The OMCs are working
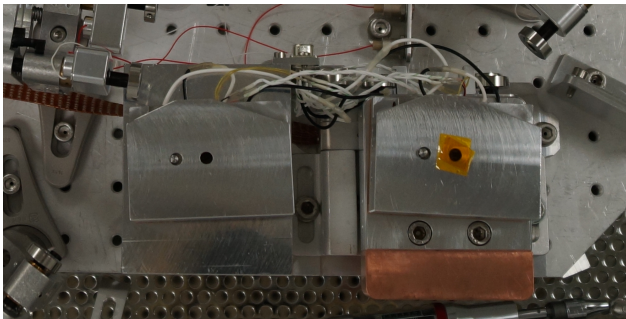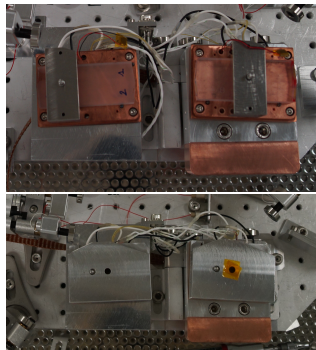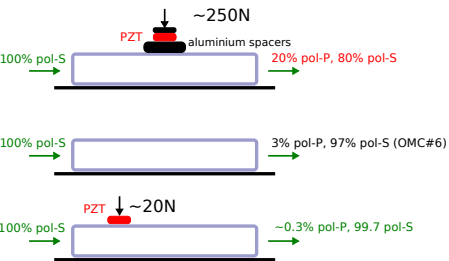
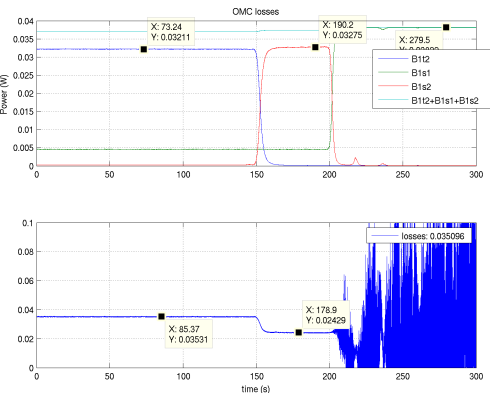### Michał Wąs
for the DET team

LAPP/IN2P3 - Annecy

Solution for birefrigence issue

- removed aluminum spacers
  - → ∼ 10 times less force for same dynamics
- correcting natural birefrigence by factor ∼ 10
- optimal PZT position depends on substrate
- setup robust for transportation
  - ▶ 20N was sufficient for keeping OMC clamped in travel from Annecy

Loss and mismatch measurements

- **On site**
  - ► OMCs characterized separately
  - ► OMC1
    - • screw torque tuned on site
    - • 0.1% created pol-P (×3 better than in Annecy)
  - ► OMC2
    - • transported assembled
    - • 0.5% created pol-P

- **Annecy**
  - ► total losses 5%
    - • 1.4% mismatch losses misalignment, birefrigence, astigmatism, ...
    - • 2.4% OMC1 scattering
    - • 1.1% OMC2 scattering
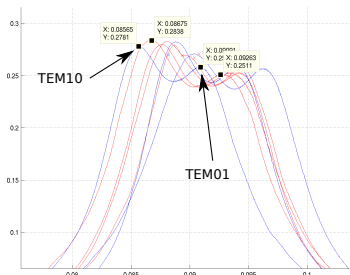 - ► OMC1 had ∼ 1% scattering six months ago
    - • applied first contact to clean OMC
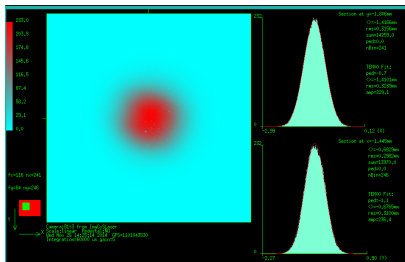   - • result unknown
  - ► hope for ≲ 4% total losses

Beam quality

waist vs distance, after OMC AdV
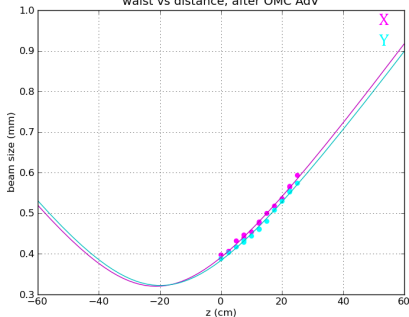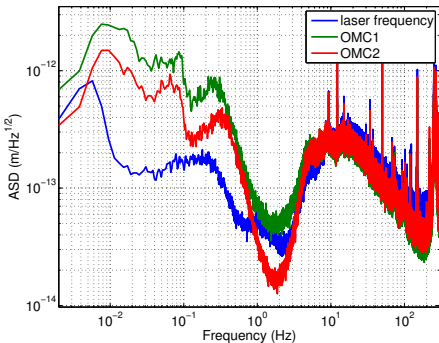

- OMC2 is slightly astigmatic $\Delta RoC \lesssim 10\%$ (substrate #5)
- direct measurements are ambiguous
  - depend on order of HOM used
- mismatch is low (total < 1.4%)
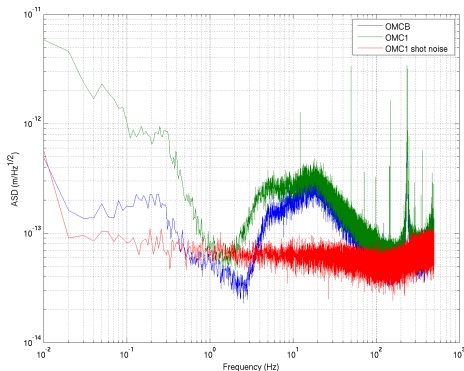- beam quality is good

Lock precision

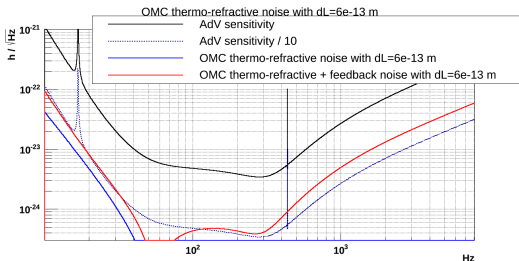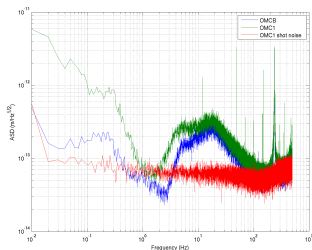- comparing error point in reflection and transmission
- OMC1 loop is shot noise limited at 1 Hz
- OMC2 modulation depth larger by factor ~ 3
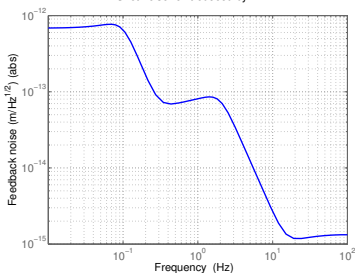
- lock precision RMS below 2 Hz
  - OMC1: 6×10^{-13} m
  - OMC2: 3×10^{-13} m
  - Requirement from thermorefractive noise VIR-0200A-13 12×10^{-13} m

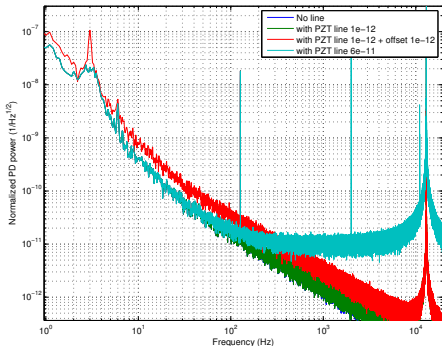# Shot noise + thermorefractive noise projection

OMC thermo-refractive noise with dL=6e-13 m

Shot noise reintroduced by PZT

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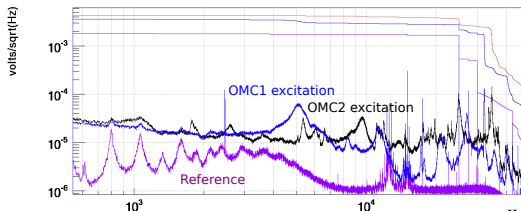- Thermorefractive (F=125) + PZT ⇒within specifications

Other noise projections

V1:MC_PD5_DmB21_flat__FFT

1101114632.0000 : Nov 27 2014 09:10:16 UTC
1101115075.37 : Nov 27 2014 09:17:39 UTC dt:0.66s nAv:99

- PZT dither modulation depth
  - power modulated by $\lesssim 0.1\%$
  - $\Rightarrow$ modulation $\lesssim 6 \times 10^{-11}$ m
  - Non-linear noise coupling at PD
    - $\sim$ thermorefractive at 200 Hz

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

Summary

- Birefrigence issue resolved
  - but solution needs fine tuning for each substrate
- Total scattering + OMC mismatch losses < 5%
  - might be < 4% after OMC2 cleaning
- Lock precision achieved better than requirements: $3 - 6 \times 10^{-13}$ m
  ⇒ OMC length noise factor 10 below AdVirgo sensitivity