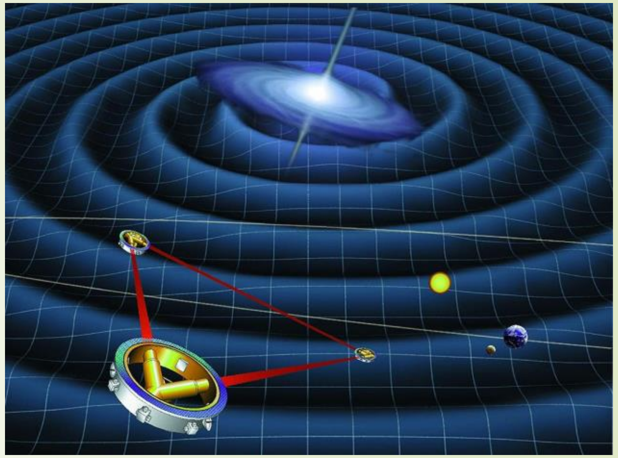


Phase A LISA detector activities @ ARTEMIS - stray light and photoreceivers -

Nicoleta Dinu-Jaeger

- *LISA Project Manager @ ARTEMIS/OCA*

GdR, Detectors OG, 25/06/2019

LISA Stray Light activities @ ARTEMIS

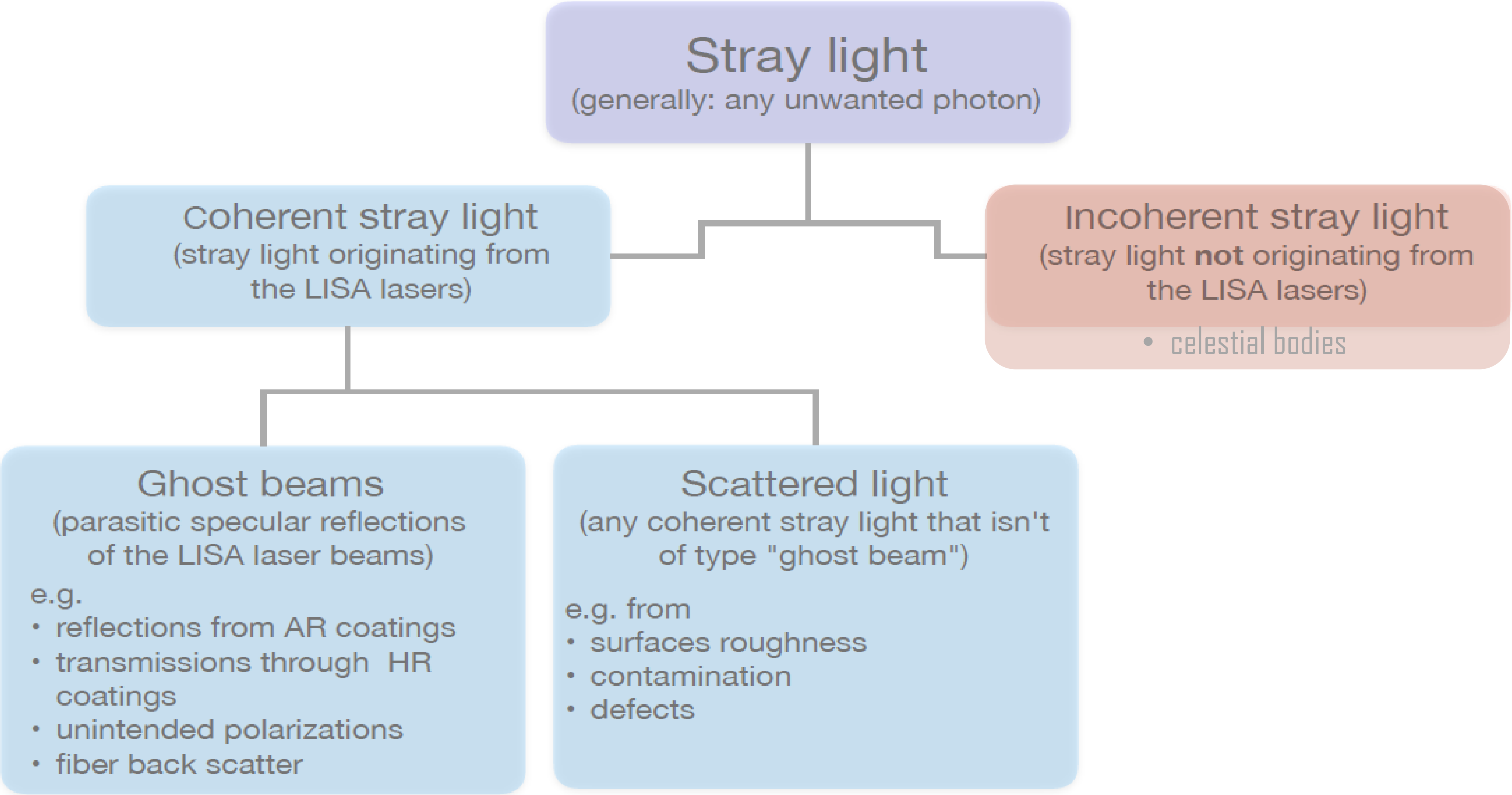
- *Main contributors: M. Lintz, V. Khodnevych, D. Huet, S. di Pace, JY. Vinet*

Financial support:
- *R&T CNES*
- *PACA Region (thesis V. Khodnevych)*
- *OCA & UCA*

LIG Stray light Working Group

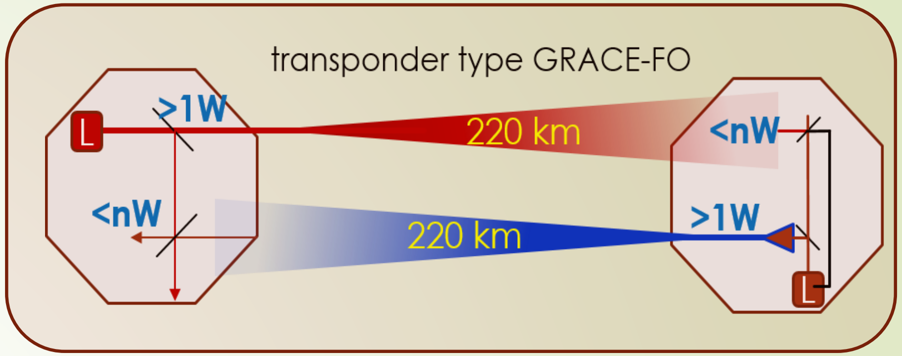
- One of the Working Groups of LISA Instrument Group (LIG)
  - Chairs: Gudrun Wanner (Albert Einstein Institute, Hanover), Michel Lintz (ARTEMIS/OCA, Nice)
- Contributors
  - Germany: Albert Einstein Institute (Hanover)
  - UK: Glasgow Univ. & UK Astronomy Tehn. Center, Edinburg
  - US: NASA Goddard Greenbelt, Florida Univ., Gainesville
  - ESA/ESTEC, Noordwijk
- French Contribution
  - APC (Univ. Paris Diderot)
  - ARTEMIS (Observatoire de la Côte d'Azur, CNRS et UCA Nice)
  - Institute Fresnel (Marseille)
  - LMA (Univ. Claude Bernard, Lyon)
  - *CNES (P. Etcheto, D. Faye)*

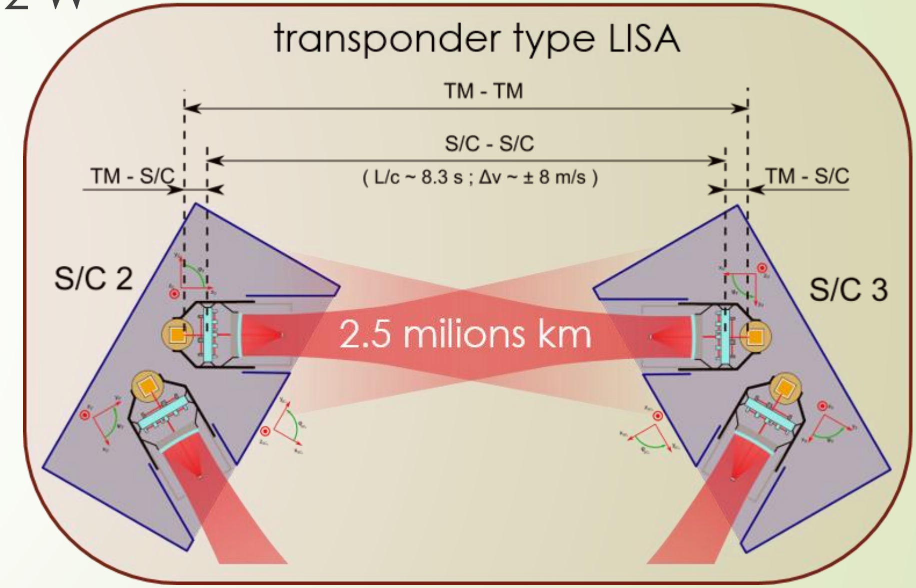
Terminology / types of stray light



Stray light in LISA

- LISA interferometric schema
  - "Transponder" type
    - Similar to interferometric scheme of Grace-FO
      - Received beam, Rx < 1nW vs. transmitted beam Tx ~1-2 W
    - LISA instrument particularity
      - The same telescope at emission and reception
        - Backscatter light by telescope is evident problem
  - Heterodyne type
    - "2 photons/s" detection

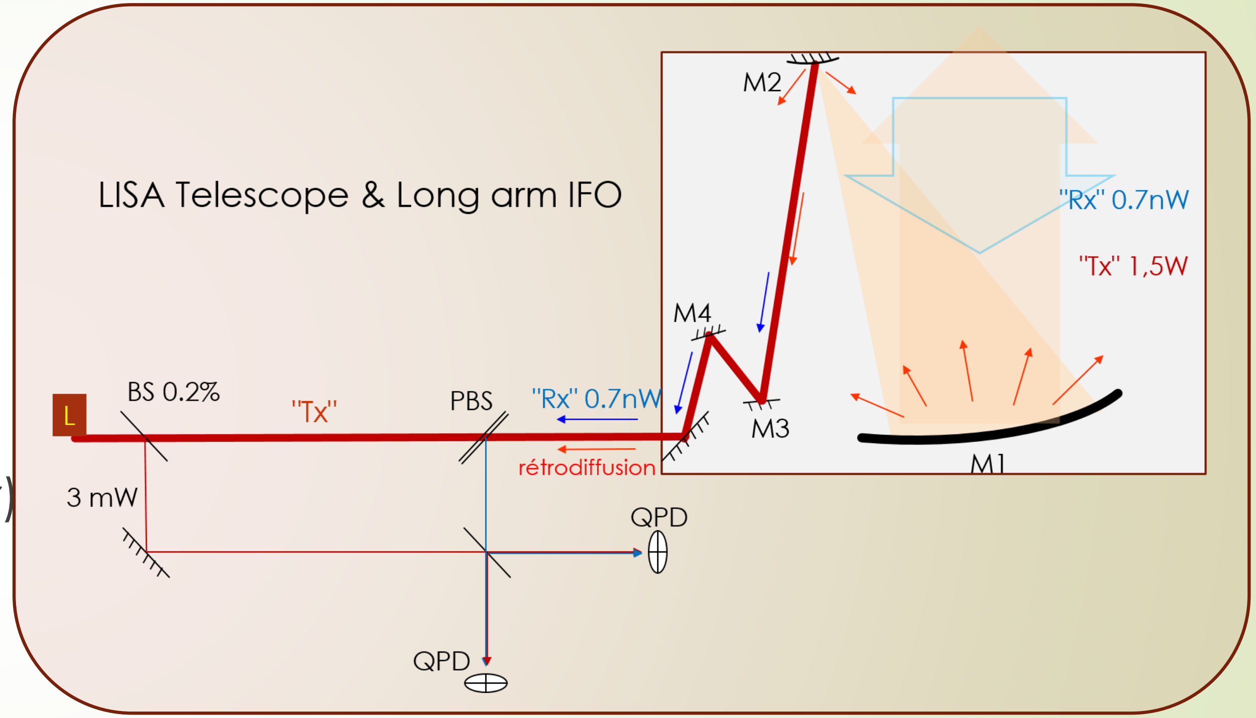




- LISA strain sensitivity allocation: ~16.5 x 10^{-21} /√Hz
  - Single link displacement noise: ~10 pm/√Hz
  - Phase measurement noise: ~ several µrad/√Hz
  - ***Request: Stray light measurement floor of ~ 10^{-12} or below***

Items related to LISA stray light work

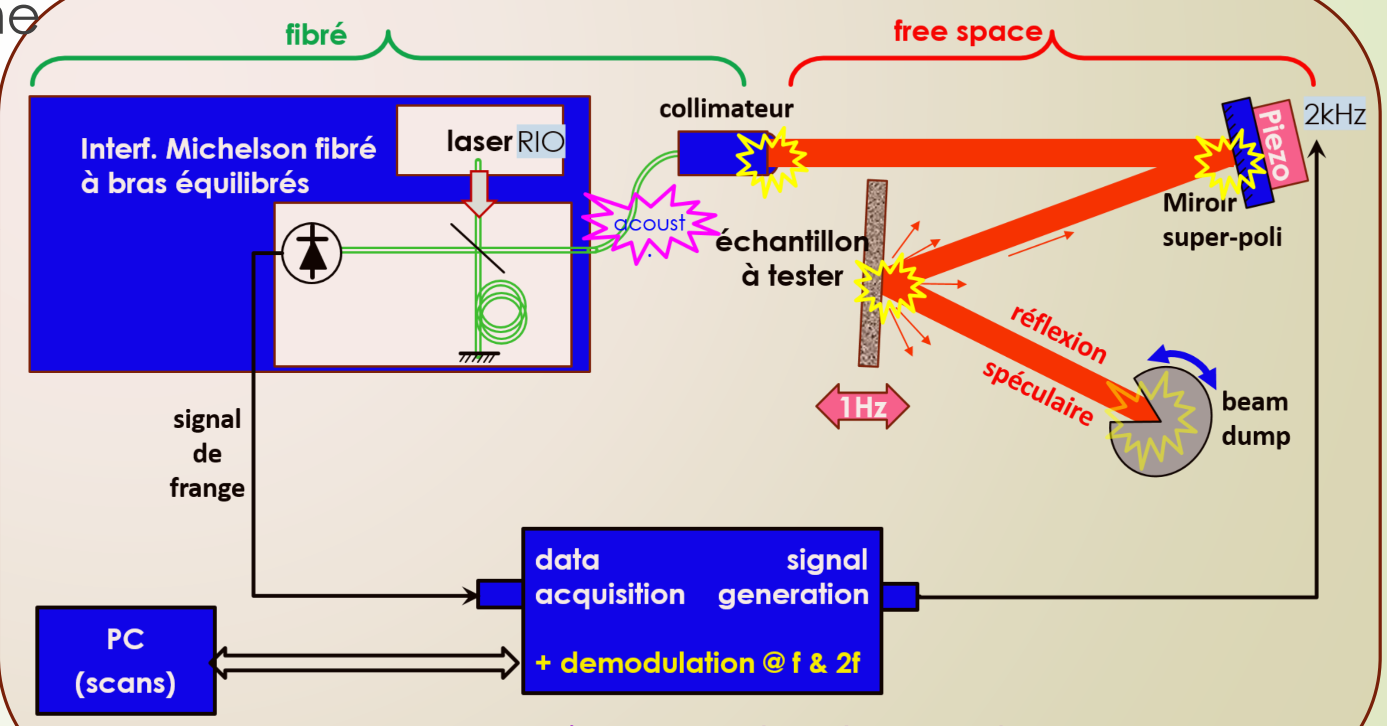
- Evaluate the noise level originating from stray light
  - Coherent stray light
    - Tx => long arm IFO
    - Rx => long arm IFO
    - Parasitic reflections & transmissions
  - Incoherent stray light
    - Stars, planets => long arm IFO
    - Tx => CAS (Constellation Acquisition Sensor)



- Provide protections against stray light
  - Rejection efficiency
  - Easy integration
- Prepare & perform measurements, characterization, particularly during AIVT
  - Guaranty a low level stray light before the launch

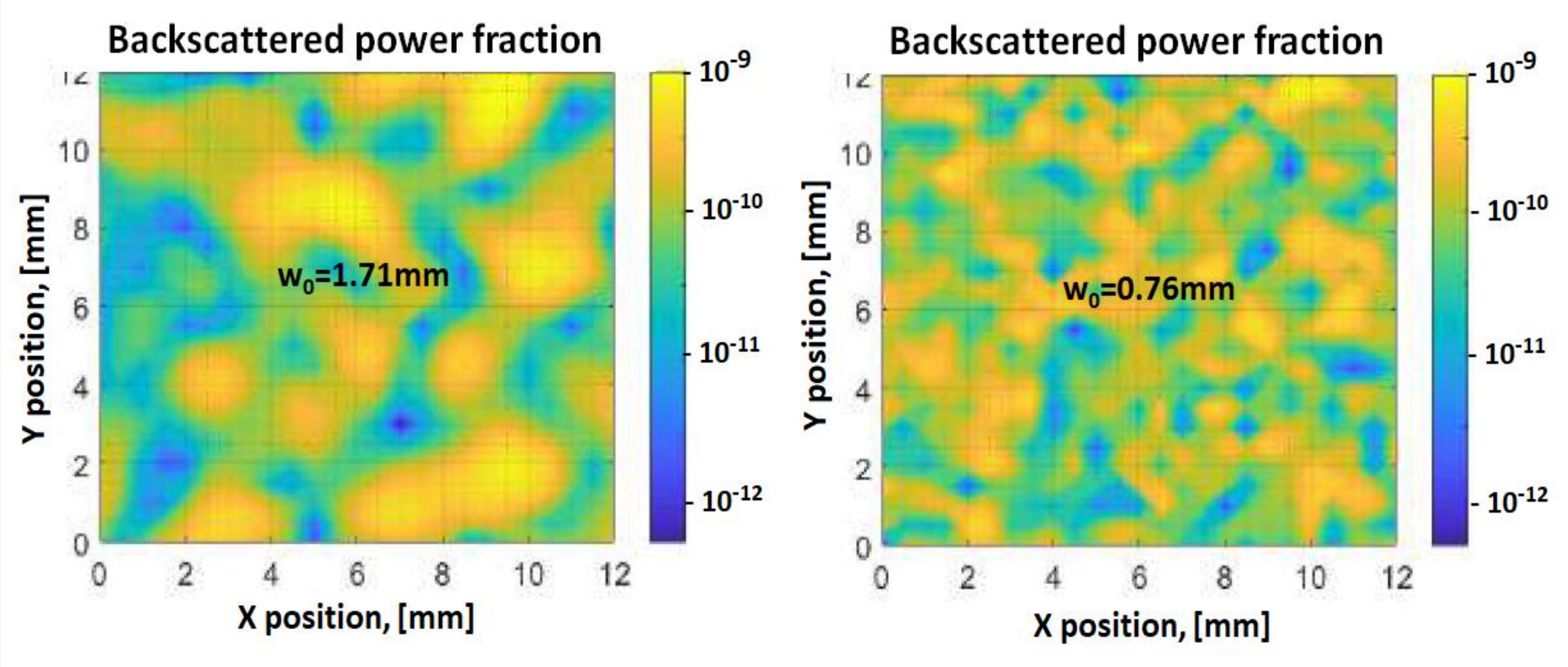
Experimental stray light studies @ ARTEMIS

- Set-up dedicated to the measurement of the coherent backscattered light on simple optical components presenting roughness or dust contamination
  - Michelson fiber interferometer of equal arms (laser wavelength @ 1.55 μm)
  - Data analysis challenge
    - Need to take care of any stray light source
    - Modulation/demodulation scheme
- Obtained detection limit of coherent backscattered light down to 10^{-13} in optical power
- Dependence of measured backscattered on
  - Spot position on the sample under test
  - Incident angle
  - Polarization



M. Lintz, V. Khodnevych

Speckle property of the backscattered light

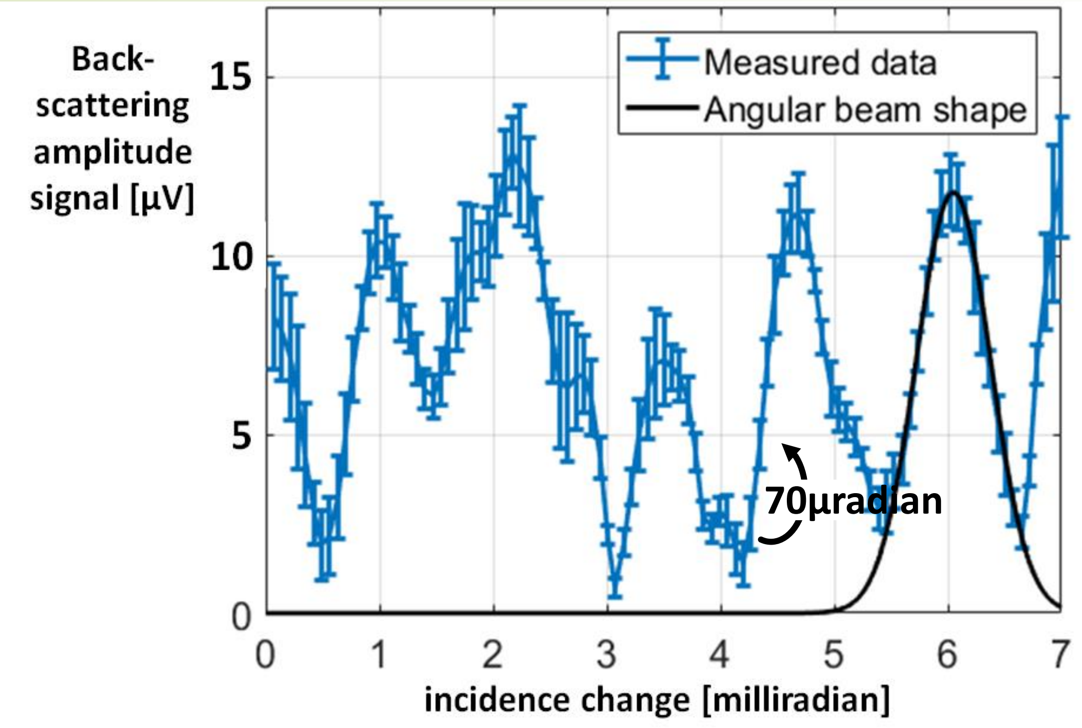


Incident angle
- 14°

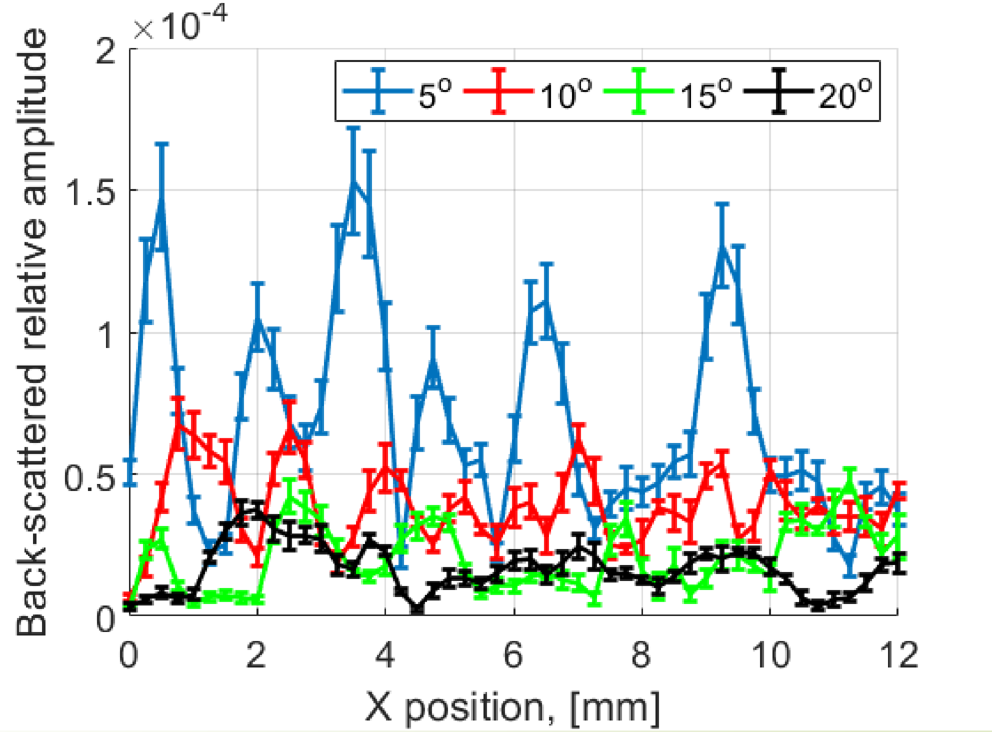
- Backscattered signal
  - Random vs position ("speckle" shape), but perfectly reproducible if the incident angle is constant
- Main speckle characteristics
  - Reveals the random character of the mirror roughness (roughness of mirror under test: 150Å RMS)
  - Speckle grain ~ beam size

Speckle properties : angular scans

Scanning over a small angular range (around 14°)



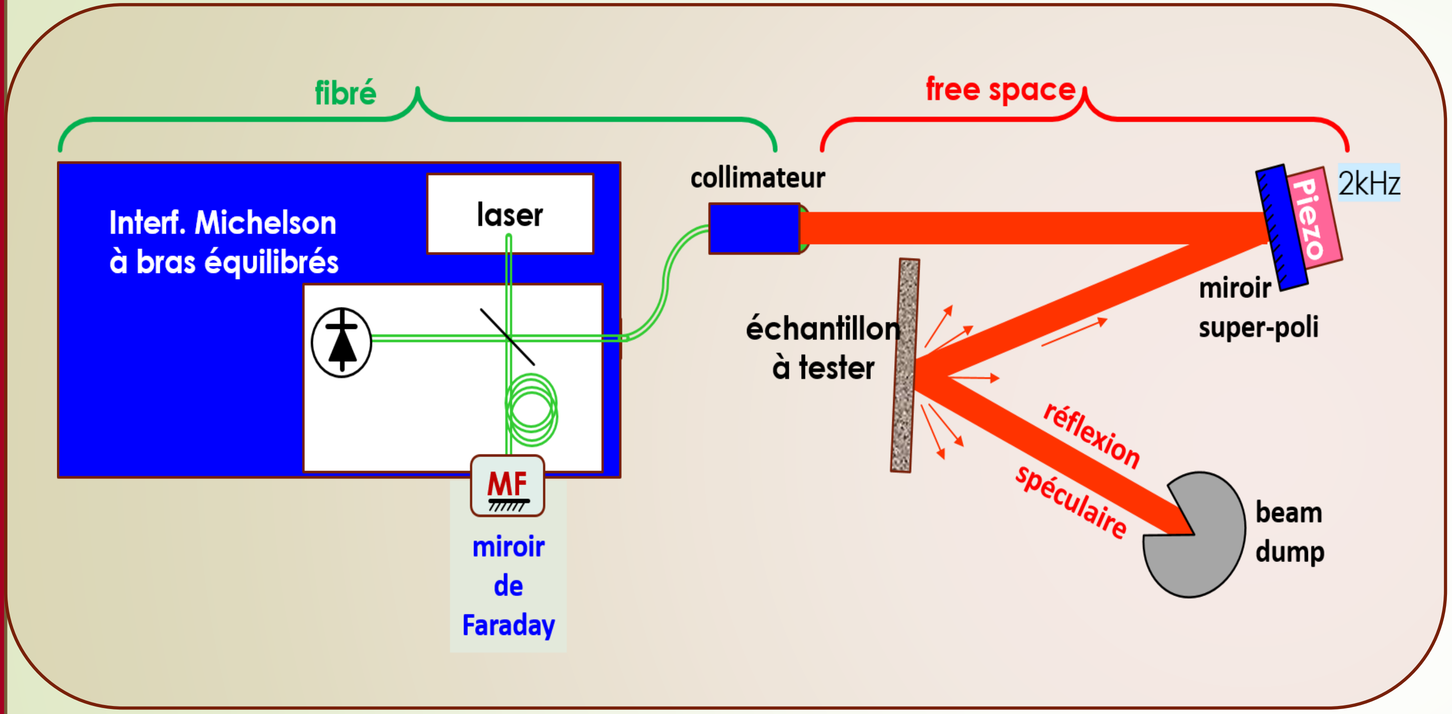
Scanning the incidence over large angular ranges

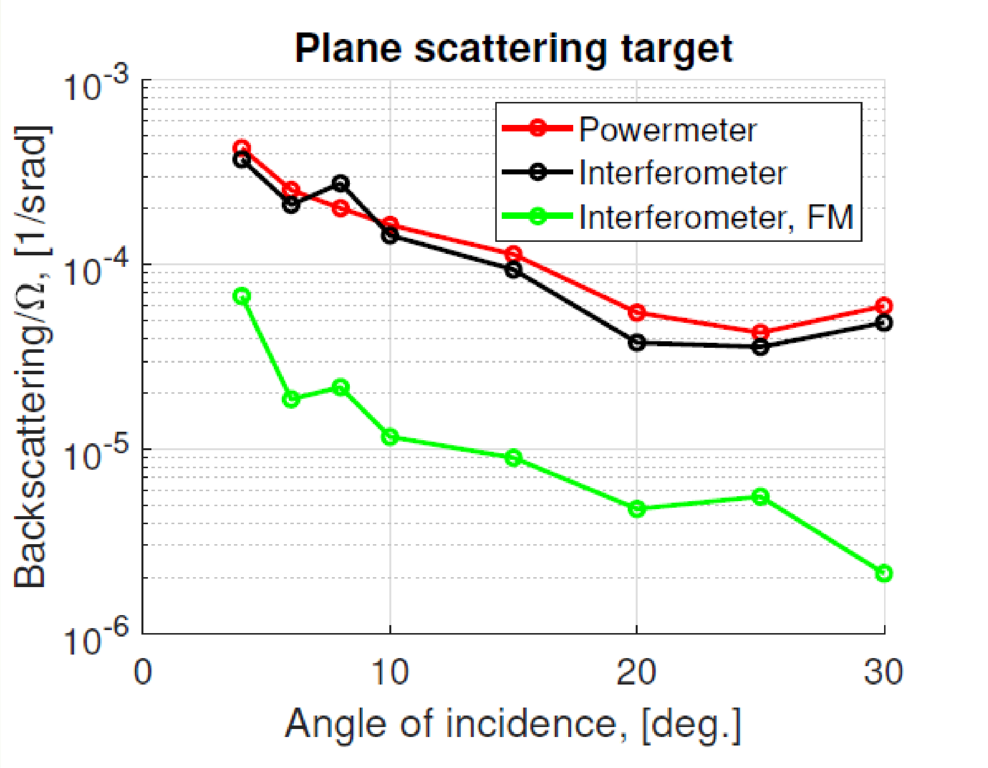


- Very fast dependence on incident angle

- The amplitude is decreasing with increasing incidence angle

Coherent backscattered light in crossed polarization





- The backscattered in cross polarization is not completely rejected
  - 10 times less (for a metallic mirror)

Conclusions on stray light activities @ ARTEMIS and immediate perspectives

- Metrology of backscattered light using Mickelson interferometer @ 1,55 µm
- Speckle properties, particularly angular
  - Reasonable orders of magnitude
- The cross-polarization is not negligible (on a metallic mirror)
- Diffusion on contamination
  - Witness exposed in an AIVT background (LAM/NISP AIVT clean room)

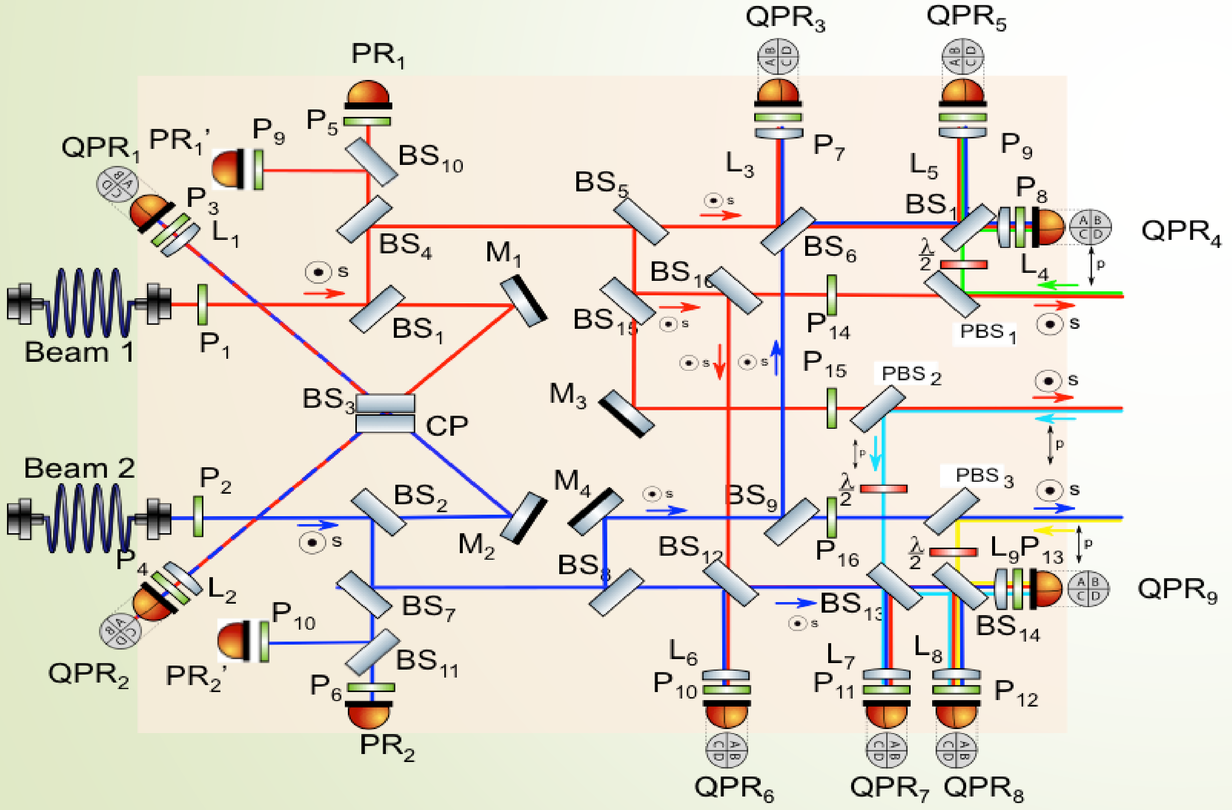
- Duplicate @ 1,06 µm (RIO diode)
- To be performed on "true" LISA mirrors
- idem
- Read the exposed witness

LISA Photoreceivers activities @ ARTEMIS

- Aim of the Photoreceivers activities in France (ARTEMIS & CPPM)
  - Contribution to the development of the OGSE for the AIVT phases
  - Contribution/help to the straylight studies
  - Contribution to the Performance model of the flight LISA instrument
    - Estimation of the degradation of photoreceivers performances under the effect of space radiation environment exposure
    - Photoreceivers WG of the LISA Instrument Group (LIG
      - Chairs: Gerhard Heinzel (AEI, Hanover) and Nicoleta Dinu-Jaeger (ARTEMIS/OCA, Nice)

Photoreceivers for the AIVT OGSE (1)

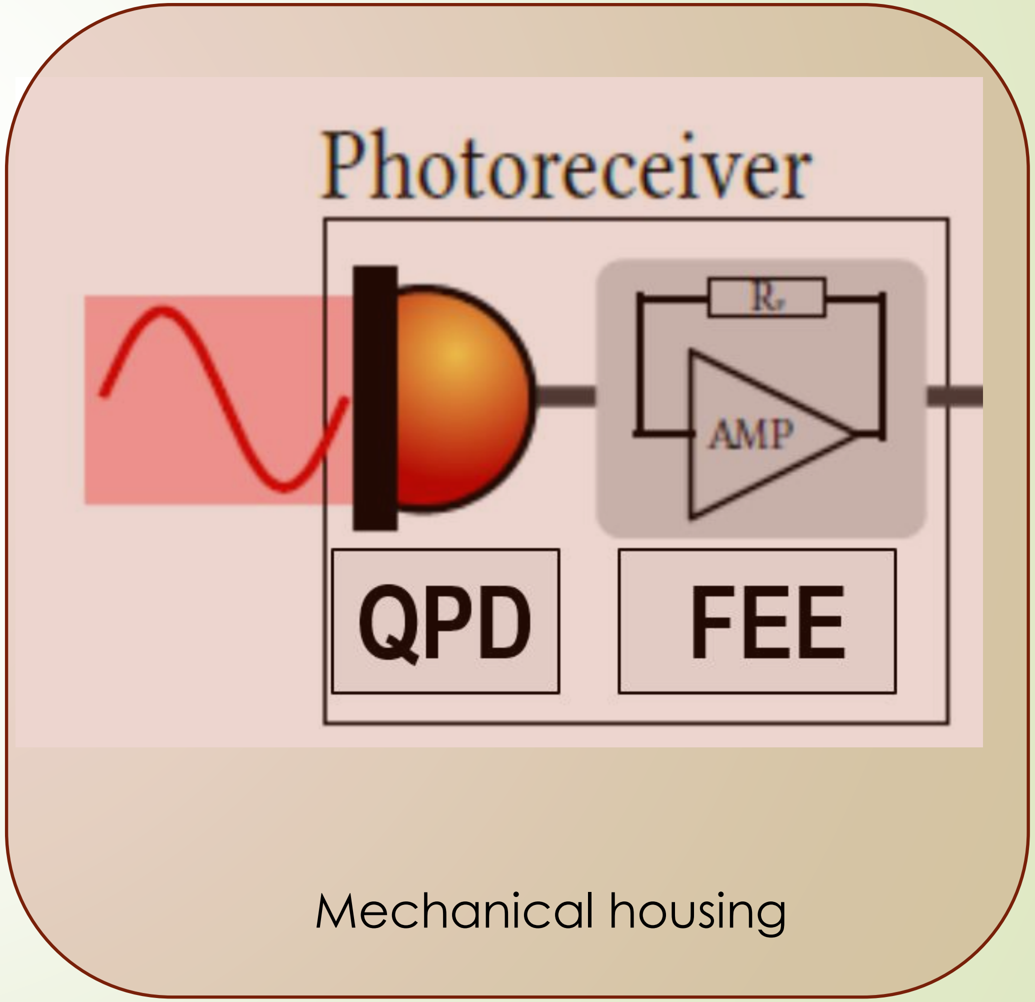
- MIFO/ZIFO design under progress (APC, ARTEMIS, CEA/IRFU, CPPM, LAM, SYRTE & CNES)
  - Main objective: Build OGSE, with optical metrology stability ~ pm/√Hz
    - Prepare the next OGSE for the MOSA AIVT phases
    - Characterize and validate the impact of test environment (temperature, vibrations, vacuum etc.)
    - Identify the main perturbing effects (polarization state, laser frequency & power stability, electronics noise, cross-talk etc.)



- Photoreceivers need
  - 9x Quadrant Photoreceivers (QPR)
    - Interferometric measurements & phase loop control
  - 4x Single element photoreceivers (SEPR)
    - 4 Lasers power monitoring and intensity loop control

Photoreceivers for the AIVT OGSE (2)

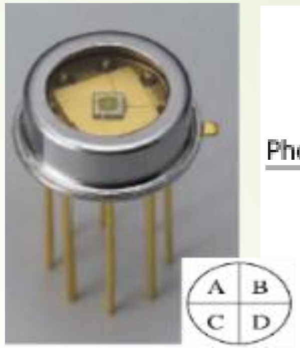
- Quadrant Photodiodes & Single element Photodiodes (InGaAs Technology, 1-2 mm diameter)
  - Aim: Optical to electrical signal conversion in the LISA bandwidth (5-25 MHz)
- Preamplifier - front end electronics (FEE)
  - Aim: amplify the electrical signal
- Mechanical housing
  - (PD + FEE) metallic box
  - Mounting structure of optical components in front of the PR (lens + polarizer)
  - Interface plate with the Zerodur

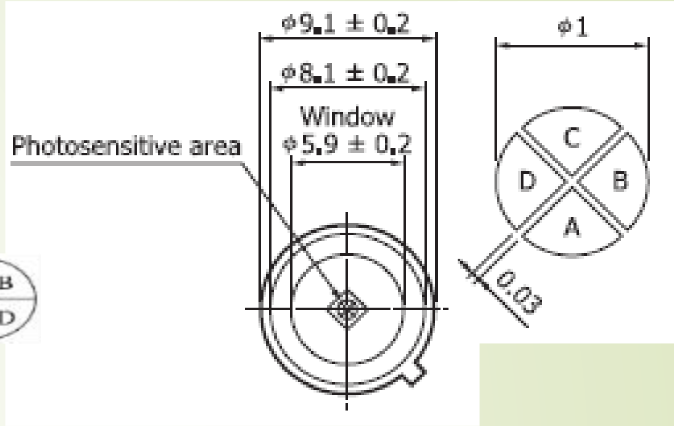


Photodetectors (PD) specs definition

- Quadrant Photodetectors (QPD)
  - Hamamatsu G6849-01 (G6849-9074, No glass window on package)

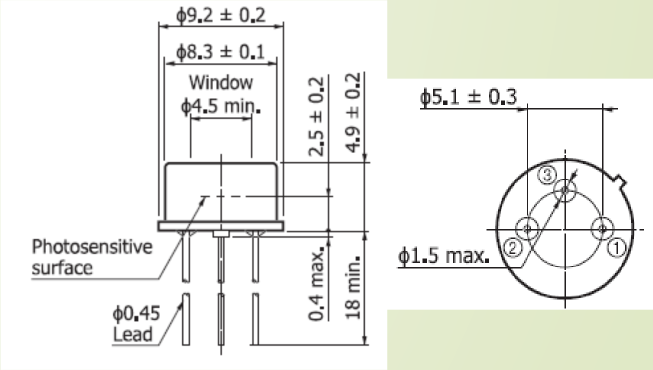
QPD Quantum efficiency @ 1064 nm	QE @ 1064 nm = 80% (Responsivity = 0.69 A/W)
QPD diameter	1 mm
QPD gap between segments	30 µm
QPD capacitance	25 pF (max 40 pF)/segment
QPD package	No window TO5 type package
Cut-off frequency	Typ. 120 MHz (min 80 MHz)





- Single Element Photodetectors (SEPD)
  - Hamamatsu G12180-020A, No glass window on package

QPD Quantum efficiency @ 1064 nm	QE @ 1064 nm = 80% (Responsivity = 0.69 A/W)
QPD diameter	2 mm
QPD capacitance	Typ. 250 pF (max 800 pF)/segment
QPD package	No window TO5 type package
Cut-off frequency	Typ 13 MHz (min 4 MHz)



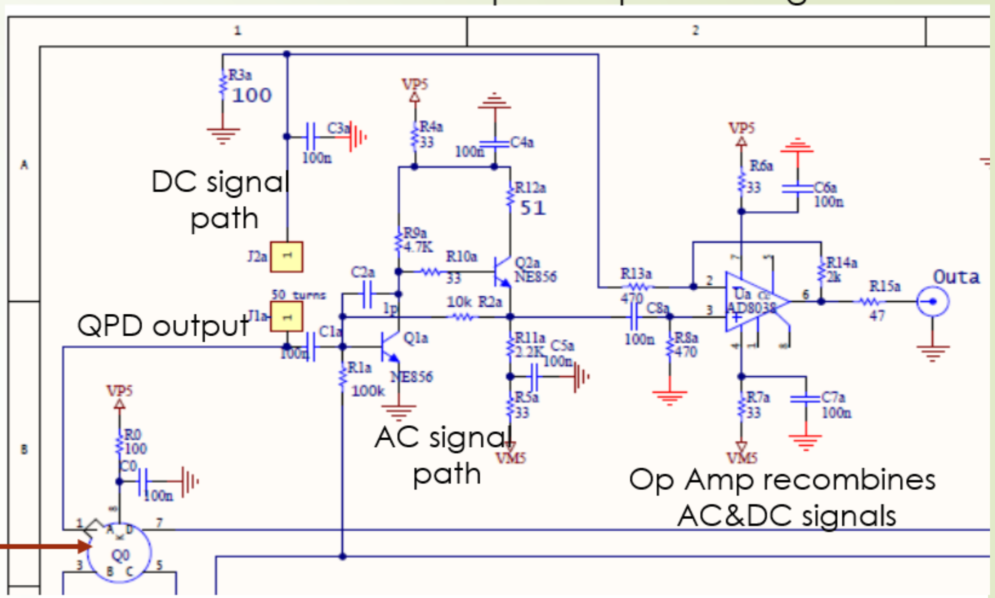
Front End Electronics (FEE) @ ARTEMIS

JP. Coulon

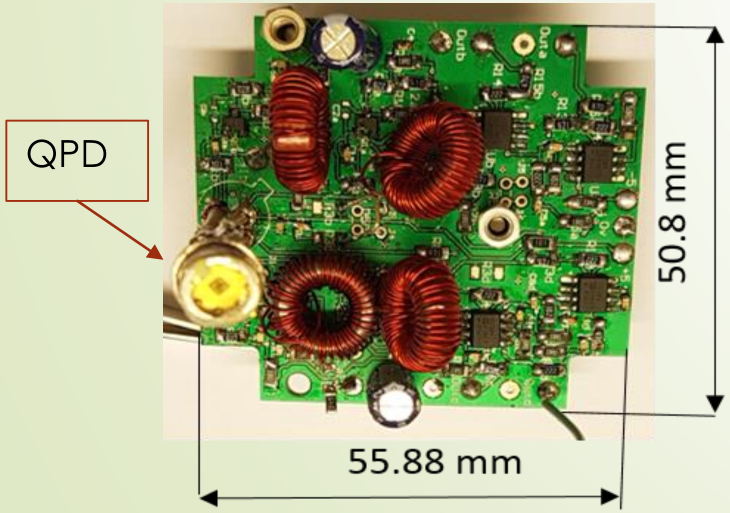
FEE-QPD

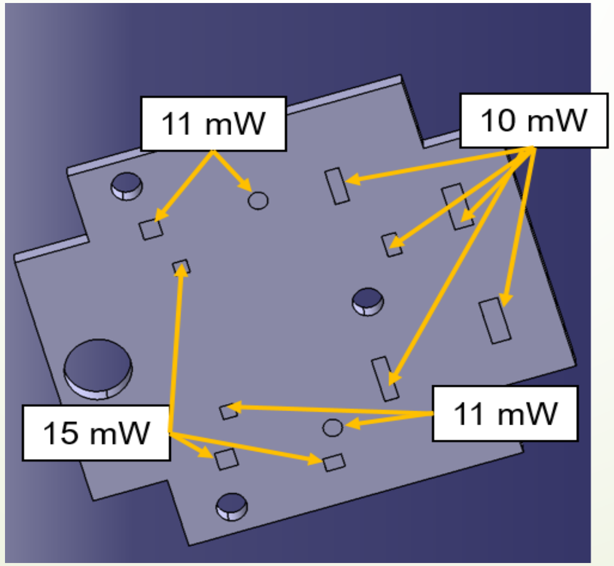
- 1^{st} prototype designed and manufactured
  - Pre-amplifier sensing similar to AEI, cascade transistors
    - First stage amplification
      - 2-discrete transistors (10 kΩ transimpedance)
    - Second stage amplification
      - Operational amplifier AD8038: gain 5.25
  - Total gain: 52.6 kΩ

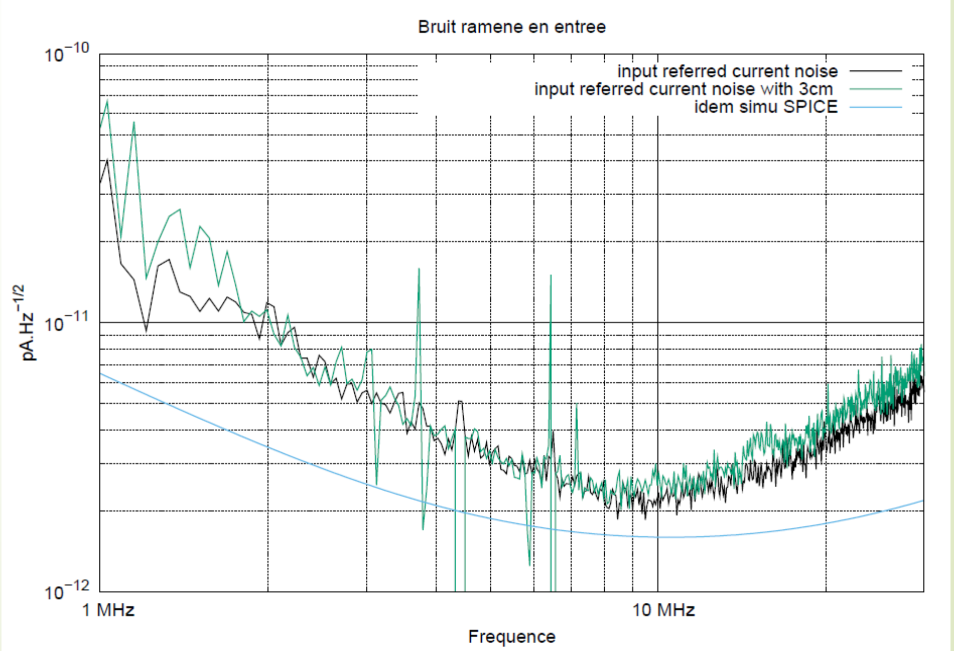
One channel pre-amplifier design



First-prototype FEE-QPD

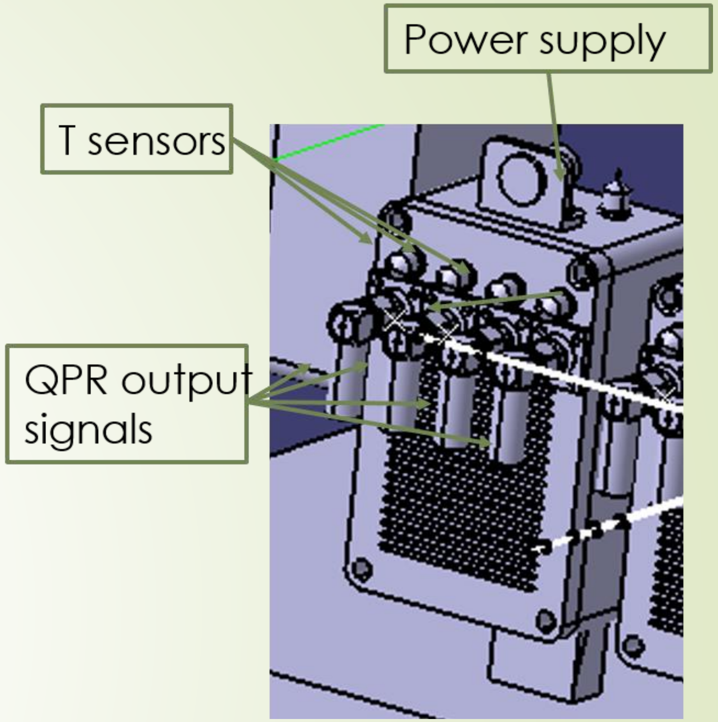






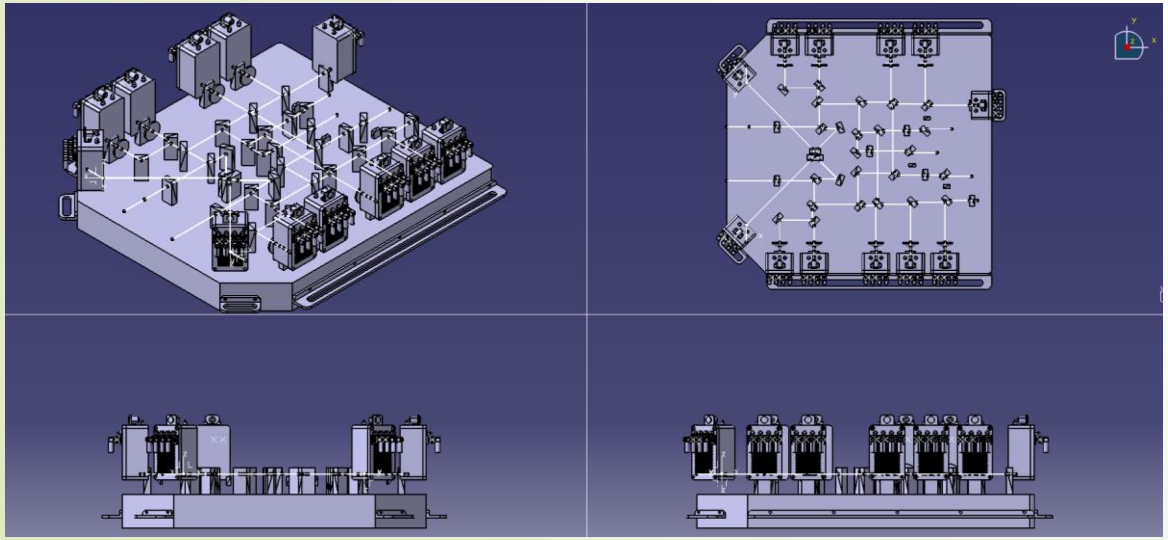
Mechanical support (MS) @ ARTEMIS

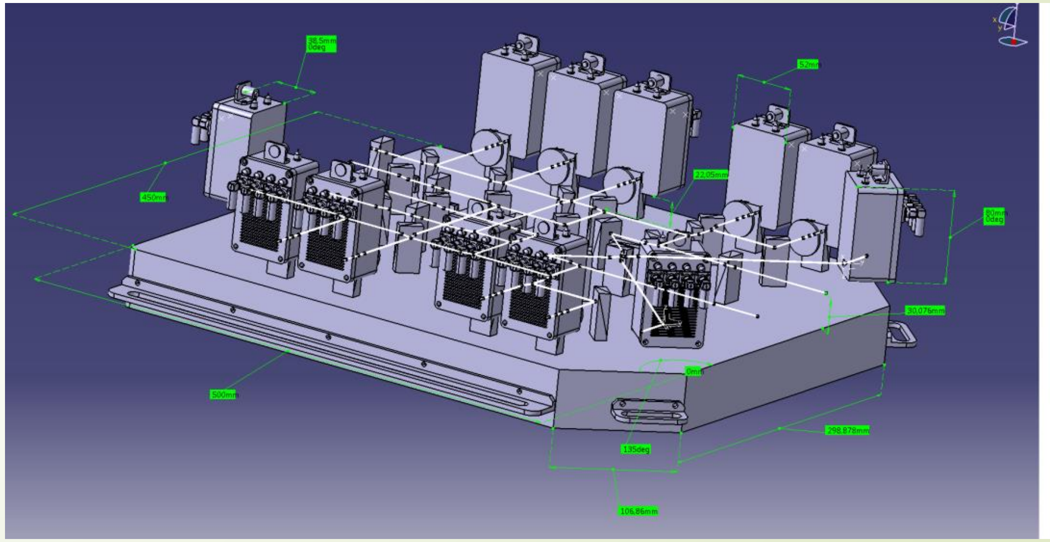
M. Merzougui



MS-QPR

- QPD pins soldered on the PCB of the FEE
- QPD + FEE in a home-made metallic box (Lxlxh = 52x38.5x80) mm
- Lent + polarizer + clip in front of each QPR on a dedicated MS
- Interface plate between MS-QPR and Zerodur
- MS-QPR + alignment tools design under progress
- 1st prototype to be manufactured in September

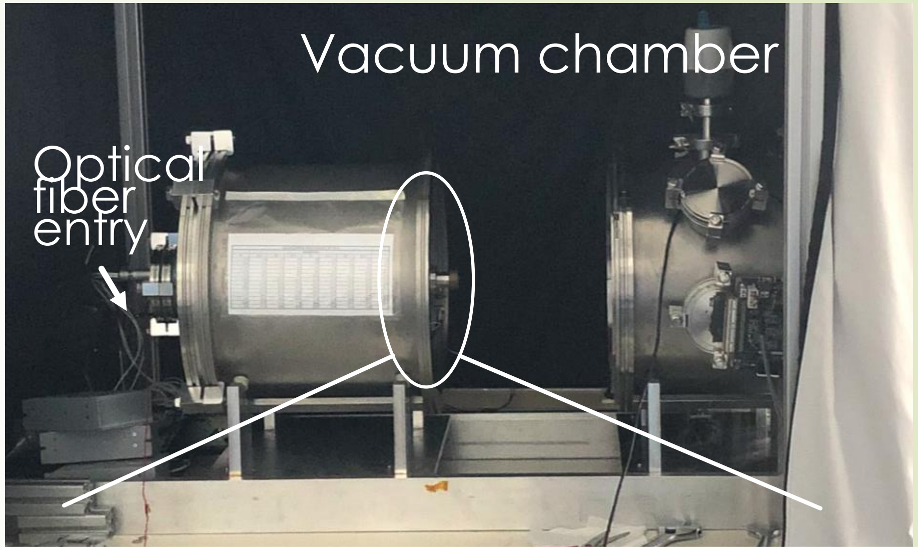


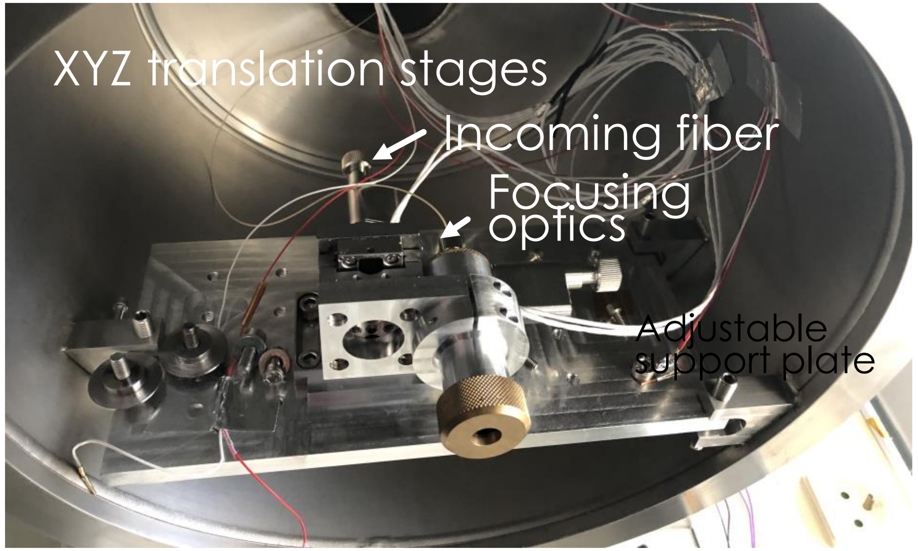


Photodiode characterization @ CPPM

- Electro-optical characterization of SEPD and QPD
- Vacuum chamber with chiller
  - 1064 nm fiber laser source
  - Beam focused on < 20 microns
  - Control of the photodiode temperature
- Parameters
  - I-V, C-V, impedance in the 0-50MHz range
  - Dark current, QE
  - Spatial response homogeneity (intra- inter- segments)
  - Crosstalk
  - Thermal coupling (-10 +30°C)

***CPPM team:** E. Kajfasz, A. Secroun, J. Royon, P. Lagier*





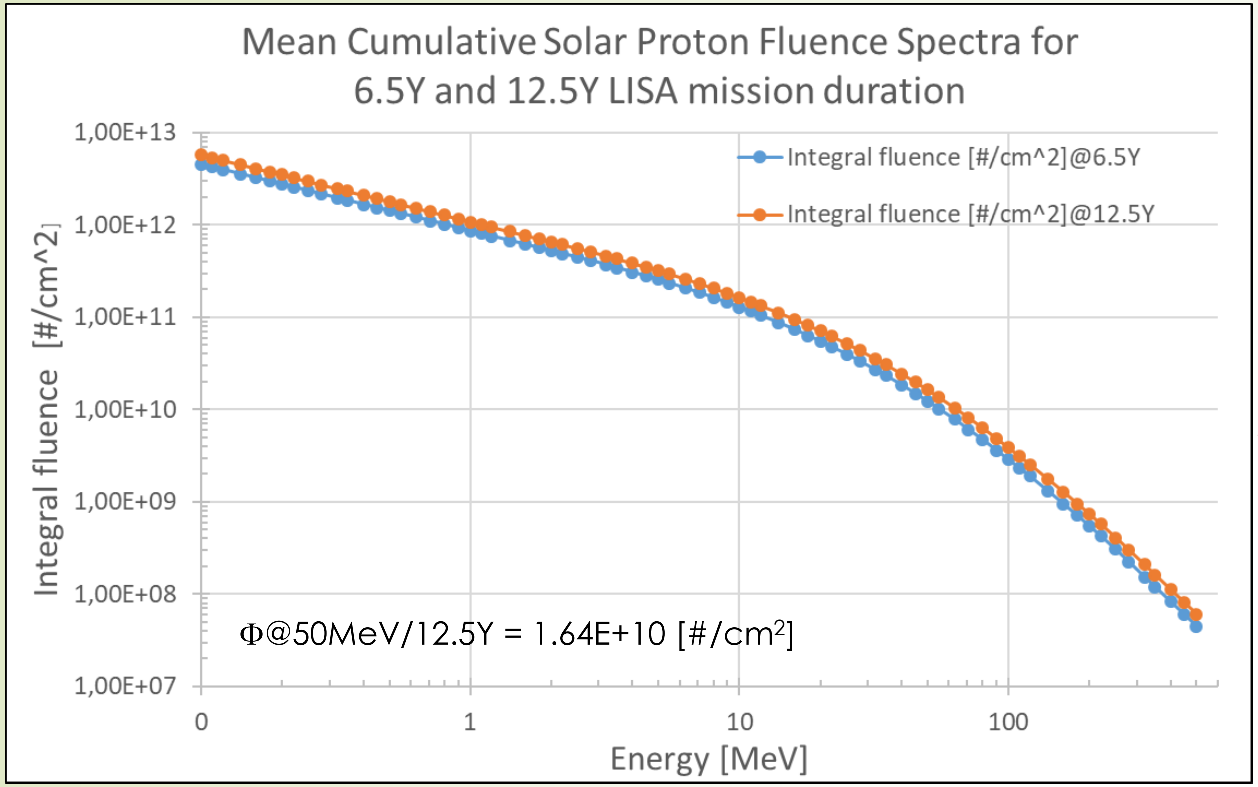
Photoreceivers characterization @ ARTEMIS

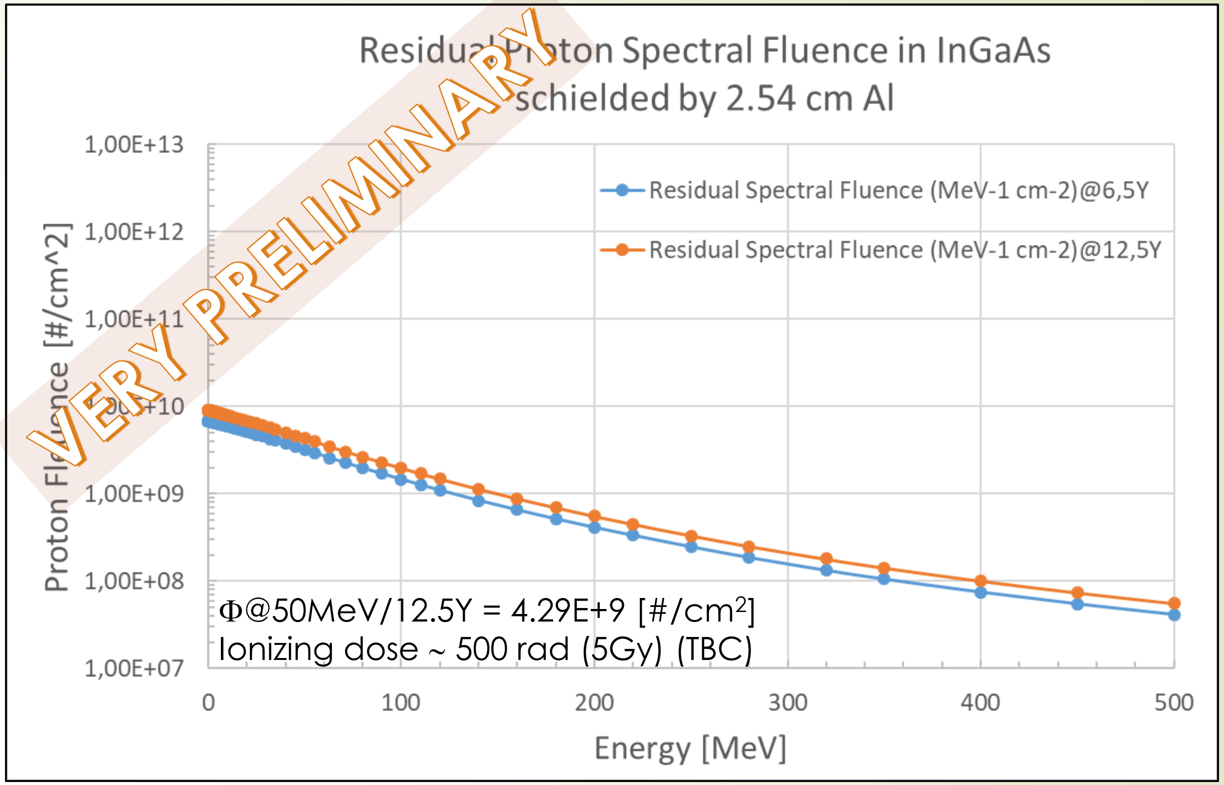
- 1st step: Electro-optical characterization in air conditions
  - 1064 nm fiber laser source
  - Parameters
    - Frequency response (amplitude, phase) using a modulated optical signal (5-25 MHz)
    - Inter & intra-segments spatial uniformity of the frequency response (beam focused on ~30 microns)
    - Intra-segments cross-talk
    - Power to phase coupling @ 1064nm & UV (Incoherent straylight)
  - Set-up build and calibration starting from July 2019

- 2nd step: Electro-optical characterization under vacuum and T control
  - Thermal coupling coefficients
    - Amplitude and phase stability with temperature

Contribution to Performance model - studies of photoreceivers performances under proton irradiations

LISA Radiation environment: Solar Protons





ESA-L3-EST-MIS-SP-001, ESA-TEC-SP-006666, 31/08/2017

- Solar proton fluencies estimated with 95% confidence for 6.5 and 12.5 years extended LISA mission
  - LISA launch 2034, including the maxima phase of the solar cycle 26
    - Solar cycle 26: starts March 2031, maxima June 2036, end 2041
    - Solar cycle 26: trend of decreasing solar activity (A.K. Singh, A. Bhargawa, Astrophys. Space Sci, 2019)

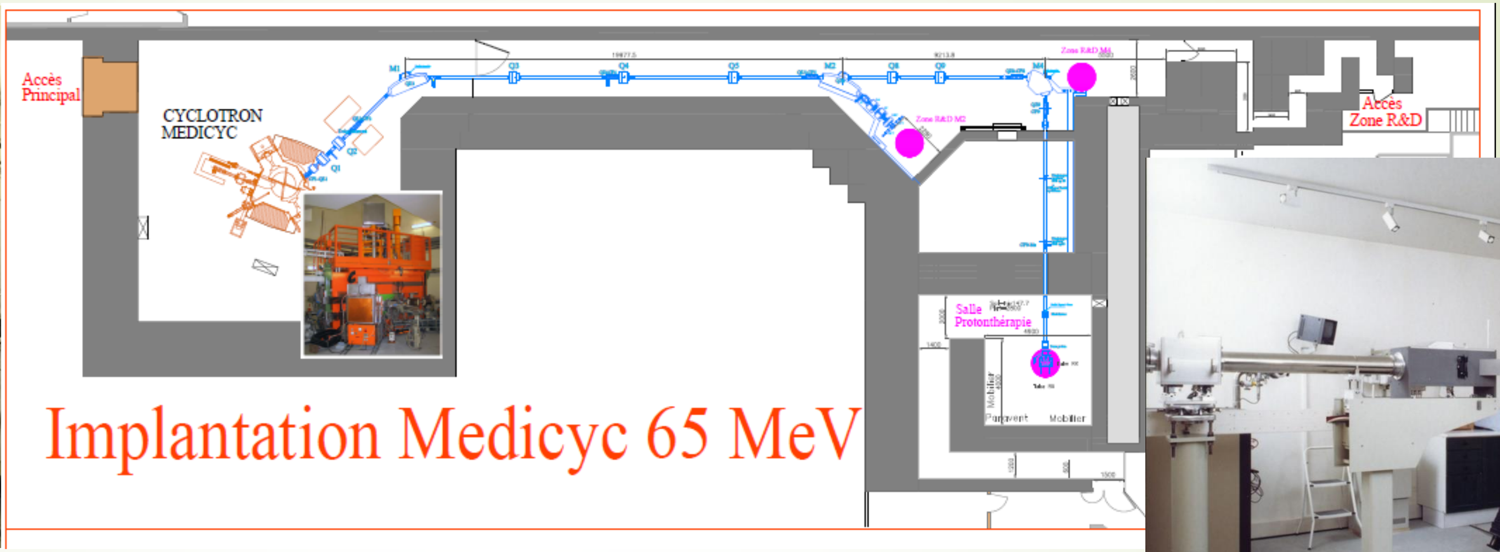
Proton beam facility at Centre Antoine Lacassagne (CAL), Nice, France

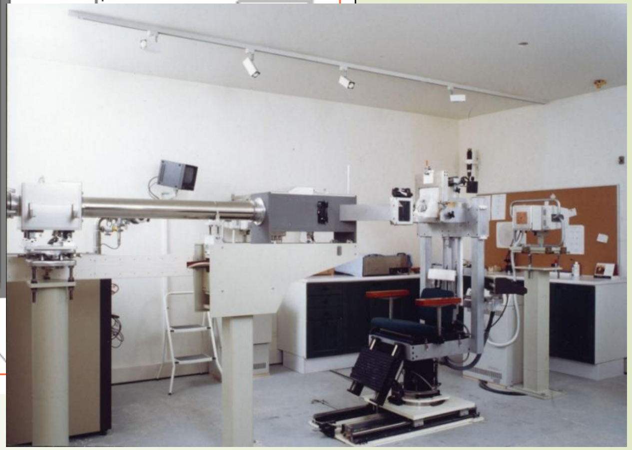
R. Trimaud, J. Hérault

Antoine Lacassagne
CENTRE DE LUTTE CONTRE LE CANCER DE NICE

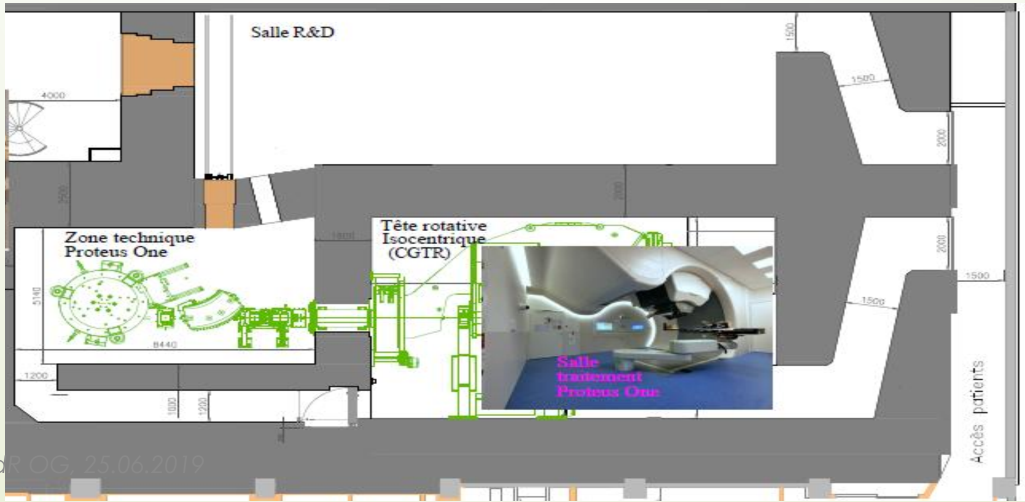
Protons facilities overview

- Isochronous cyclotron P 65 MeV, Juin 1991 (MEDICYC)





- Super-conducting synchrocyclotron IBA PROTEUS ONE, P226 MeV, September 2016



Protons and photon beams characteristics @ CAL IMPT

Isochronous cyclotron (Medicyc)

Proton BE		
Time structure	Macrostructure (ns)	Microstructure (ns)
	continuous	5 / 40 (25 MHz)
Dose rate	Minimum ($Gy.min^{-1}$)	Maximum ($Gy.min^{-1}$)
	1 (lower possible if adapted detection system)	100
Field size	Minimum (ϕ mm)	Maximum (ϕ mm)
	1	60
Energies	Min (MeV)	Max (MeV)
	0.1	65

X-rays 6 MV (~1 MeV)		
Dose rate	Minimum ($Gy.min^{-1}$)	Maximum ($Gy.min^{-1}$)
	2	-
Field size	Minimum (ϕ mm)	Maximum (ϕ mm)
	5	60

Super-conducting synchrocyclotron (Proteus)

Proton HE		
Time structure	Macrostructure (ms)	Microstructure (ns)
	1	1.5 (63 MHz)
Dose rate	Minimum ($Gy.min^{-1}$)	Maximum ($Gy.min^{-1}$)
	2	-
Field size	Minimum (mm^2)	Maximum (mm^2)
	100x100	200x250
Energies	Min (MeV)	Max (MeV)
	100 (lower with range shifter)	226

Organigram - LISA ARTEMIS team @ Phase A

Group 1

LISA ARTEMIS/OCA team @ Phase A activities
Scientific leader: Nelson Christensen
Project manager: Nicoleta Dinu-Jaeger

Performance

WP 5000: MOSA Performance tests WG
Frederic Cleva
Noel Dimarcq
Nary C. Man

WP 4000: Instrument Performance
Jean-Yves Vinet
Nelson Christensen
Nicoleta Dinu-Jaeger: Photoreceivers
Guillaume Boileau, Straylight noise studies
CDD IR Straylight simulation

AIVT

WP 3000: AIVT system activities
Nicoleta Dinu-Jaeger

WP 2200, 6000, 6100, 6200: Straylight (component & system architecture)
Michel Lintz
Vitalii Khodnevych
Dominique Huet
Nicoleta Dinu-Jaeger
Nelson Christensen
Jean-Yves Vinet
Nary C. Man
Mikhael Pichot du Mazeray
Mourad Merzougui
Guillaume Boilot
CDD IR-simulation - CNES

WP 9000 OGSE/ MIFO/ZIFO Demonstrator
Nicoleta Dinu-Jaeger
Frederic Cleva
Jean-Pierre Coulon
Mourad Merzougui
Engineer Master student

WP 7000: MGSE
Mourad Merzougui
Jean-Marie Delannoy, (Consortium subs. needed)
2x Ing OCA (Consortium subscription needed)

DDPC

Simulation tools for GW sources identification
Neil Cornish
Natalia Korsakova
Guillaume Boileau
Nelson Christensen

Science

Stochastic GW background search
Nelson Christensen
Guillaume Boileau
Neil Cornish
Astrid Lamberts

Un-modelled transient signal searches
Marie-Anne Bizouard
Neil Cornish

Sources separation by machine learning algorithms
Natalia Korsakova

Multimessengers Astrophysics
Michel Boer
Astrid Lamberts

Noise simulations
Neil Cornish
Nelson Christensen
Guillaume Boileau
Marie-Anne Bizouard

Management

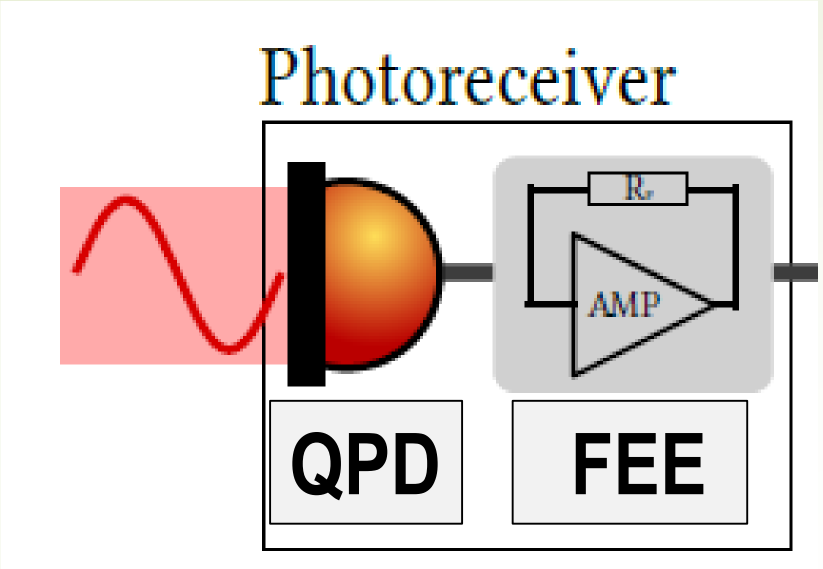
LISA Consortium Board
Nary. C. Man

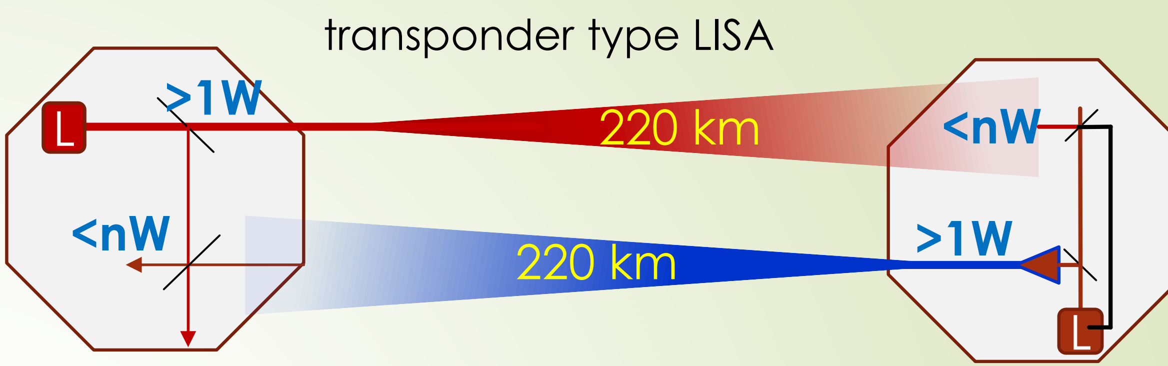
LISA ARTEMIS scientific leader
LISA Publication committee leader
Nelson Christensen

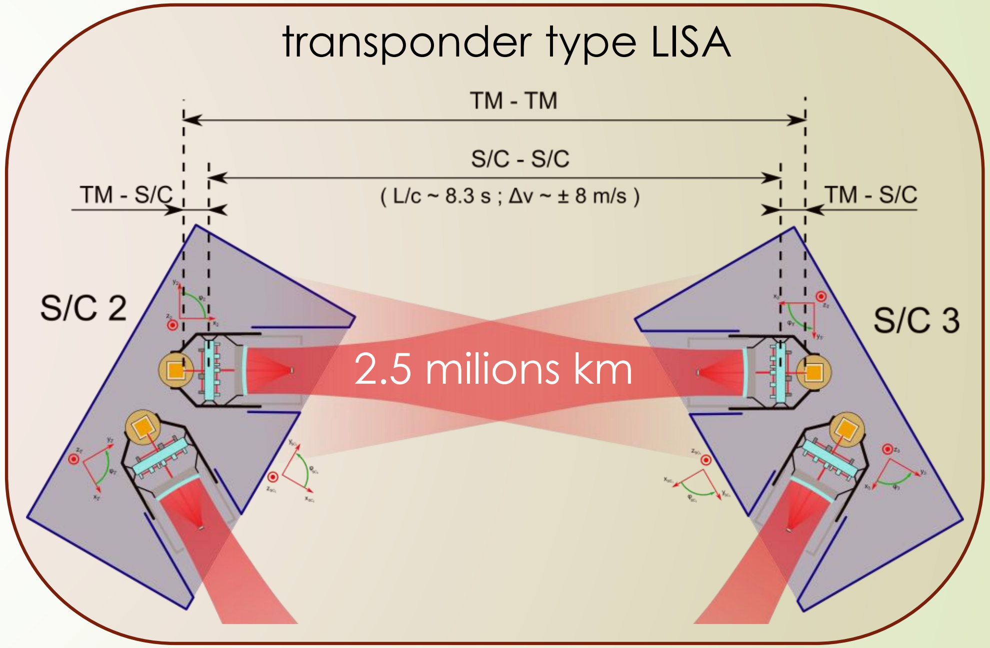
LISA ARTEMIS Project Manager
LIG Photoreceiver WG co-leader
Nicoleta Dinu-Jaeger

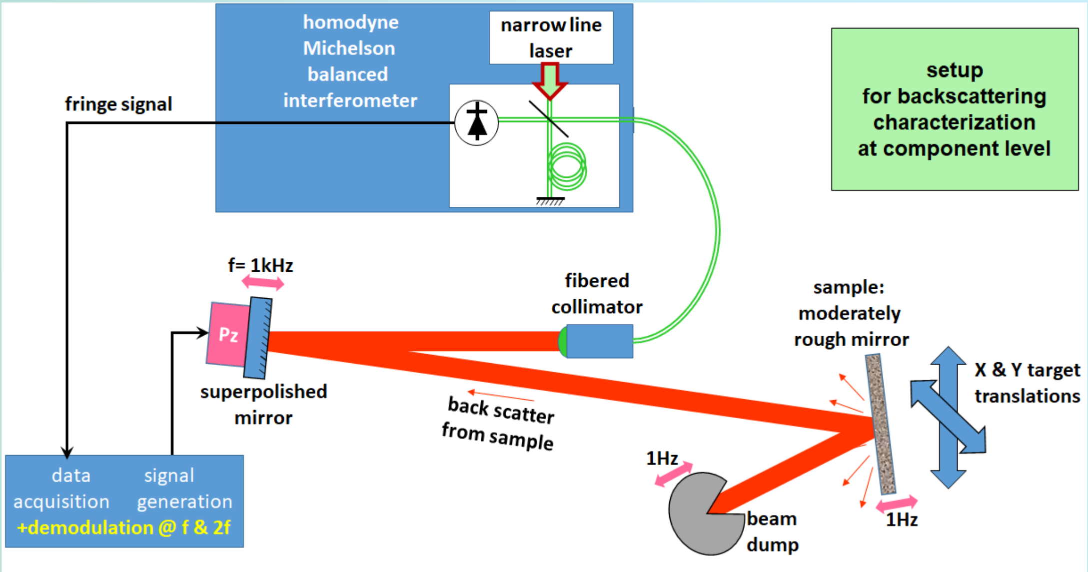
LIG Stray light WG co-leader
France Stray light WP leader
Michel Lintz

Additional slides



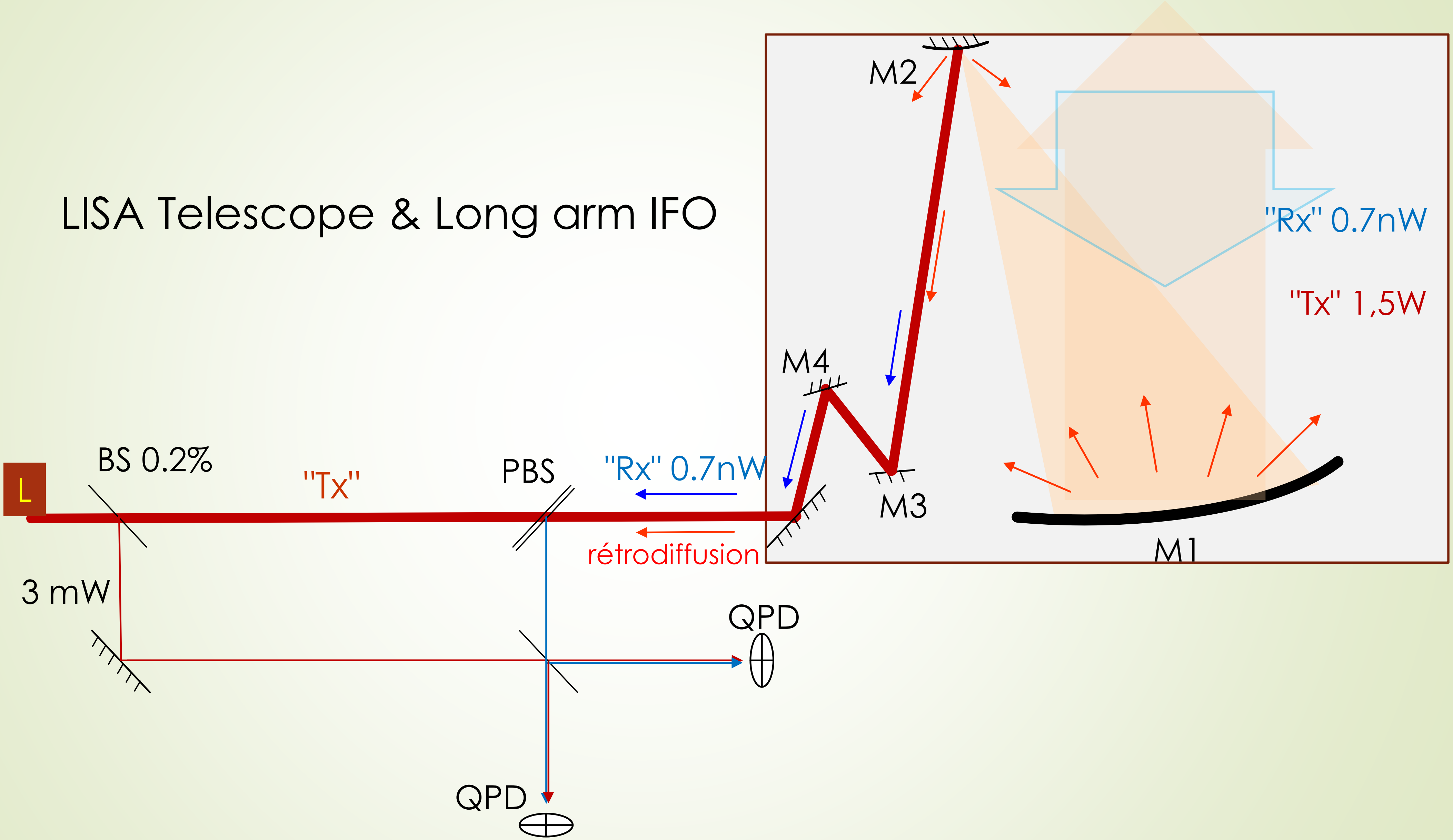




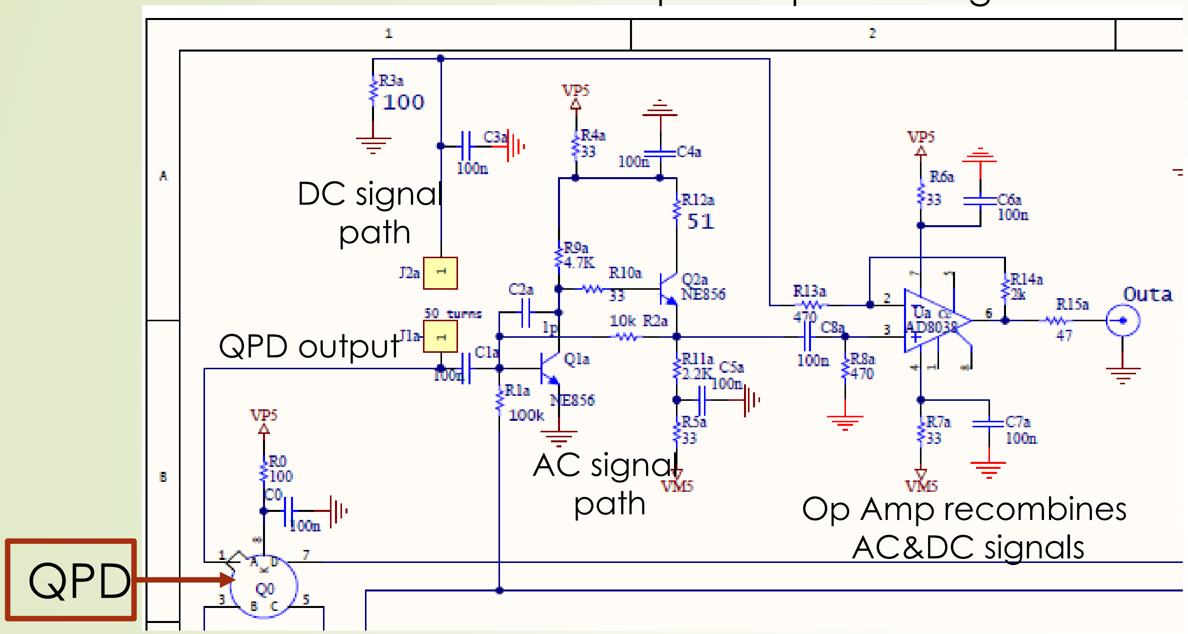


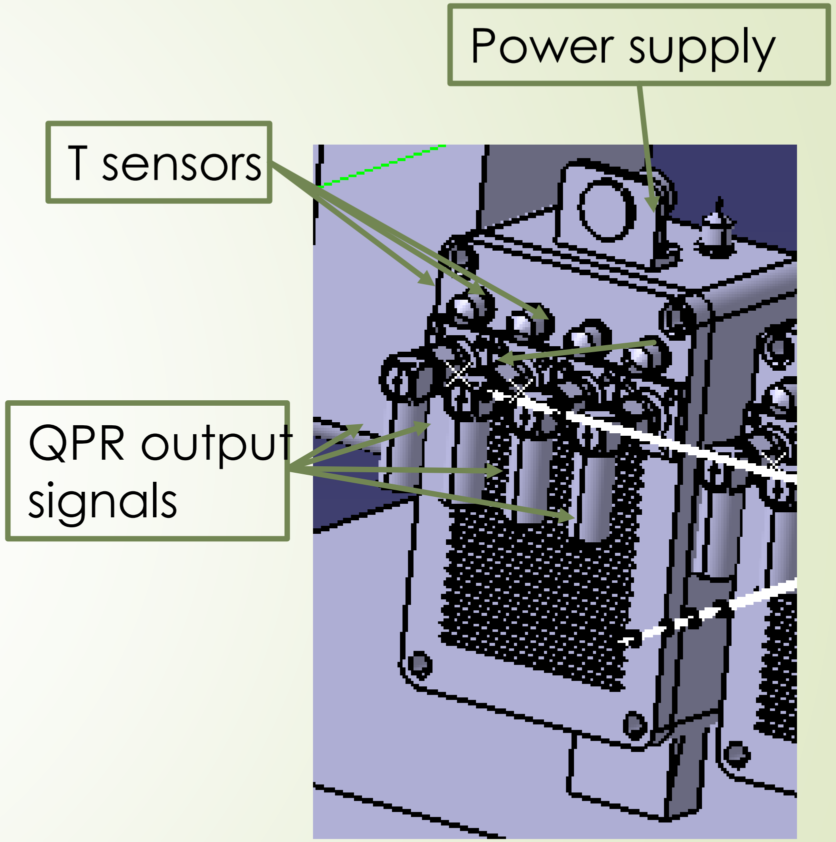
M. Lintz, V. Khodnevych

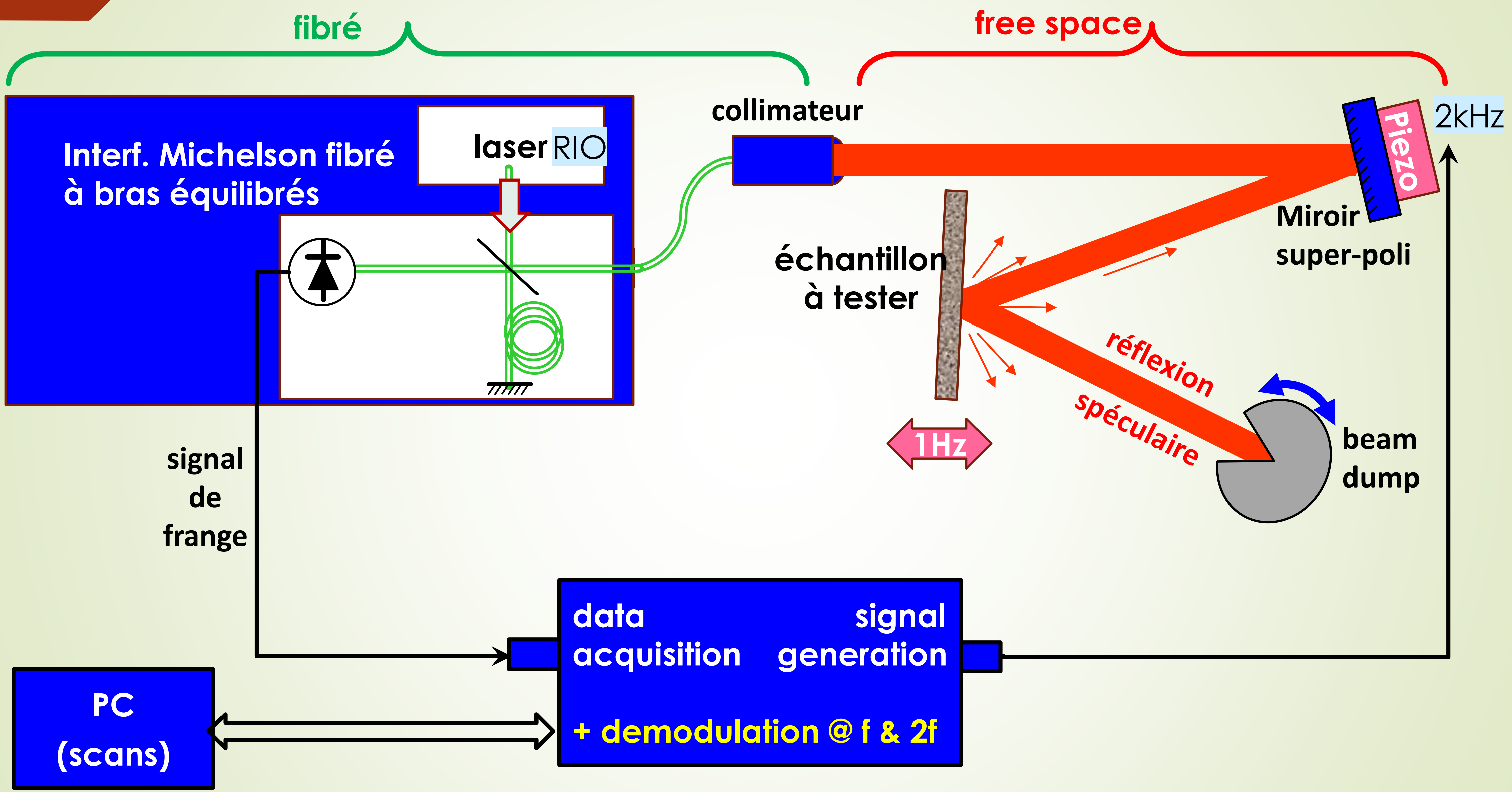
LISA Telescope & Long arm IFO

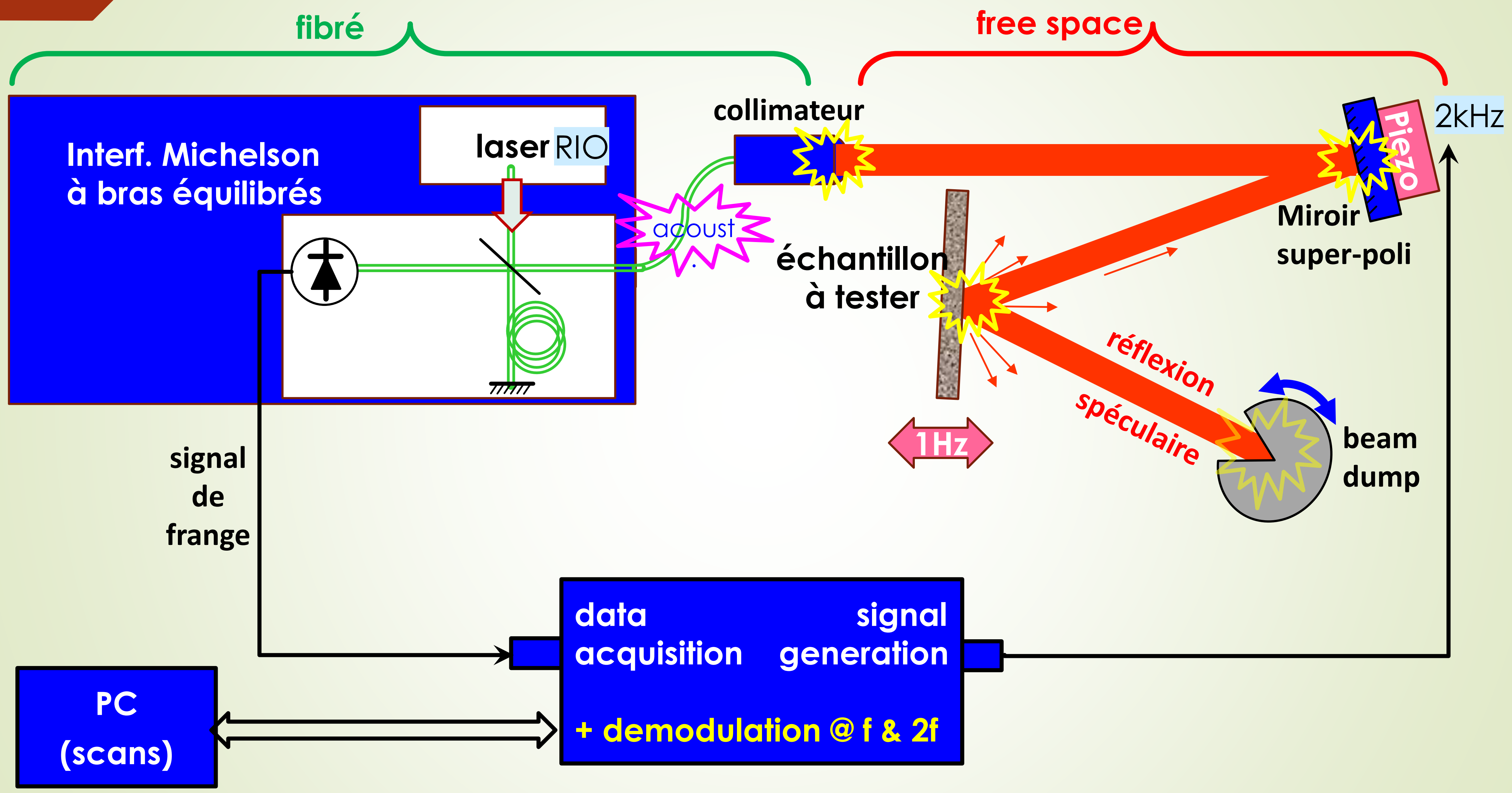


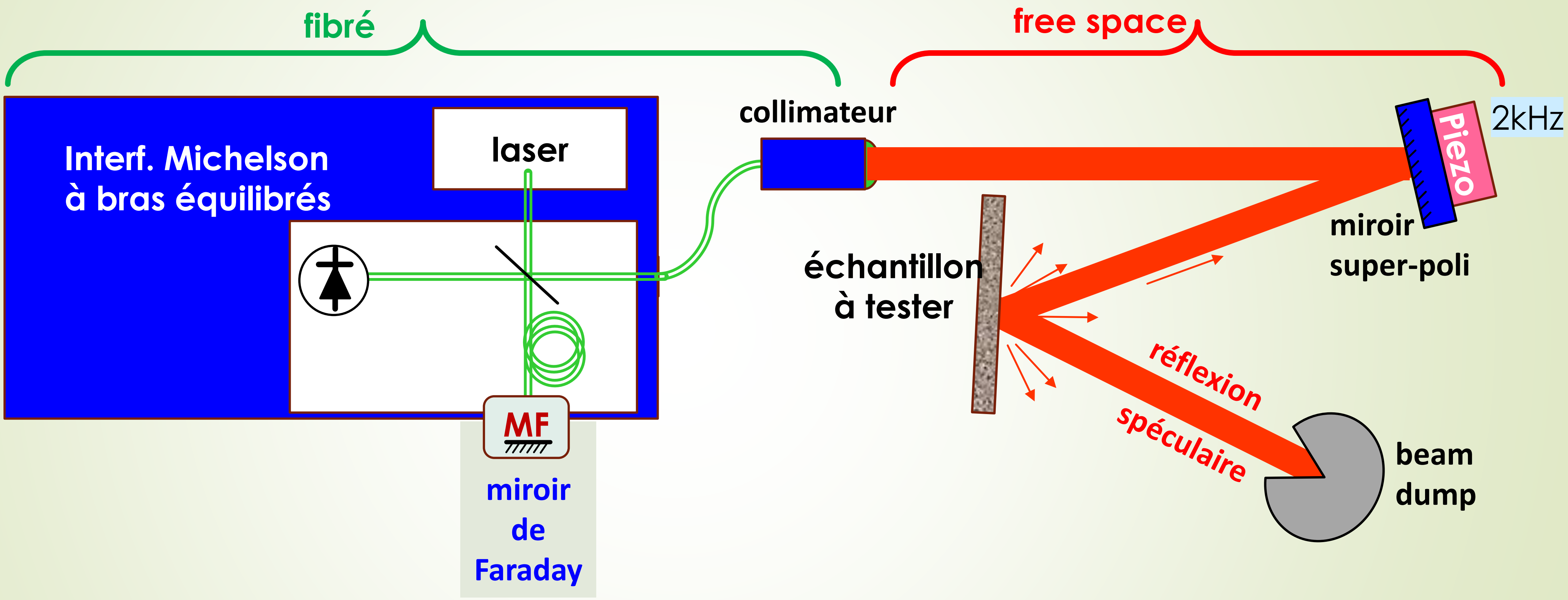
One channel pre-amplifier design






fibré
free space
Interf. Michelson fibré
à bras équilibrés
laser RIO
collimateur
Piezo
2kHz
Miroir
super-poli
échantillon
à tester
réflexion
spéculaire
1Hz
beam
dump
signal
de
frange
data
acquisition
signal
generation
+ demodulation @ f & 2f
PC
(scans)


fibré
free space
Interf. Michelson
à bras équilibrés
laser RIO
acoust
collimateur
2kHz
Piezo
Miroir
super-poli
échantillon
à tester
réflexion
spéculaire
1Hz
beam
dump
signal
de
frange
data
acquisition
signal
generation
+ demodulation @ f & 2f
PC
(scans)



fibré
free space
Interf. Michelson
à bras équilibrés
laser
collimateur
2kHz
Piezo
miroir
super-poli
échantillon
à tester
réflexion
spéculaire
beam
dump
MF
miroir
de
Faraday