Laboratoire d'Annecy de Physique des Particules

Squeezing at Virgo for O3

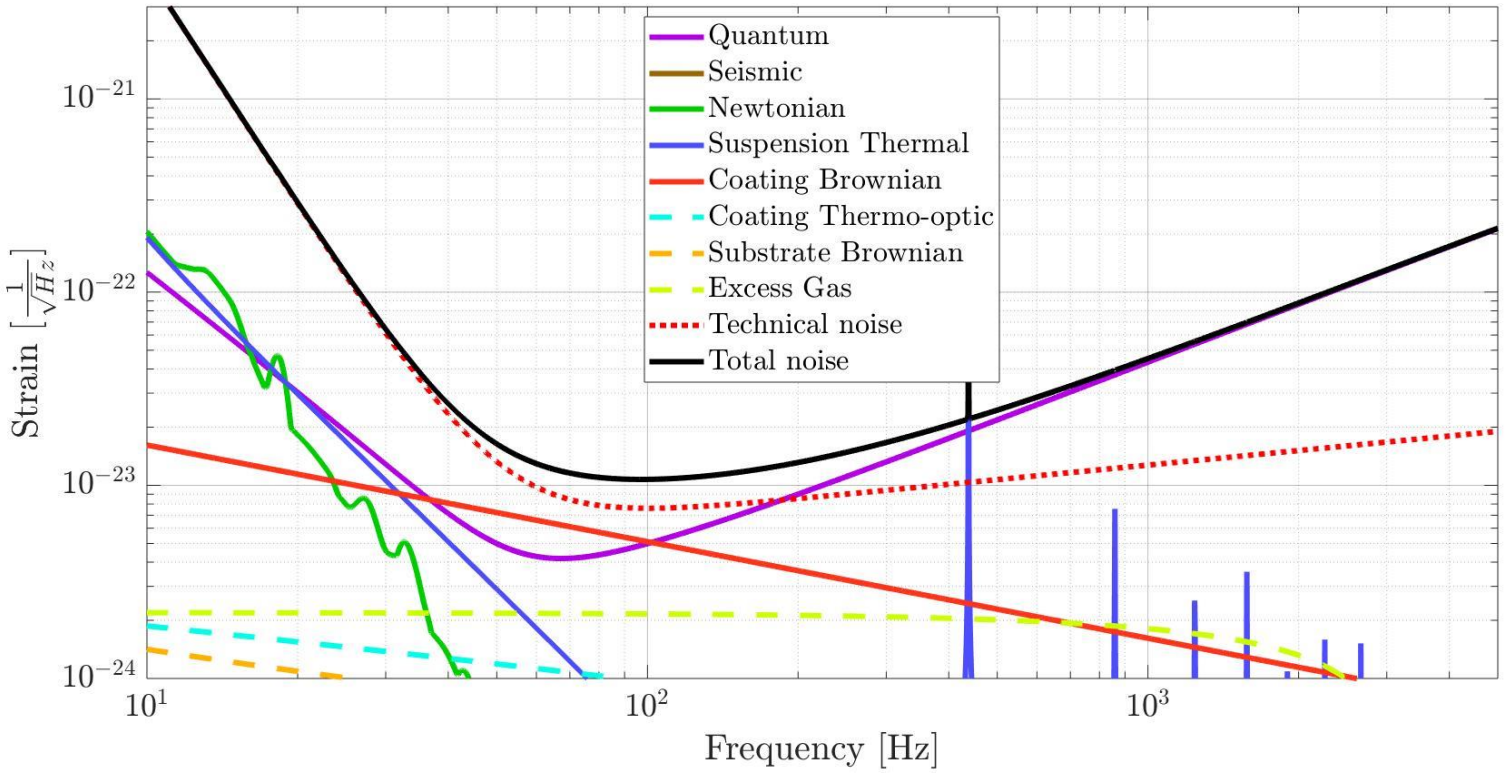
Marc Eisenmann for the Squeezing team

Friday 11 October 2019

cnrs

UNIVERSITÉ SAVOIE MONT BLANC

Sensitivity and quantum noise



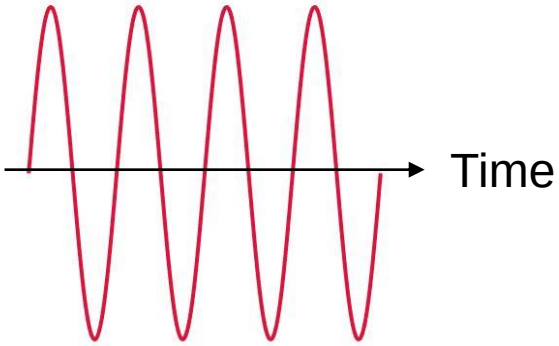
- Quantum noise : shot noise + radiation pressure noise

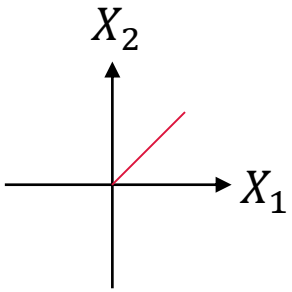
  Limiting the sensitivity from ~100 Hz

Goal of Squeezing injection : Reduce the shot-noise to improve the sensitivity

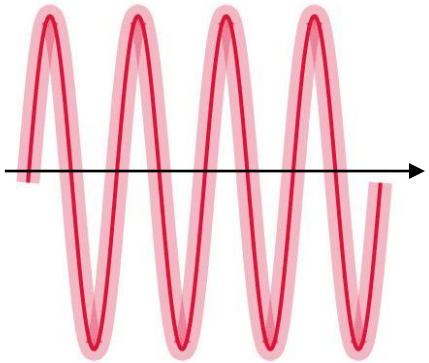
Quantum description of a laser field

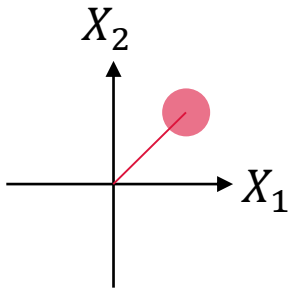
Classical picture





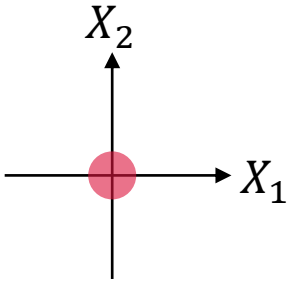
A Coherent State

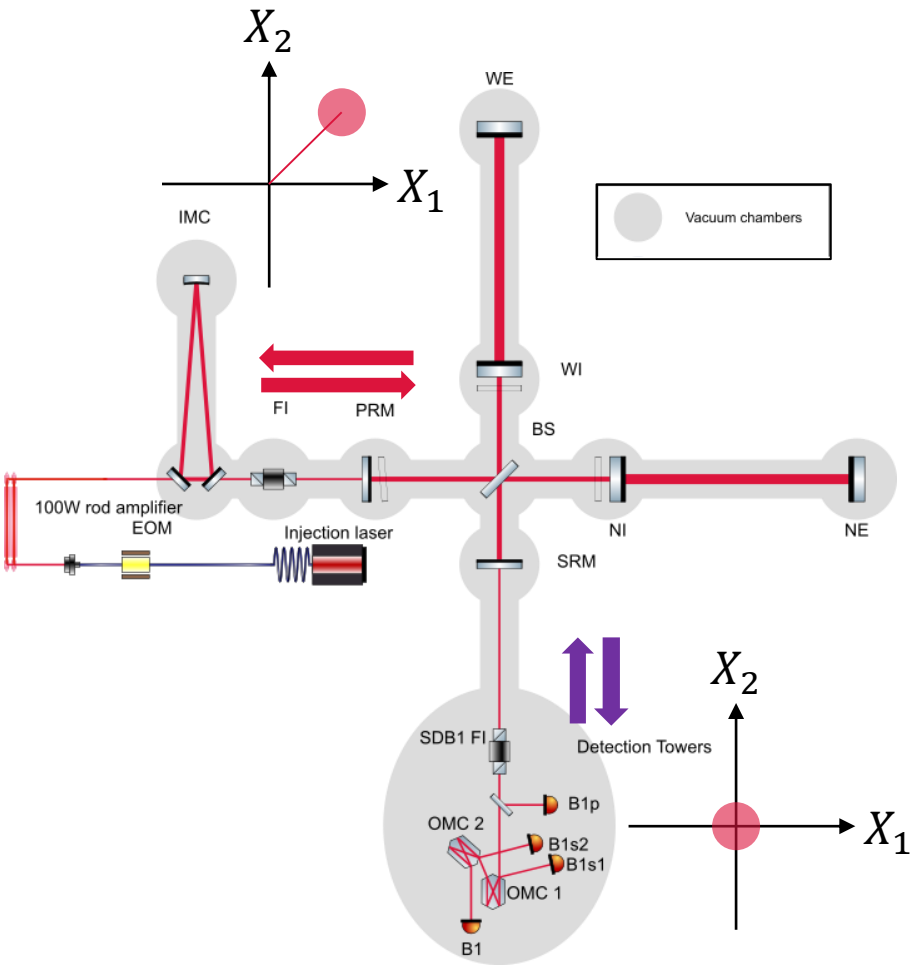




A Vacuum State

$$X_1(t) = X_2(t) = 0$$



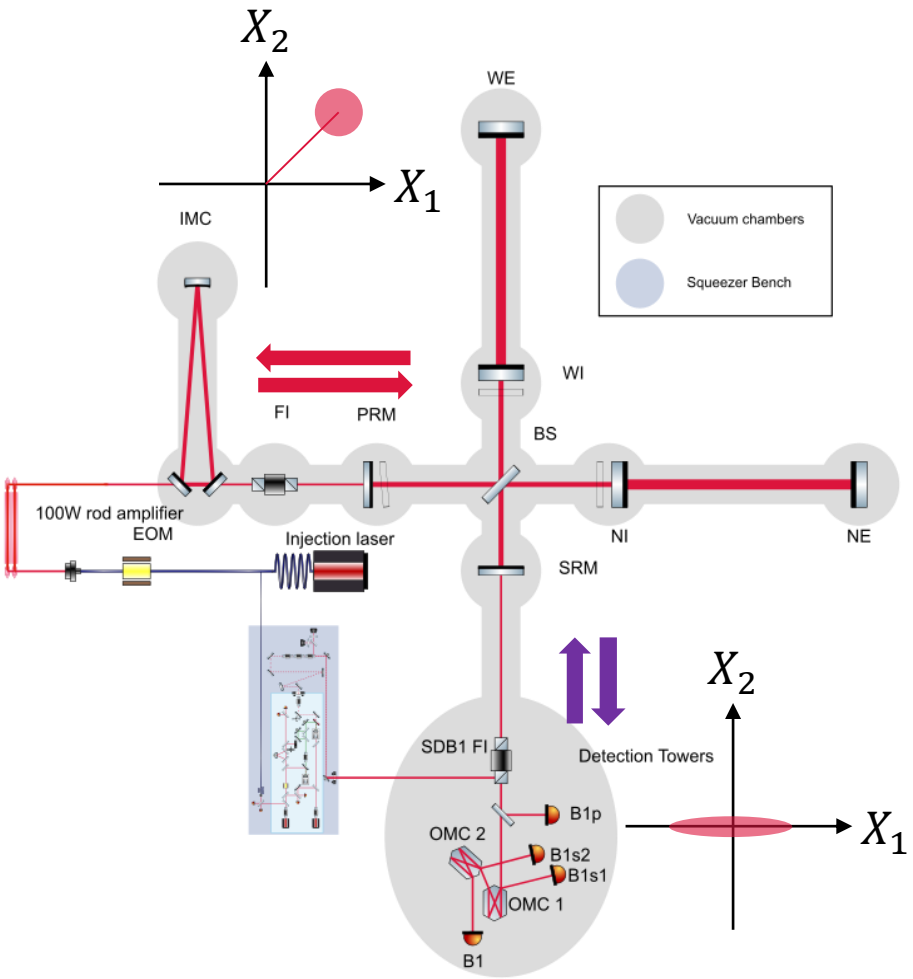


- Shot-noise : photon counting error

$$\propto \sqrt{\frac{\Delta X_2^{vac}}{P}}$$

- Radiation-pressure noise : response of free masses to circulating light

$$\propto \sqrt{P.\Delta X_1^{vac}}$$



- Shot-noise : photon counting error

$$\propto \sqrt{\frac{\Delta X_2^{vac}}{P}}$$

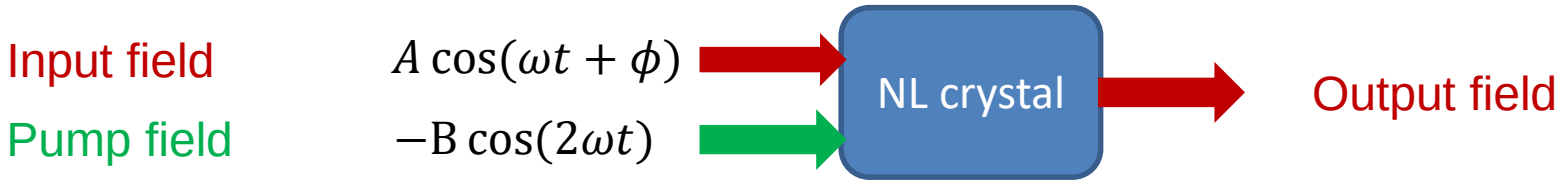
- Radiation-pressure noise : response of free masses to circulating light

$$\propto \sqrt{P.\Delta X_1^{vac}}$$

Squeezed vacuum states generation

- Through Non-Linear process :

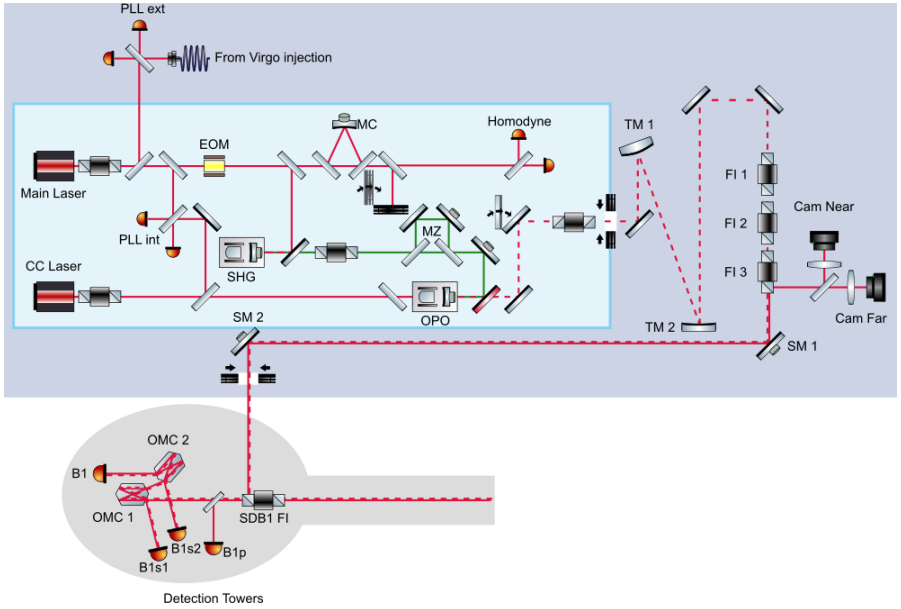
$$P(\mathcal{E}) = \varepsilon_0(\chi^{(1)}\mathcal{E} + \chi^{(2)}\mathcal{E}^2 + \chi^{(3)}\mathcal{E}^3 + \ \ldots)$$

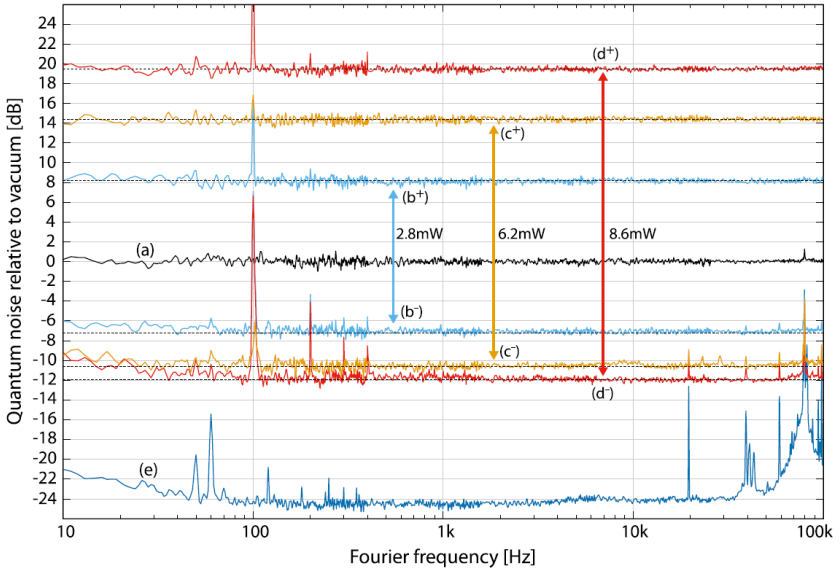


$$P_\omega(t) = A\varepsilon_0\chi^{(1)}\cos(\omega t + \phi) - AB\varepsilon_0\chi^{(2)}\cos(\omega t - \phi)$$

- Depending on ϕ the input field is deamplified (squeezed) or amplified (anti-squeezed)
- Strength can be varied with B
- This is also true for quantum fluctuations

Installed in January 2018



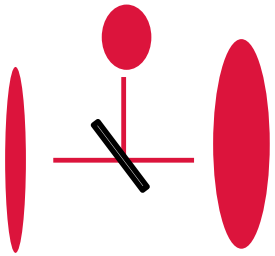


- Produced squeezing up to 14 dB
- Optical losses ~5.3%
- Phase noise ~3.5 mrad

M. Mehmet and H. Vahlbruch, CQG 36, 015014 (2019)

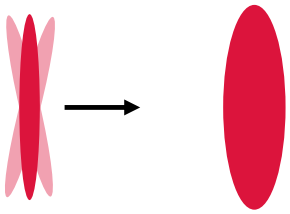
Squeezing degradation

- Optical losses L :



$$(1-L)\,\text{●}\,+\,L\,\text{●}$$

- Phase Noise :

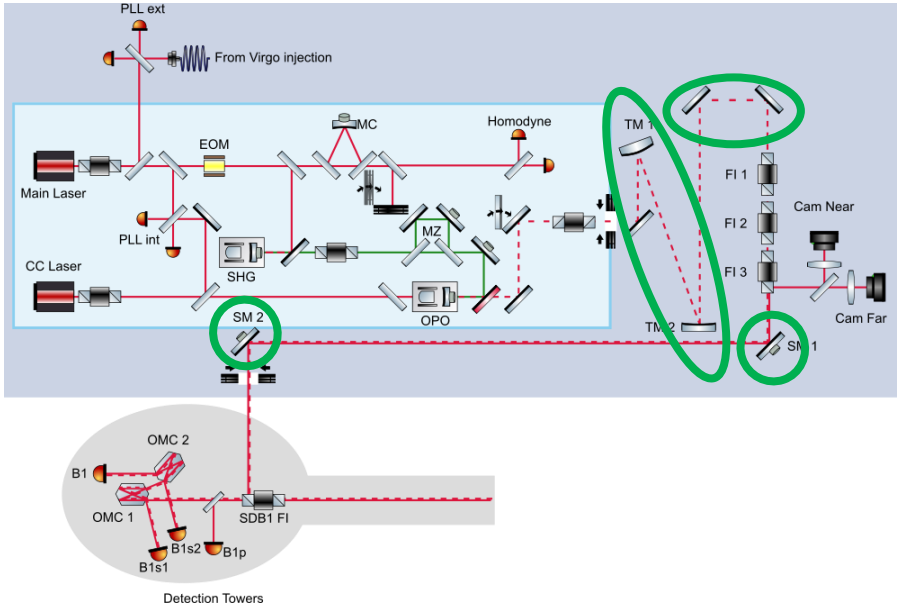


$$(\cos\tilde{\theta})^2\,\rightarrow\,\leftarrow\,+\,(\sin\tilde{\theta})^2\,\downarrow\,\uparrow$$

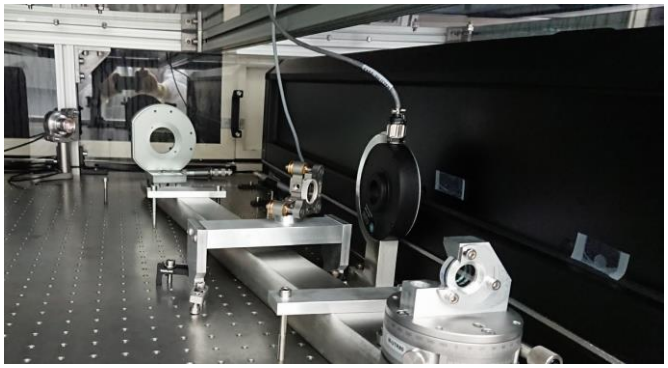
Keep them as low as possible to benefit from the squeezing injection

Alignment and Mode-matching with Virgo

Goal : reduce optical losses



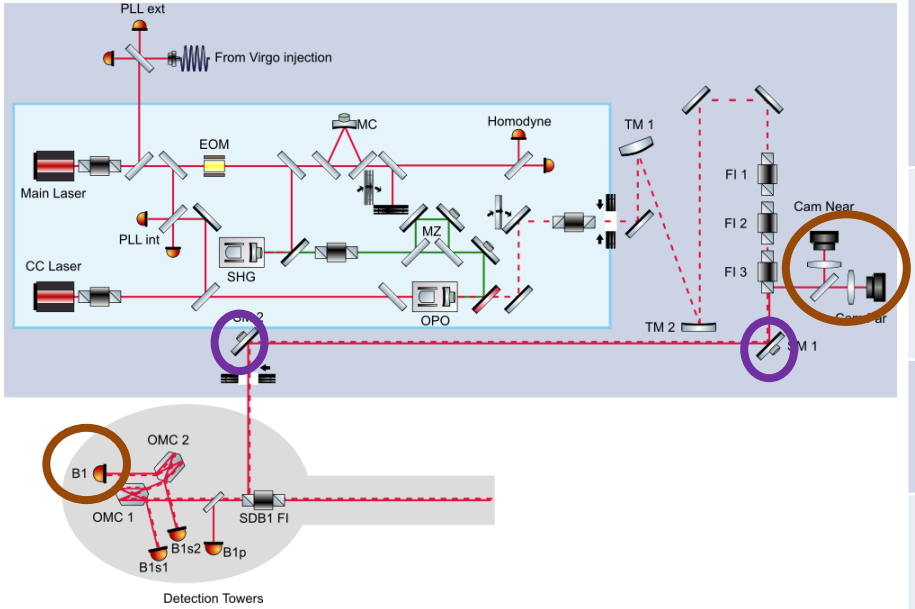
PZT actuated steering mirrors
Reflective telescope



- Alignment losses : 1,54%
- Mode-mismatch losses : 1,14%

Goal : reduce optical losses

Error signal Actuation

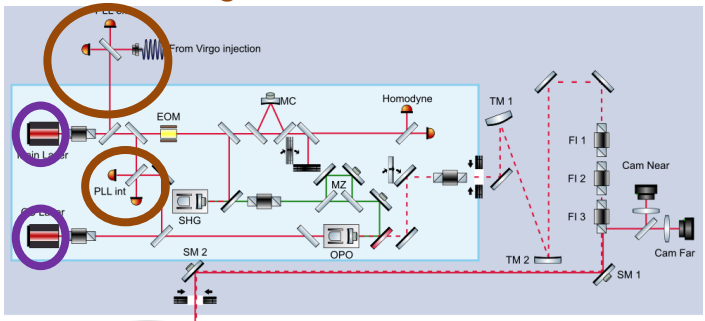


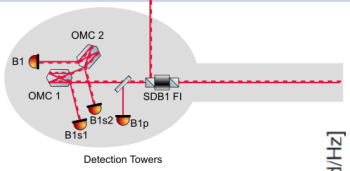
	Pre-alignment	Finer alignment
Sensor	Cameras on ESQB	Demodulated dither lines on B1
Actuator	Steering mirrors PZT	Steering mirrors PZT
UGF	0,1 Hz	0,1 Hz
Pros	Works without squeezed beam	Accurate sensing of alignment

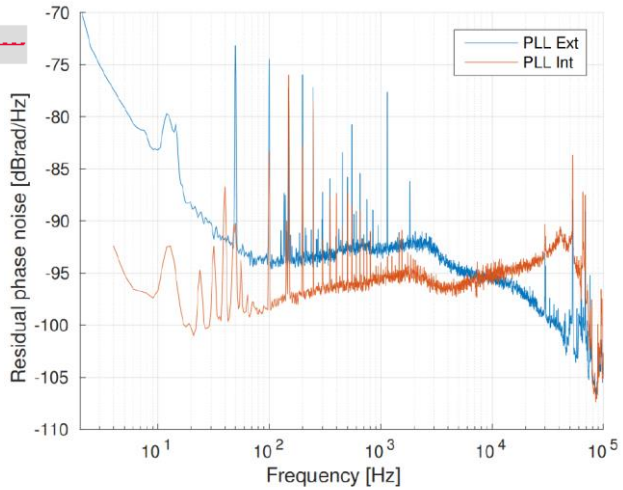
Residual losses ~1%

- Goal : reduce phase noise
  - Stabilize in frequency the squeezer main laser to Virgo laser
  - Stabilize the CC laser at 7MHz from Virgo laser

Error signal Actuation





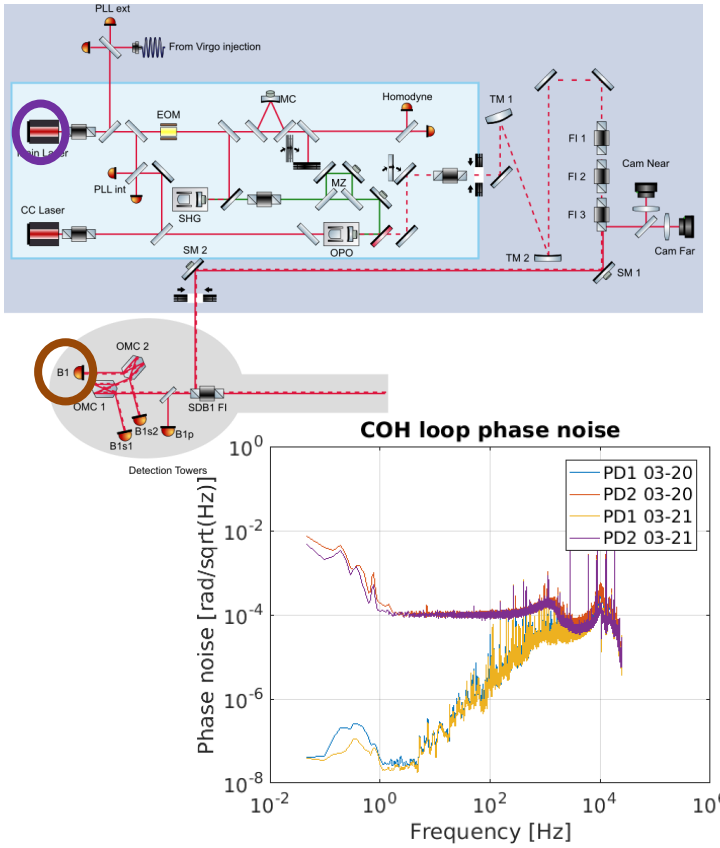


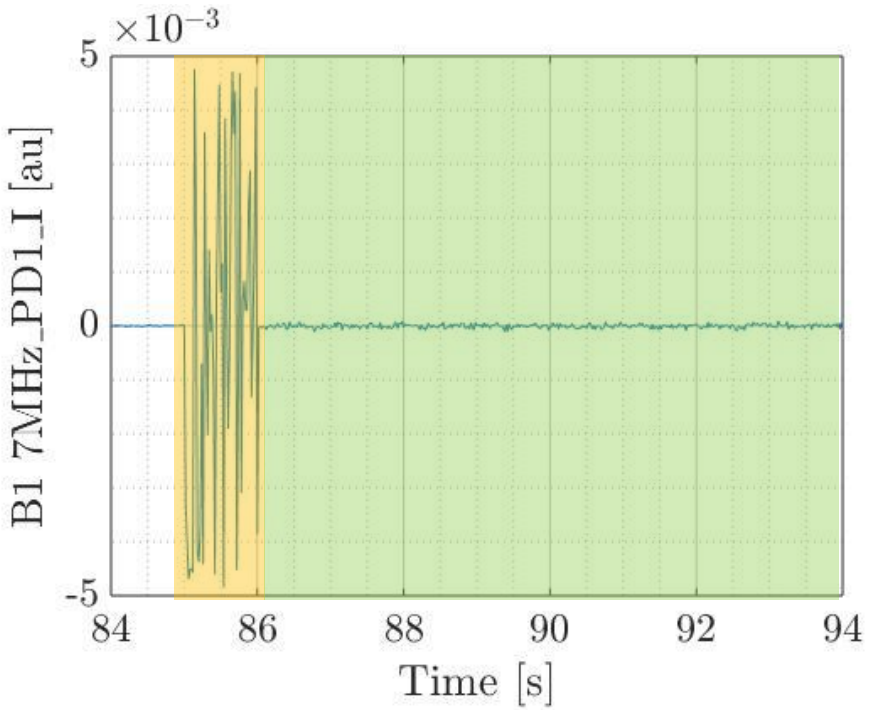
- Slow loop :
  - Acts on laser Peltier cell
  - UGF ~ 0.1 Hz
- Fast loop
  - Acts on laser PZT
  - UGF ~30 kHz

Residual phase noise <5mrad

- Goal : reduce phase noise
  - Keep the squeezed quadrature aligned with GW signal

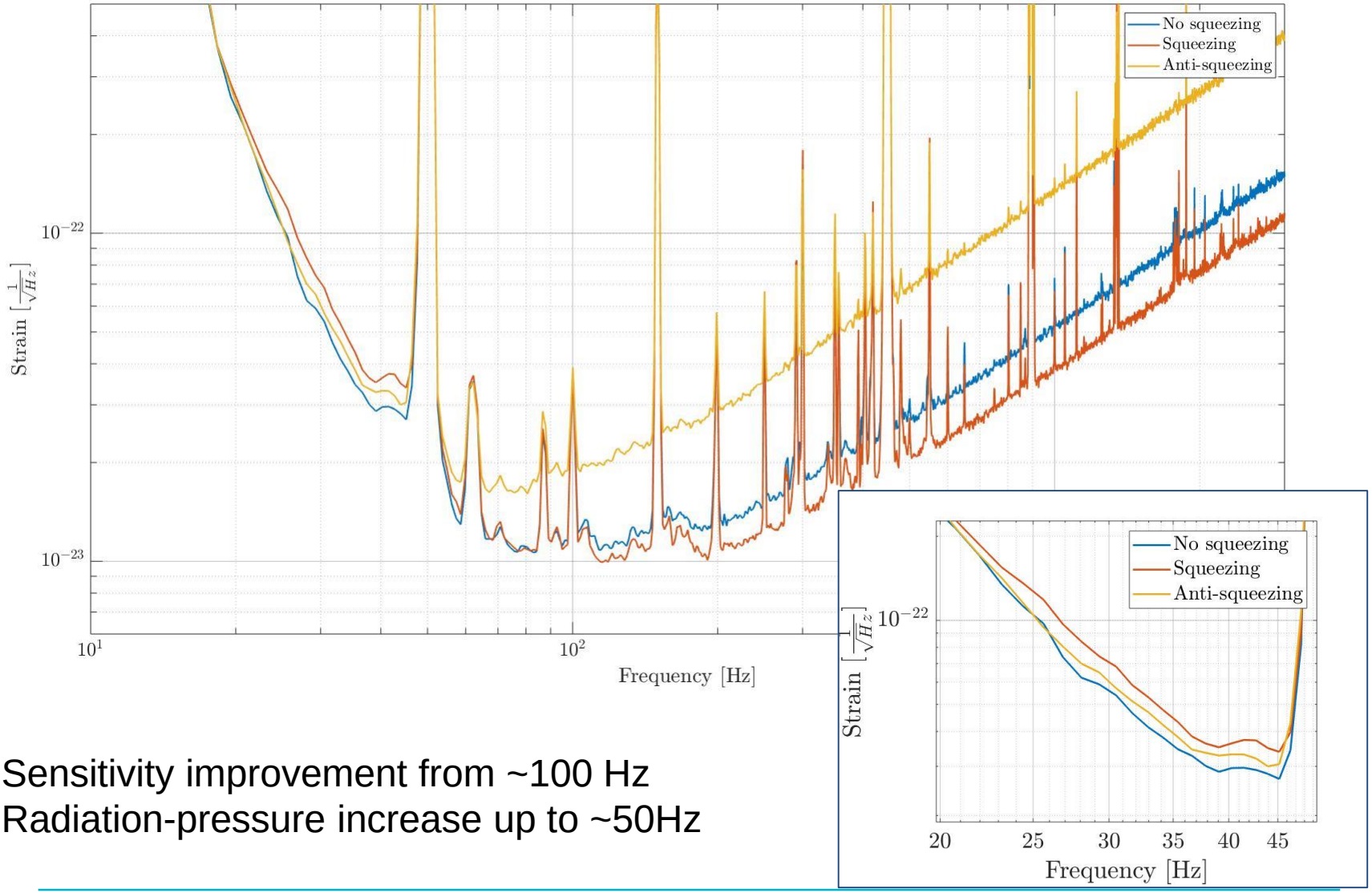
Error signal Actuation



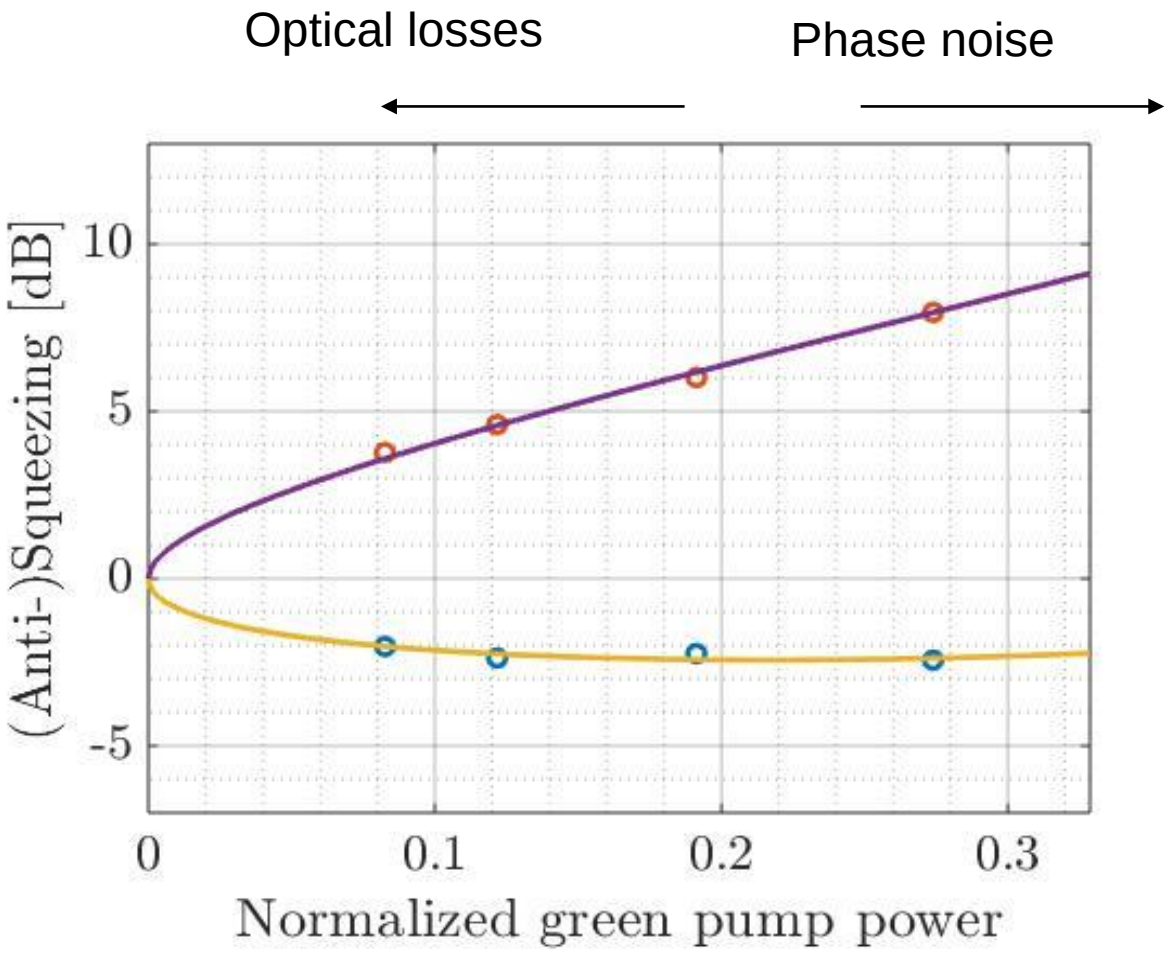


Phase noise rms ~20 mrad

Effect on sensitivity



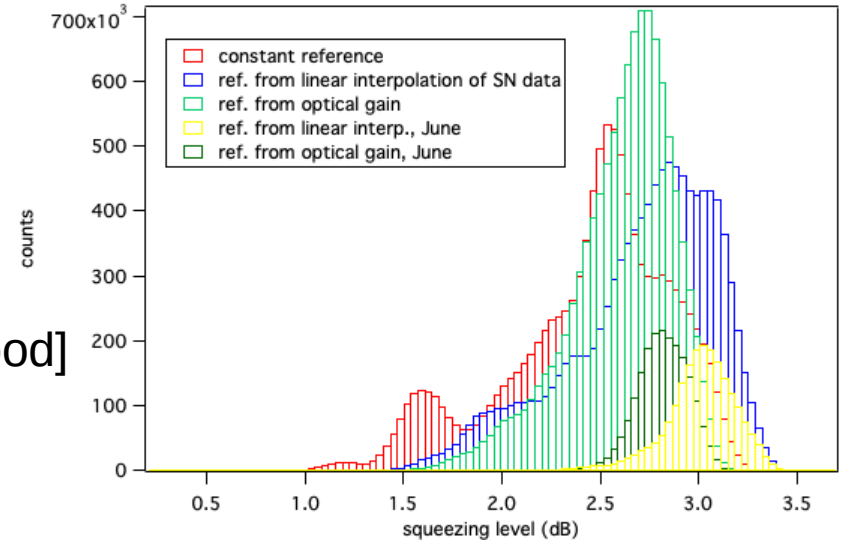
- Sensitivity improvement from ~100 Hz
- Radiation-pressure increase up to ~50Hz



OPO threshold power : 23 mW
Optical losses : 42%
Phase noise rms : 132 mrad

O3 performances

- Squeezer duty cycle > 99%
- Max produced squeezing : 14dB
- Max measured squeezing : 3,2 dB
- Optical losses : ~40% [25% understood]
- Phase noise : ~120 mrad [100mrad understood]



- Understanding of optical losses and phase noise
- Decrease optical losses and phase-noise
- Improve squeezing level stability
- Prepare for frequency-dependent squeezing