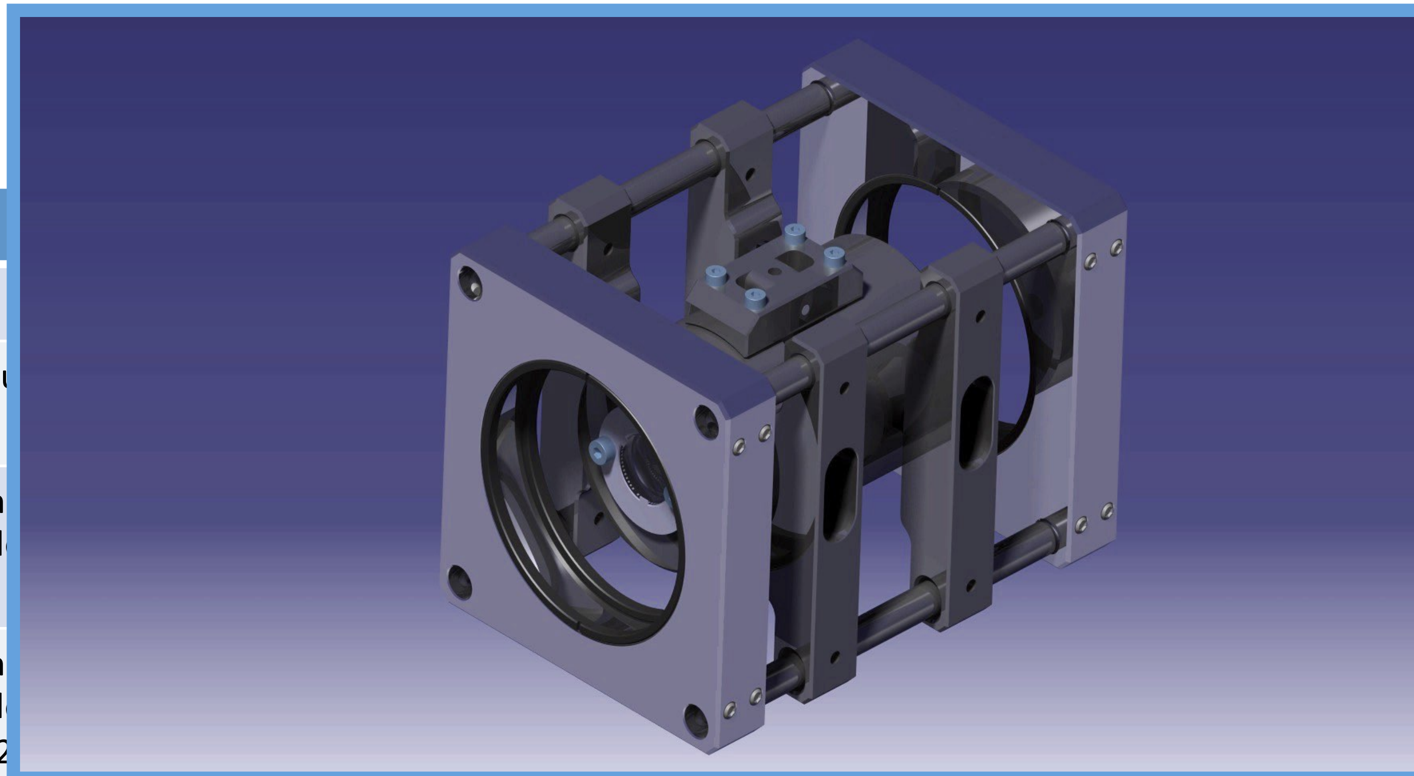

| | |
|---|---|
| | |
| Vacu | a |
| Min<br>und | s,<br>es |
| Min<br>und<br>10-2 | For the moment: isolation guaranteed above 10Hz + cylinder design (to maximise dynamical properties) and massive cavity (to increase eigenfrequency) |

# Work in progress

- Next :
  - First resonating cavity
  - First noise measurements

# Conclusion

- Noise level have to meet our expectations
- Performances comparison between InSight's VBBs & optical readout
- Final objective : optical seismometer prototype ≈ Next generation of planetary seismometers
- On Moon or Mars : better knowledge of internal structure