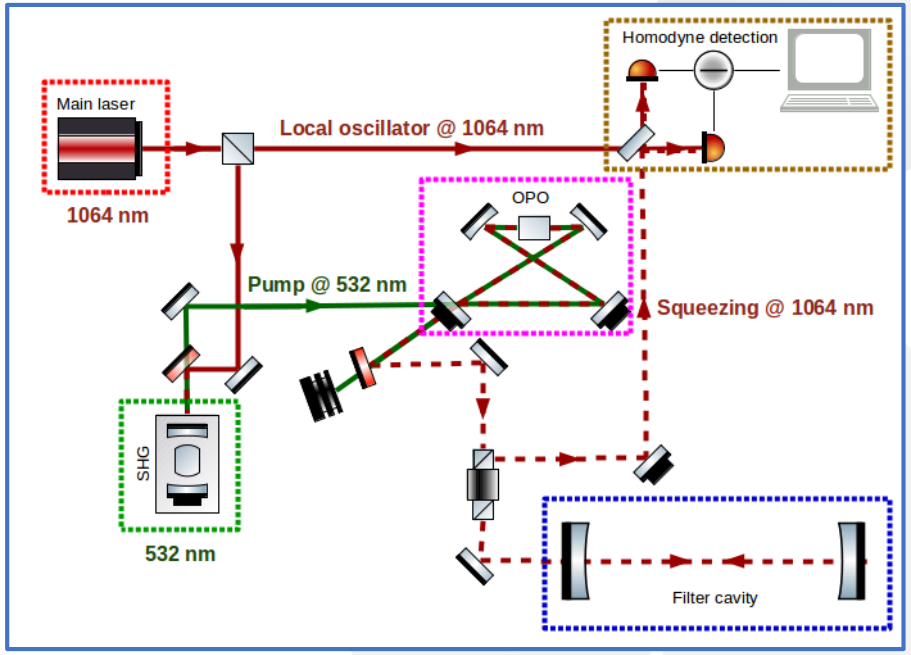
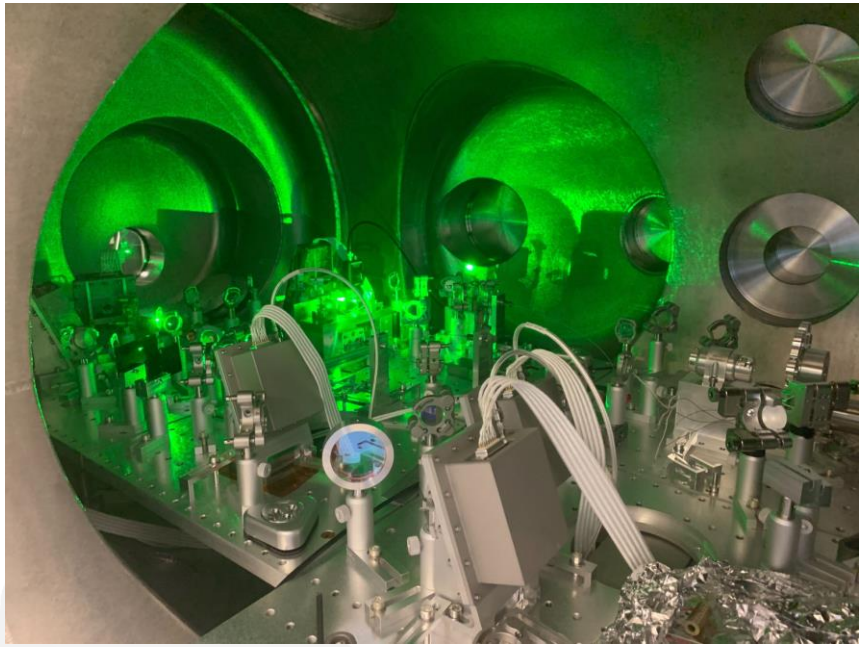
R&D at IJCLab





A. van de Walle, M. Andia, F. Glotin, A. Lartaux, N. Leroy, V. Loriette, P. Stevens

Context of the experiment

ANR EXSQUEEZ (2015-2019)
ANR QFILTER (2019-2024)

Goal :

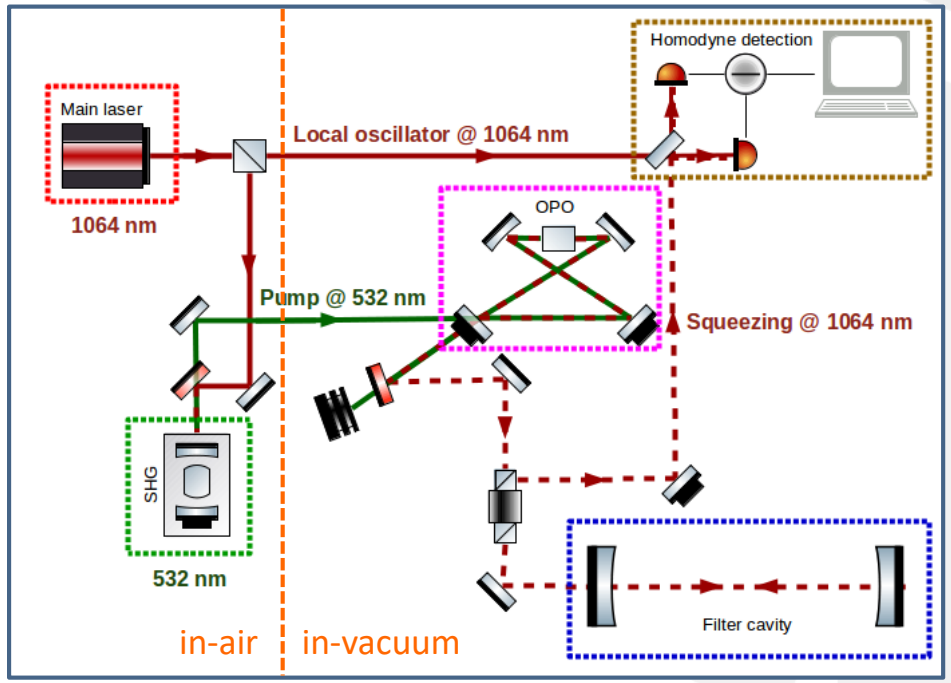
- Demonstrate under vacuum frequency dependent squeezing (FDS) in the prospect of the Advanced Virgo detector O5 run and ET detector development => improve GW detector sensitivity in its whole bandwidth
- Adjust the squeezing angle corner frequency => more flexibility

- Squeezing source from LKB
- Existing 50-m filter cavity on the CALVA facility at IJCLab
- Optics coatings from IP2I/LMA
- Electronics from LAPP in the Virgo standards

Squeezing under vacuum

ANR EXSQUEEZ

- Demonstrate the impact of placing the squeezing under vacuum in the prospect of the Advanced Virgo detector O5 run and ET detector development.



Simplified scheme

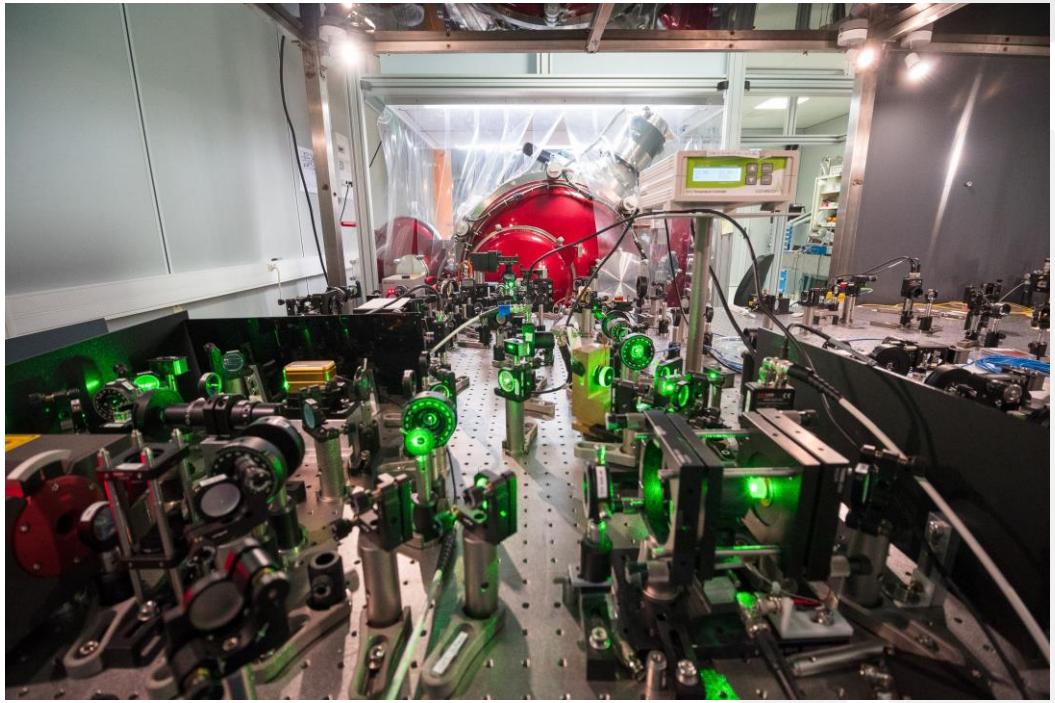
Others main interest points :

- OPO bow-tie type like LIGO
  - Impact on the stray light
- Bench under vacuum but not suspended
- SHG done in air and send under vacuum by a window and not a fiber.
- Modified Coherent Locking (MCL) scheme :
  - Using an frequency shifted infrared beam that will share a phase relation with the squeezing to lock the squeezing angle
- A 50-m long suspended cavity

Squeezing under vacuum

ANR EXSQUEEZ

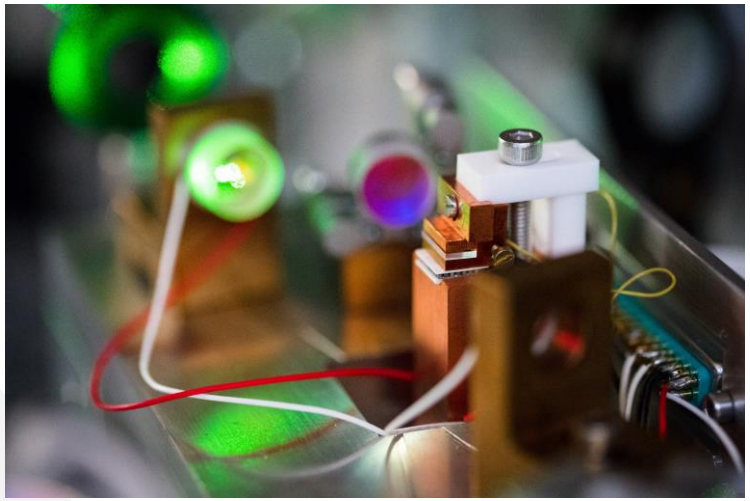
- Demonstrate the impact of placing the squeezing under vacuum in the prospect of the Advanced Virgo detector O5 run and ET detector development.



In-air bench experiment setup

First results :

- Experimental setup has been implemented
- OPO characterized
- Anti-squeezing observed

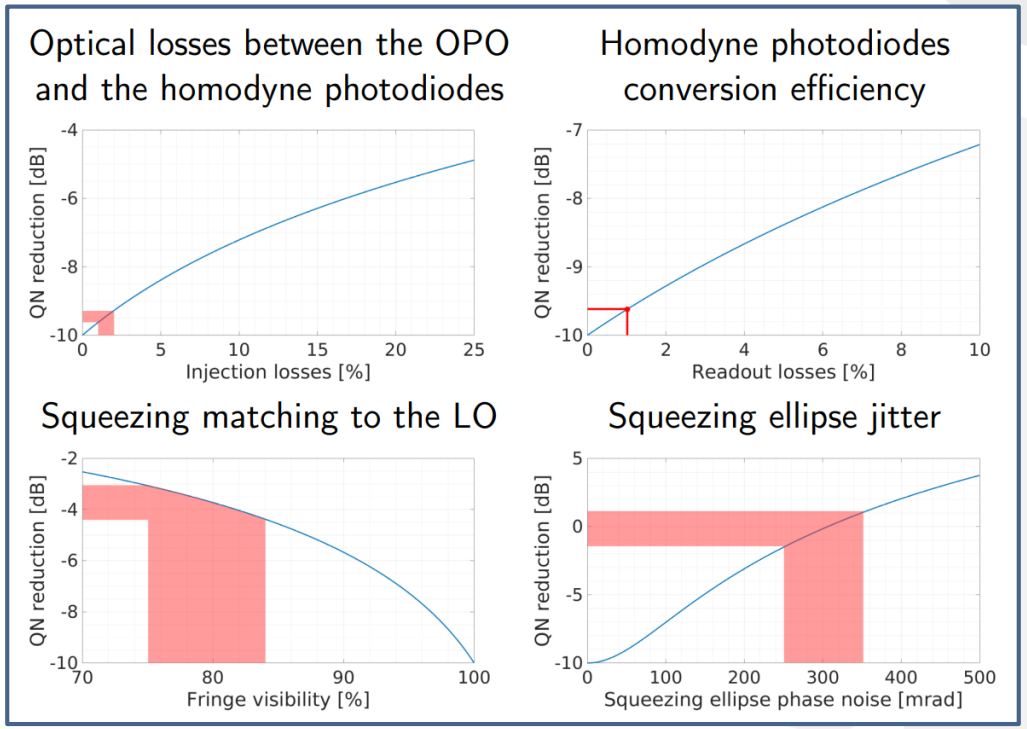


Bow-tie OPO

Squeezing under vacuum

ANR EXSQUEEZ

- Demonstrate the impact of placing the squeezing under vacuum in the prospect of the Advanced Virgo detector O5 run and ET detector development.



Squeezing loss sources

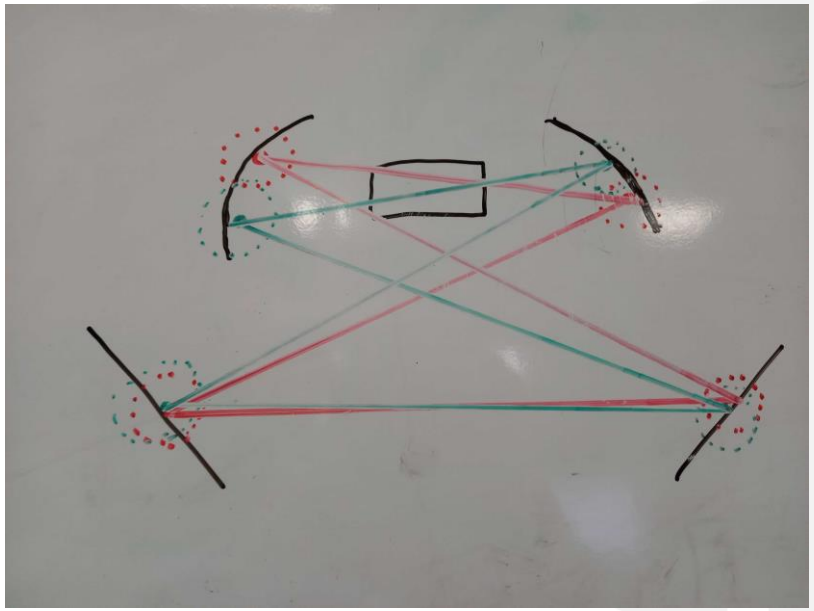
No squeezing observed due to mainly 2 limitations :

- Matching of the LO and squeezing on homodyne detection
- Squeezing ellipse angle control

Squeezing under vacuum

ANR EXSQUEEZ

- Demonstrate the impact of placing the squeezing under vacuum in the prospect of the Advanced Virgo detector O5 run and ET detector development.



Scheme of OPO with
not superposed but resonant beam

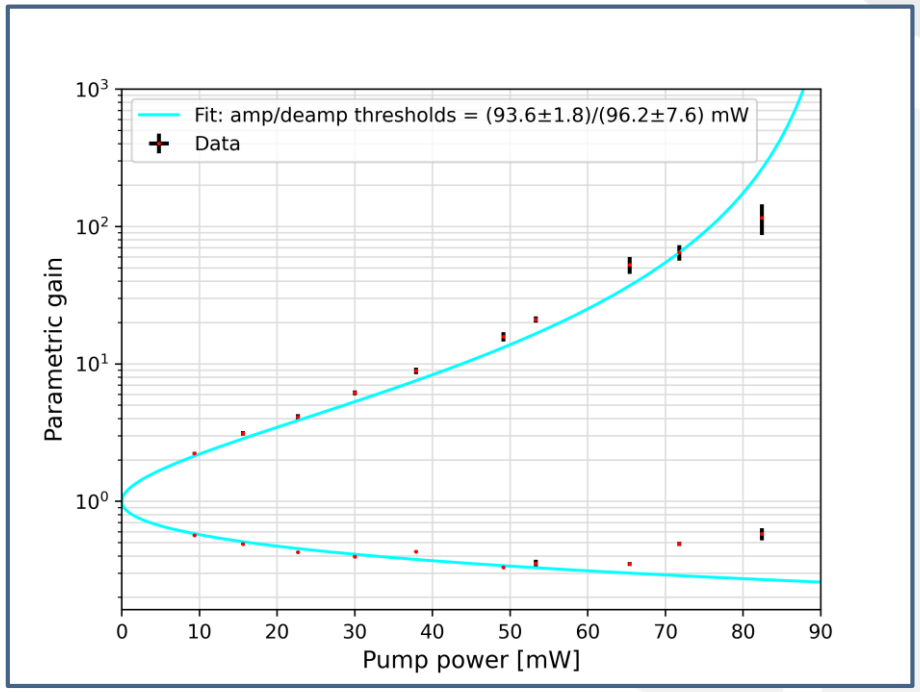
Some problems during the last years :

- Climatization failure :
  - Summer 2021 : Experiment that unaligned itself in the spam of few hours
  - Full alignment of the experiment needed at the end of the problem
- Main laser failure :
  - May to September 2022 : internal fan failure
  - Back in January 2023 with Gaussian parameter changed which entails experiment adaptation
- Unexpected OPO alignment difficulty :
  - A mirror unglued itself : Full realignment after change
  - Strange chromatic alignment dependence : Infrared and Green both resonant but not superposed

Squeezing under vacuum

ANR EXSQUEEZ

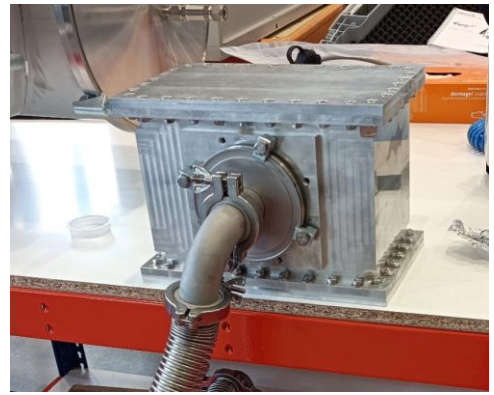
- Demonstrate the impact of placing the squeezing under vacuum in the prospect of the Advanced Virgo detector O5 run and ET detector development.



OPO threshold measurement

Improvements since then :

- Hardware and software development for squeezing angle control loop
- OPO has been realigned and characterized
- Preparation of a vacuum sub-tank to decorrelate squeezing measurement improvement between :
  - vacuum squeezing generation
  - vacuum homodyne detection (HD)

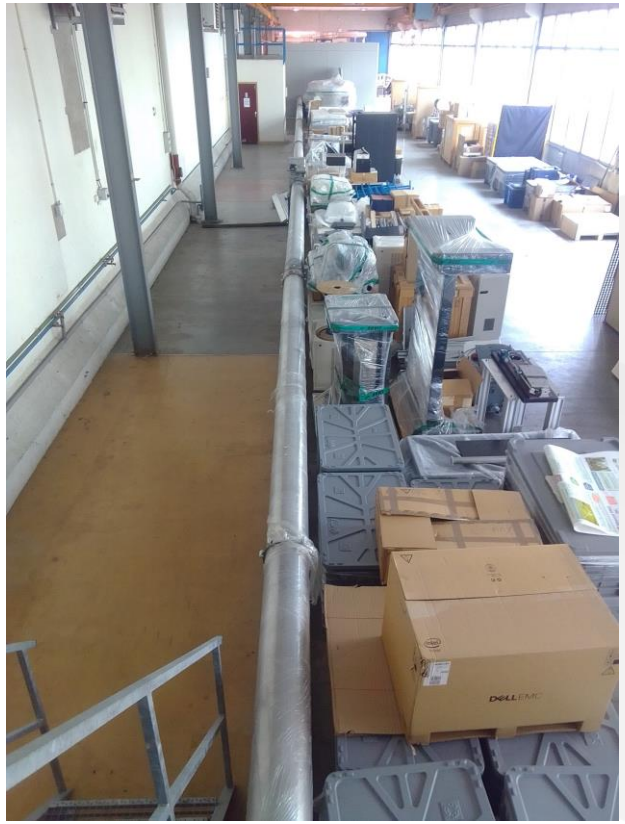


Vacuum tank for HD

Filter cavity : 3-mirrors cavity

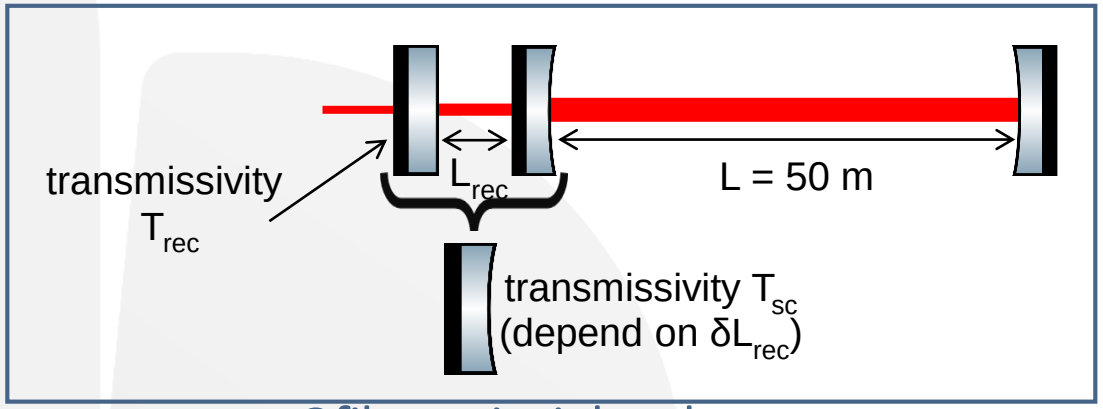
ANR QFILTER

- Study the design constrains of a 3-mirrors cavity



50m vacuum cavity at CALVA facility

- Use a “small cavity” as a variable transmission mirror to tune the squeezing angle corner frequency without change of mirrors :
  - \+ Faster adaptation implementation
  - \+ No supplementary cost once installed
  - ? Stability and control of coupled cavities

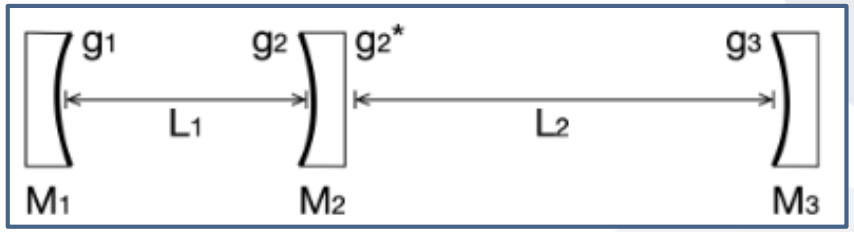


Qfilter principle scheme

Filter cavity : 3-mirrors cavity

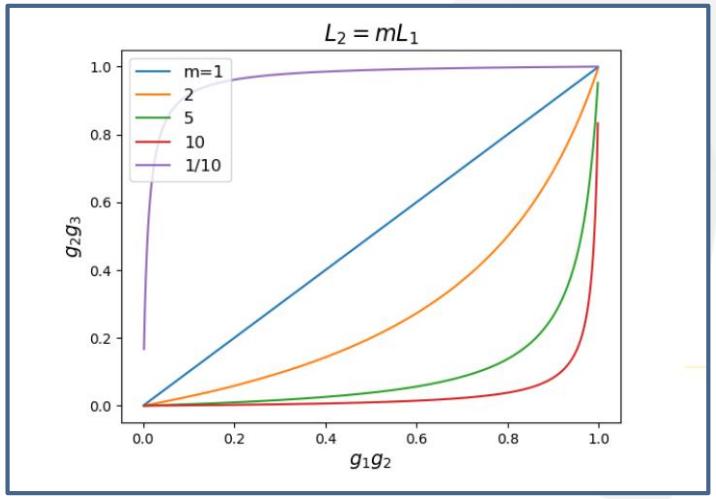
ANR QFILTER

- Study the design constrains of a 3-mirrors cavity

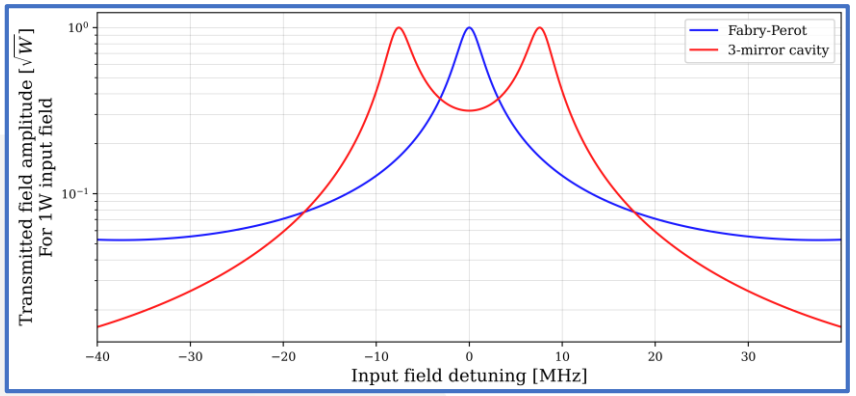


Coupled cavity notation

- Characterize the exotic properties of coupled cavities and the impact on cavity design



Effect of cavity length dissymmetry on stability



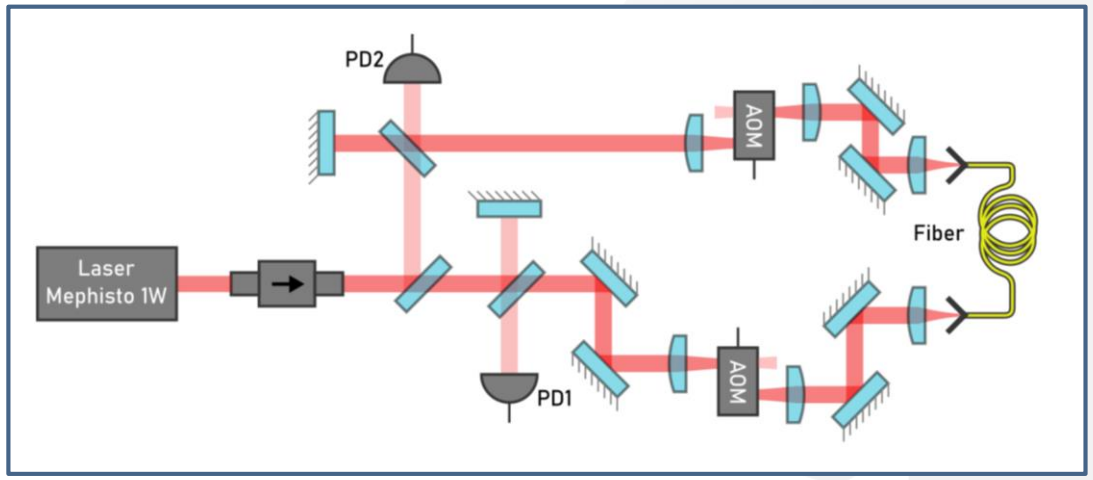
Double resonance peaks of a 3-mirrors cavity VS “classical” resonance peak of 2-mirrors cavity

Phase noise inside fibers

- GW detectors are large scale facilities and it's necessary for several application to distribute laser beams and theirs phase safely at different place of the interferometer

=> Fibers are a convenient transport method but the phase noise developed inside them is problematic

Squeezing on Virgo is one of the sub-system impacted by this problem

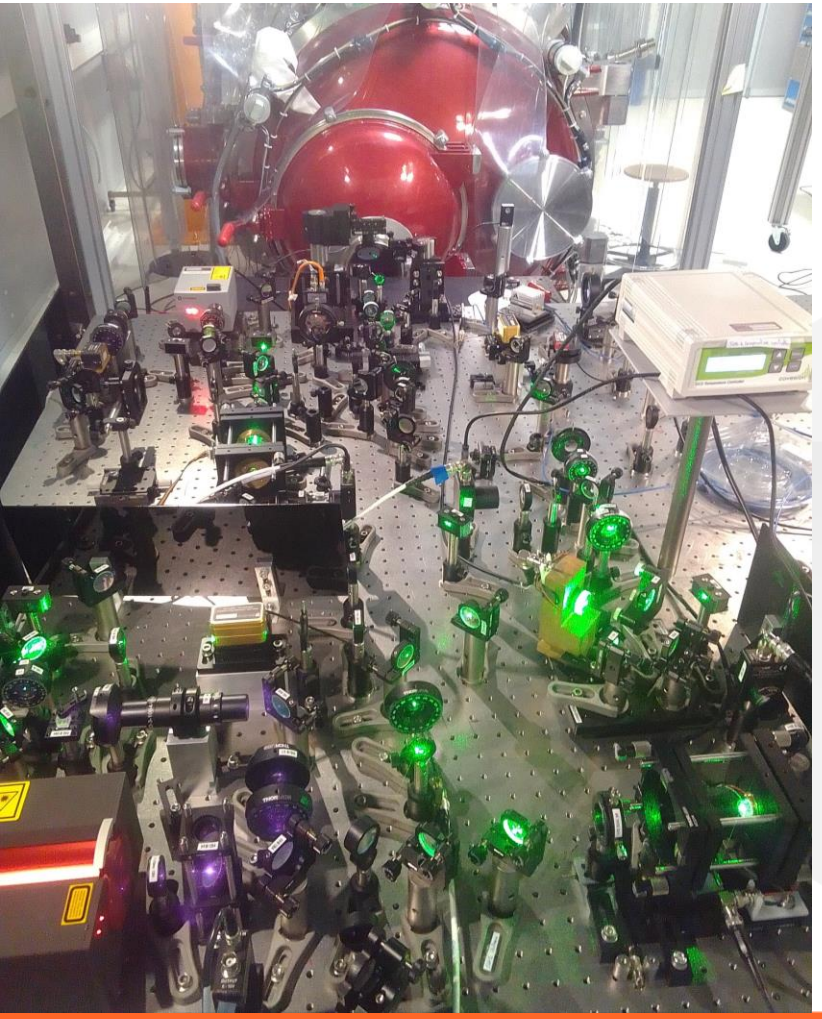


Fiber noise cancellation experiment planned at IJCLab (based on SYRTE)

A first meeting has taken placed and more are planned.

Several teams plan to work on this subject :

- Padova
- Nikhef
- EGO
- IJCLAB



Any questions ?