

# Performance of the ANU Travelling-wave Squeezing Cavity for the LIGO H1 Squeezing Injection Experiment



Eighth Edoardo Amaldi Conference  
on Gravitational Waves

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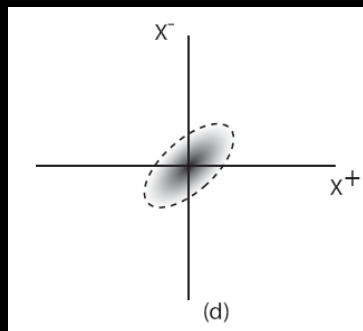
LIGO-G0900518-v1

Centre for Gravitational Physics  
Australian National University – Canberra



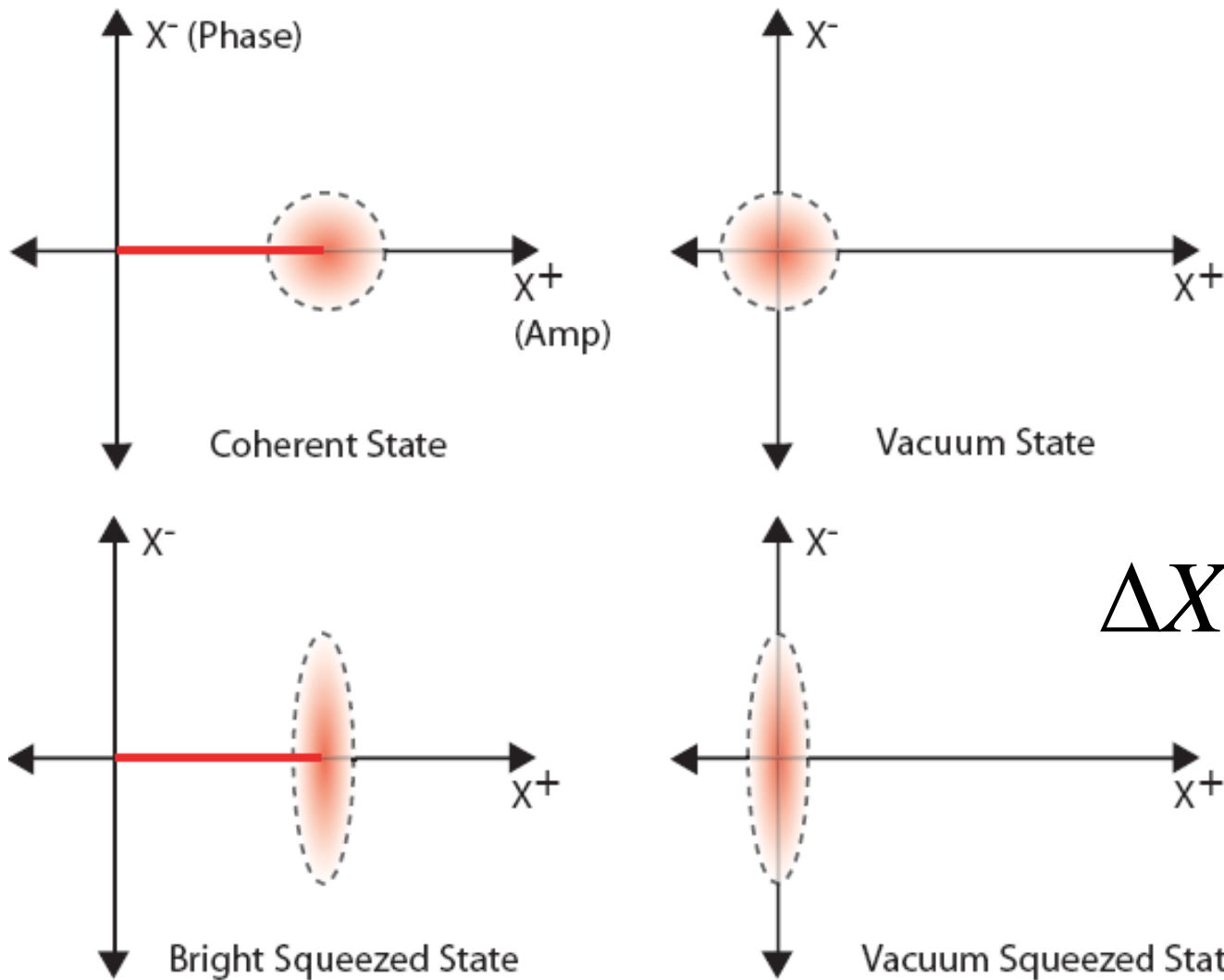
## In – brief: LIGO H1 Squeezing Project

For more details, talk to be given by Daniel Sigg



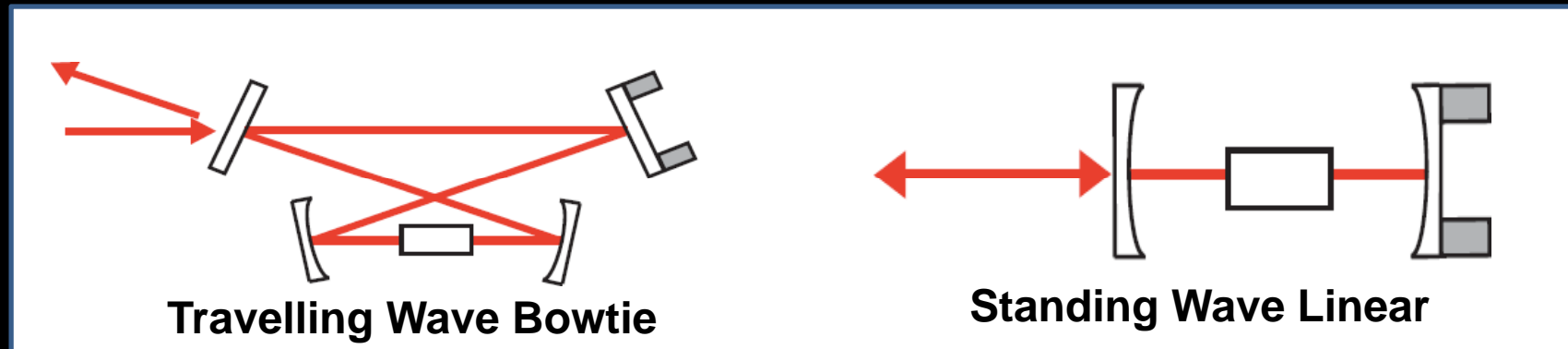
- Quantum noise is a limitation to interferometer sensitivity.
- 6dB squeezing  $\equiv$  Factor 4 increase in laser power
- Squeezed light to be injected into Hanford 4km interferometer, scheduled early 2011.
- Goal of injection of 6dB squeezing, looking at its effect on the quantum-noise-limited detection region (100Hz – 10kHz)
- New squeezer to be constructed:
  - ANU – Optical Parametric Oscillator (OPO)
  - AEI – Homodyne Detector
  - MIT – Lasers, SHG and Integration Lab
  - LIGO Hanford – Injection optics

# What is meant by squeezing?



$$\Delta X^+ \Delta X^- \geq 1$$

## Optical Parametric Oscillator

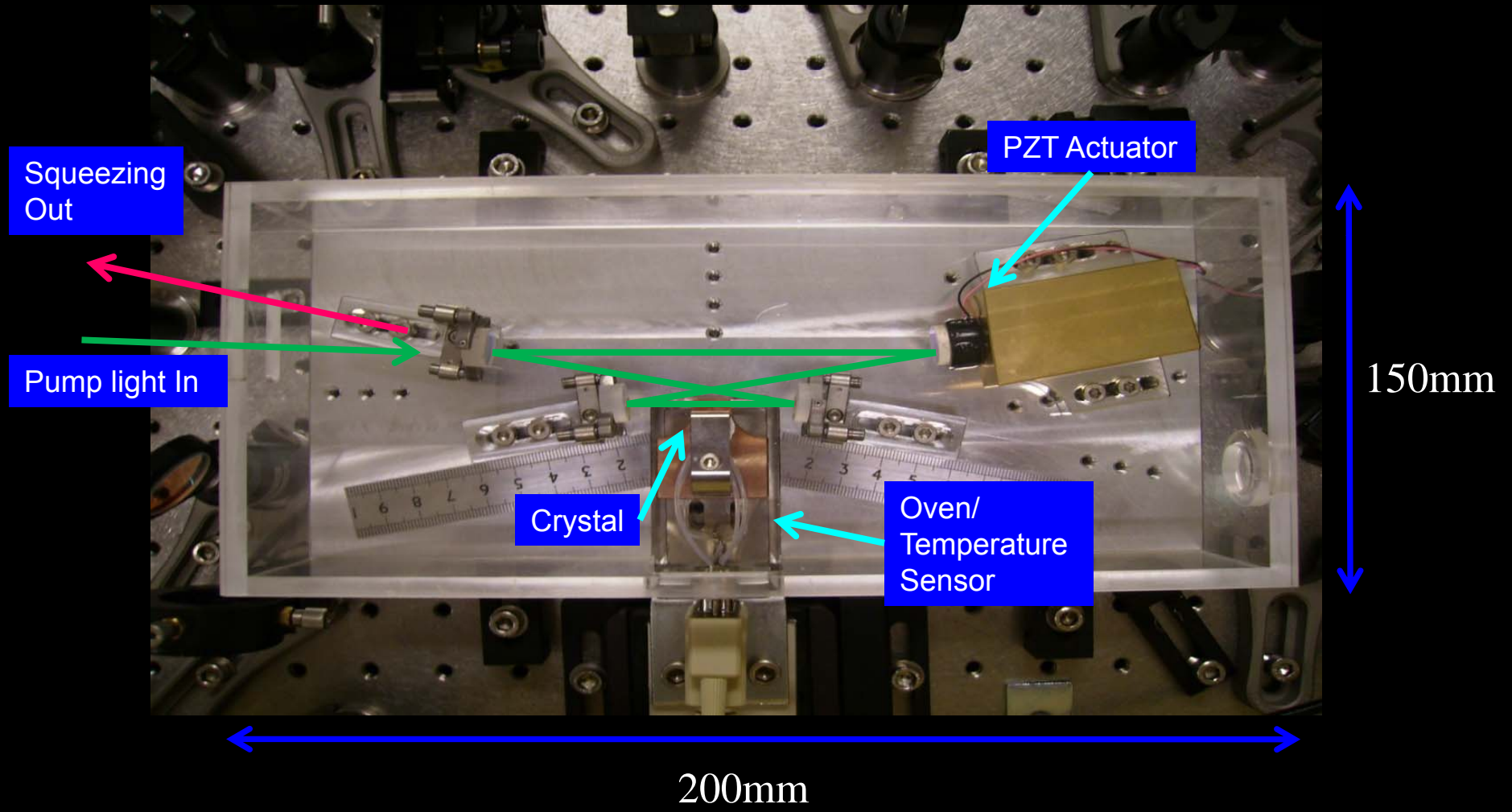


- The OPO is a device that provides the asymmetric amplification process that produces squeezed light.
- Travelling-wave design gives first-order immunity to backscatter
- Backscattered light is a source of OPO seed light which masks squeezing in the audio GW detection band. This was first shown by McKenzie [1], leading to first observation of squeezing within the audio GW detection band [2].

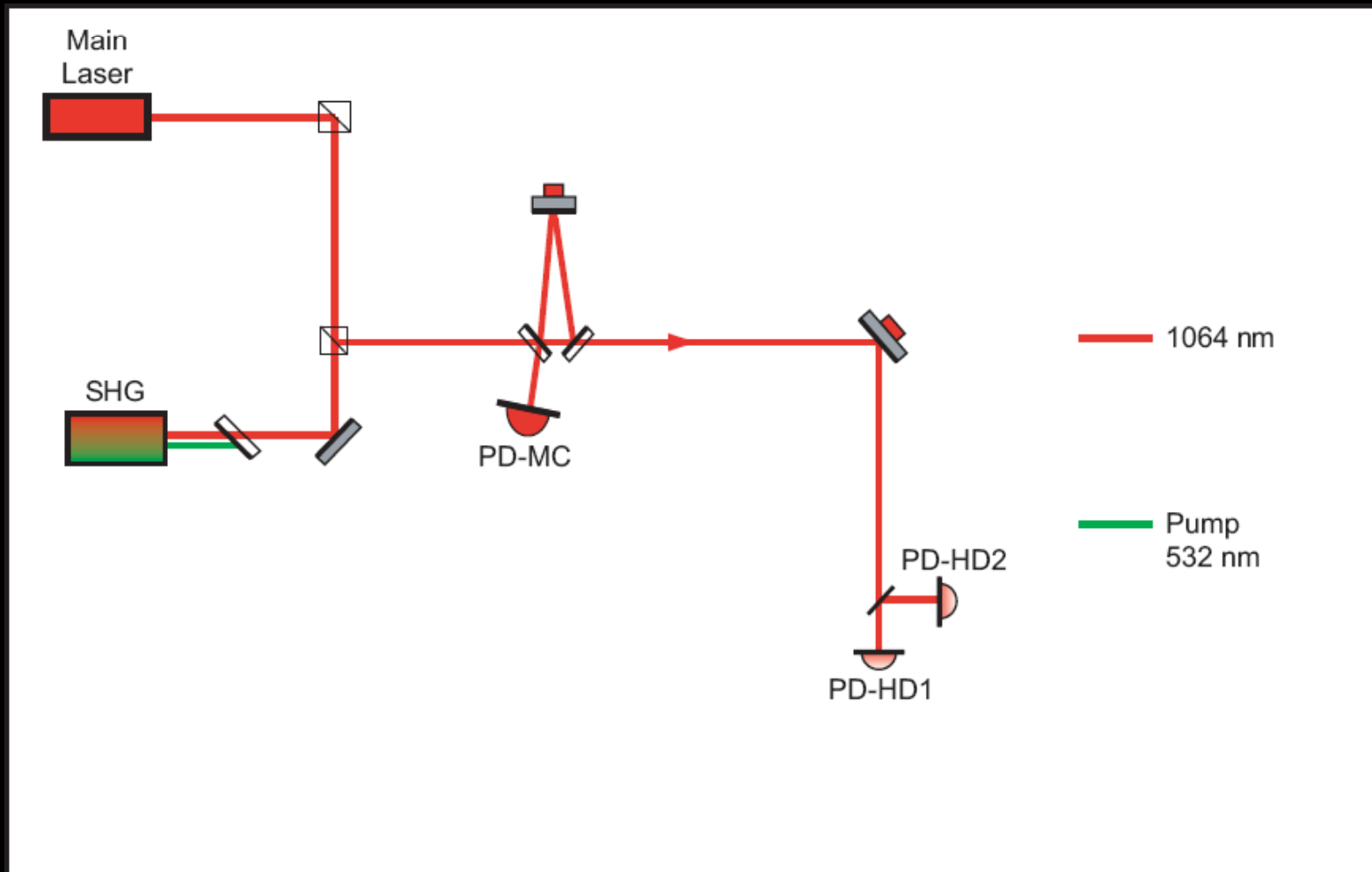
[1] McKenzie et. al. Phys. Rev. Lett. 93, 161105 (2004)

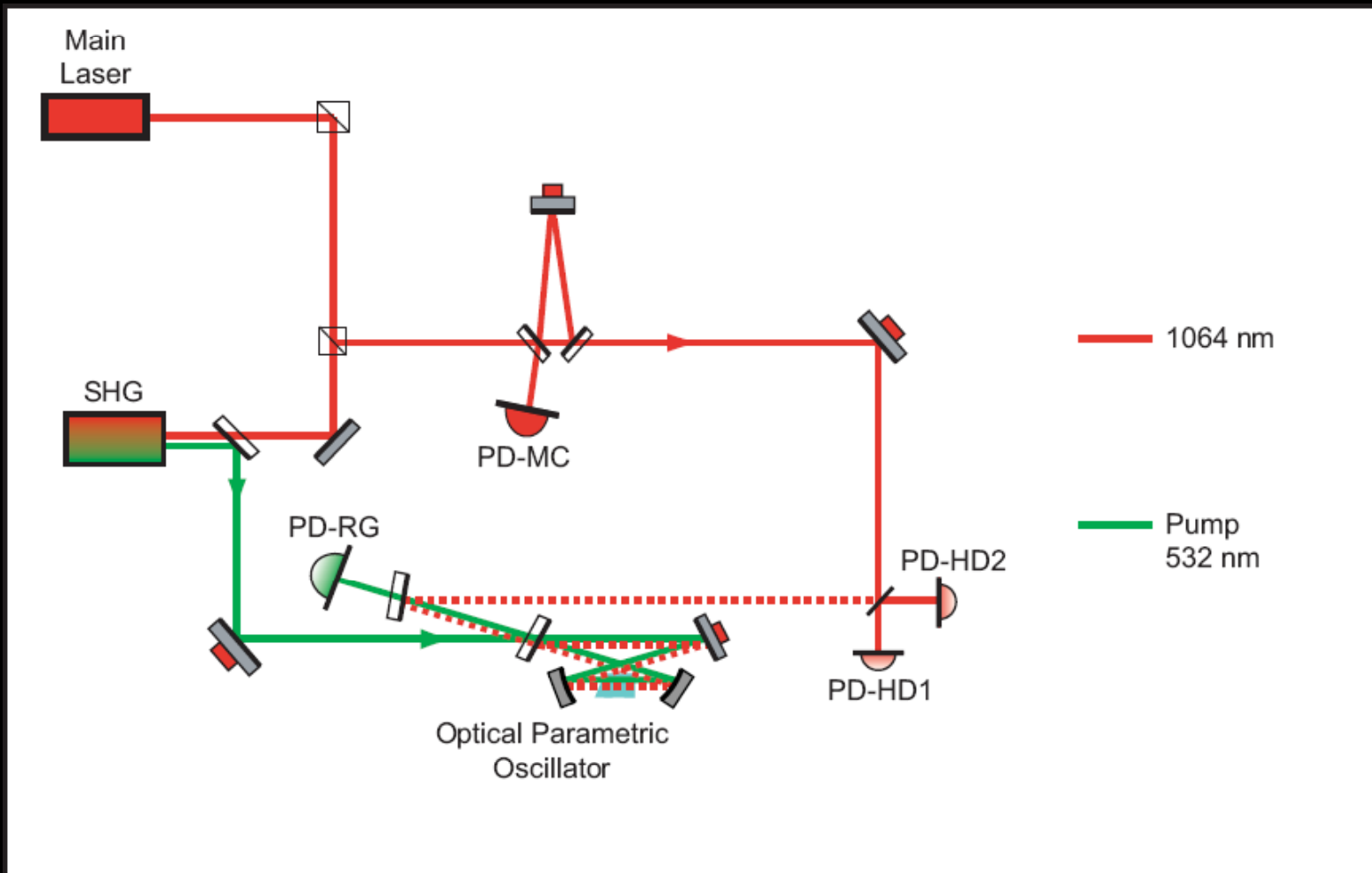
[2] McKenzie et. al. Class. Quantum Grav. 23 S245-S250 (2006)

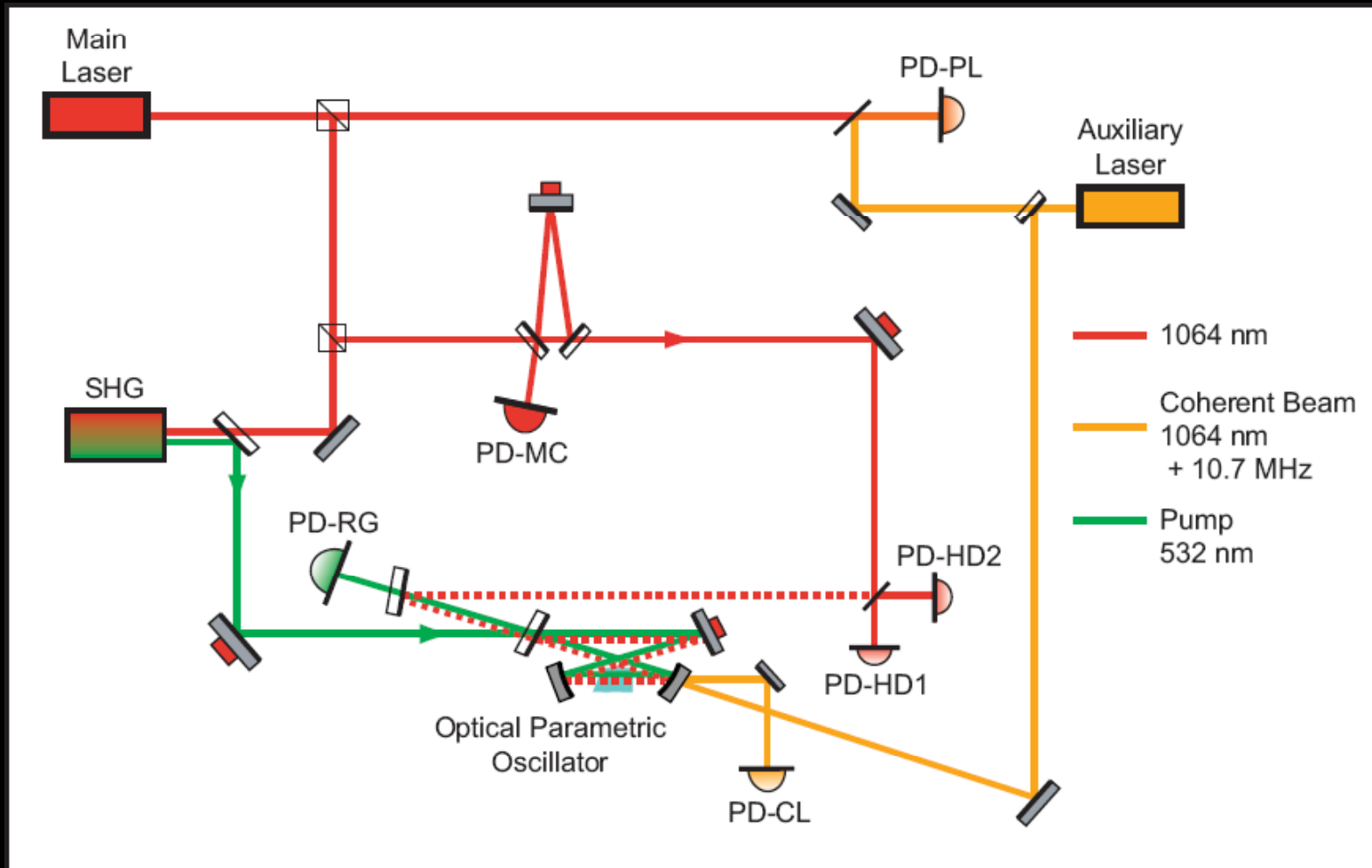
# The Current ANU OPO







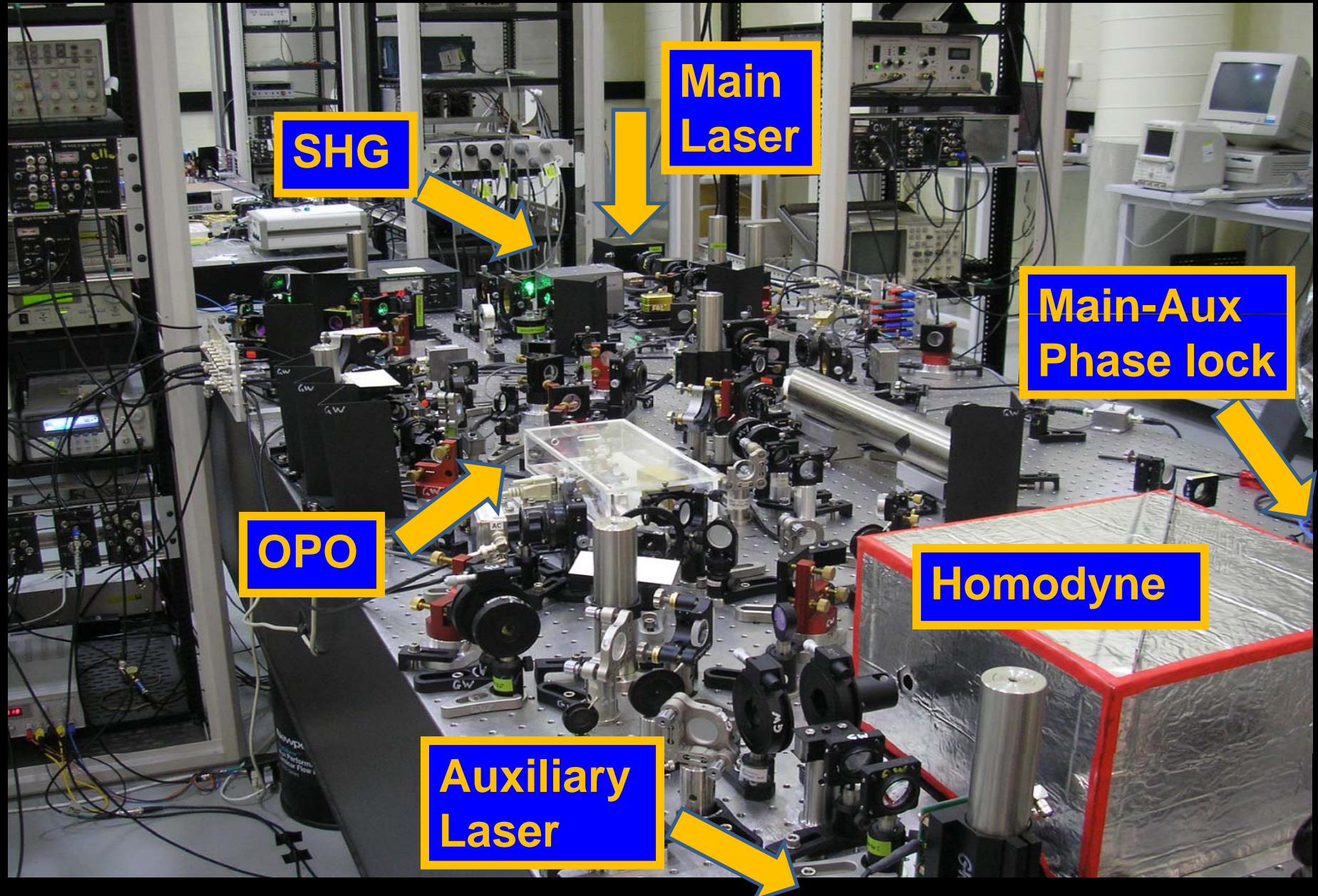




- Coherent Locking technique [3] to be used in the LIGO H1 Experiment

[3] Vahlbruch et. al. Phys. Rev. Lett. 97, 011101 (2006)

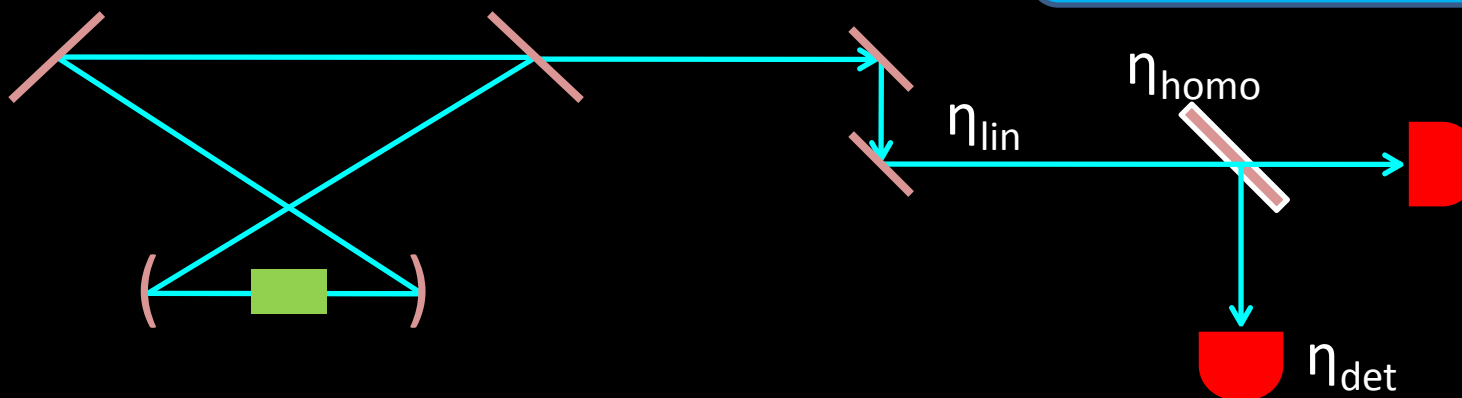




## Squeezing Measurement

- Squeezing measurement is strongly degraded by loss.
- $\eta_m$  – Measurement efficiency of the squeezing produced from the OPO.
  - Example: 20dB squeezing produced and with  $\eta_m = .89$  results in only 9dB squeezing observed.
- At ANU,  $\eta_m = 0.89$

$$\eta_m = \eta_{\text{lin}} \eta_{\text{homo}} \eta_{\text{det}}$$



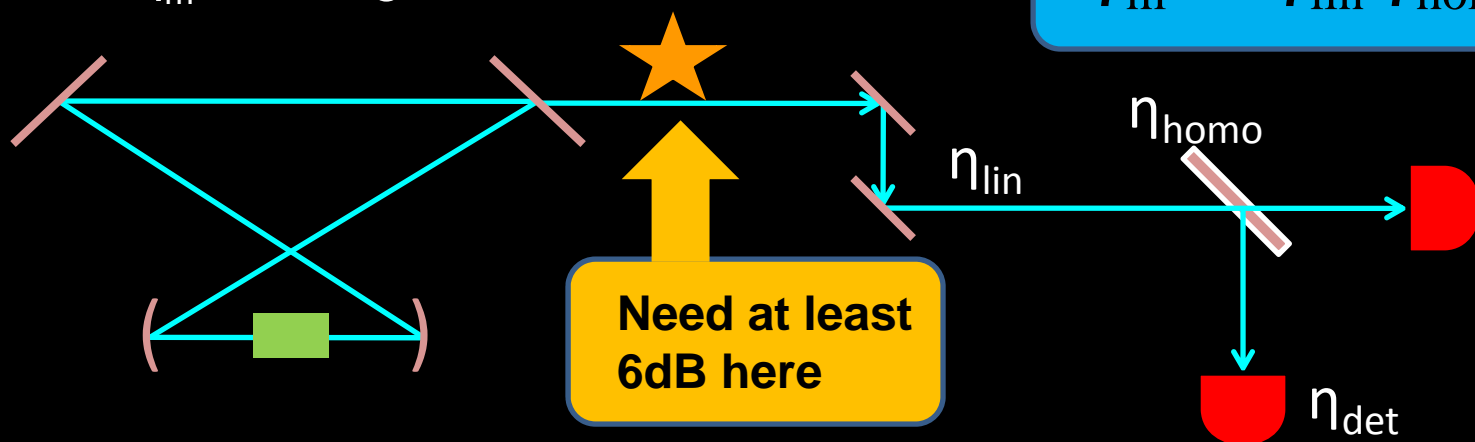
$\eta_{\text{lin}}$  – Transmission Efficiency  
 $\eta_{\text{homo}}$  – Homodyne Efficiency  
 $\eta_{\text{det}}$  – Detector Efficiency

→ From Cavity to Detection  
 → Square of the Fringe Visibility  
 → Photodetector Efficiency

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- At ANU,  $\eta_m = 0.89$
- 6dB with  $\eta_m = 0.89$  gives 4.8dB

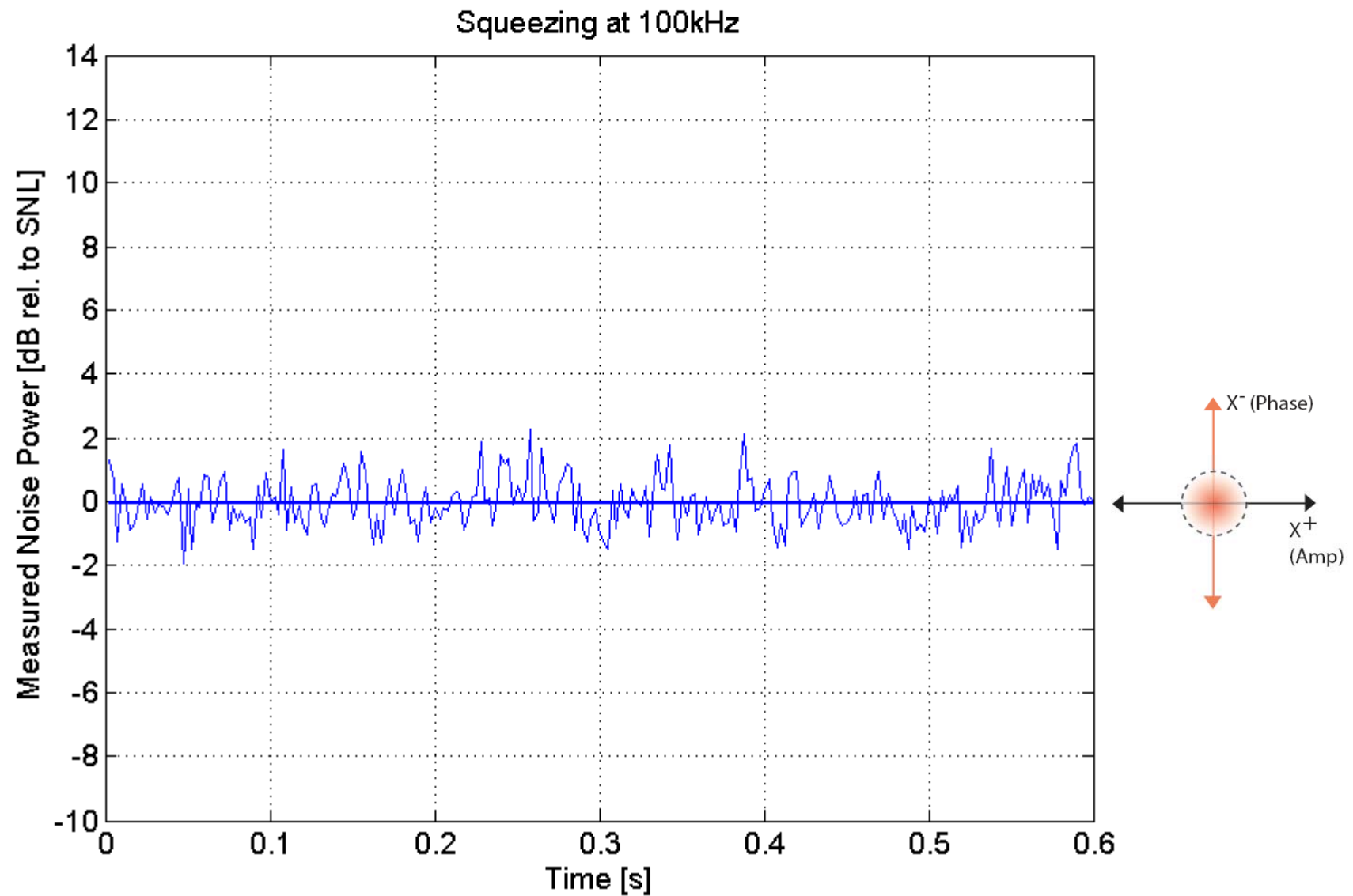
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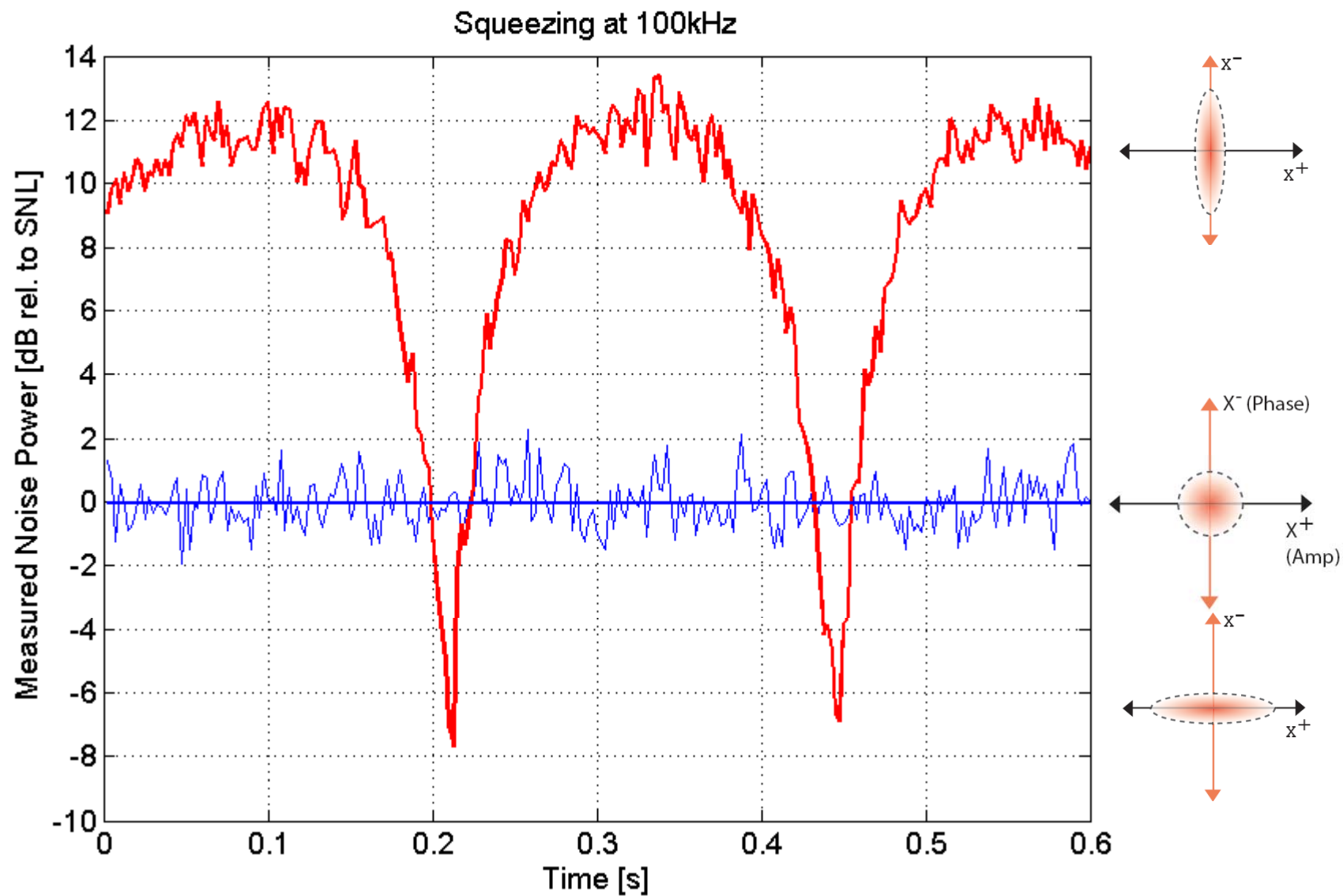
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# Squeezer Performance (I)

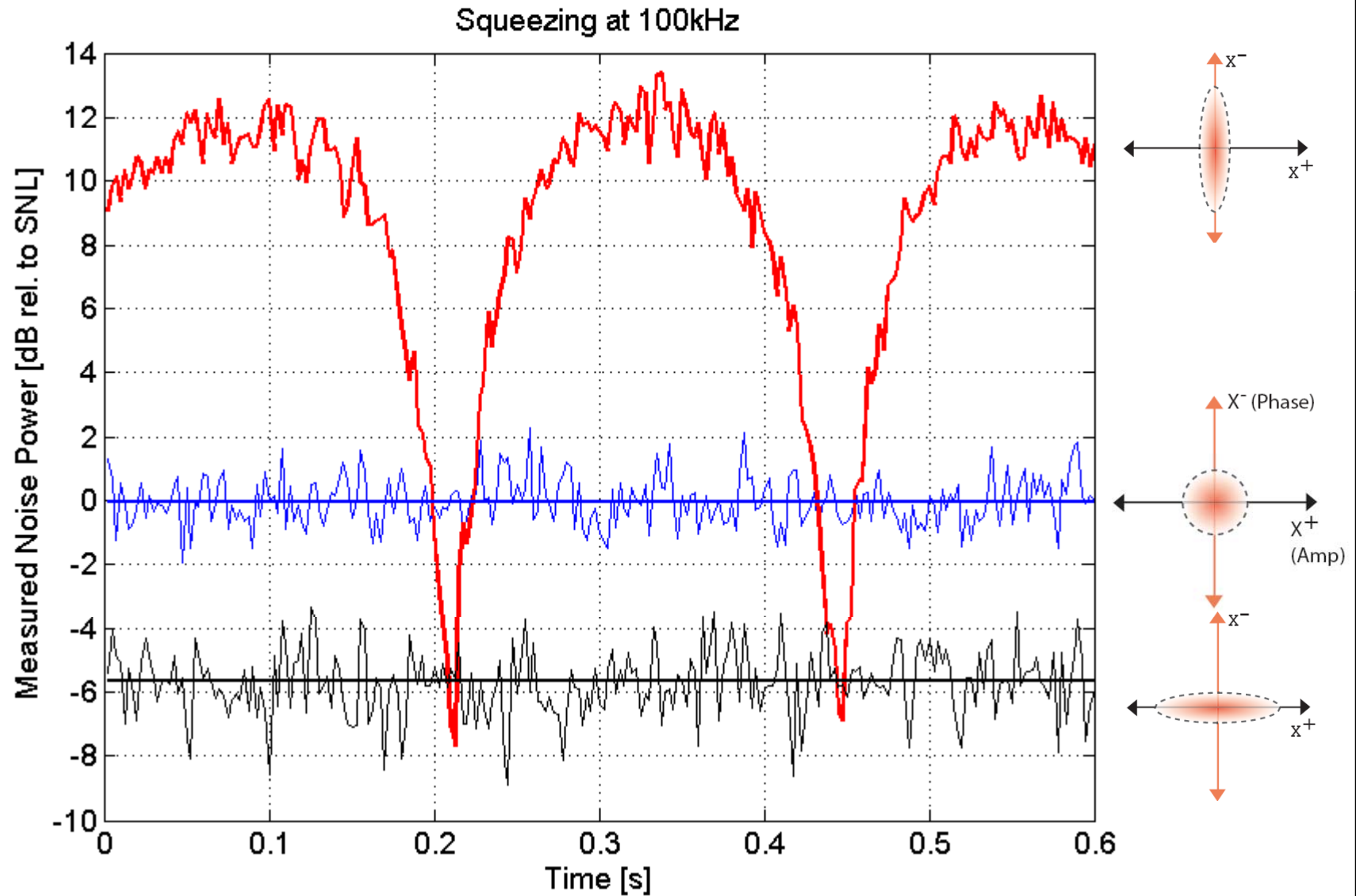


# Squeezer Performance (I)





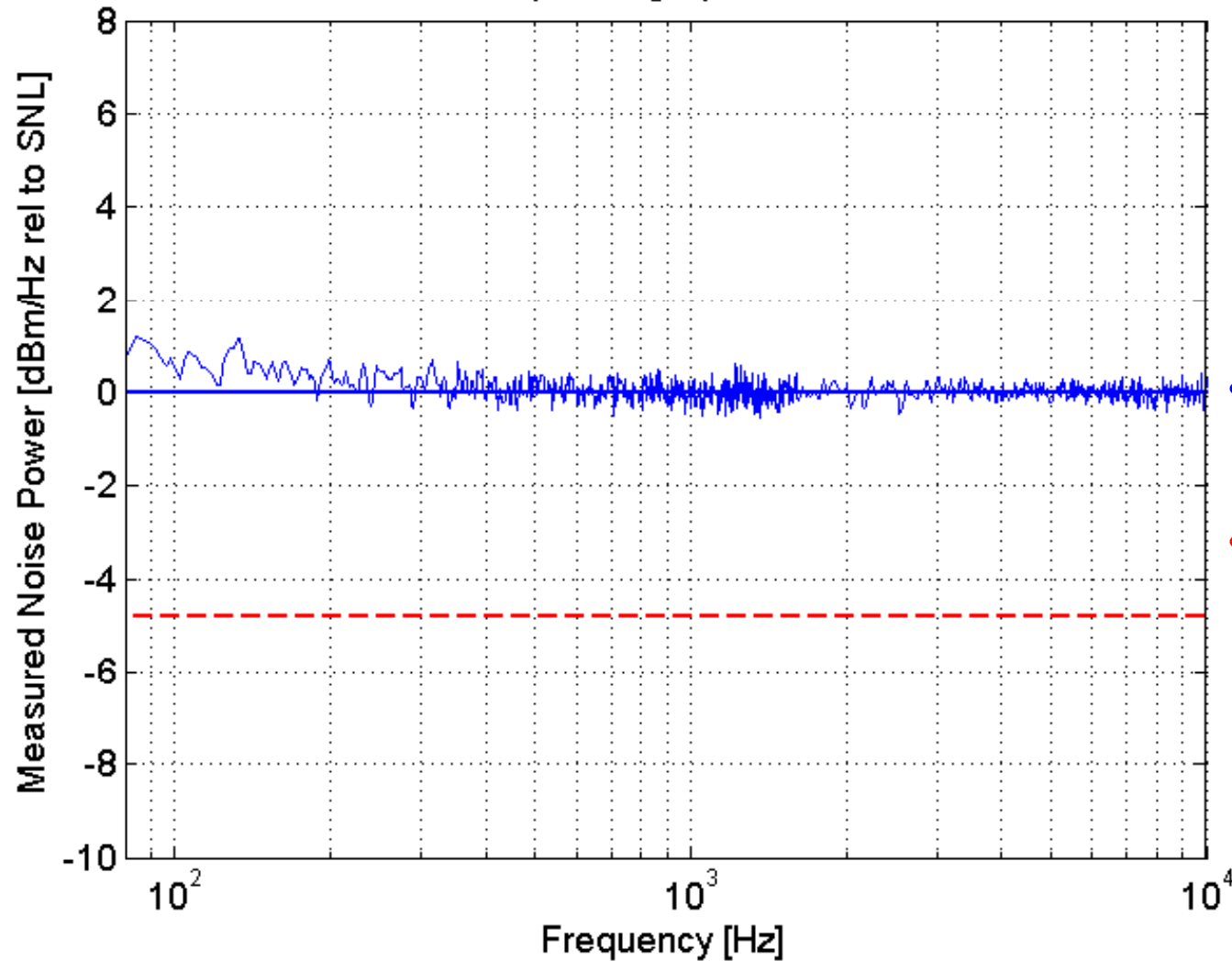
# Squeezer Performance (I)



# Squeezer Performance (II)

Squeezing Spectrum

$$\eta_m = 0.89$$



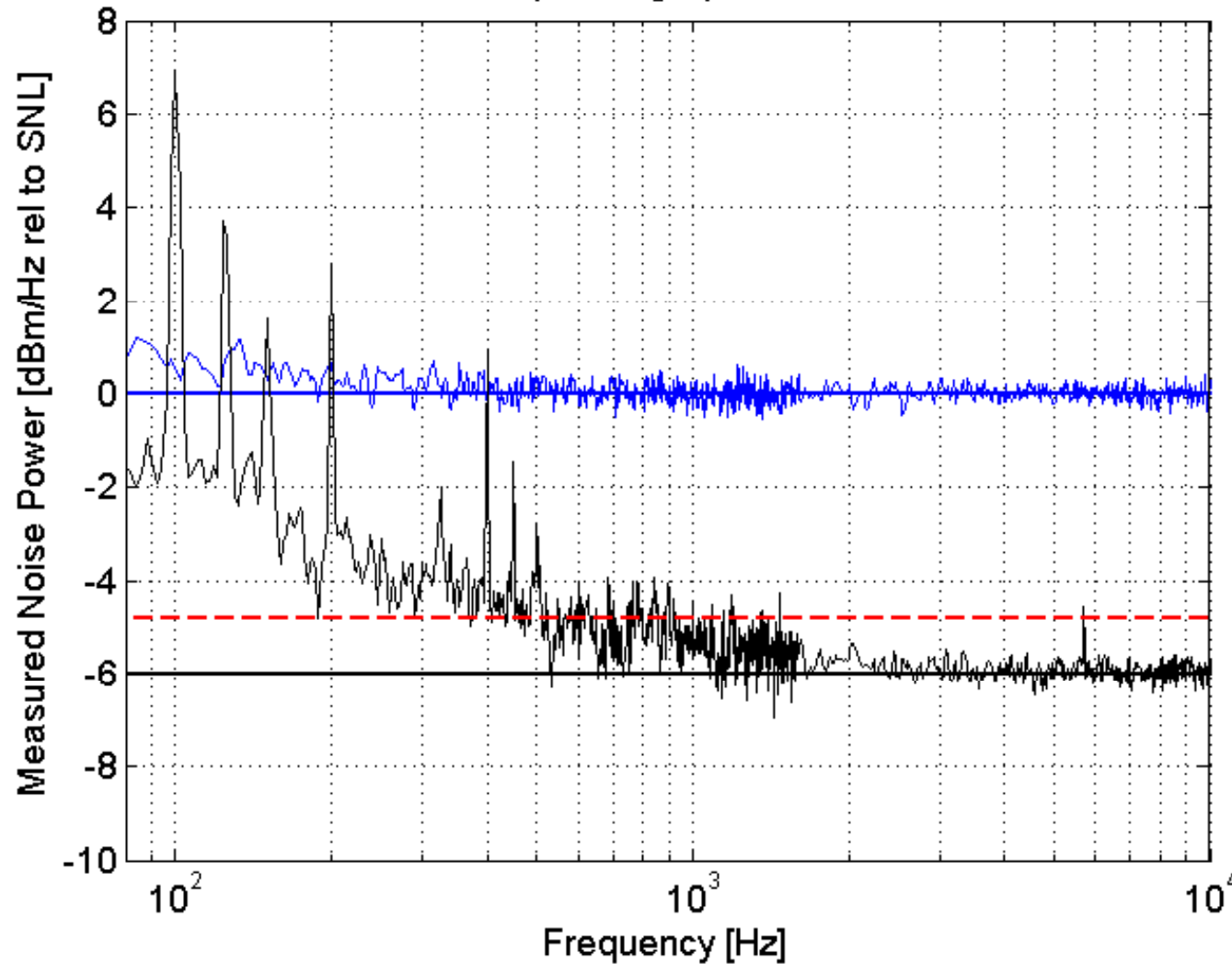
- Quantum Noise
- Squeezing Minimum requirement



# Squeezer Performance (II)

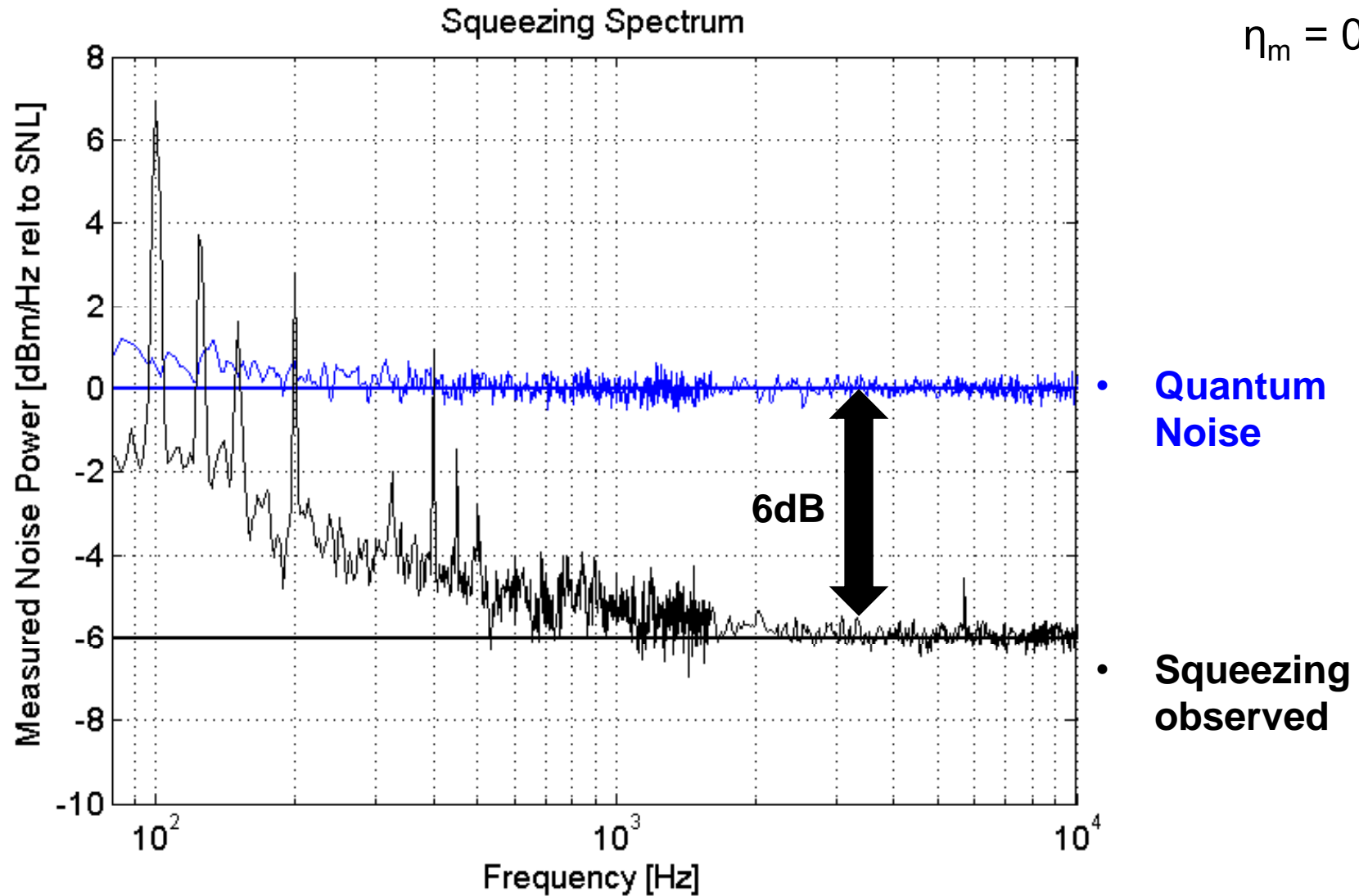
Squeezing Spectrum

$$\eta_m = 0.89$$



- Quantum Noise
- Squeezing Minimum requirement
- Squeezing observed

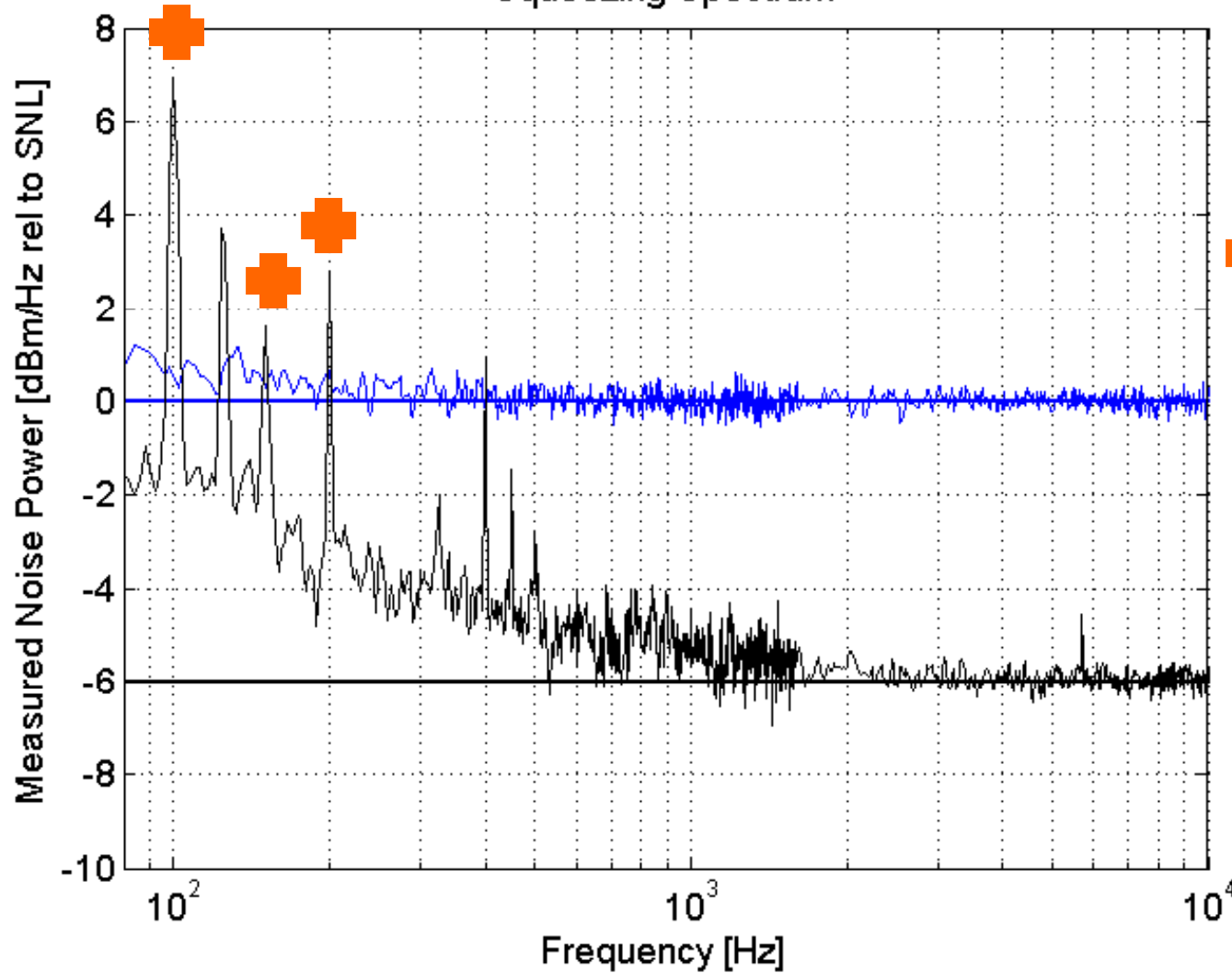
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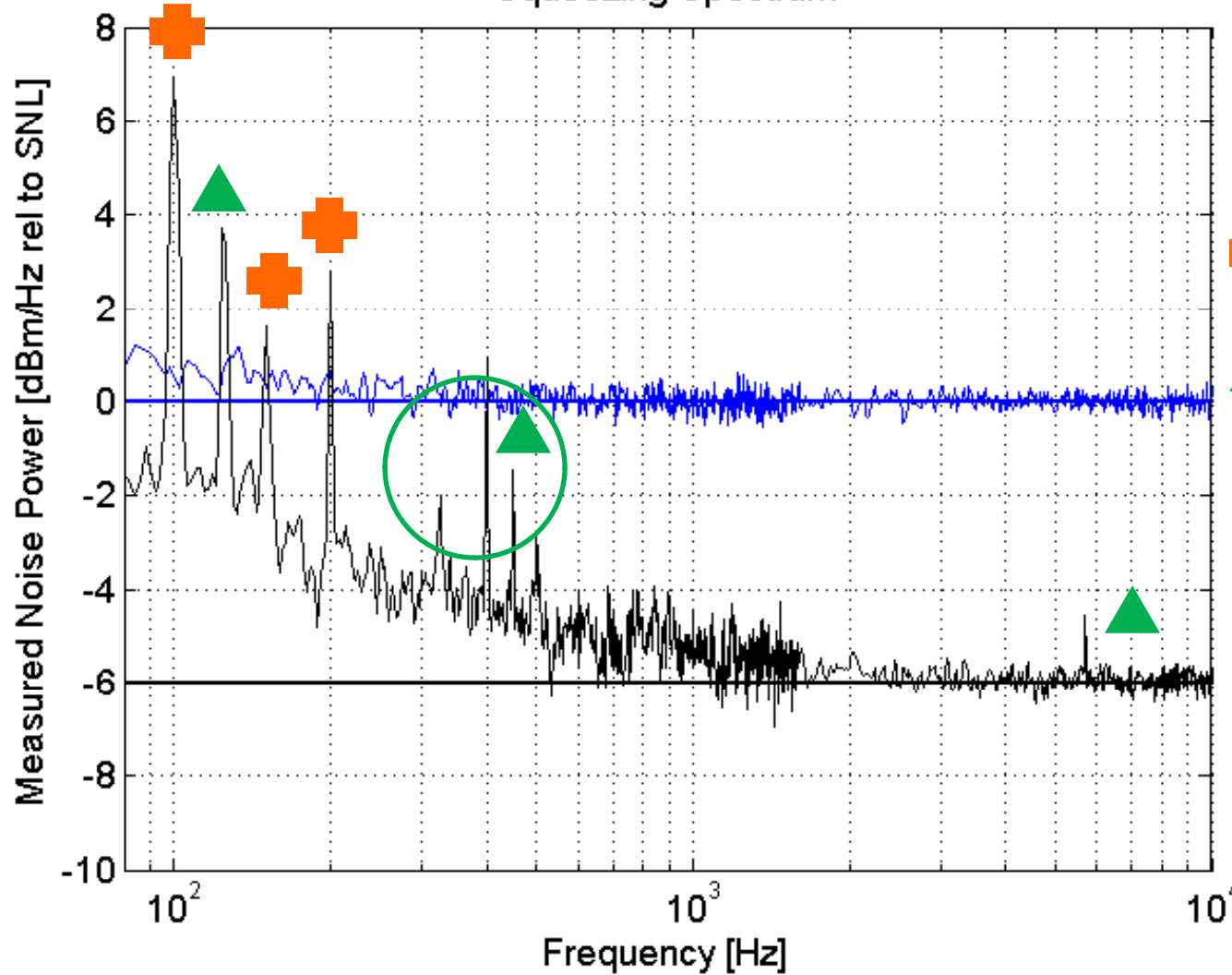


**Electronics**  
**Mains harmonics**

# Squeezer Performance (II)

Squeezing Spectrum

$$\eta_m = 0.89$$



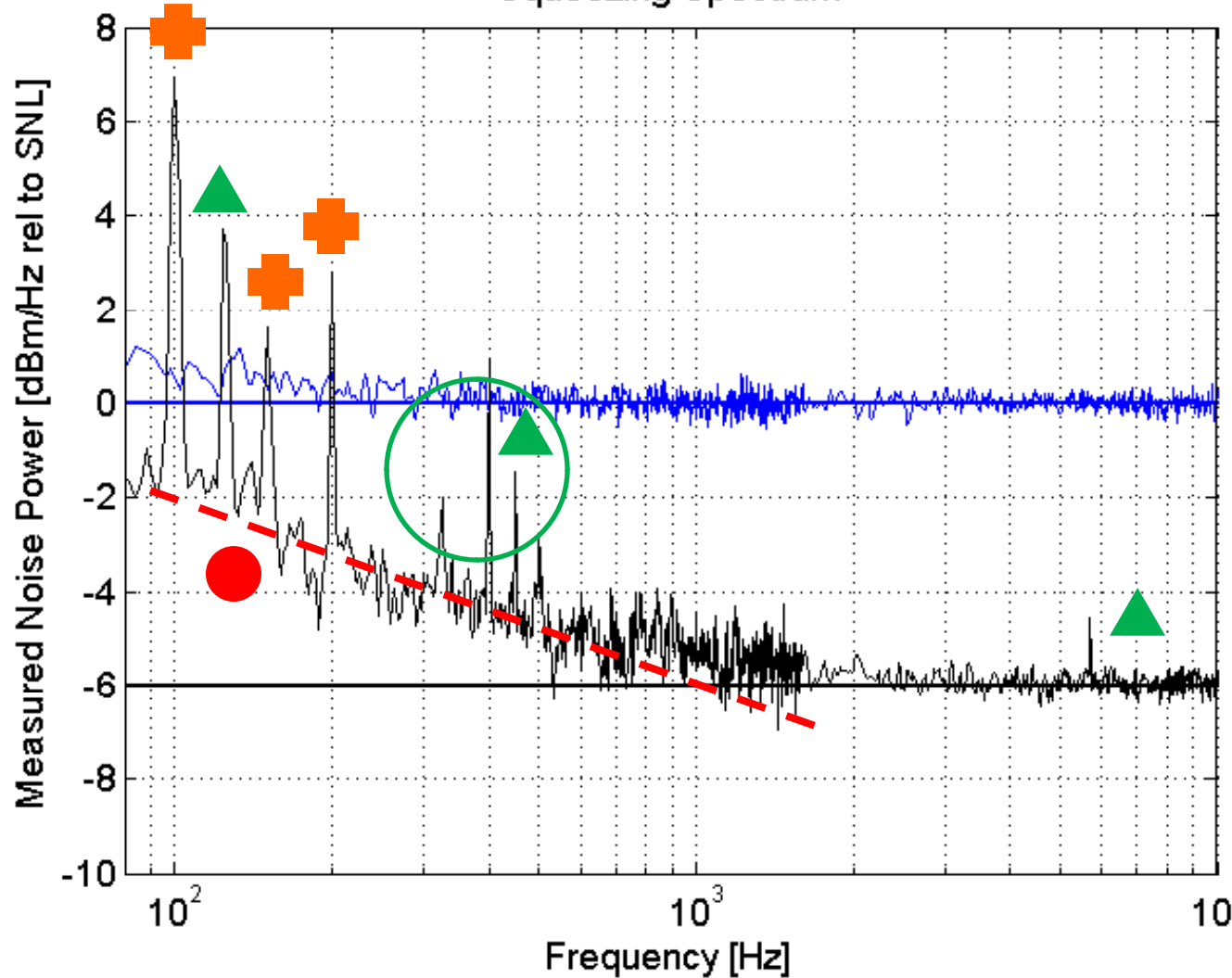
## Electronics

- ✚ Mains harmonics
- ▲ Cross coupling from Coherent Lock

# Squeezer Performance (II)

Squeezing Spectrum

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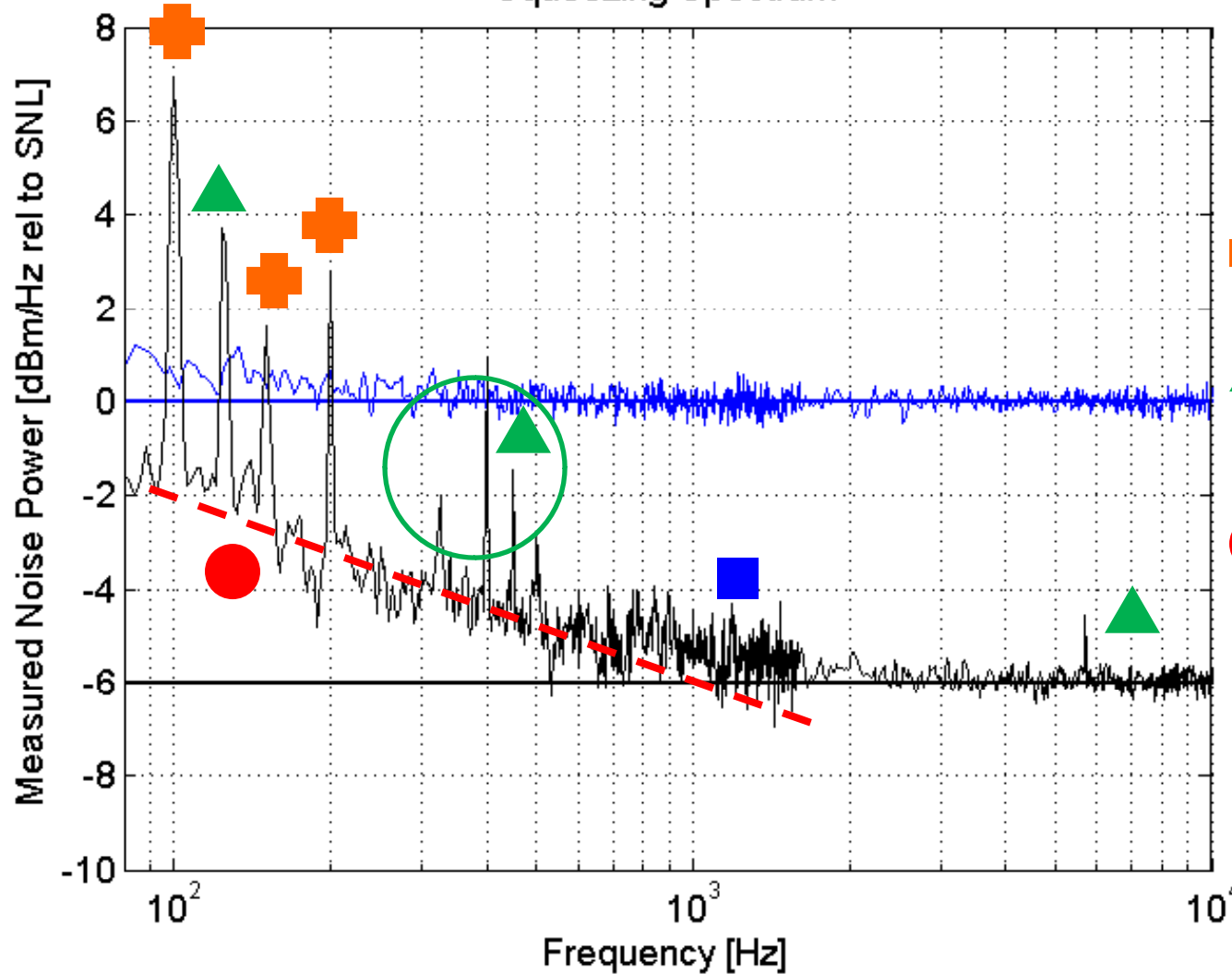
## Electronics

- + Mains harmonics
- ▲ Cross coupling from Coherent Lock
- Electronic Noise?

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Squeezing Spectrum

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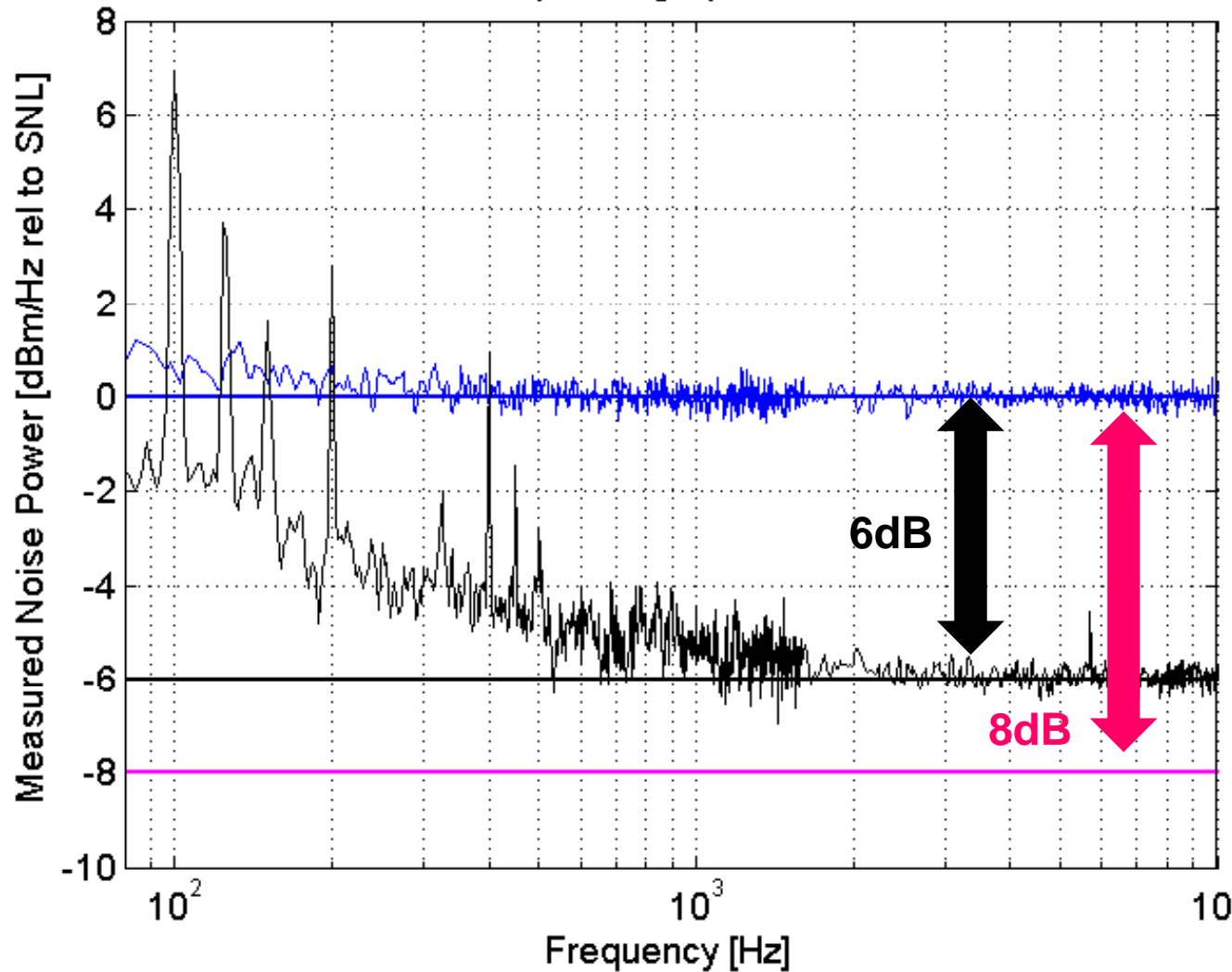
## Lab environment

- Acoustic Noise

# Squeezer Performance (II)

Squeezing Spectrum

$$\eta_m = 0.89$$

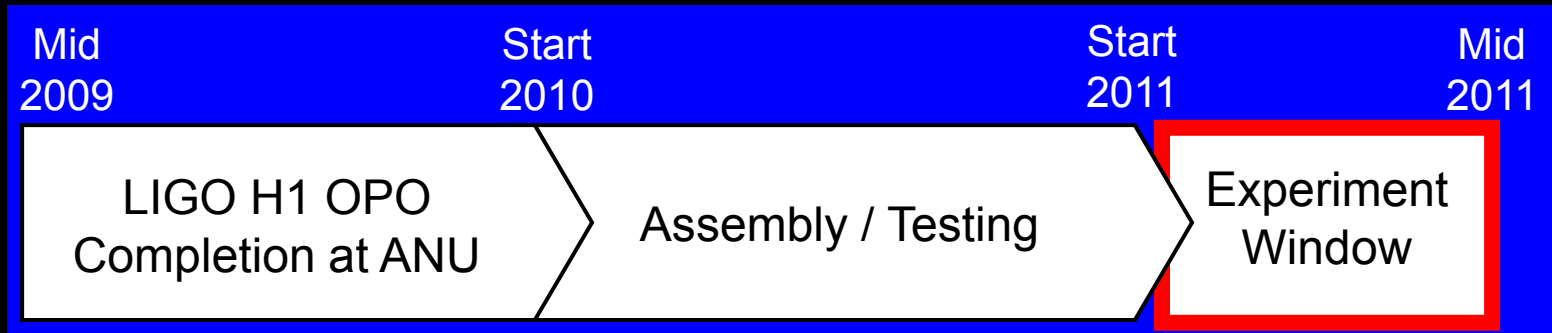


• Quantum Noise

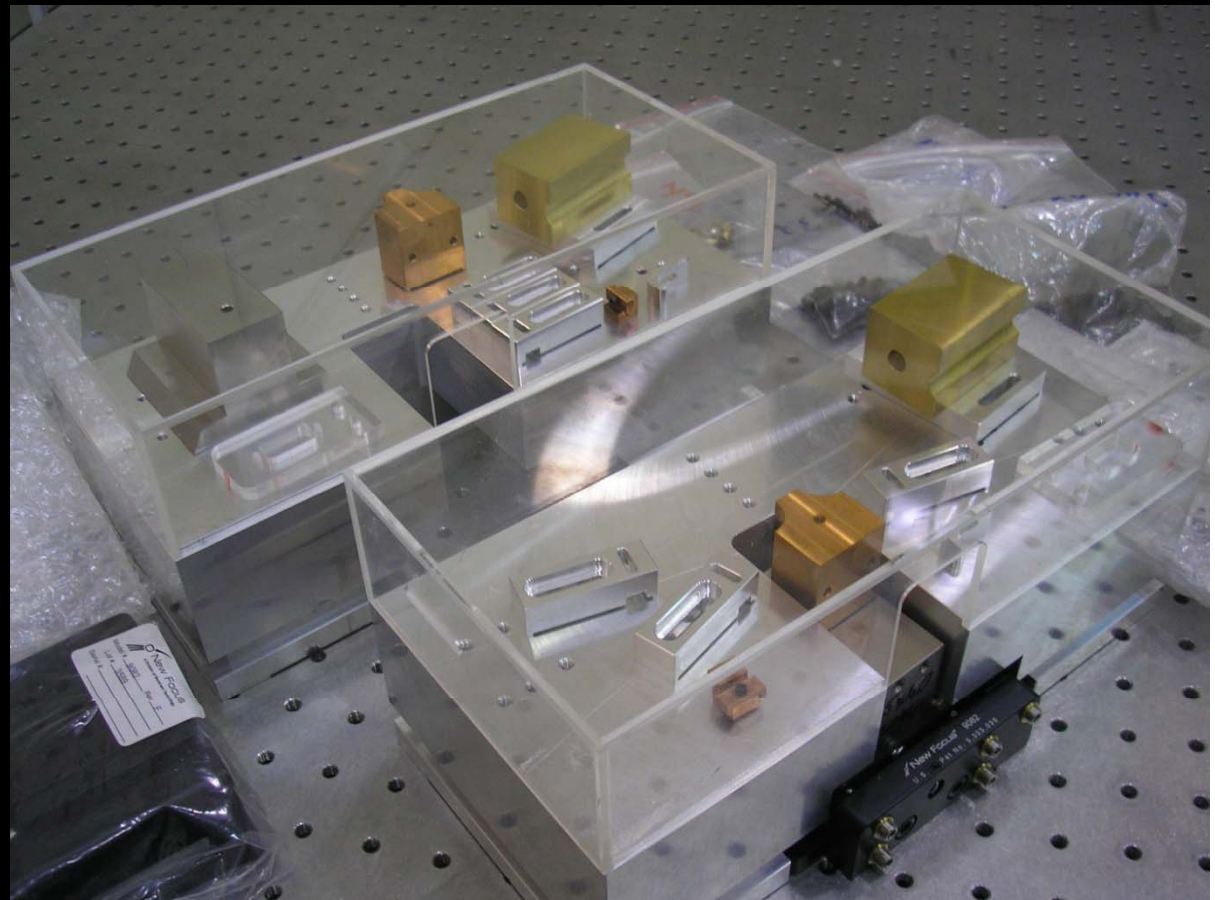
• Squeezing observed

• Inferred Squeezing



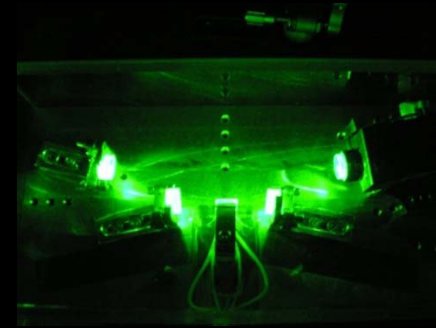
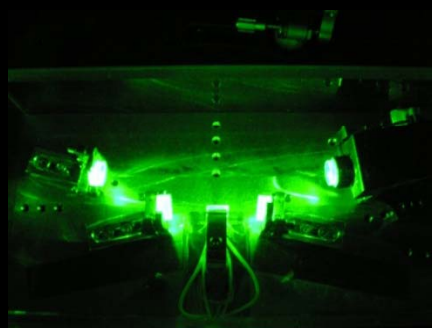


- Test of LIGO H1 OPOs at ANU with improved electronics
- Send to MIT for integration onto the LIGO H1 Squeezer breadboard (start of 2010 – on schedule)



## Summary

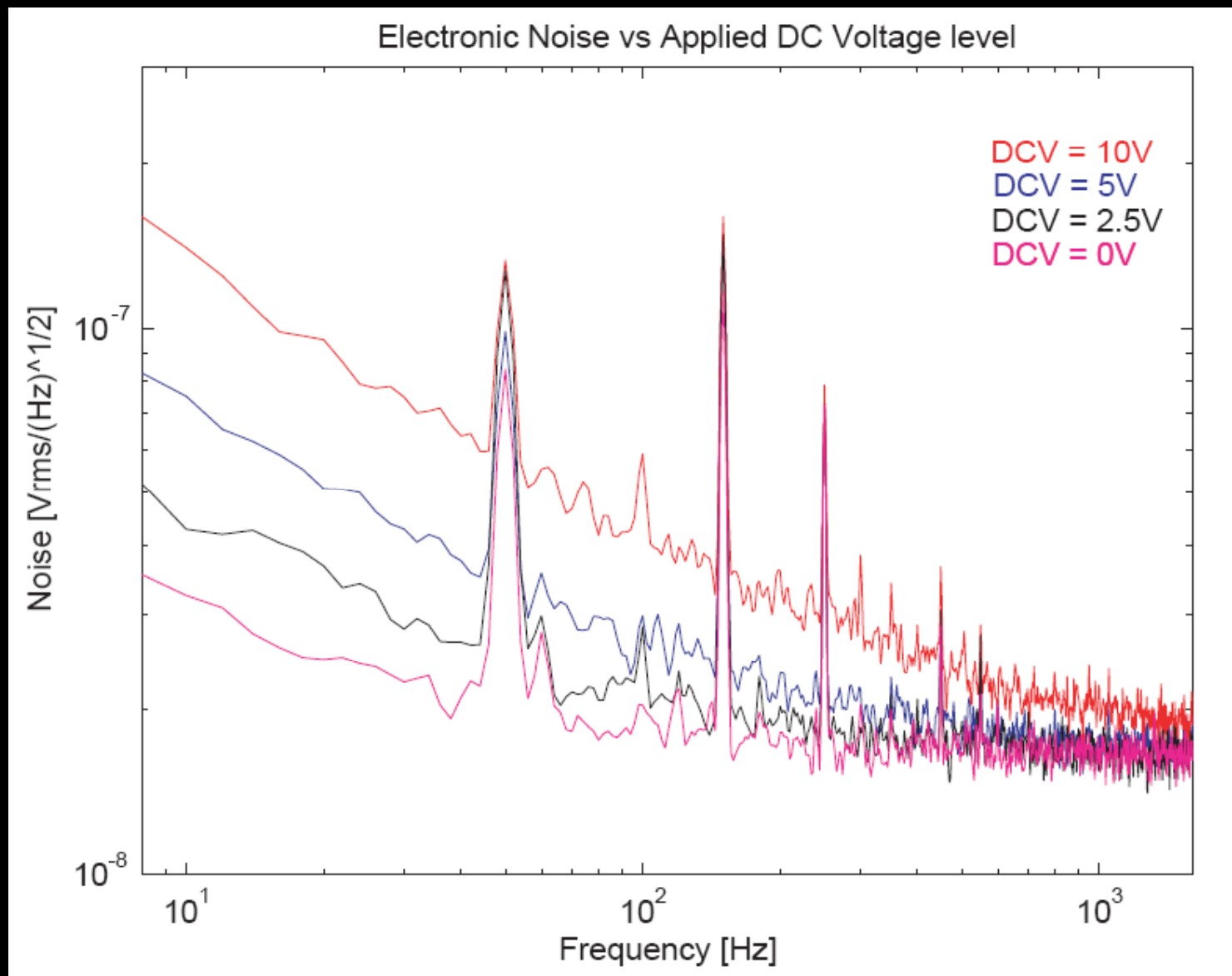
- Squeezed light is to be injected into Hanford 4km, with an ANU designed/ constructed travelling-wave bowtie OPO.
- 6dB squeezing measured between 2kHz to 10kHz, 5dB squeezing measured between to 500Hz and 2kHz (with  $\eta_m = 0.89$ ). 8dB squeezing inferred.
- Lower frequency squeezing measurement hampered by detection losses (not production of squeezing).
- Completion of LIGO H1 OPOs and improvement of electronics are the very near term goals.
- LIGO H1 OPO on schedule for delivery to MIT by early 2010 for integration onto the squeezer breadboard.





# Spare Slides

# Electronic Noise – Preliminary Result



# Injection into LIGO

Squeezing and Carrier are drawn spatially separately for clarity.

