Status of the AdV detection subsystem

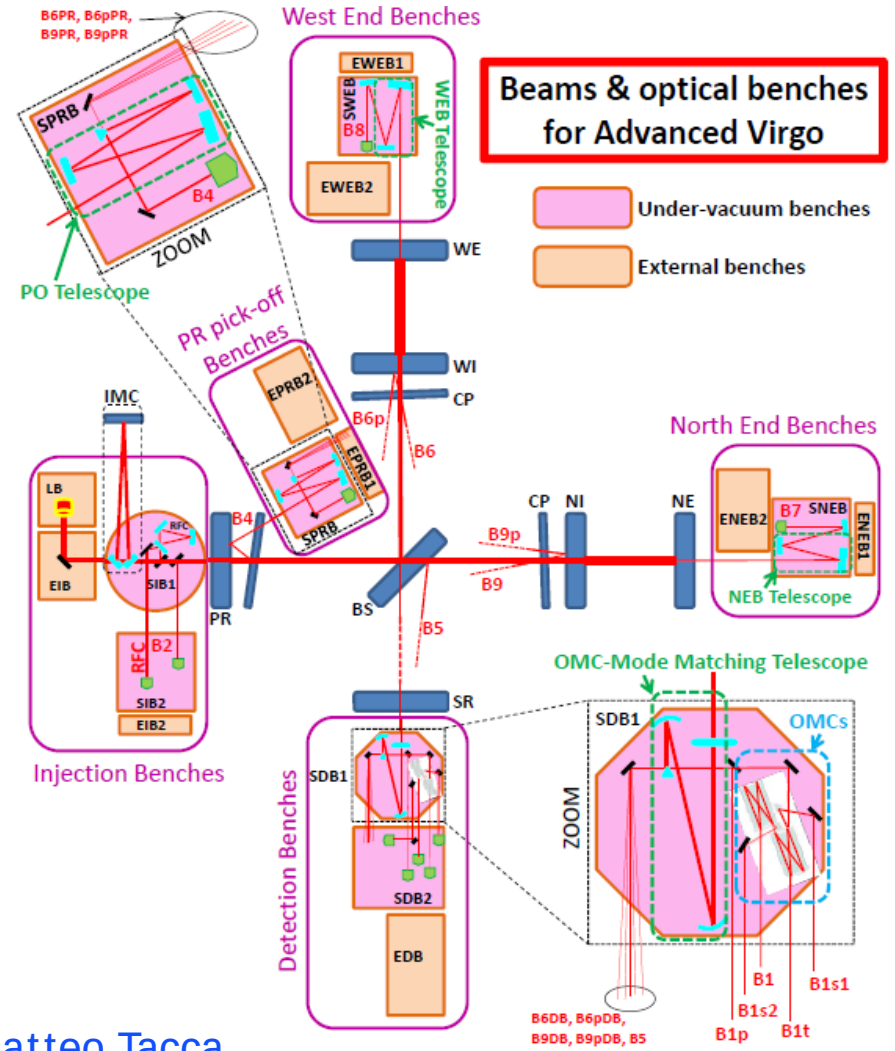
March 17, 2015

Benoit Mours for the DET group

LAPP Annecy

The DET subsystem

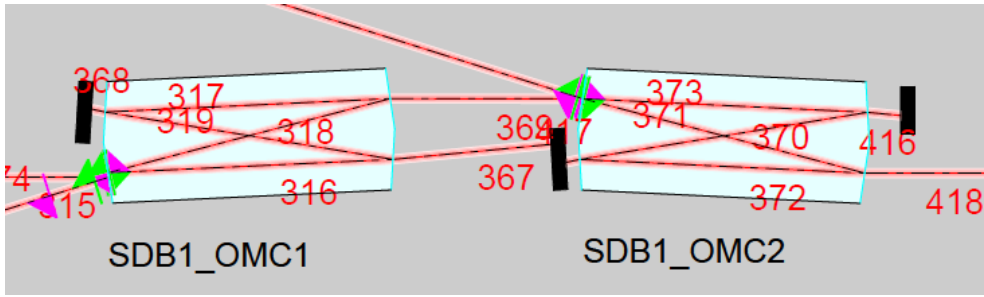
- Senses the beams coming out
  - Six suspended optical benches
  - Photodiodes, quadrant photodiodes, cameras, phase cameras..
  - OMC
- Key new features for AdV:
  - DC readout → new OMC
  - Signal recycling→ one more bench squeezed in the PR cavity
  - More suspended benches
    - » To mitigate diffuse light effects
    - » → minitowers
  - New photodiode chain with digital demodulation for RF signals
    - » More flexible solution;
    - » more compact for multiple frequencies
  - More phase cameras

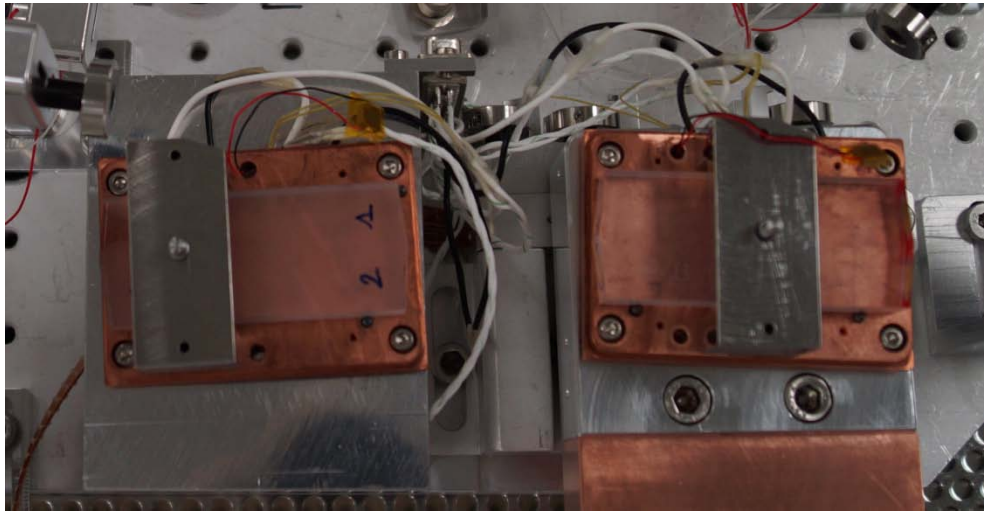


See next talk on mode matching telescopes by Matteo Tacca

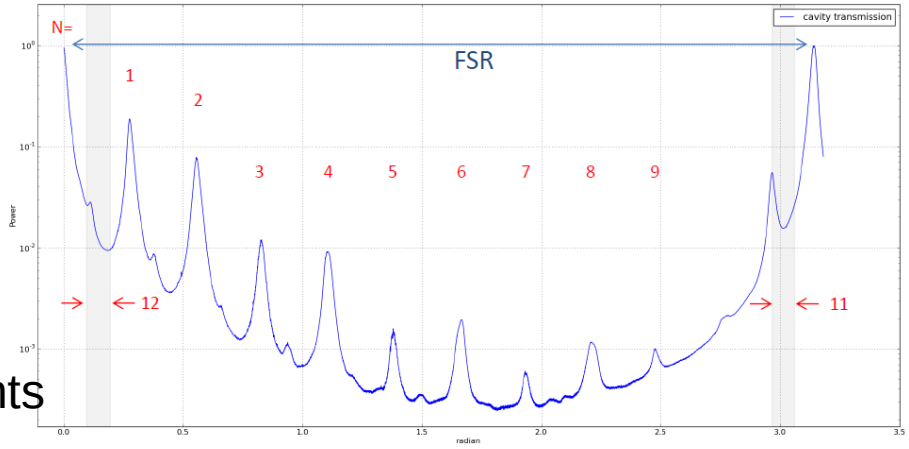
The AdV OMC

- DC readout requires RF side bands rejection
  - Higher finesse cavity
- Evolution of the initial Virgo design :
  - Two small monolithic cavities
  - Thermal control + PZT
    - » PZT: length modulation
    - » PZT not along cavity axis





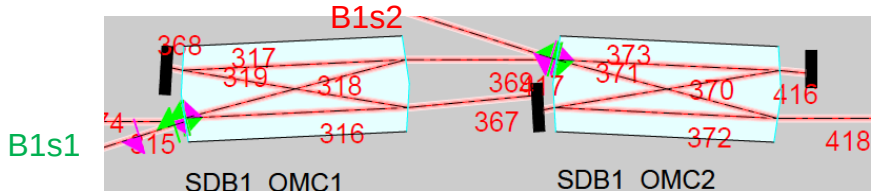
OMC Finesse

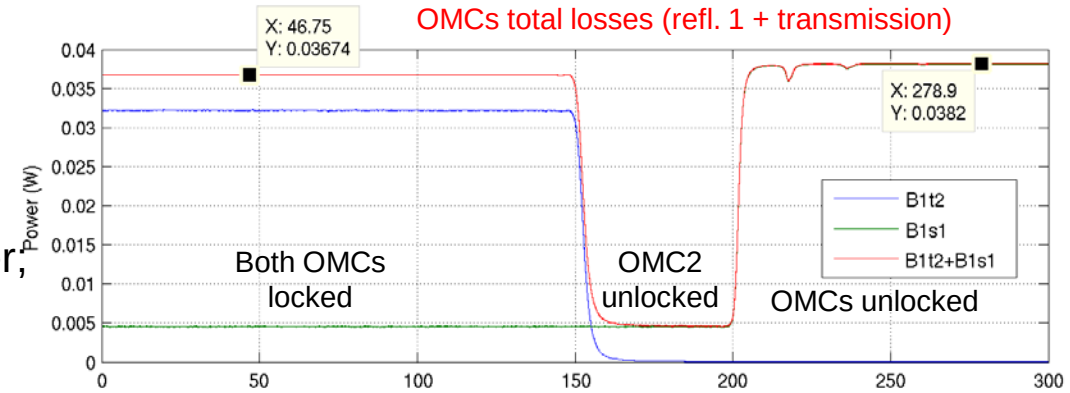


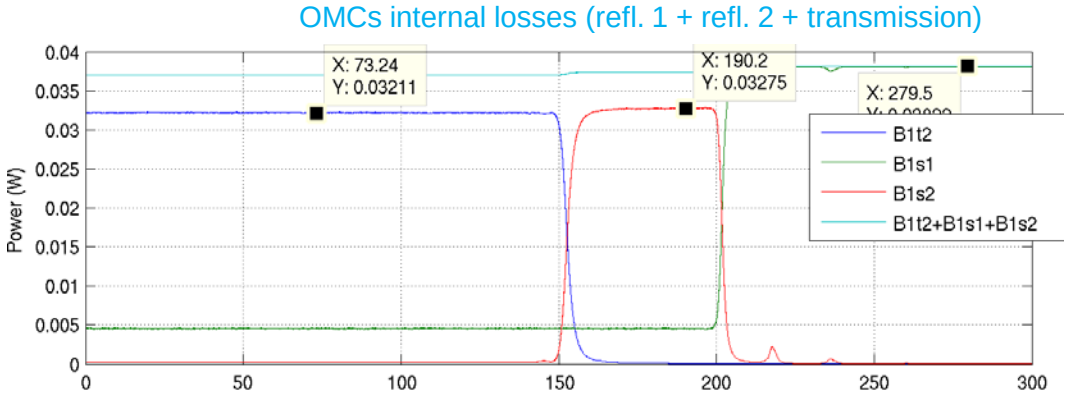
- Specification : 143
- All measurements: ~ 125
  - Cavity scans
  - Cavity pole measurement
  - Reflection coefficients measurements
- Smaller finesse but still ok for filtering
  - "double" safety factors
    - » Requested DARM accuracy to prevent noise up-conversion: $\Delta L\_DARM \leq 10^{-15}$ m
      - Includes a factor 10 of safety margin
      - Do not include non-linear response correction
    - » Low frequency SB noise could spoil DARM accuracy → set constraint on SB residual power after OMC: PSB ≤ 80 μW (per side band) + SB dP/P ≤ 4%
      - Includes another factor 10 of safety margin.
    - → Impact on sensitivity of lower finesse (nominal PSB x 1.5) is negligible

OMC losses

- Measured total losses 5%
  - 1.4% mismatch losses:
    - » Misalignment,
    - » Birefrigence (≤ 0.6%)
    - » Astigmatism
    - » ...
  - 2.4% OMC1 scattering
    - » was ~ 1% twelve months earlier; applied first contact to clean it; result still unknown
  - 1.1% OMC2 scattering
- Hope for ~ 4% total losses

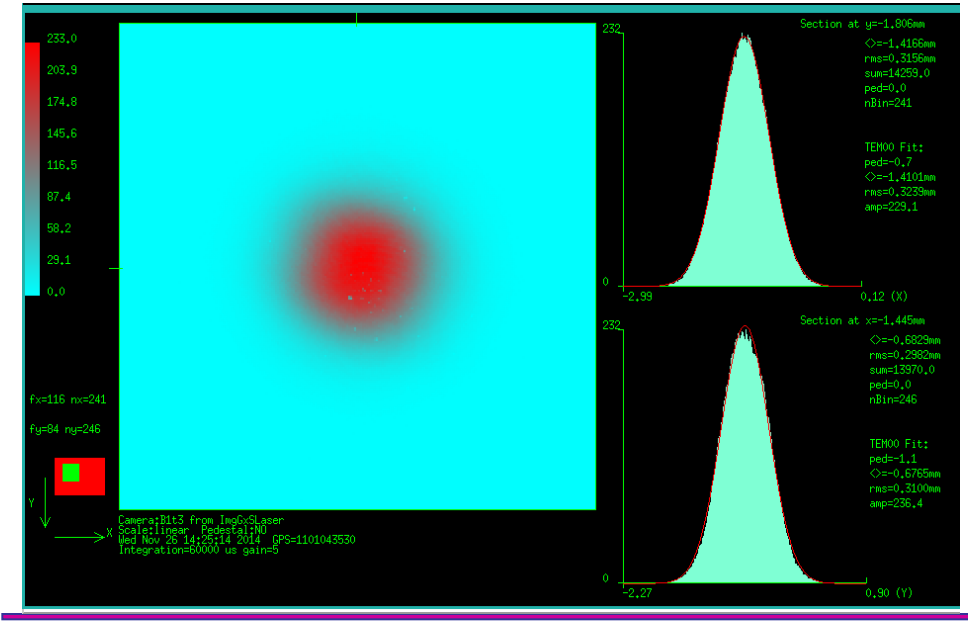


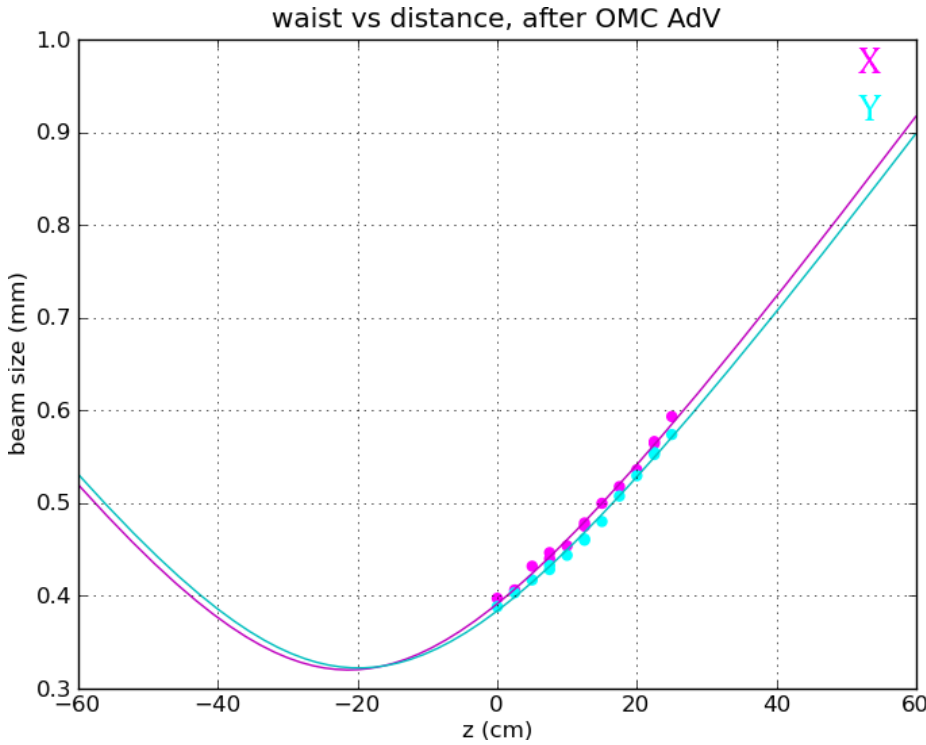




OMC beam quality

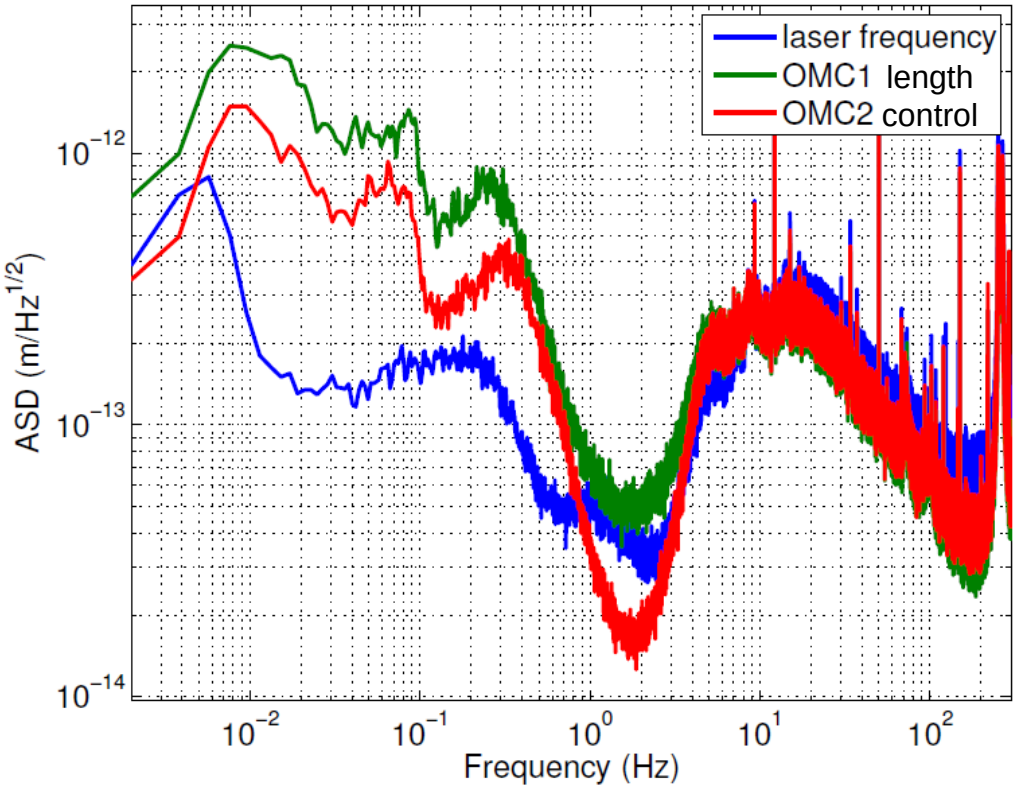
- OMC2 is slightly astigmatic: $\Delta RoC \leq 10\%$ (substrate #5)
- Direct measurements are ambiguous
  - Depend on order of HOM used
- Mismatch is low (total < 1.4%)
- Beam quality is good

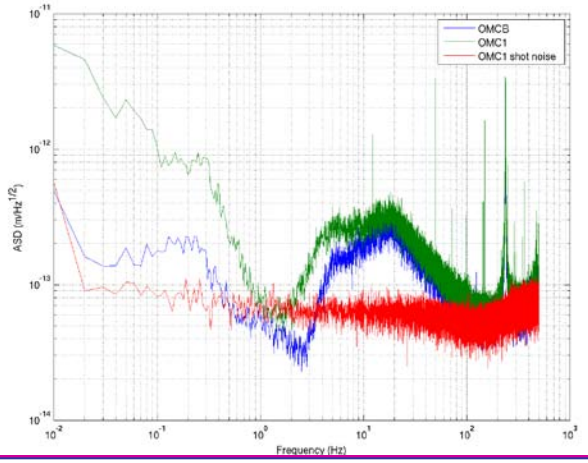




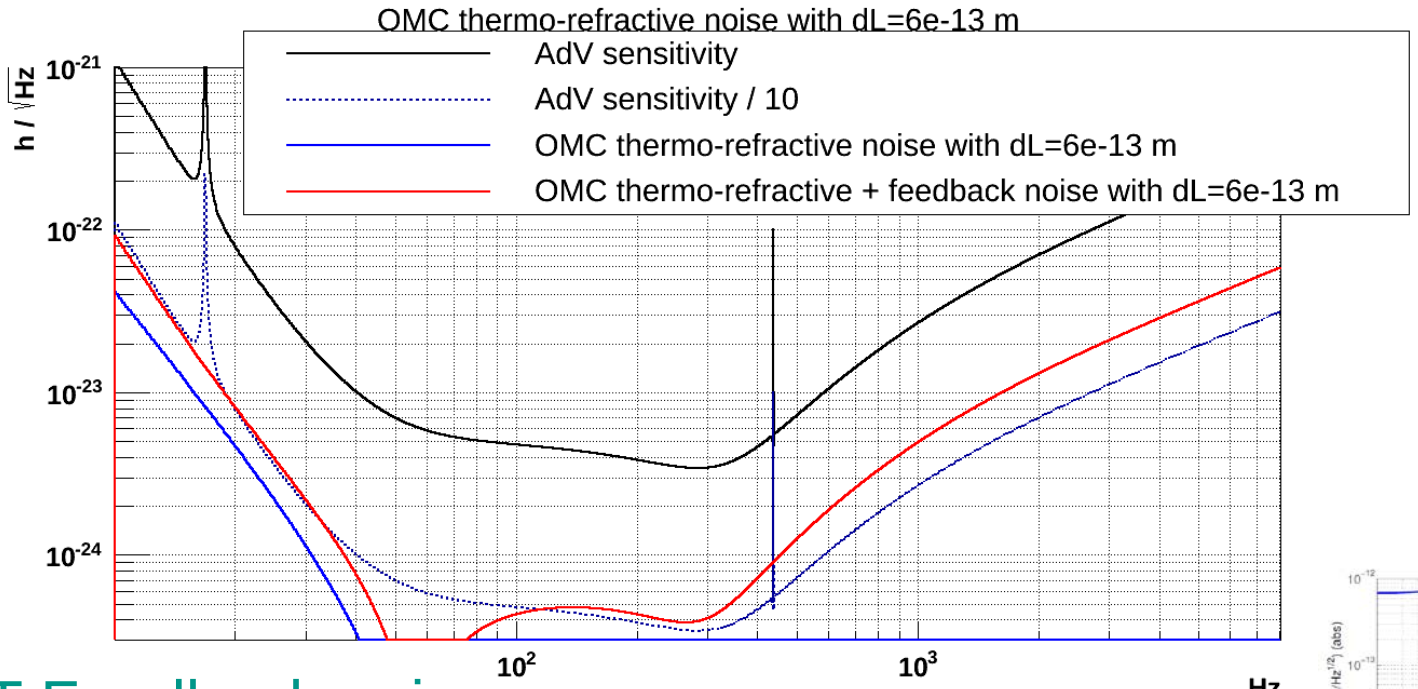
Lock precision

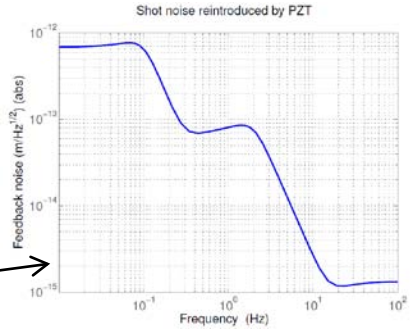
- lock precision RMS below 2 Hz
  - OMC1: 6 x 10^{-13} m
  - OMC2: 3 x 10^{-13} m
  - Requirement from thermorefractive noise:12 x 10^{-13} m
  - Remarks:
    - » OMC1 is shot noise limited at 1Hz
    - » OMC2 modulation depth larger by a factor ~3





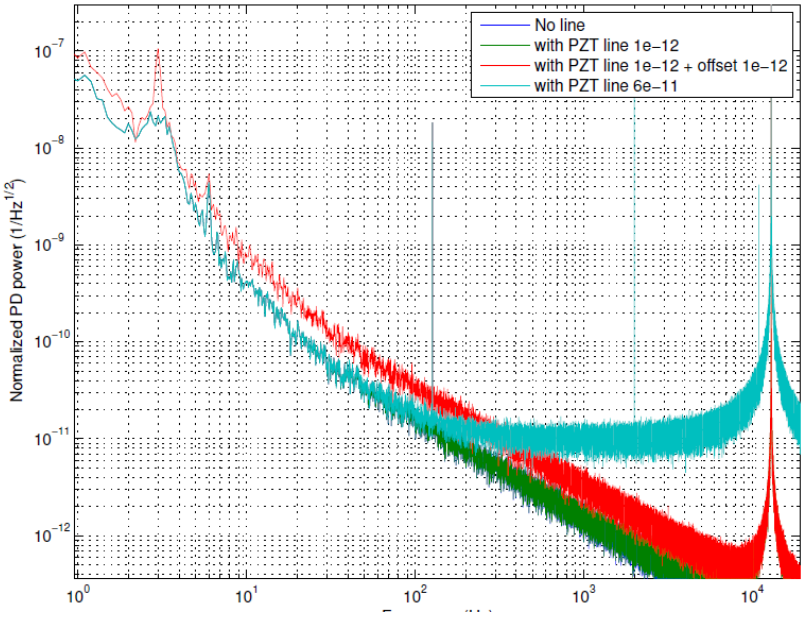
Shot noise + thermorefractive noise projection



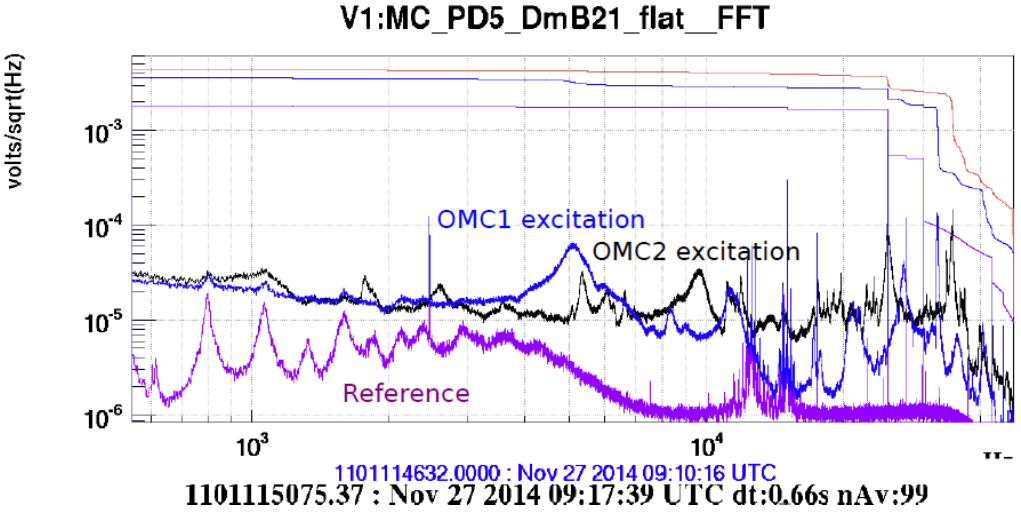


- PZT Feedback noise
  - 7 x 10^{-14} m/Hz - shot noise
  - ~10^{-15} m/Hz @ 10 - 100 Hz shaped by PZT loop filter
  - Noise above 100 Hz can be easily suppressed by an additional low-pass
- Thermorefractive (F=125) + PZT ⇒within specifications

Other noise projections



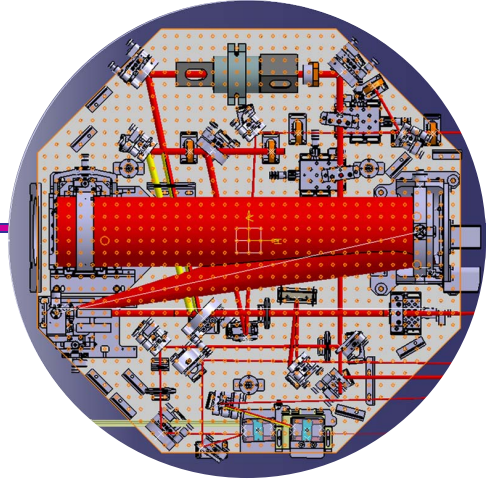
- PZT dithering modulation depth
  - power modulated by ≤ 0.1%
    ⇒modulation ≤ 6 10^{-11} m
  - Non-linear noise coupling at PD
  - ~ thermorefractive at 200 Hz
  - Not an issue



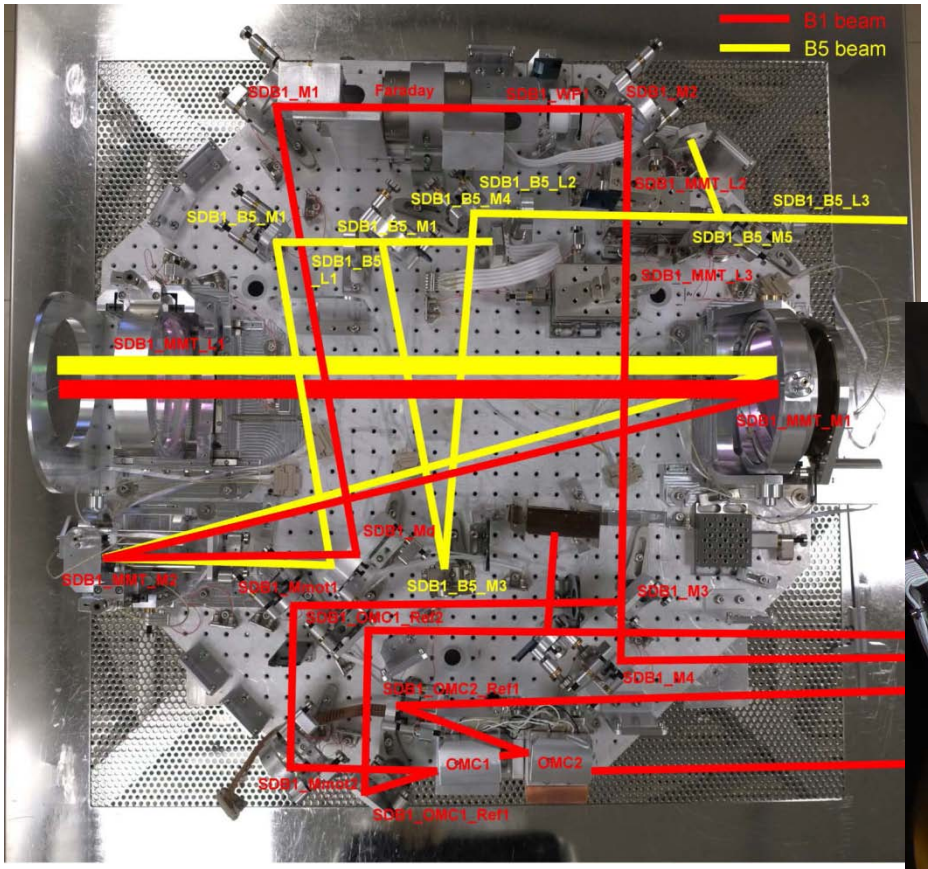
- Internal resonances
  - Injecting white noise into PZT
  - Mechanical resonances > 5 kHz

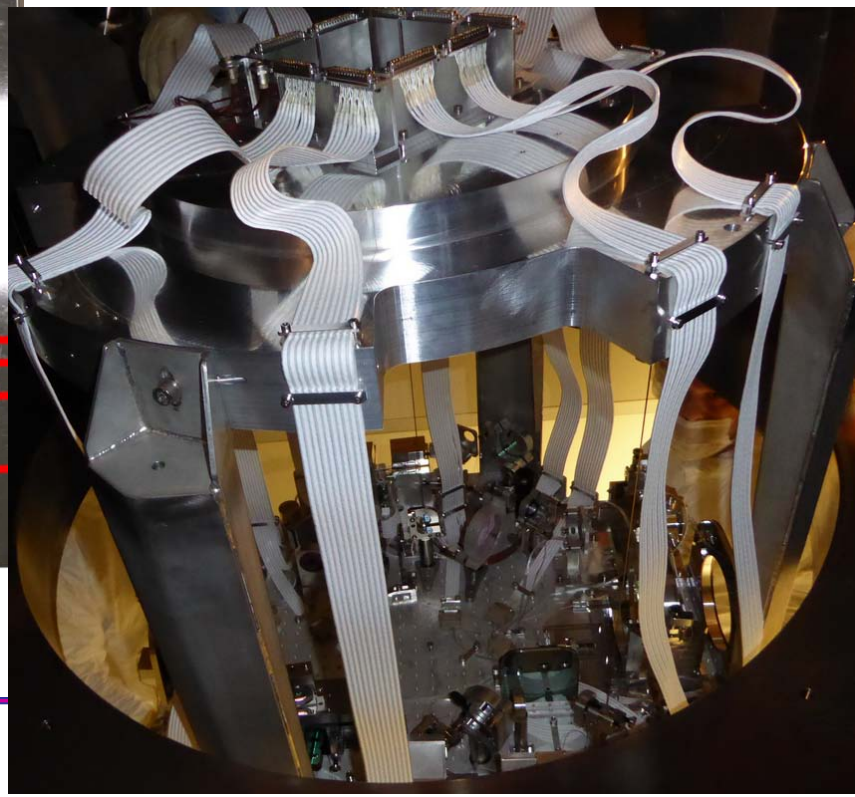
- OMC length noises expected a factor 10 below AdV sensitivity

OMC bench status



- OMC bench assembled over the last months

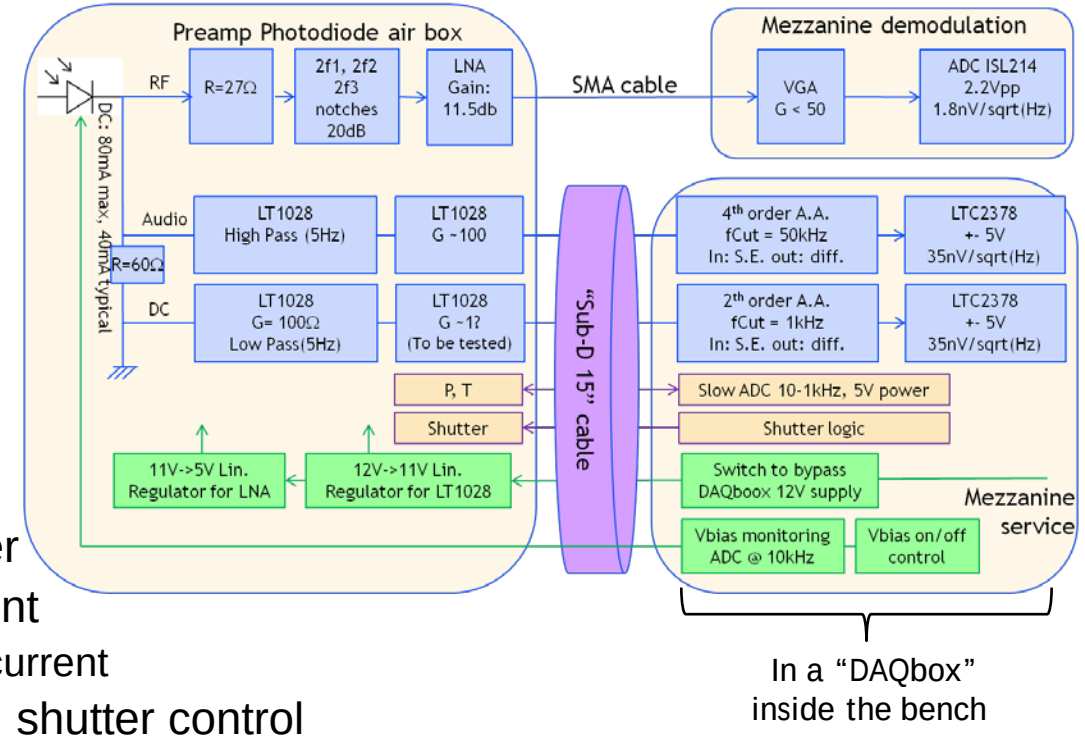




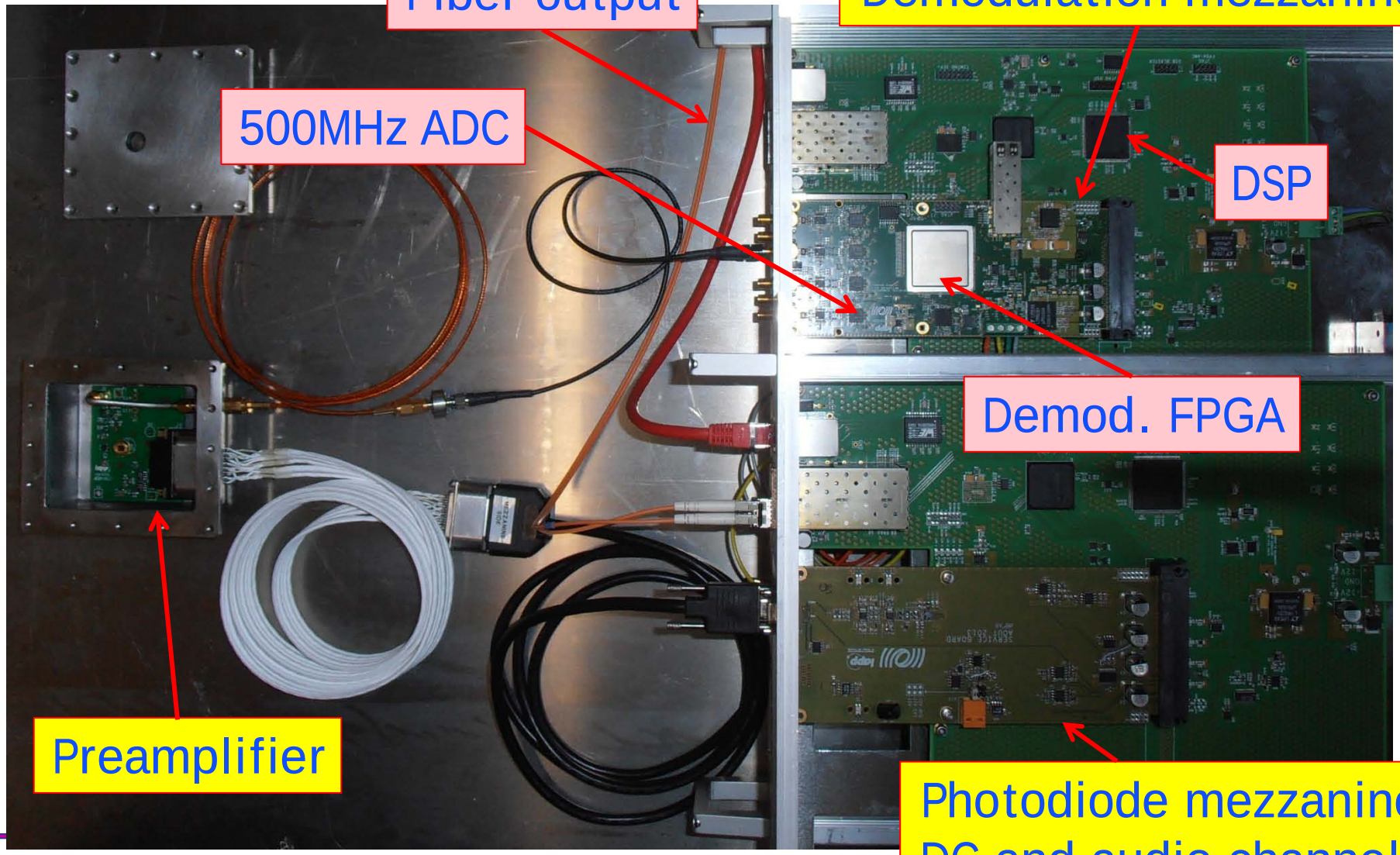
- Moved to the “tower” on Feb. 12

Photodiode electronic layout

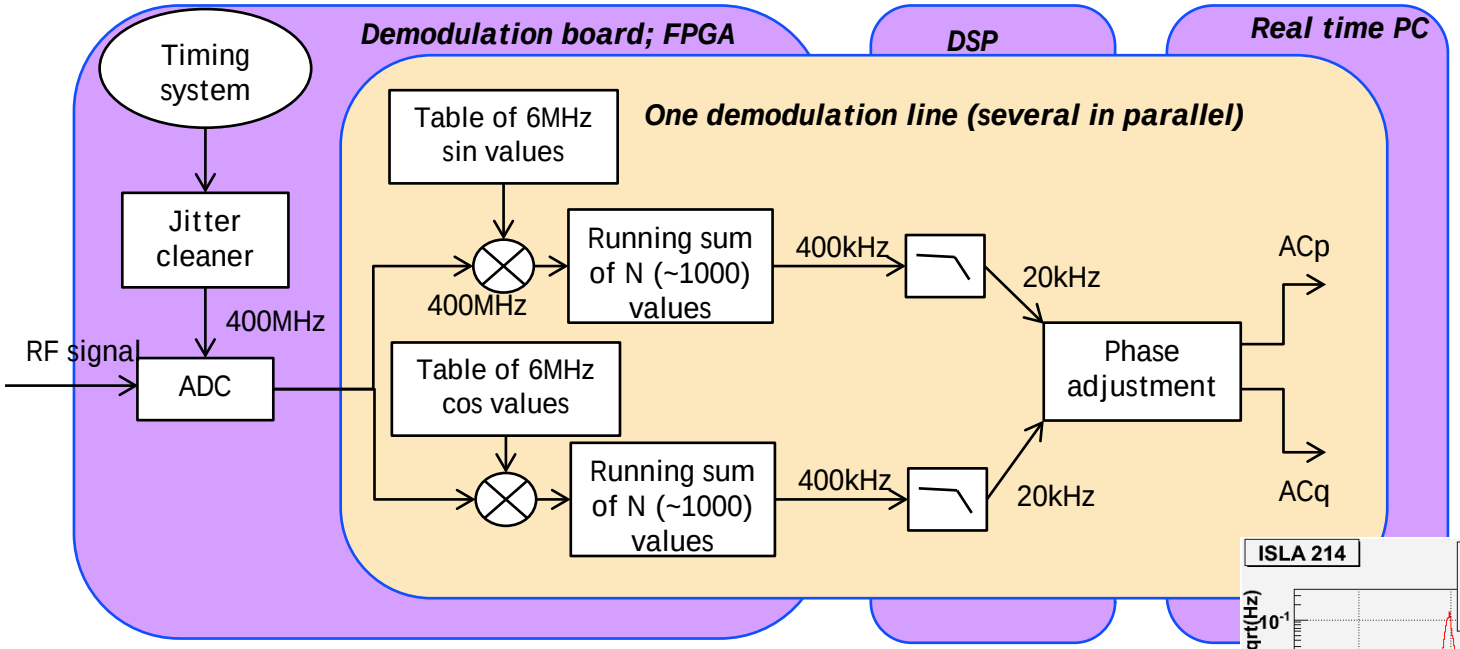
- The photodiode provide audio and RF signals
- Preamplifier
  - Use simple load resistors followed by voltage amplifiers
  - 3 channels provided
    - » DC from 0 to ~ 5 Hz(well more)
    - » Audio: 5 Hz to 10-50 kHz
    - » RF: 1 Mhz to ~100 MHz
- Demodulation mezzanine
  - Handle the RF channel
  - Provide demodulated signals
- Service mezzanine
  - Audio and DC channels readout
  - Provide power to the preamplifier
  - Provide/monitor Vbias and current
    - » includes safety in case of over current
  - Provide P and T measurements, shutter control



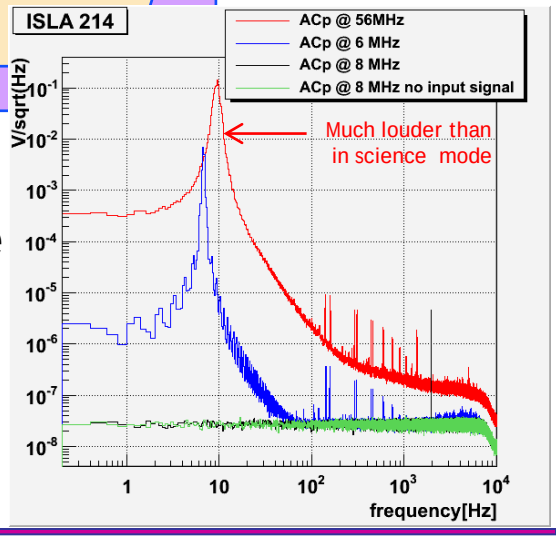
New photodiode chain



RF signal demodulation

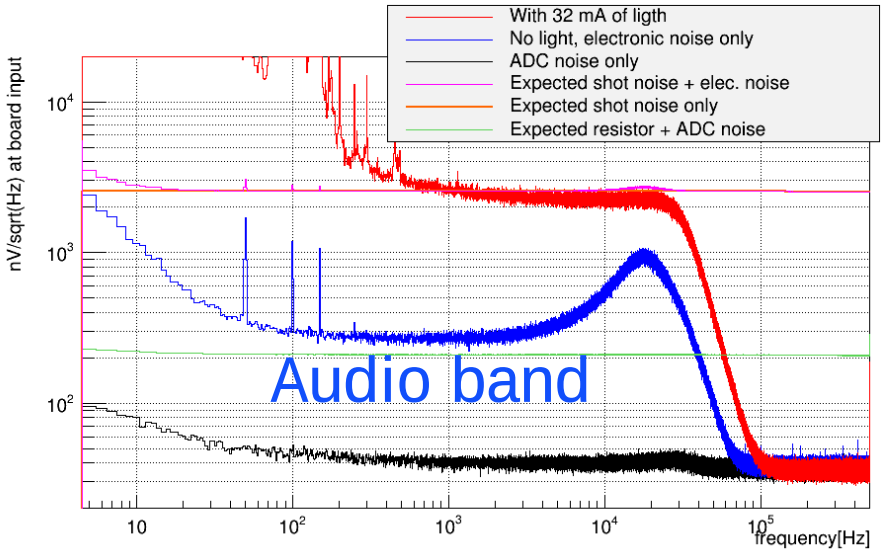


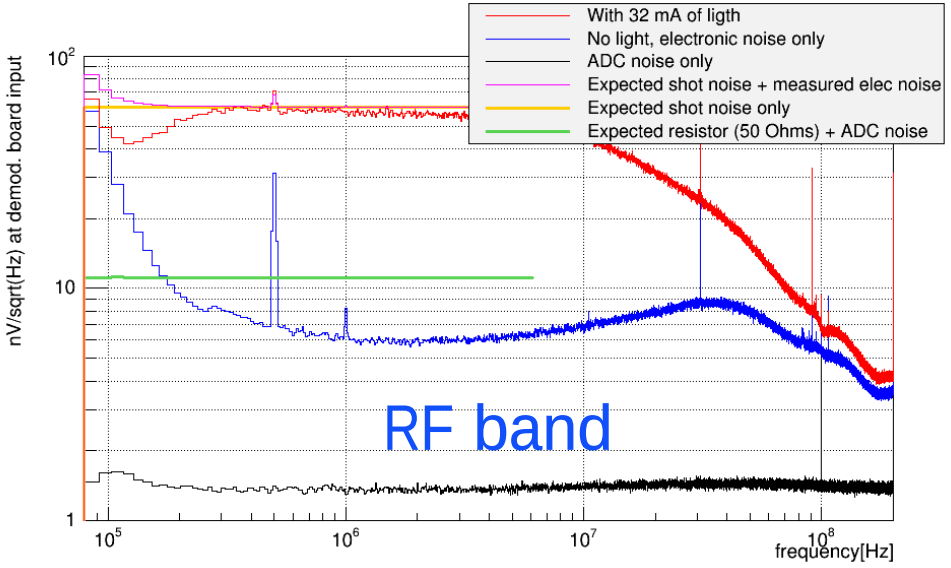
- Digital demodulation:
  - Provides up to 9 demodulated signals per photodiode
  - Possible to do phase correction using “2f” signals
  - Tested on electronic signals
  - Requires a wide band preamplifier and readout chain



Photodiode chain status

- Tests: full chain successfully tested
  - Low noise channels in their frequency band
  - We can get the electronic noise at ~ shot noise/10

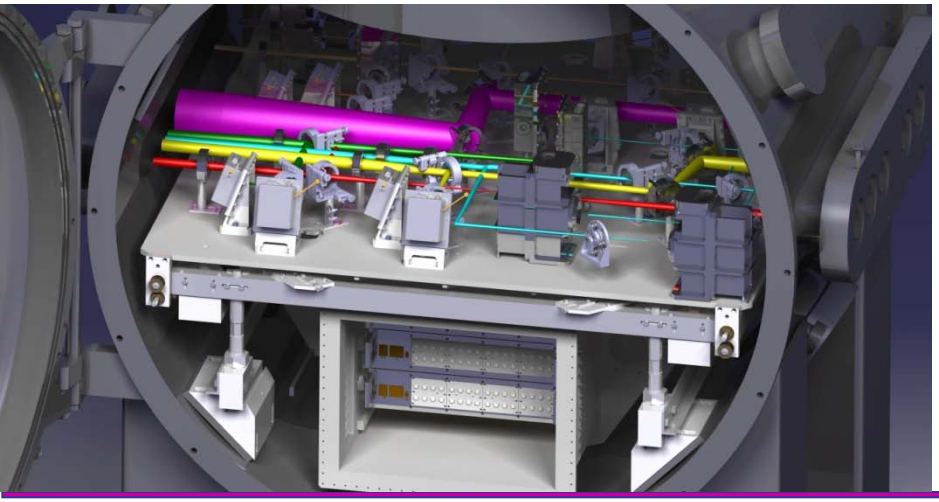


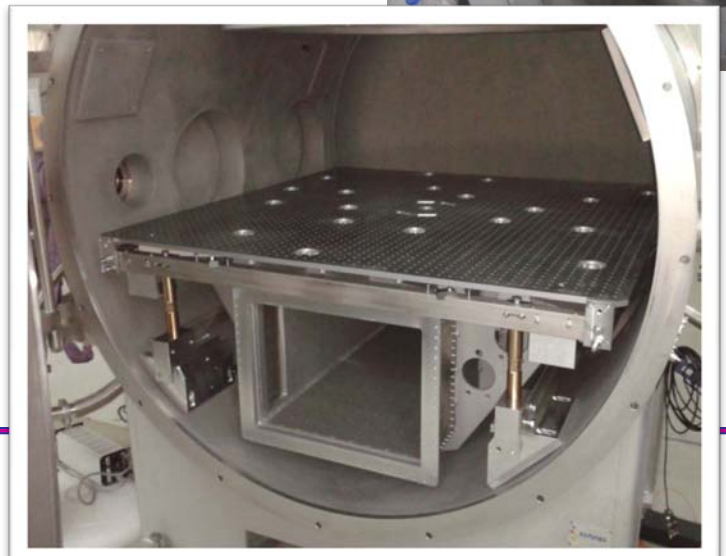


- Production of all parts on going

The minitower suspended benches

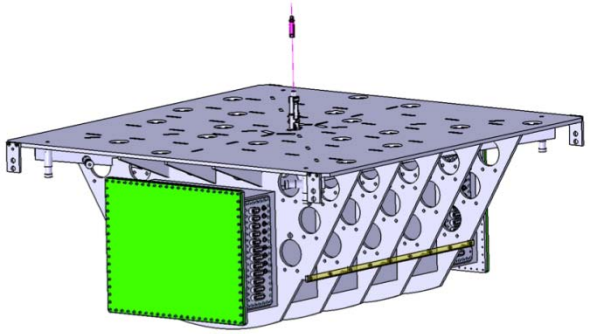
- Required to mitigate diffused light noise
- The challenge: limited space
- The solution:
  - Bench in “small” vacuum tank: “minitower”
  - A compact isolation system build by Nikhef
  - Electronic “inside” the bench
    - » To avoid spoiling the seismic isolation by cables
    - » Additional challenges: heat dissipation



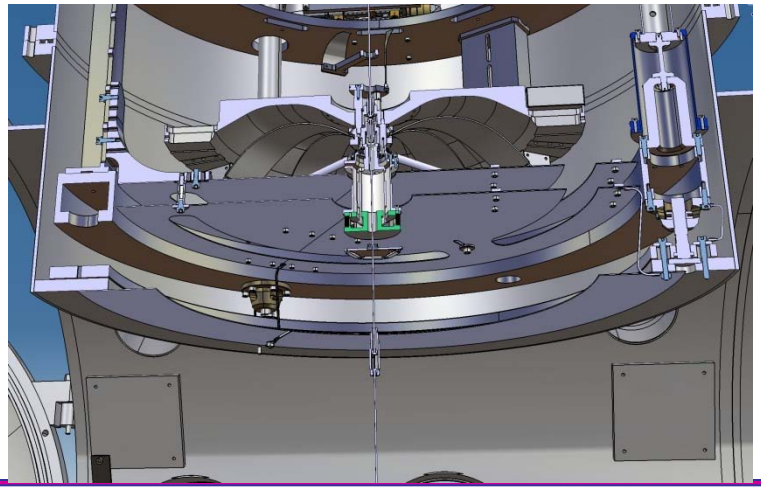


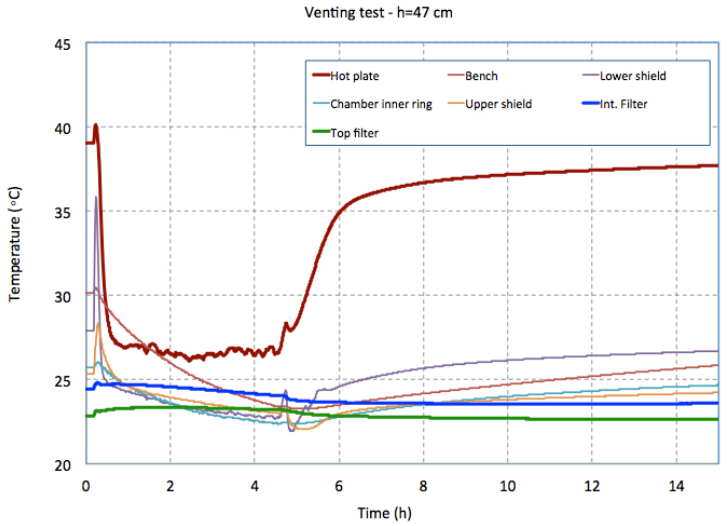
Heat dissipation tests

- Checked that the heat could be evacuated through radiation
  - Upper limit: 300 W on the most crowded bench
  - Increase heat transfer by
    - » Anodizing the benches
    - » Sand blasting the minitower
  - Test: bench temperature stay below 40°C



- Checked that the multSAS is well shielded
  - No suspension retuning while opening the minitower doors





Minitower benches: status

- 3 out of 5 minitowers installed with their seismic isolation
  - Extensive tests at Nikhef of the multiSAS isolation system
- All benches produced
  - vacuum tested
- Production of optics & electronic well advanced
- Starting bench assembly
  - In clean room at LAPP-Annecy
  - First quadrants received from Nikhef
- To be installed at the site in the coming months…