Advanced Virgo: status and prospects

J. Degallaix for the Virgo Collaboration

LISA Symposium 2012 – Paris

Menu

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Overview of the Advanced Virgo design

The foreseen challenges

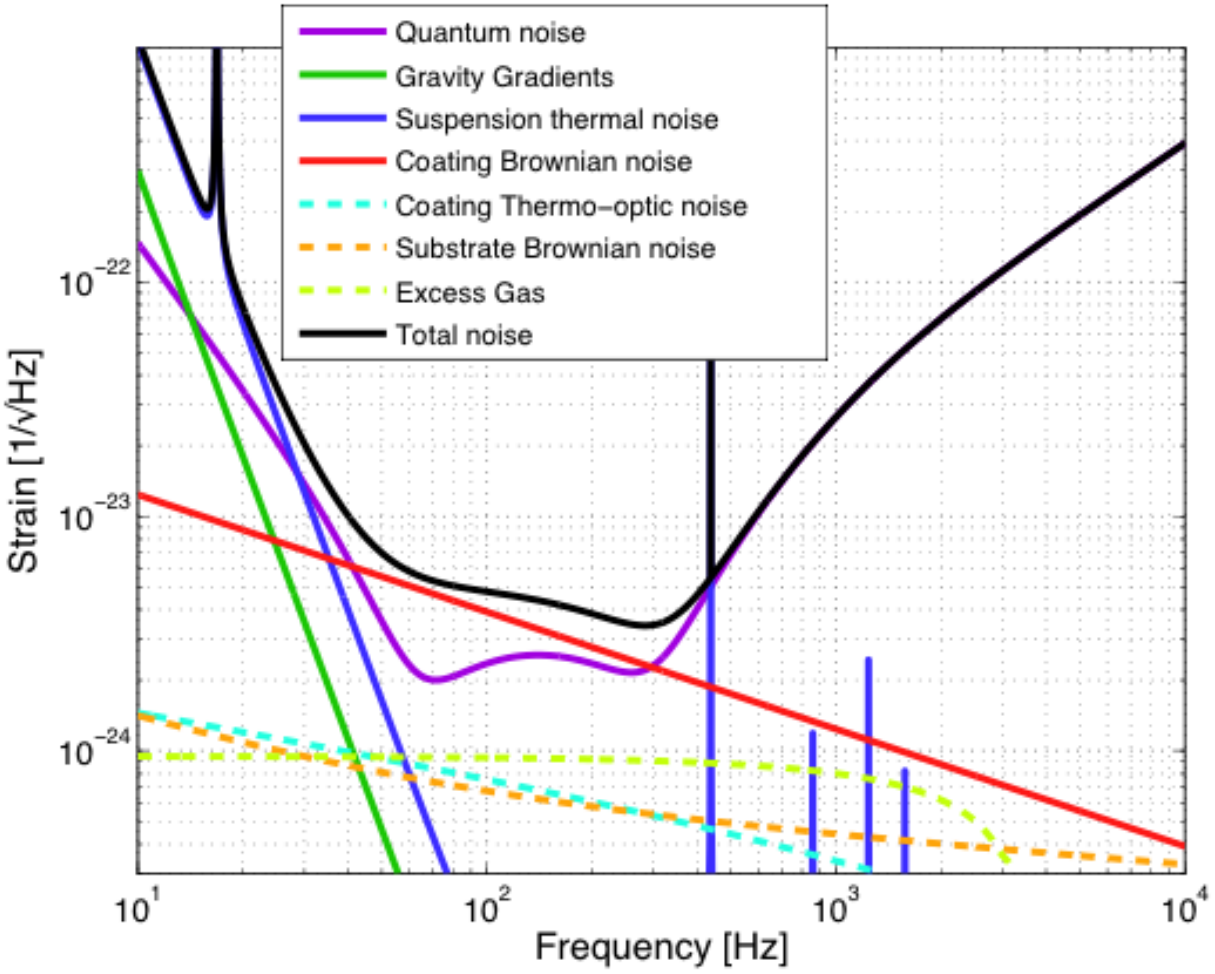
Status and plan

Part I:
Advanced Virgo design

Piazza Fabry Pérot

The sensitivity goal

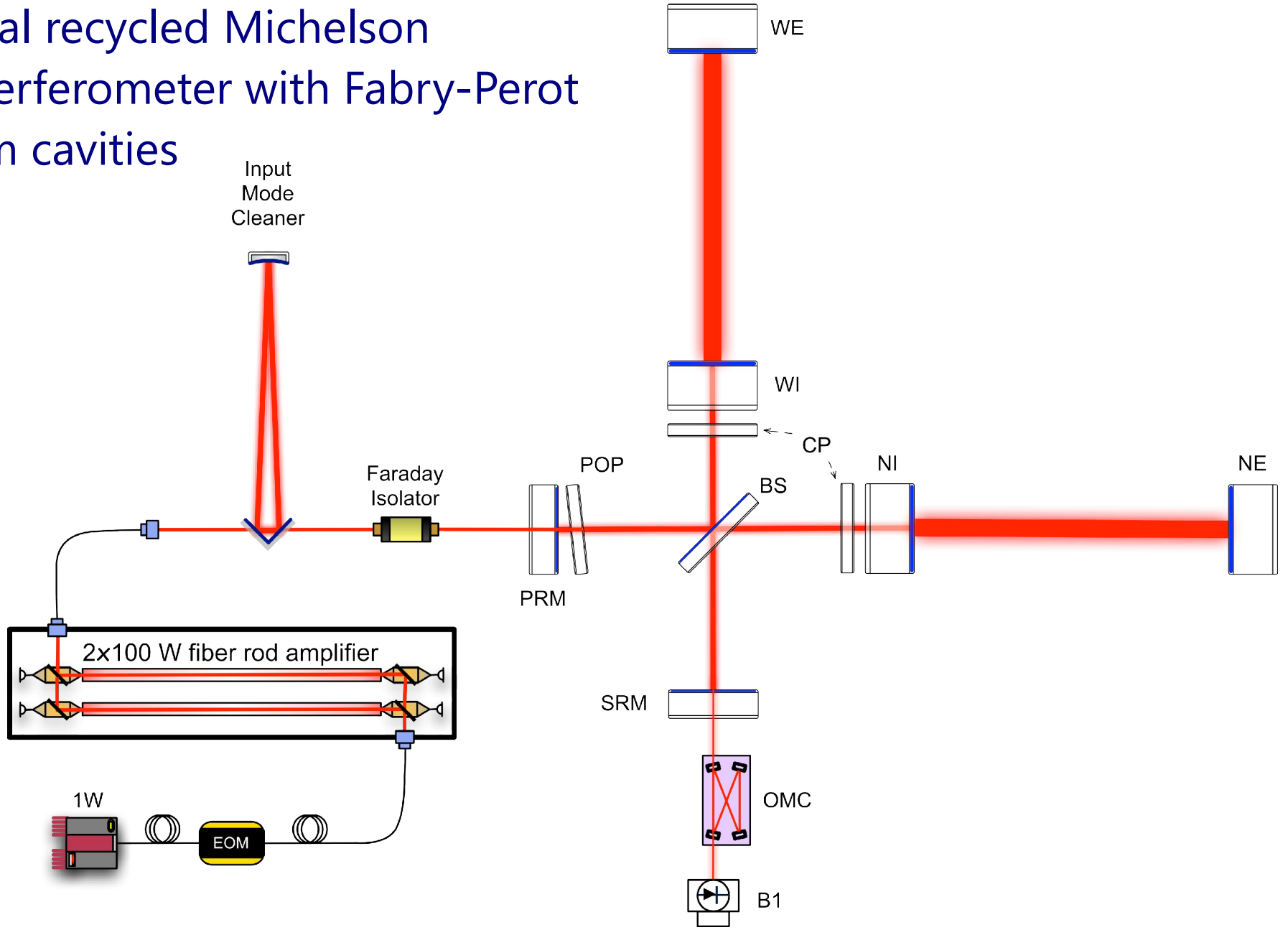
- Detect gravitational waves on a regular basis
- Inspiral range for NS/NS binaries: 134 Mpc, event rate: 40 / year [1]
- Inspiral range for BH/BH binaries: 1020 Mpc, event rate: 20 / year [1]



[1] With the LIGO-Virgo network doi:10.1088/0264-9381/27/17/173001

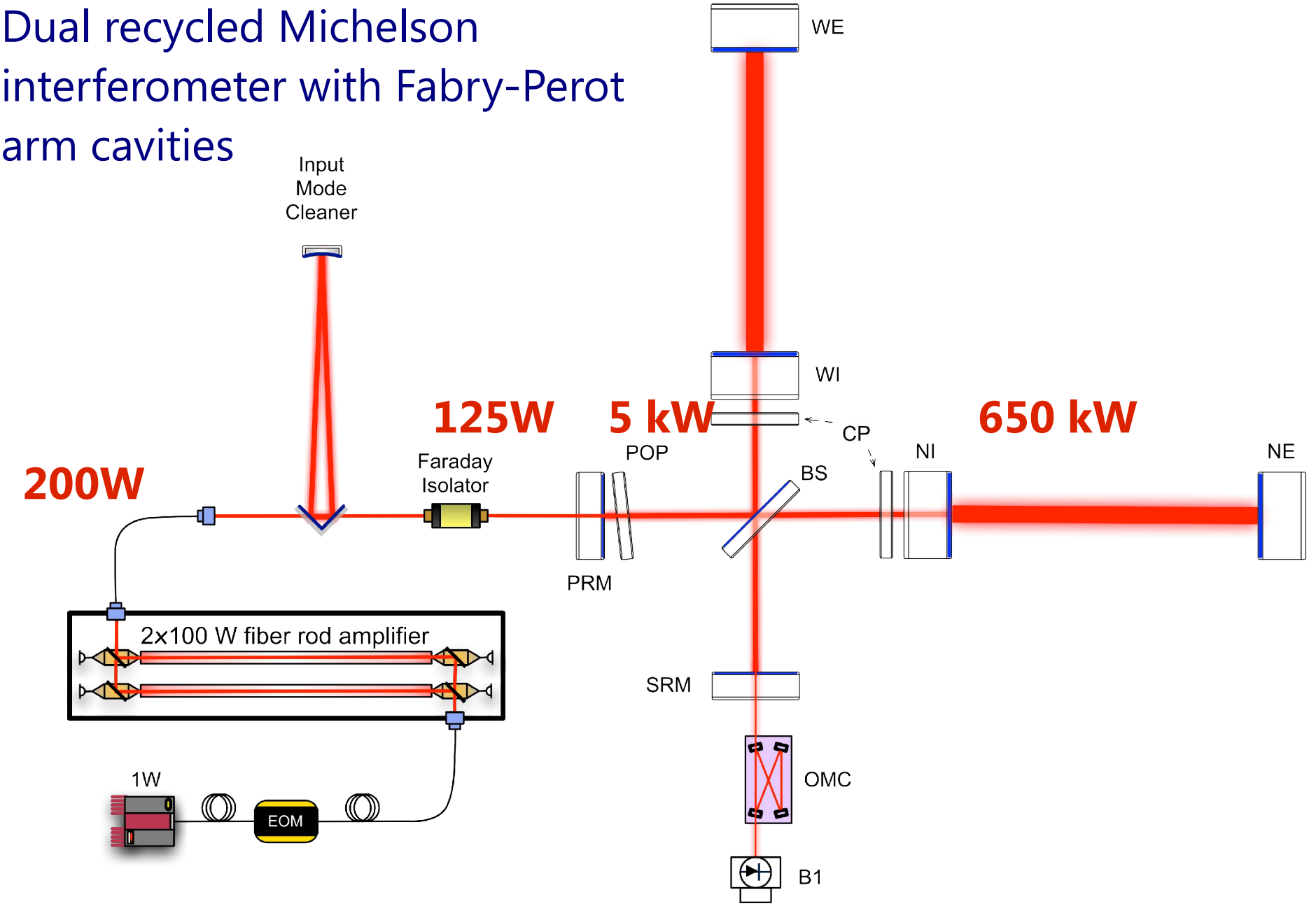
Advanced Virgo optical design

Dual recycled Michelson interferometer with Fabry-Perot arm cavities



Advanced Virgo optical design

Dual recycled Michelson interferometer with Fabry-Perot arm cavities

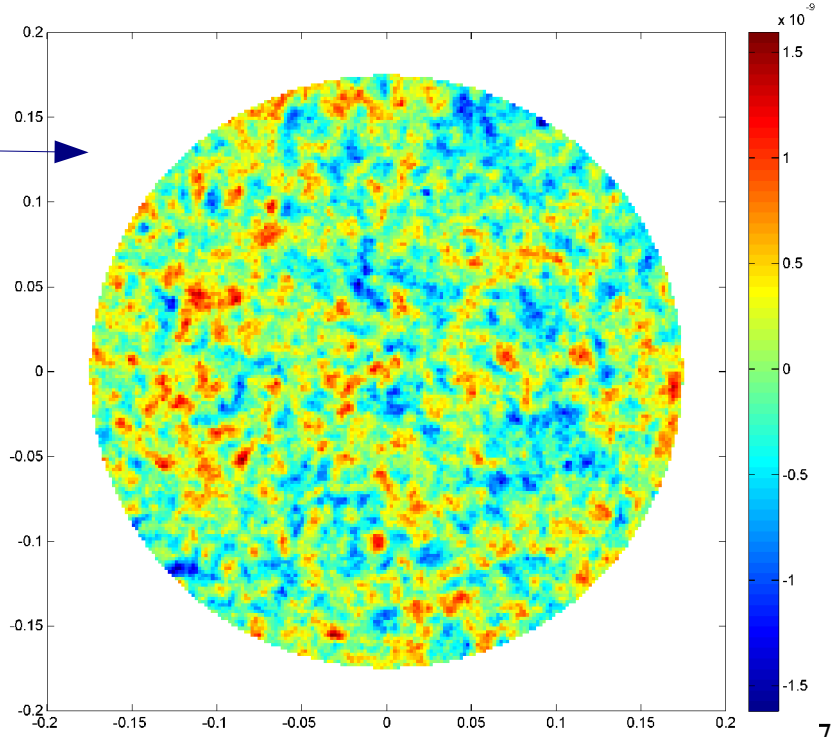


The arm cavities

- 3 km long Fabry Perot cavities
- where the GW signal is measured

The arm cavities must store as much light as possible.
The light round trip loss must be less than 75 ppm.
Give constraint on:

- size of the laser beam (5 cm)
- mirror flatness (< 0.5 nm RMS)
- mirror micro-roughness (0.1 nm)
- optical absorption (< 0.5 ppm)



Left: example of an acceptable simulated mirror surface with a P-V of 3 nm

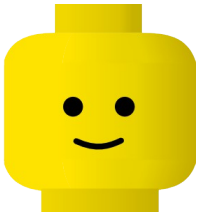
The recycling cavities

Recycling cavities serve 2 goals:

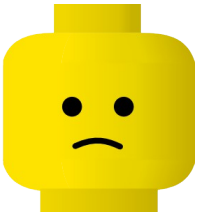
- Enhance the circulating power (power recycling)
- Shape the optical response (signal recycling)

- First generation and Adv. Virgo: marginally stable cavities
- Adv. LIGO: stable recycling cavities

Why this choice of recycling cavity ?



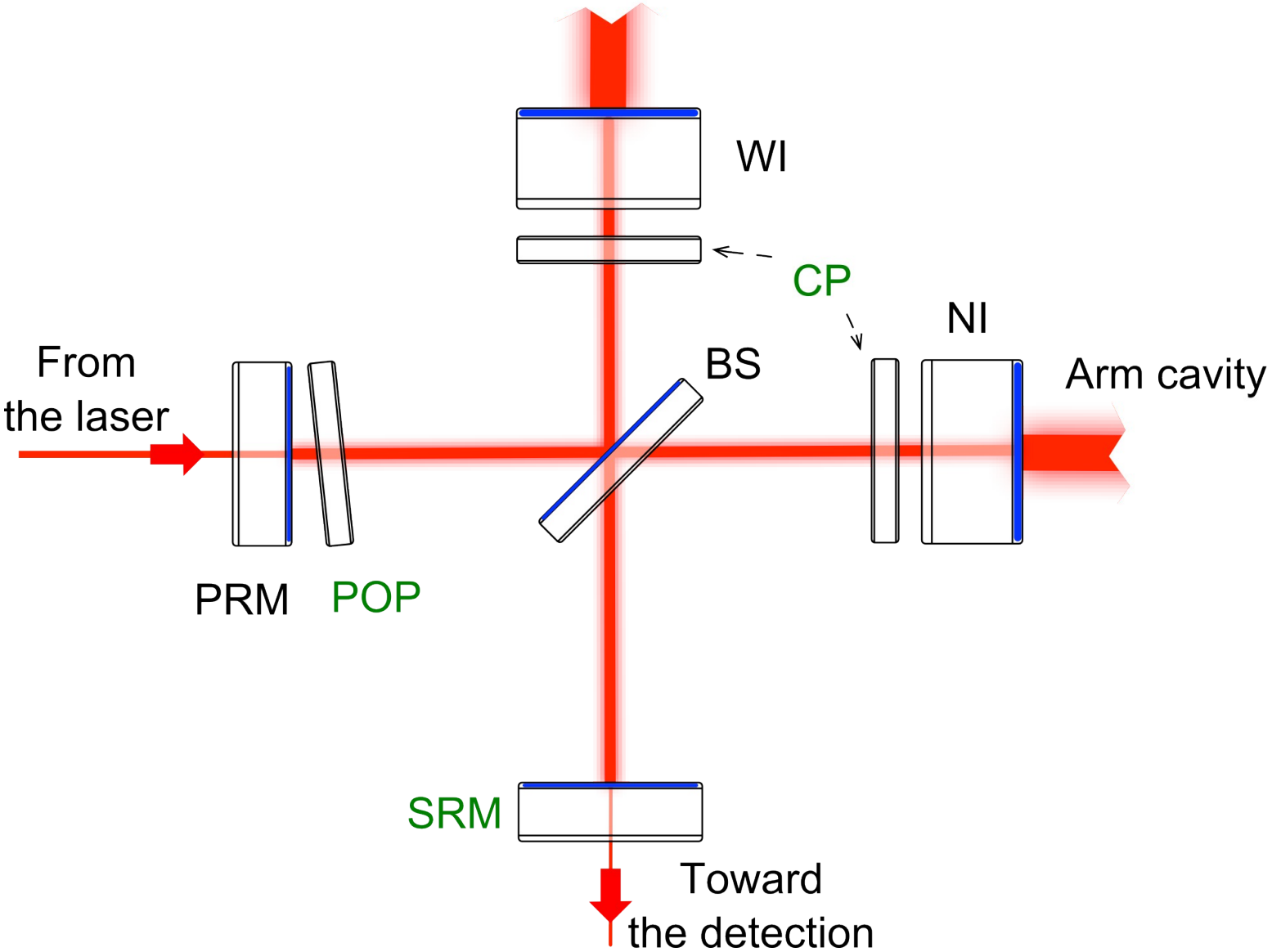
- Known
- Simple
- Cost and space friendly



- Very sensitive to aberrations
- Need extra telescope

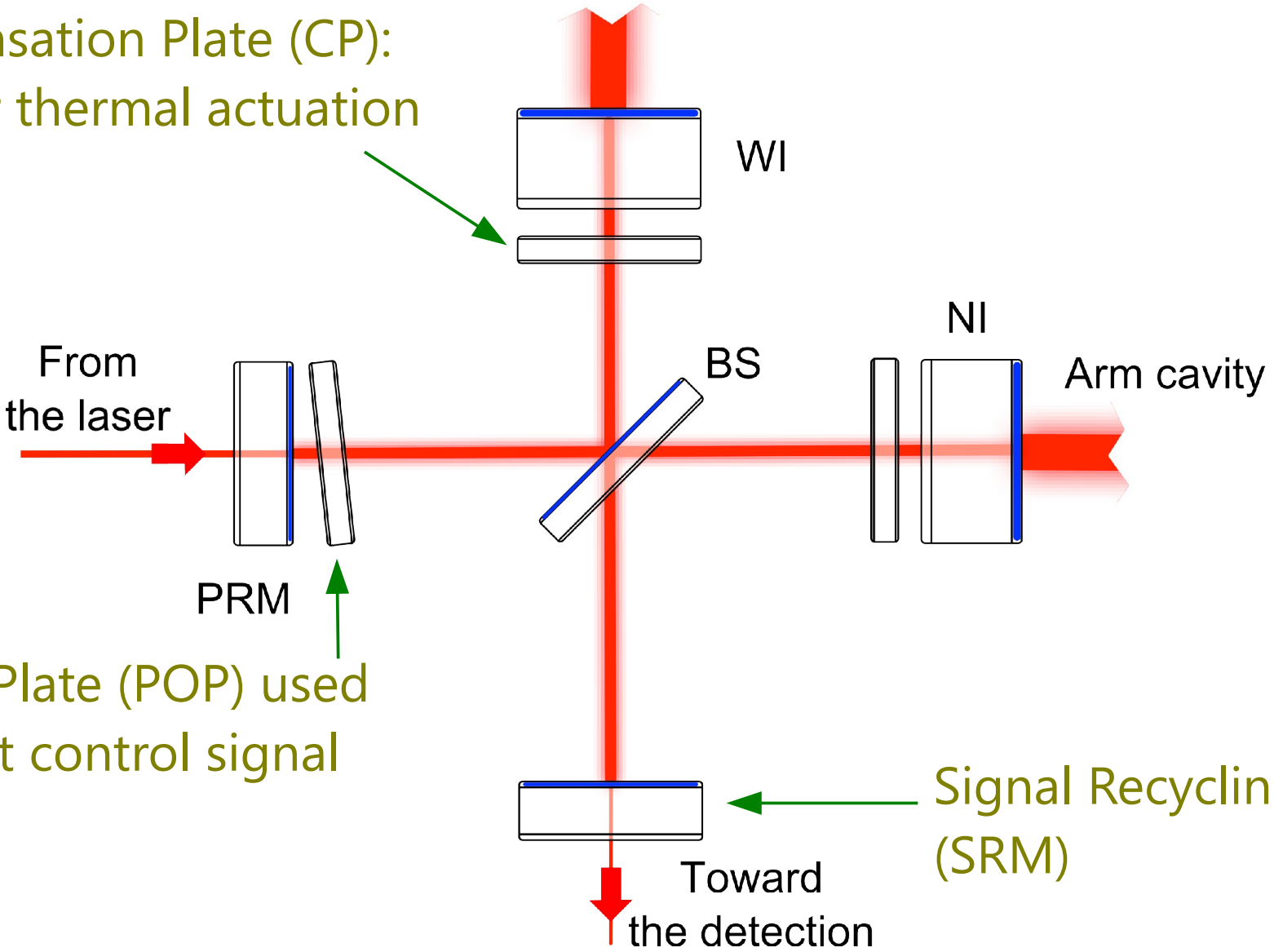
The recycling cavities in details

Similar to Virgo



The recycling cavities in details

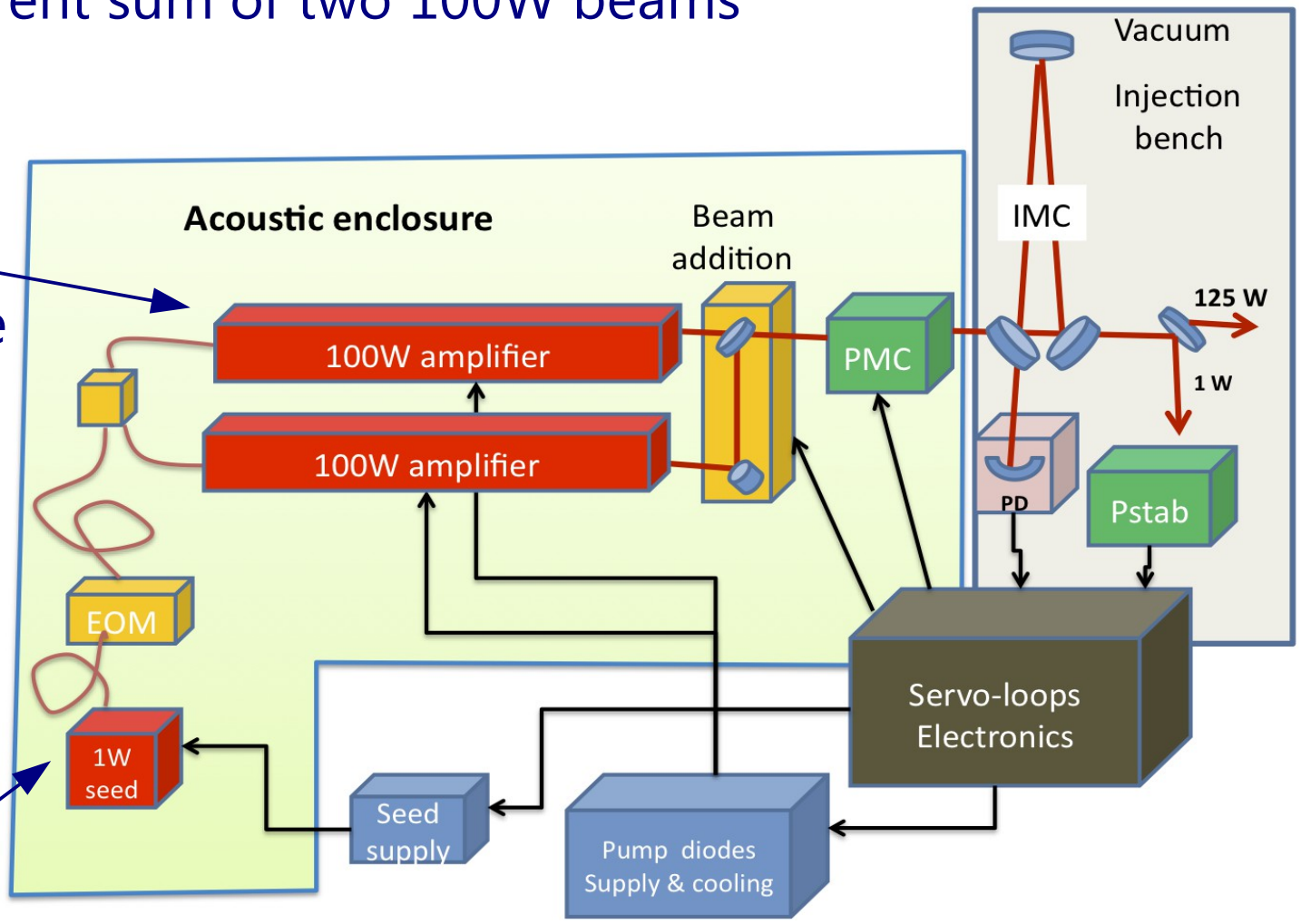
Similar to Virgo but with additional optics



The 200 W laser

- Fiber laser allows a simpler design and less optics
- 200W is the coherent sum of two 100W beams

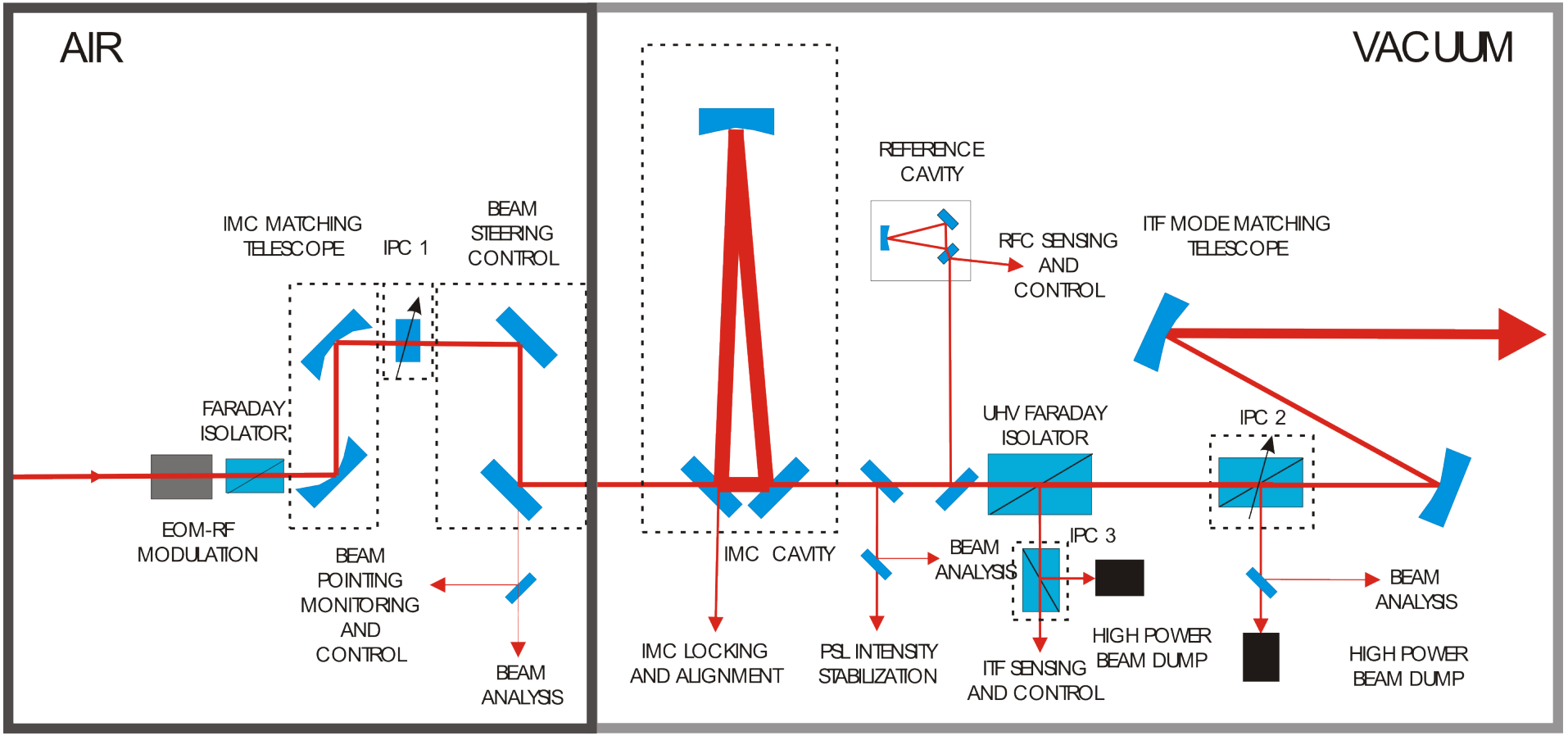
Ytterbium doped rob fiber with single mode operation

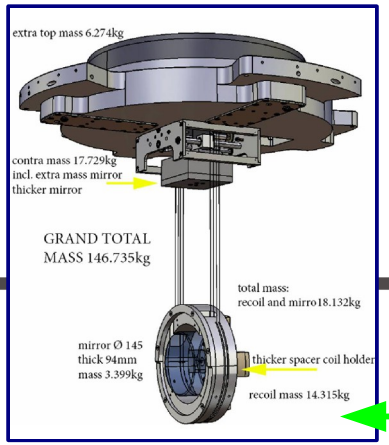


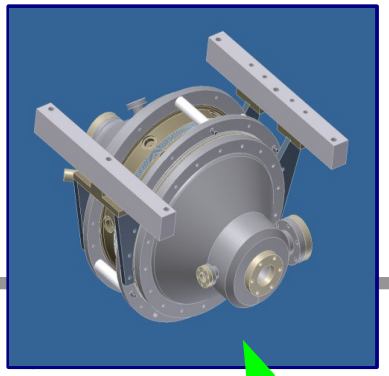
1W Nd:YAG laser

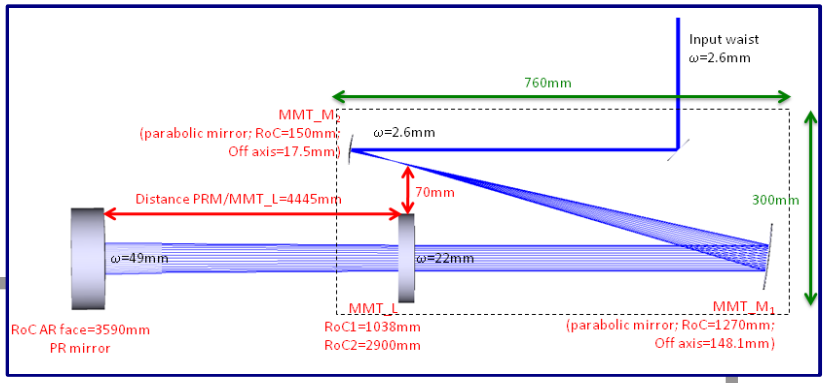
The injection system

- Between the laser and the interferometer
- Modulate, stabilize and shape the beam









AIR

REFERENCE CAVITY

RFC SENSING AND CONTROL

ITF MODE MATCHING TELESCOPE

VACUUM

IMC MATCHING TELESCOPE

IPC 1

BEAM STEERING CONTROL

FARADAY ISOLATOR

EOM-RF MODULATION

BEAM POINTING MONITORING AND CONTROL

BEAM ANALYSIS

IMC CAVITY

IMC LOCKING AND ALIGNMENT

PSL INTENSITY STABILIZATION

UHV FARADAY ISOLATOR

BEAM ANALYSIS

IPC 3

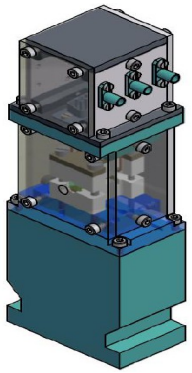
ITF SENSING AND CONTROL

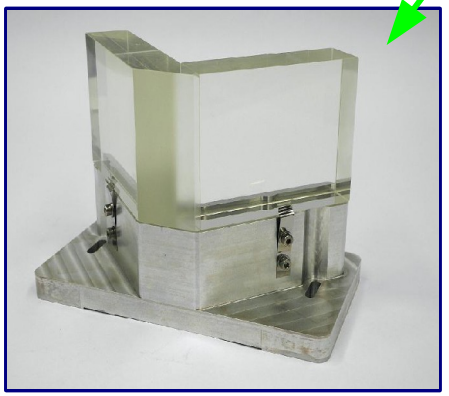
HIGH POWER BEAM DUMP

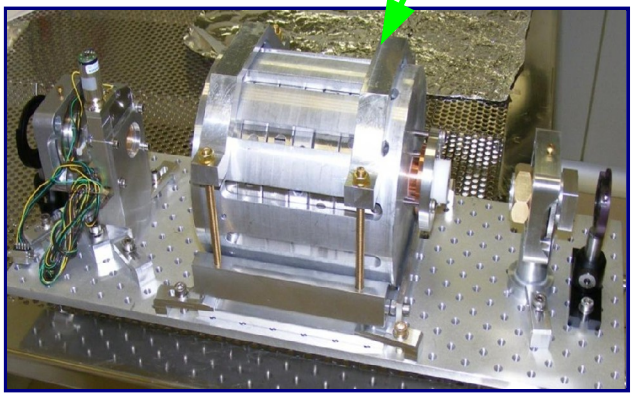
IPC 2

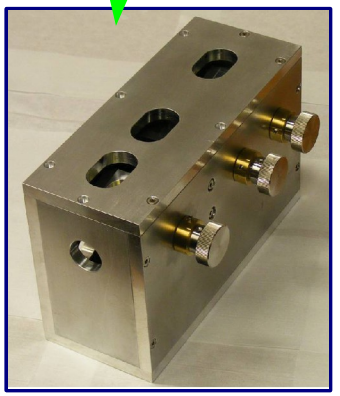
BEAM ANALYSIS

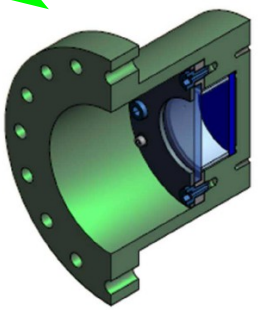
HIGH POWER BEAM DUMP





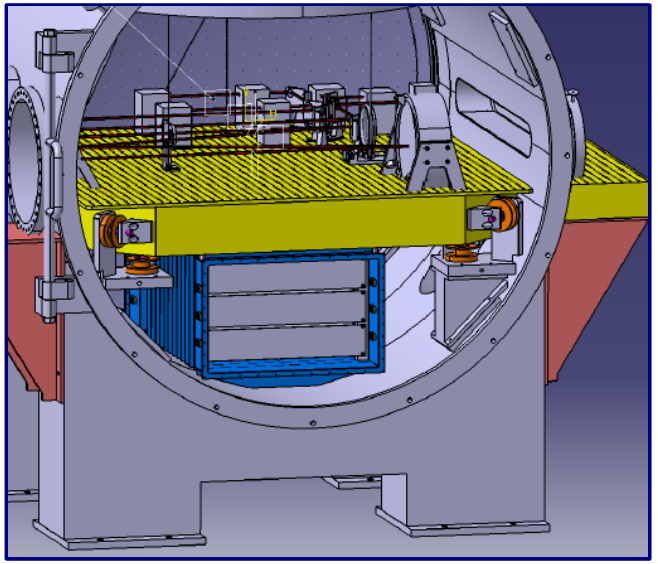


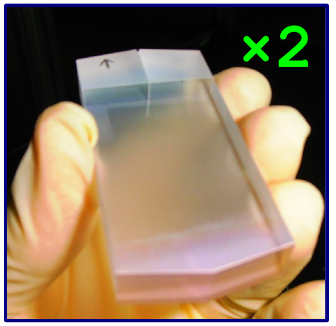


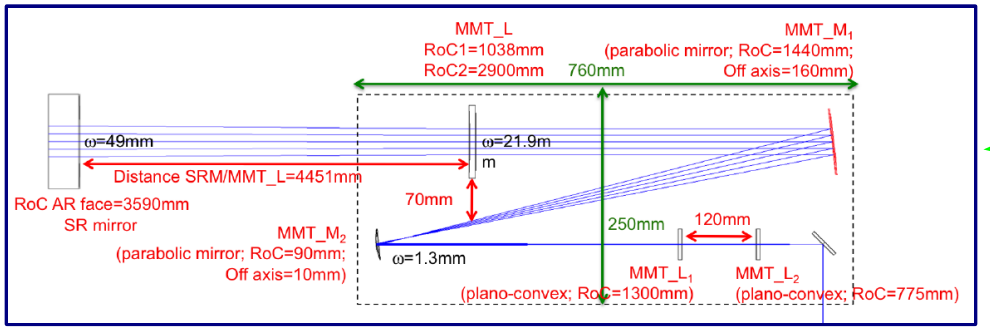


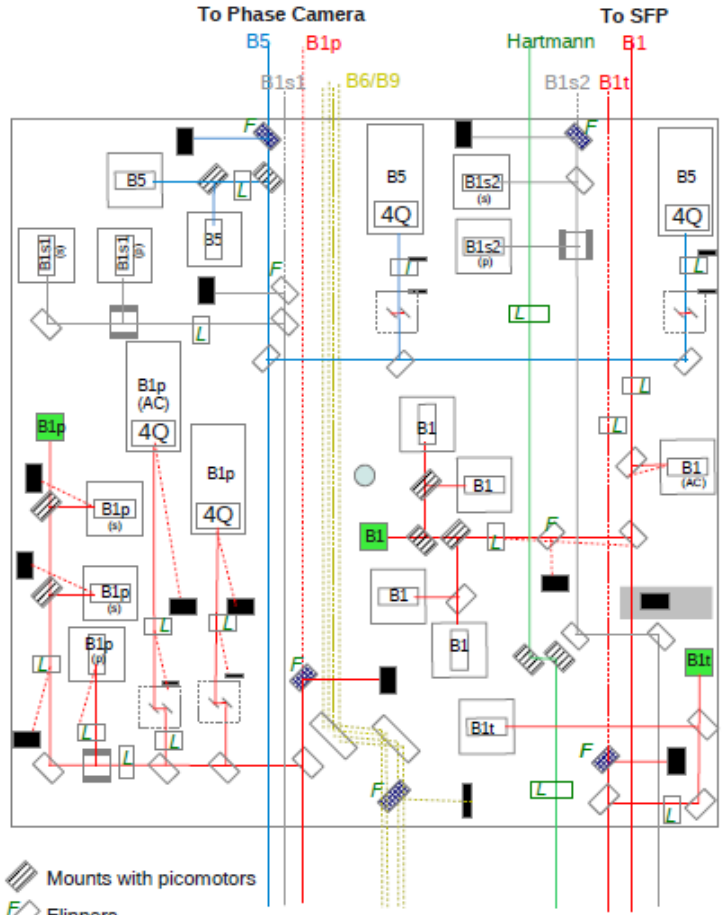
The detection setup

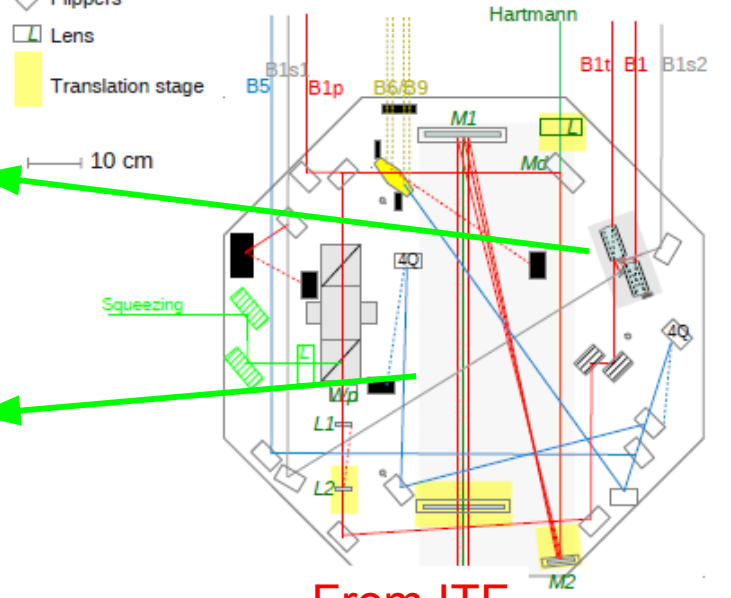
- Give signals to control the interferometer
- Read the GW signal
- Dedicated benches at the dark port (right) and also behind the arms (below)





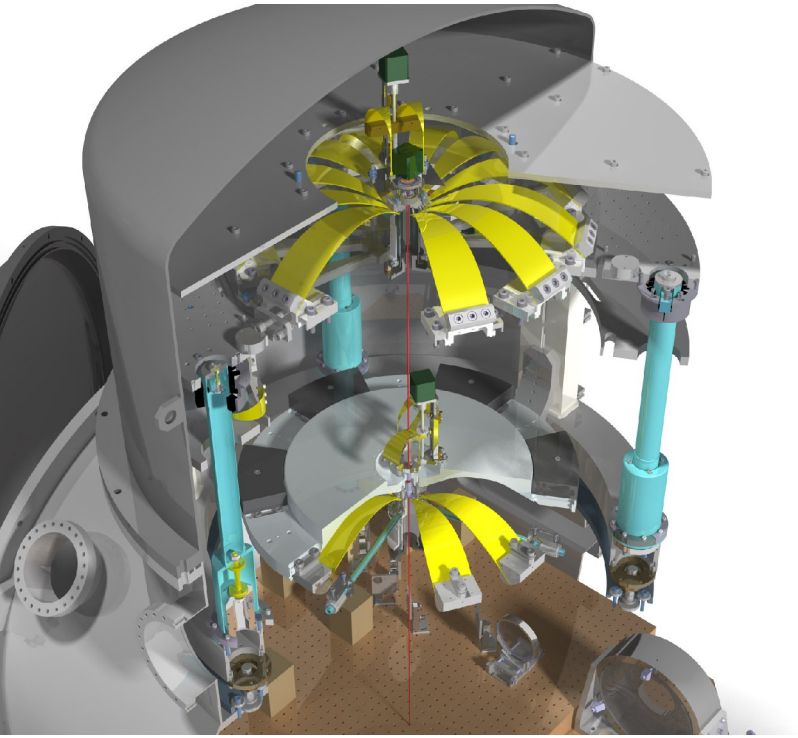




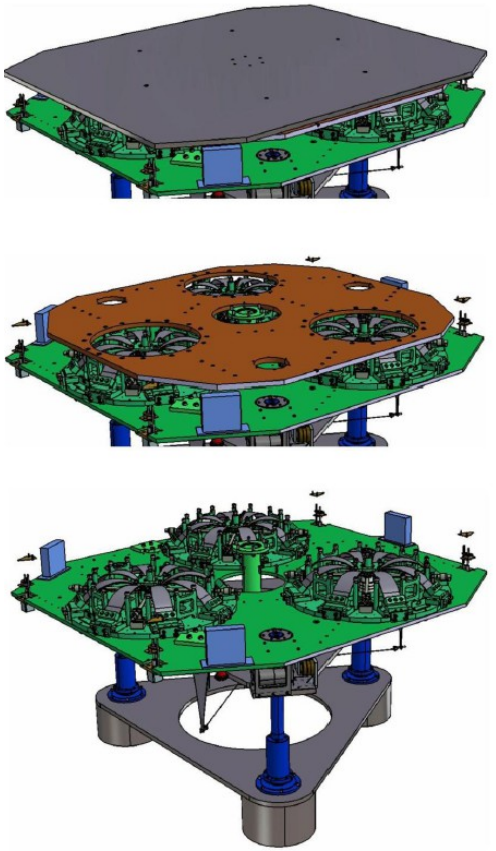


Suspension: the superattenuator and co.

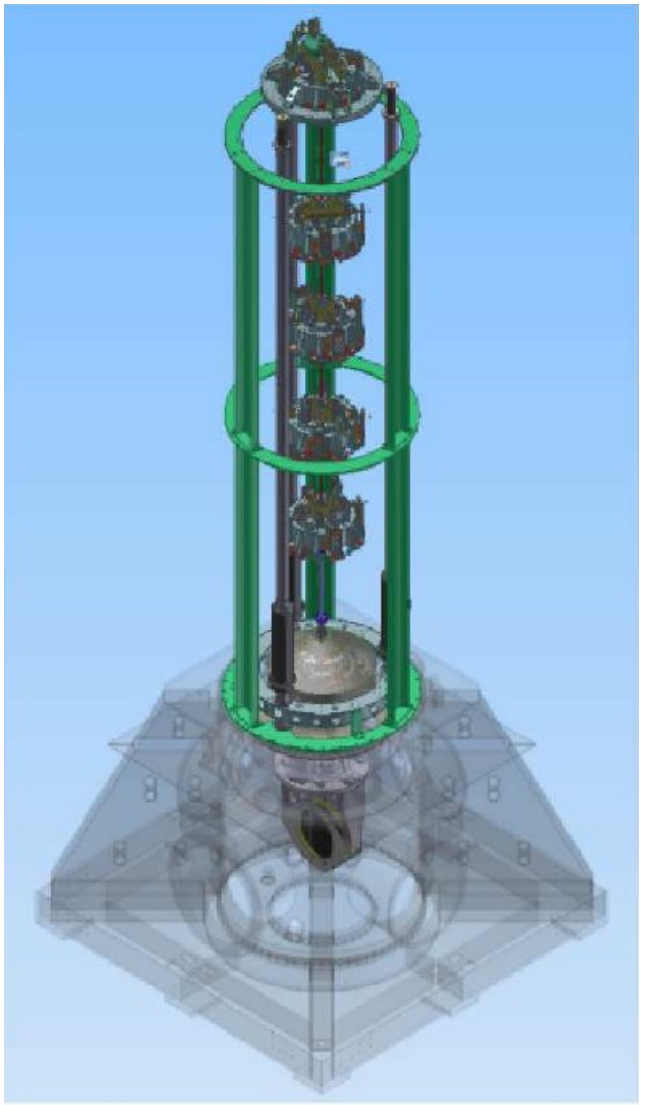
- Isolate optics from the ground motion
- Main attenuator already compliant but some upgrades are foreseen
- New isolated benches for injection or detection



Isolation for mini tower

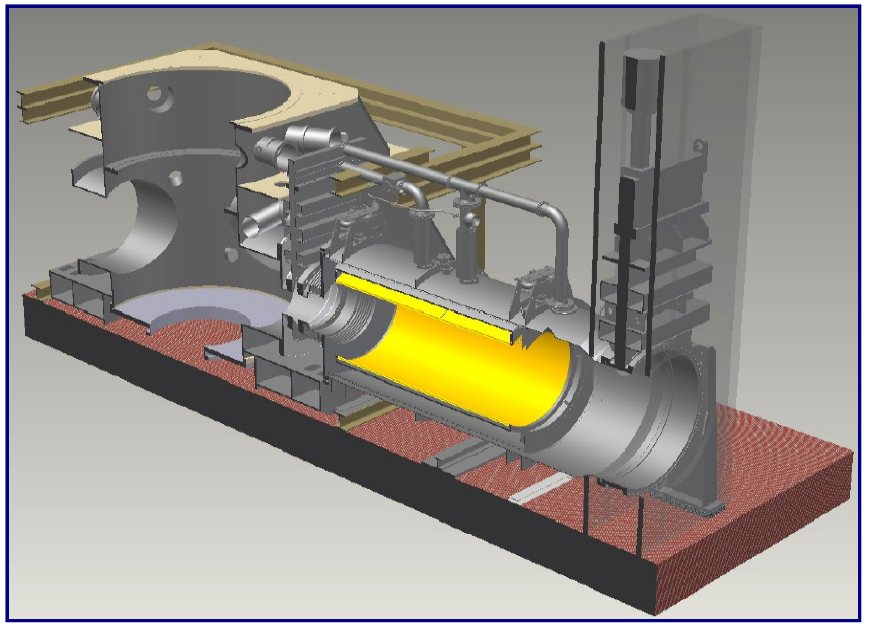


Suspended bench

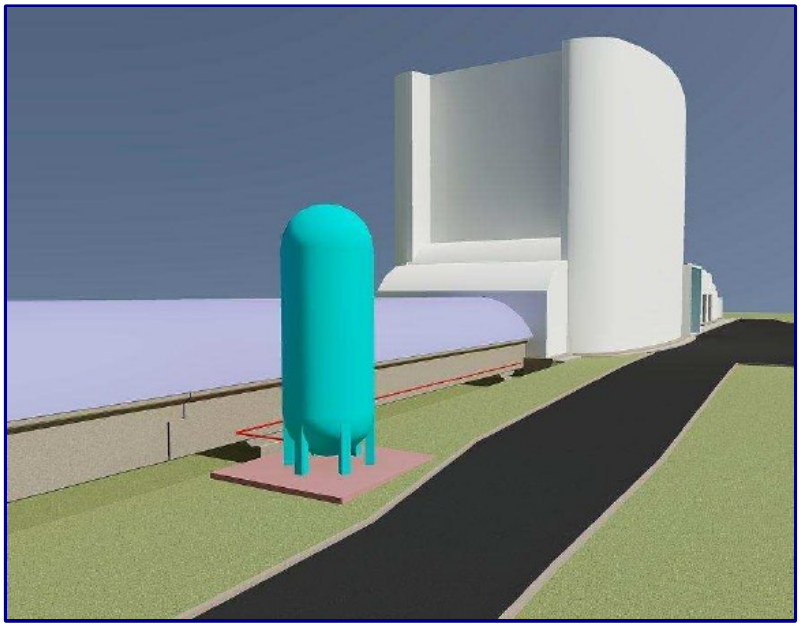


SAT for SRM

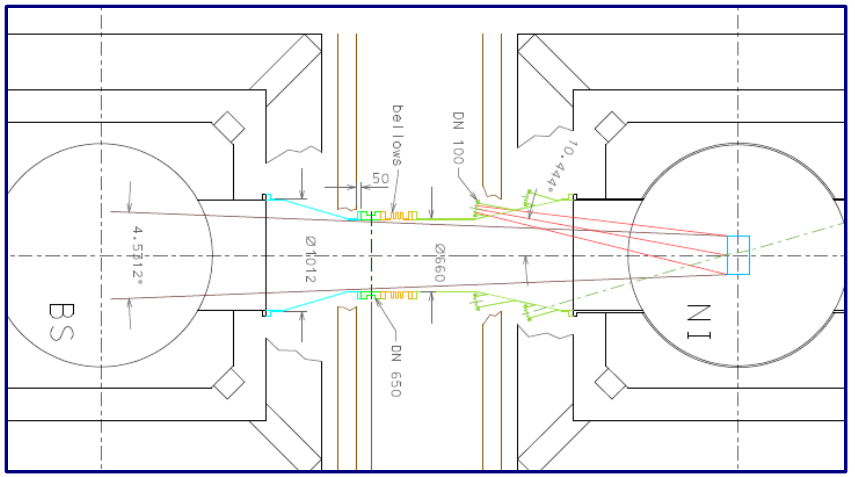
Upgrade of vacuum system and infrastructure



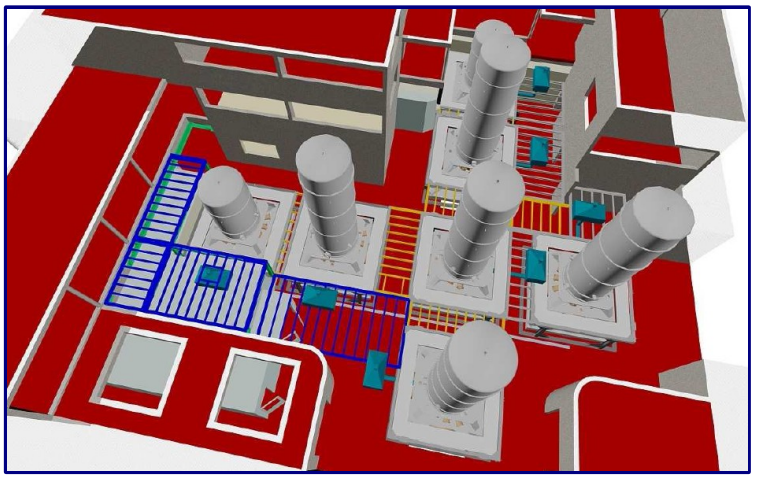
Add 4 cryotraps



Build liquid nitrogen tank



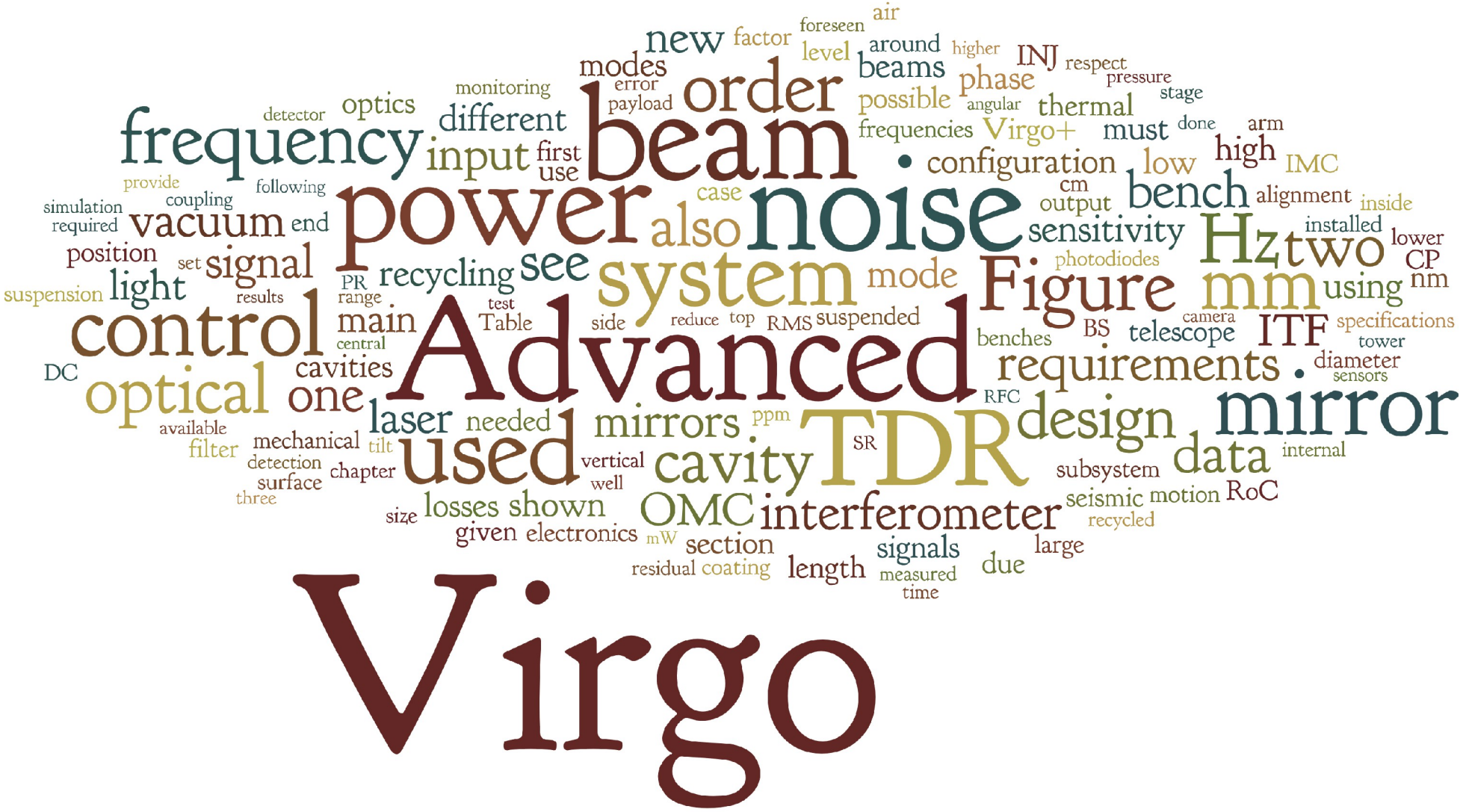
Enlarged central vacuum link



Add new clean rooms

To know further

The reference document for the Advanced Virgo design is available here:
https://tds.ego-gw.it/itf/tds/file.php?callFile=VIR-0128A-12.pdf



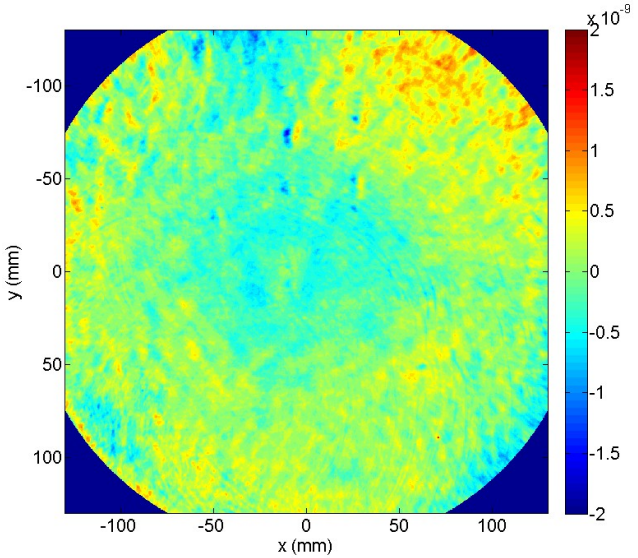
Part II:
Challenges ahead!

Mode cleaner tube and the west arm

Reaching the surface quality of the mirror

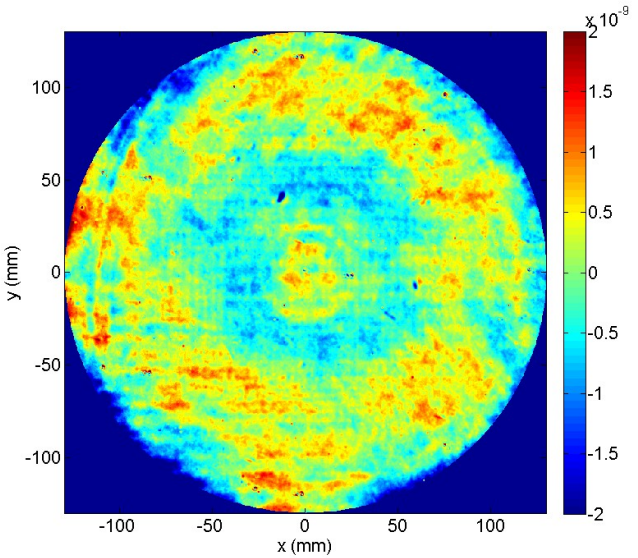
- Requirement: 0.5 nm RMS on the central 150 mm
- A two steps strategy to reach such a flatness:

1. Mechanical polishing down to 2 nm RMS
2. Ion beam polishing **OR** corrective coating



RMS: 0.20 nm

Height color scale:
4 nm P-V



RMS: 0.36 nm

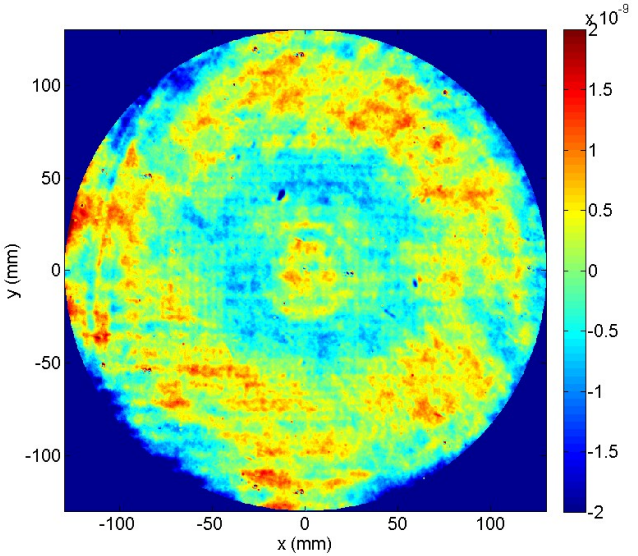
Starting with a 2.1 nm RMS mirror

The strategy

- Requirement: 0.5 nm RMS on the central 150 mm
- A two steps strategy to reach such a flatness:

1. Mechanical polishing down to 2 nm RMS
2. Corrective coating

Installation of the robot in the coater chamber



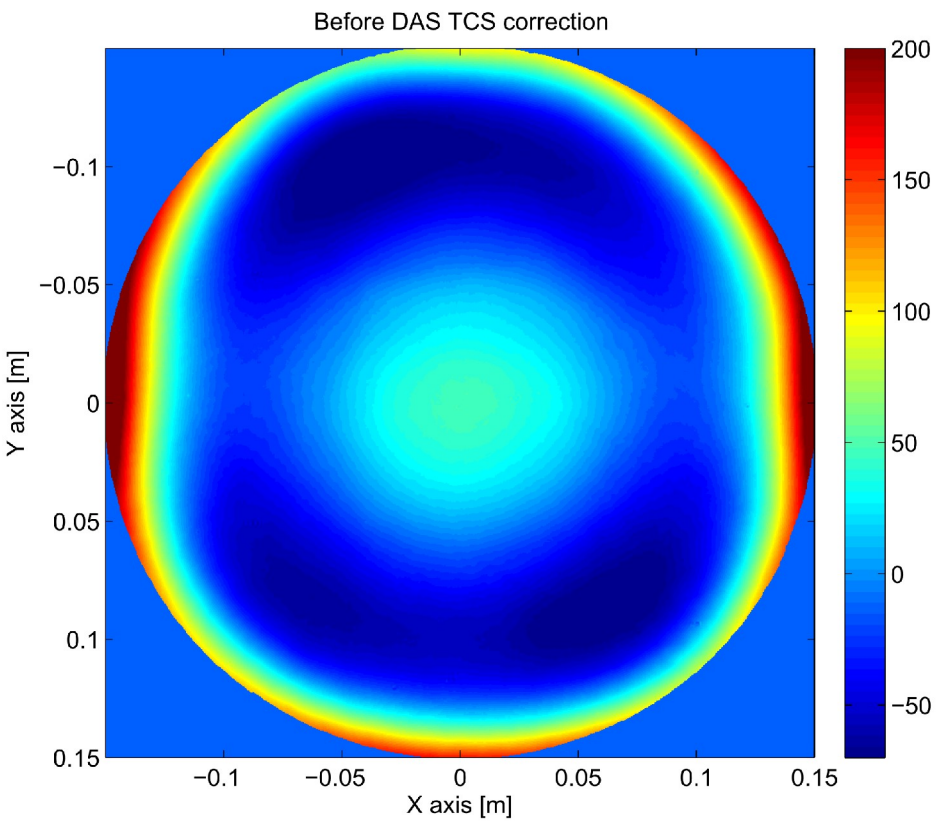
RMS: 0.36 nm

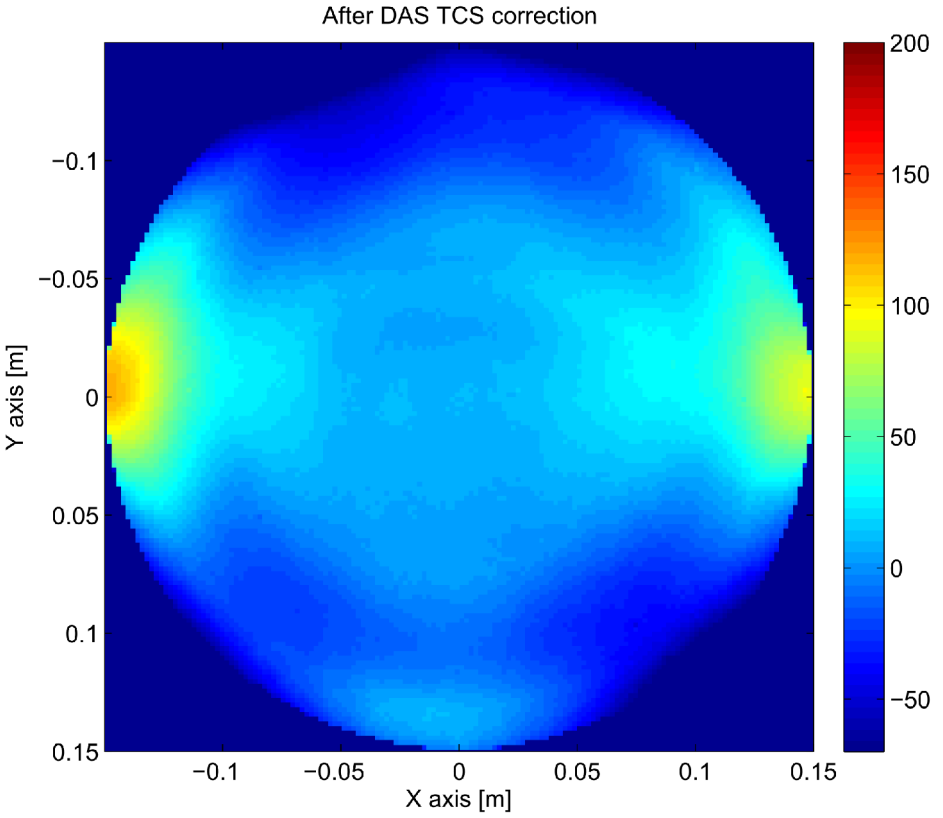
Starting with a 2.1 nm RMS mirror

The thermal compensation system

- Goal: aberration free interferometer
- Correct the effects of optical absorption but also all the other cold distortion (RoC error, surface flatness,...)
- Required from the start even at low power

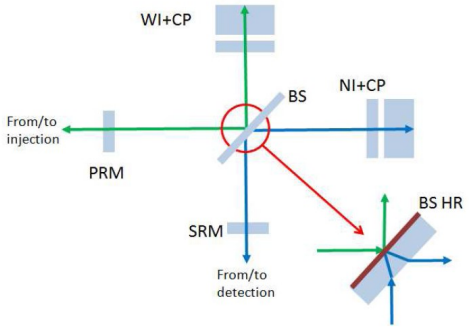
Example of cold defect: the input mirror substrate inhomogeneity





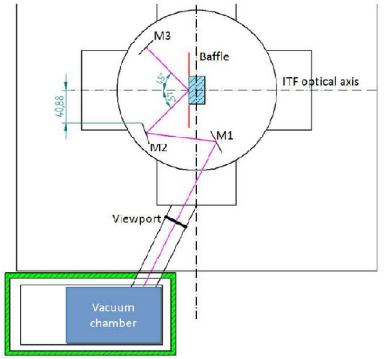
The thermal compensation system

3 main sensors....



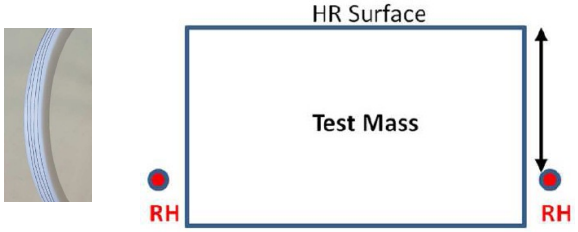
Hartman wavefront sensing

Phase camera

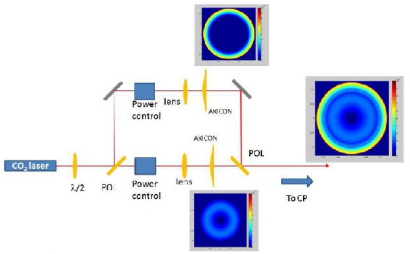


HR surface sensing

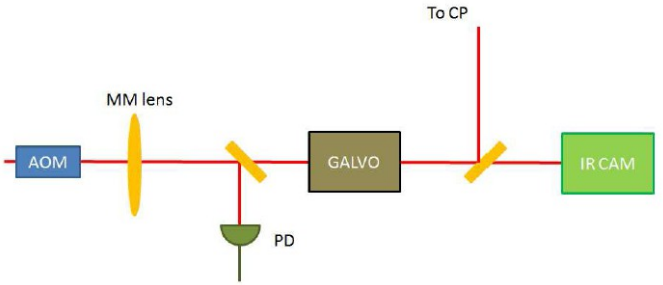
... for 3 main actuators



Heating ring



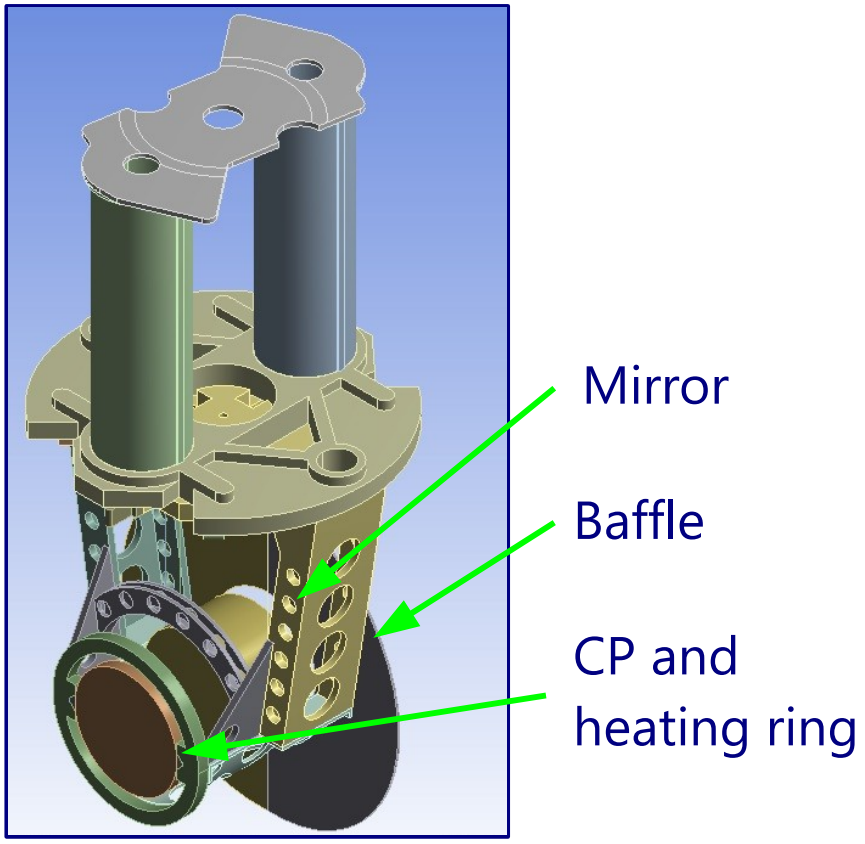
CO_2 laser with 2 axicons



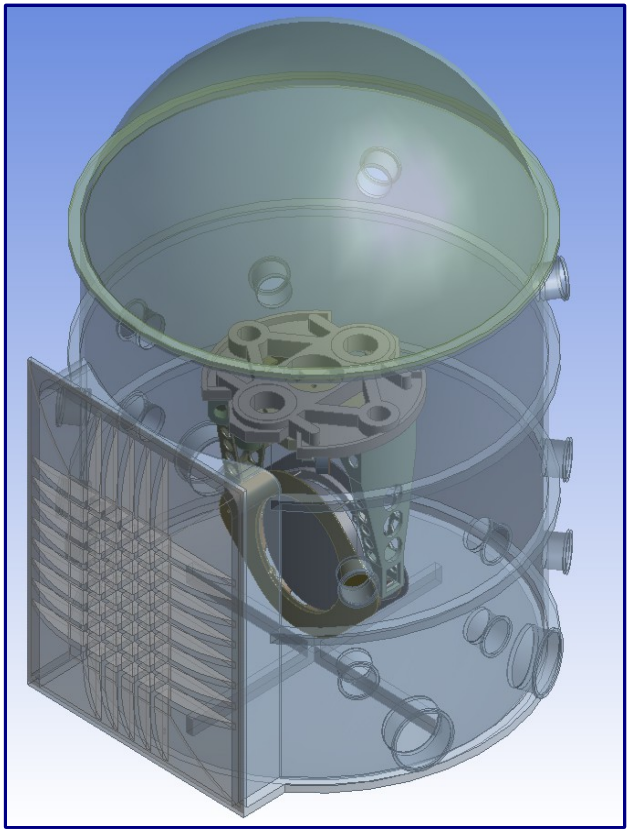
Scanning CO_2 laser

Payload

- Goal: attach the mirror to the suspension
- More complex than in Virgo+ (now heating ring, CPs, baffles must also be attached)
- New quality factor measurement facility



Last stage of the suspension for the input mirror

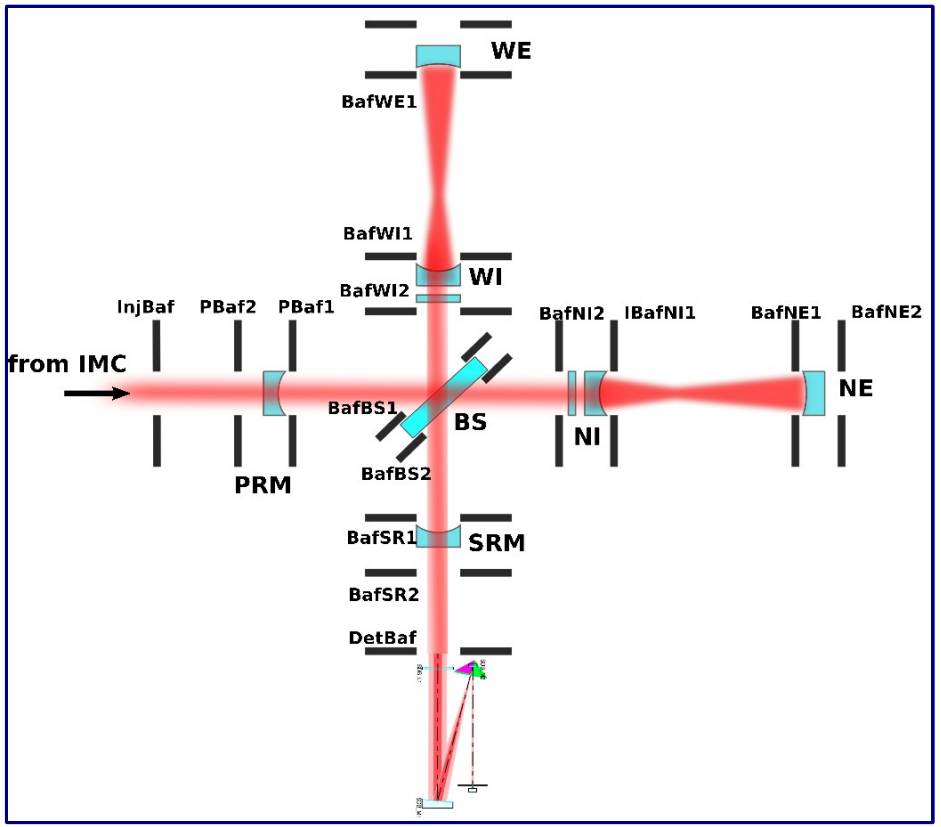


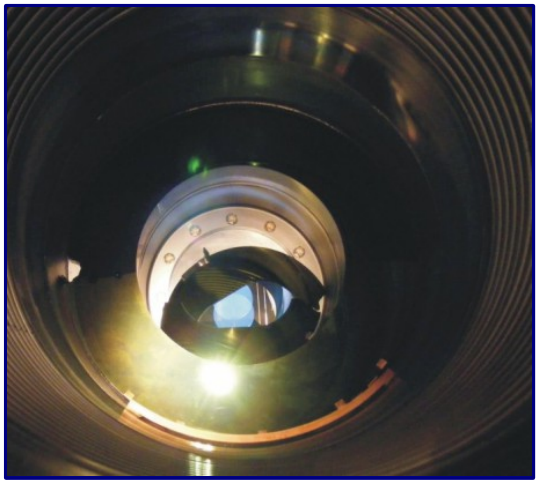
Vacuum facility for Q measurement

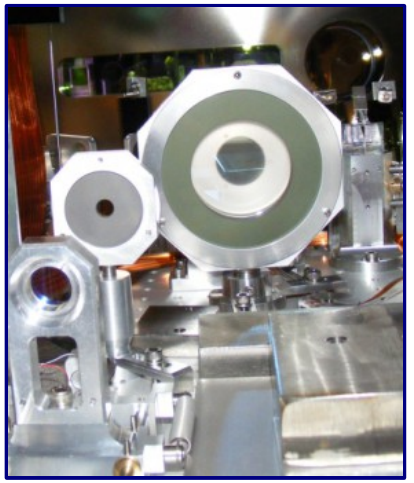
Managing the scattered light

- Goal: trap the 100W of scattered light
- Solution: add new baffles
- Extensive research to know size, position and material for the baffles

Light falling outside a mirror







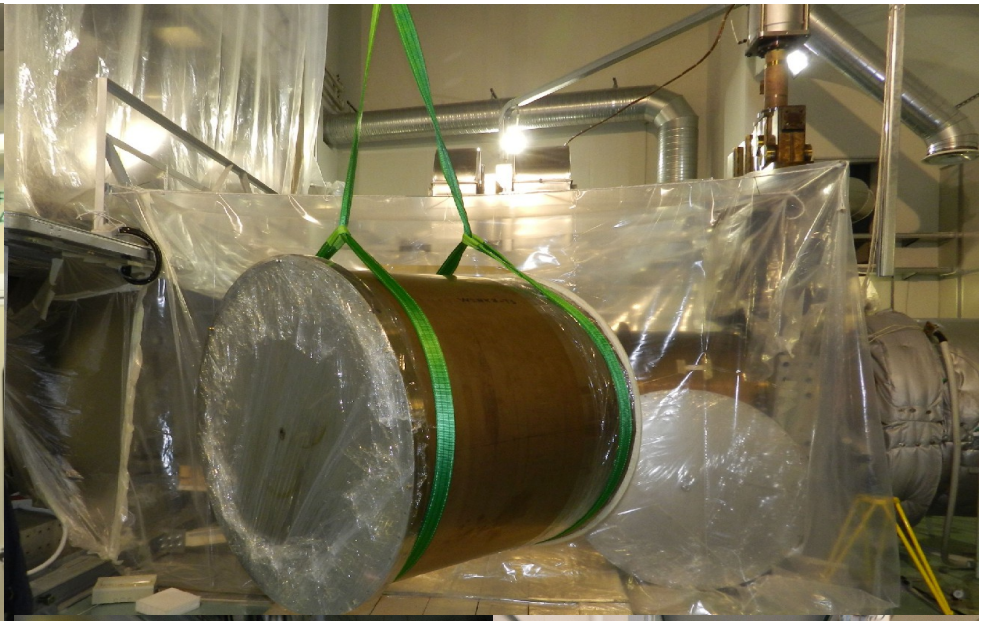
Examples of baffles already installed

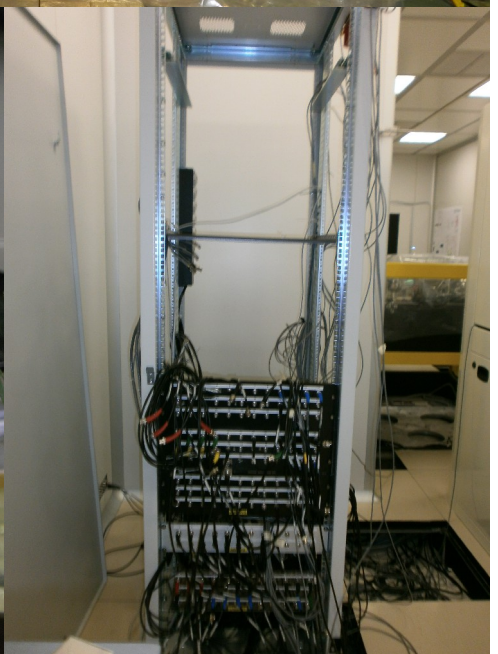
Part III:
Advancement and plan

The north arm

The decommissioning of Virgo+

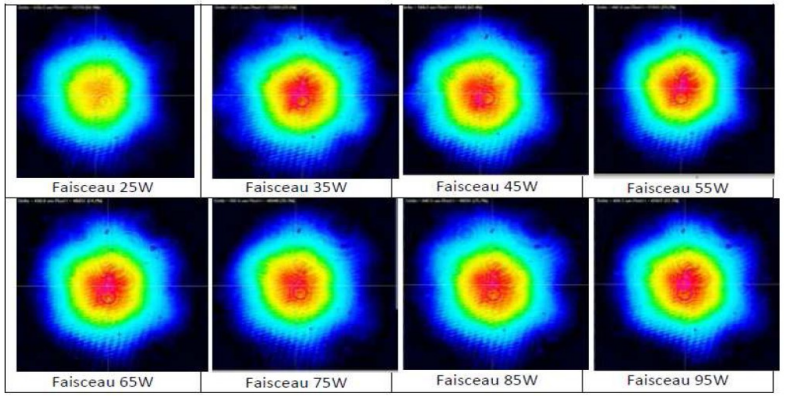
Started since the end of the last year, making room for Advanced Virgo



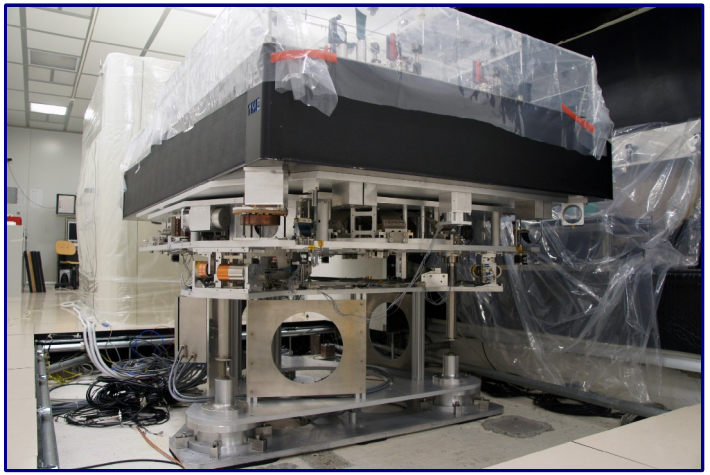


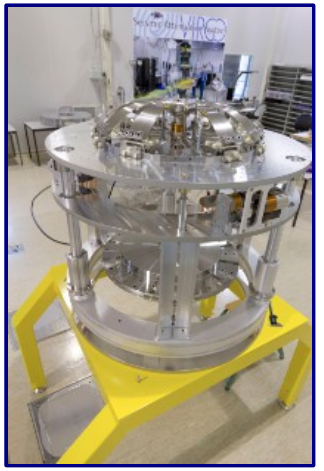
Parts are coming...

- All the mirror substrates delivered
- Call for tender for polishing sent



- 100W fiber laser build and tested
- At high power, > 90% in TEM_{00}





- Suspended bench tested
- Suspension for mini tower assembled

Conclusion and brief timeline

- Advanced Virgo design (almost) finalized
- Procurement and prototyping of parts at full speed
- Installation on site has started

Some key dates:

- Mid 2014 — mirrors coated and polished
- End 2014 — installation completed
- Beginning 2015 — one arm lock
- Mid 2015 — 25W input power, interferometer locked (no SRM)
- Mid 2017 — installation SRM
- Later — rise the input power to 200W

Advanced space time simulation