Prospectives IN2P3, GT08

Low loss signal detection

Context

- Sensitivity of GW detector limited by quantum noise:
  - ➢ Radiation pressure noise at low frequency
  - ➢ Shot noise at high frequency

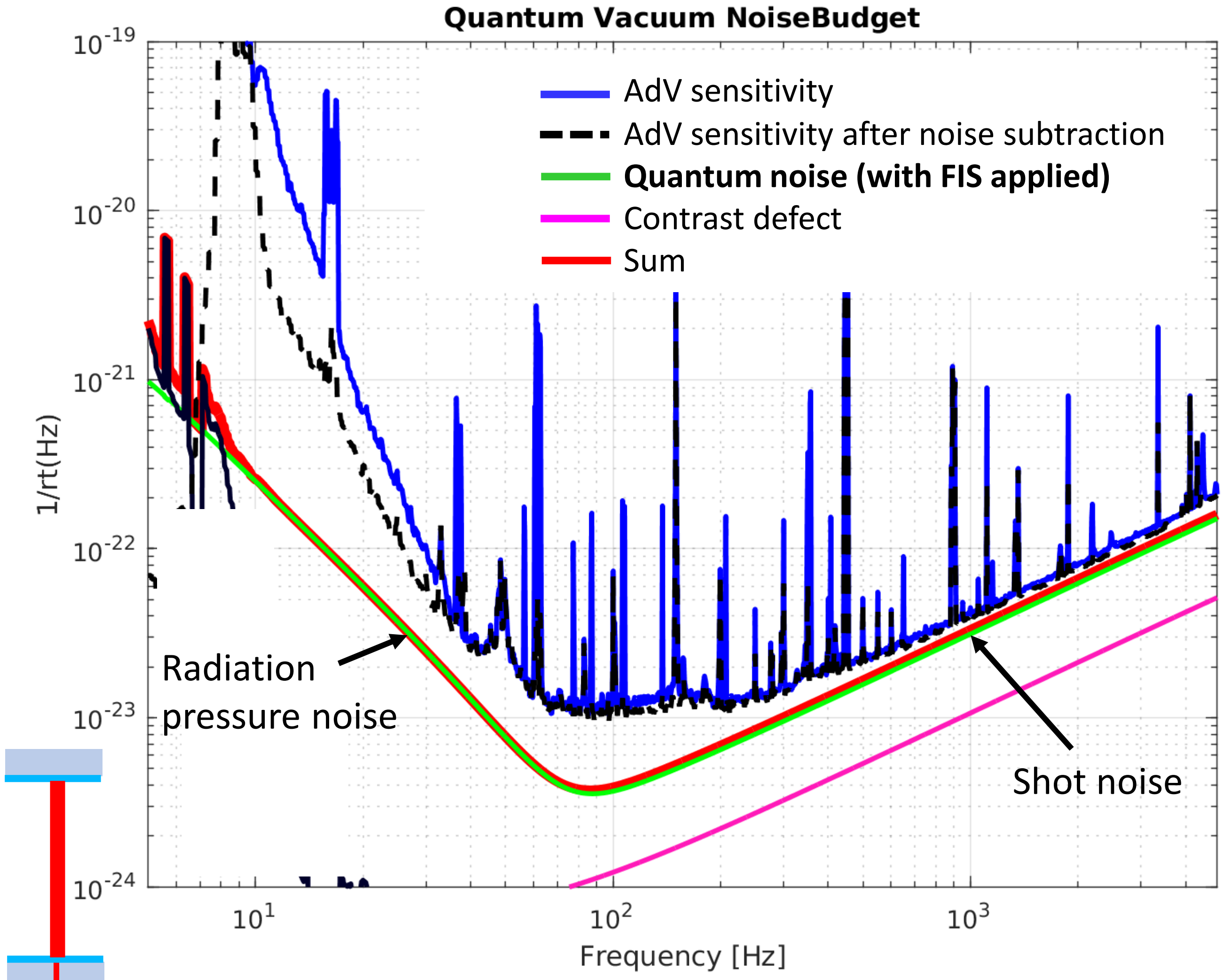
- Quantum noise can be reduced by injecting a squeezed vacuum state in the interferometer:
  - ➢ Frequency Independent Squeezing to reduce shot noise: already implemented in advanced detectors
  - ➢ Frequency Dependent Squeezing to enhance the sensitivity at all frequencies: foreseen in AdV+

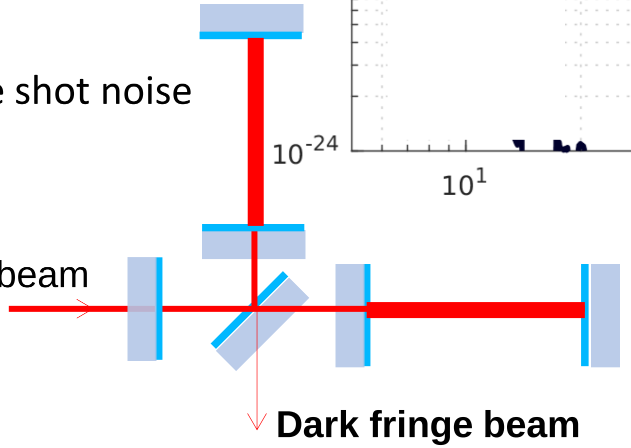
- Benefit of squeezing limited by losses and signal detection noises → This requires:
  - ➢ **Low losses optics**
  - ➢ **High Quantum Efficiency photodiodes**
  - ➢ **Low noise photodiode electronics**

- GW detectors are operating at dark fringe to minimize shot noise This makes them very sensitive to contrast defect

  → Requires an output mode cleaner filtering cavity

Advanced Virgo sensitivity on Jan 17th, 2020 (03)

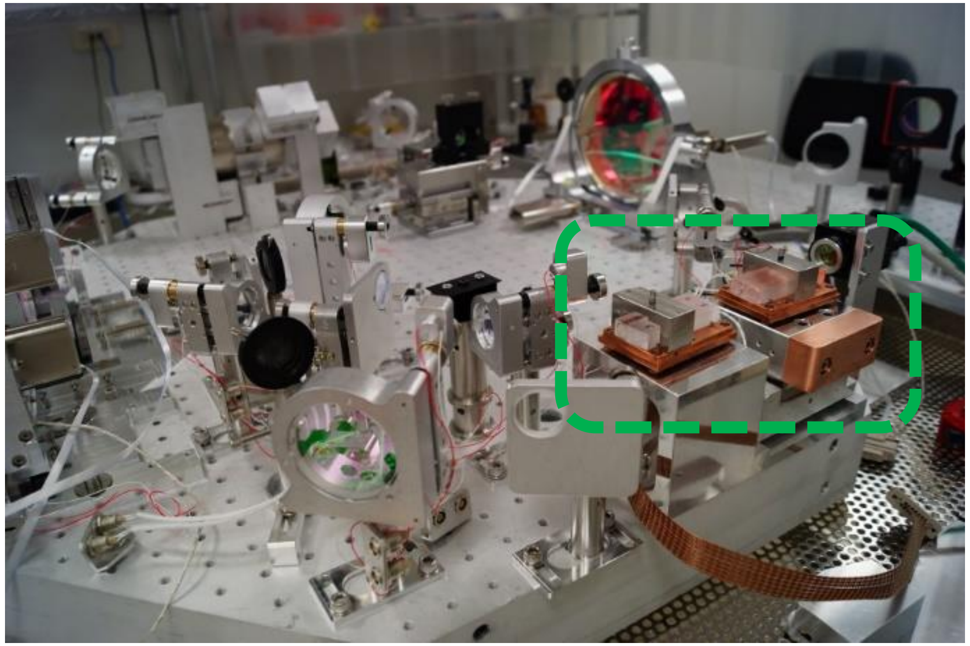


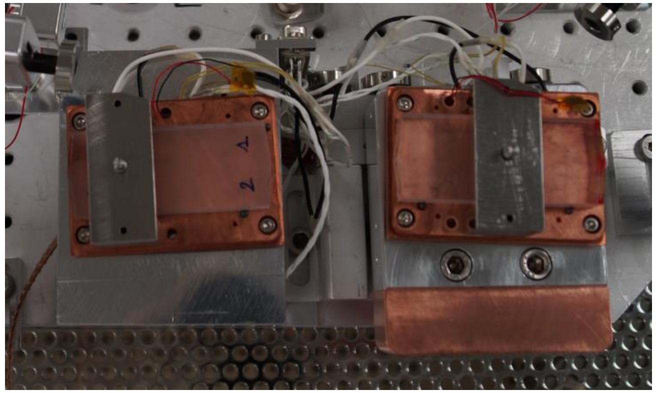


Output Mode Cleaner

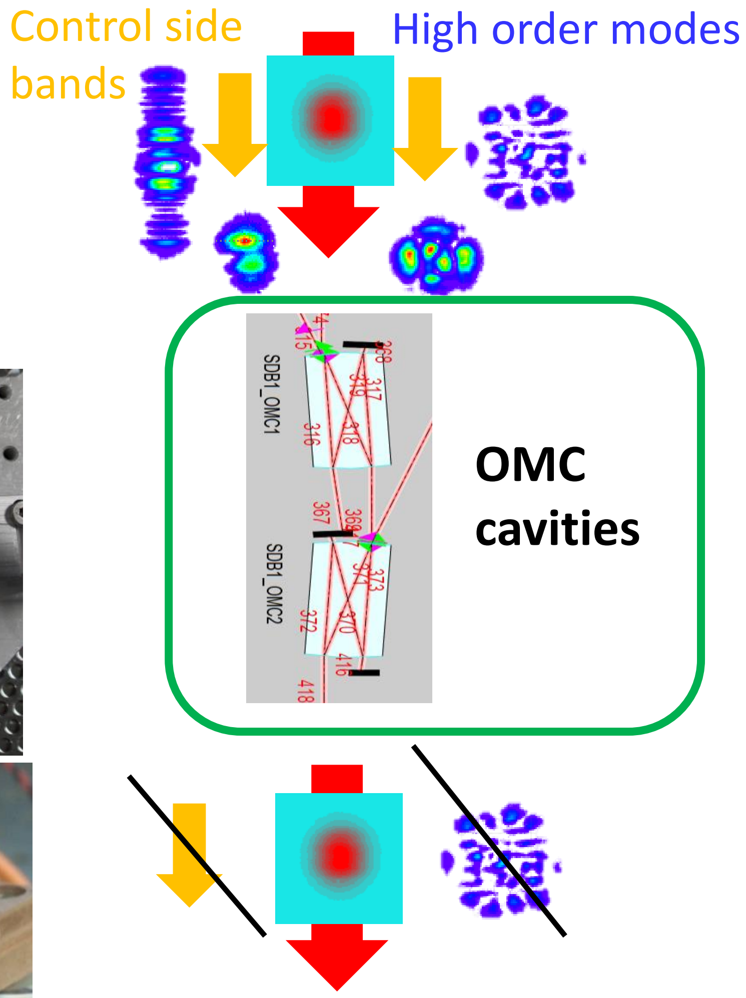
- **Goal:** Filter the Dark Fringe to keep only the component carrying information on Differential Arm Motion → **improve interferometer contrast defect**

- AdV OMC made of 2 cavities of fused silica, in serie:
  - Cavity finesse ≈ 125
  - Beam propagates inside fused silica
  - Cavity length controlled to keep it at resonance of the fundamental mode





From the interferometer



To the photodiodes

Losses induced by the OMC

- Internal losses:
  - **Scattering on the reflective surfaces**
    proportional to OMC finesse and to (surface roughness)^2
    → requires high quality polishing (roughness < 0.3 nm RMS for AdV OMC)
  - **Absorption in OMC substrate**
    → requires low absorption material (fused silica Suprasil 3001 for AdV OMC)
  - **Absorption in surfaces coating**
    → high quality coating performed at LMA

- Mismatching losses between incident beam and OMC cavity:
  - **Mode mismatch** → requires a telescope
  - **Misalignment**
  - **Polarization mismatch**

- Mismatching losses between the two OMC cavities

Proposed improvements for a lower loss signal detection

- Replace the 2 OMC cavities by a single OMC cavity of higher finesse (≈1000)
  → Will get rid of mismatching losses between the 2 cavities
  - Must learn how to control the high finesse cavity with good precision
- Improve polishing: roughness below 0.1 nm RMS → will mitigate scattering losses
- Implement more actuators on the suspended bench optics to allow a precise mode matching and polarization tuning when the bench is in vacuum
- Implement an automatic alignment based on new quadrant sensors to correct OMC alignment drifts during interferometer operation
- Explore lower absorption materials, better coating
- Explore an evolution of the OMC design towards an empty cavity (beam propagating inside vacuum)
- Develop a lower noise preamplifier for the high quantum efficiency photodiodes
- Choice of photodiode technology to be revised in view of Einstein Telescope and new wavelengths