

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
- LIGO -  
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| Technical Note                                              | <b>LIGO-T2500310-v2</b> | 2025/11/04 |
| <b>A+/O5 strain curve projections</b>                       |                         |            |
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# 1 Overview

This document contains new projections of strain noise spectra for LIGO for the O5 observing run. We are taking the run designation ‘O5’ to apply only once all LIGO test masses have been replaced with A+ test masses that have lower coating thermal noise<sup>1</sup>. The projections are given for a scenario where there are three epochs of O5 (a, b, c), with increased sensitivity from epoch to epoch. The last epoch, O5c, is thus foreseen as reaching the final sensitivity for the A+ upgrade.

# 2 Noise models

The original A+ target strain sensitivity is given in [T1800042](#). It shows only the final A+ design strain noise, based only on fundamental noises (no technical noise included). In this note we update the models for the coating thermal noise and the quantum noise, and include a model for technical noise. With these updates we make total strain noise projections for the different episodes of O5.

**Coating thermal noise.** The original goal for A+ was to reduce the test mass thermal noise due to the mirror coatings by a factor of 2 (in equivalent strain amplitude). Although significant progress in new coating materials has been made, a full factor of 2 reduction is currently not foreseen for the O5 test masses. Our new projections for O5 assume a 30% reduction in coating thermal noise. This is also expressed as being 0.7 times the current thermal noise level, and corresponds to a strain noise level from test mass thermal noise of  $1.95 \times 10^{-24} / \sqrt{\text{Hz}}$  at 100 Hz.

**Squeezing and quantum noise.** The original squeezing target for A+ was frequency-dependent squeezing (FDS) with -6 dB effective at high frequencies. Since the LLO interferometer has already seen close to -6 dB of squeezing in O4, we now project somewhat higher squeezing for O5. The detailed quantum noise model for O5 is given separately, in [T2500348](#), which shows projected squeezing of 6.8 to 7.3 dB at frequencies above 200 Hz.

Figure 1 shows the quantum noise with FDS in strain units for different arm powers. At each power, the filter cavity detuning is optimized for maximum binary neutron star merger range; all other squeezing parameters are fixed, as given in [T2500348](#). The optimization depends on the level of coating thermal noise, which is set at 0.7×aLIGO coating thermal noise.

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<sup>1</sup>This note thus does not make projections for any observing runs that may occur prior to this.

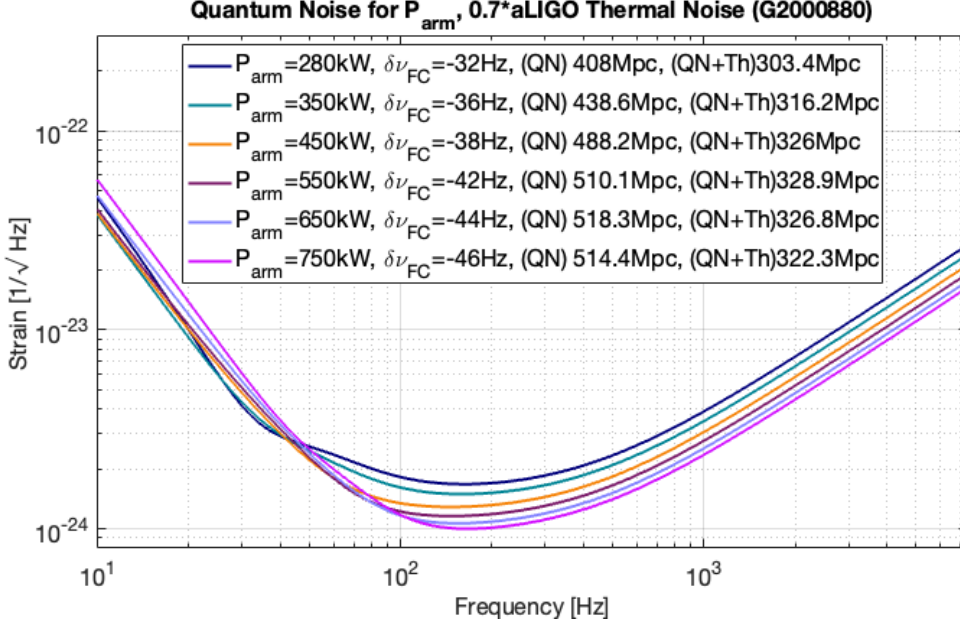


Figure 1: Quantum noise projections for arm powers  $P_{arm}$  from 280 kW to 750 kW.  $\delta\nu_{FC}$  denotes optimal filter cavity detuning, (QN) denotes BNS range calculated using only quantum noise and (QN+Th) denotes BNS range calculated for quantum noise added in quadrature with coating thermal noise (CTN), where CTN is 0.7 times the CTN measured for aLIGO coatings. The filter cavity finesse is fixed at the present (O4) value for all curves.

**Technical Noise.** Technical noise is estimated using the L1 strain noise spectrum. We start with a noise budget taken at the same time as the best quantum measurements; from that measured spectrum, the modeled quantum noise, thermal noises, and residual gas noise are all subtracted. This yields the full technical noise, some of which is of unknown origin. There are also known technical noises, which can be measured or calculated, that sum to a level lower than the full technical noise. For the O5 estimate, we take the (geometric) average of the two, which assumes that some of the unknown noise will be reduced, but not all. This is shown in Fig. 2. Then, for each stage of O5, a/b/c, we further reduce this “average technical noise” by some fraction, informed partly by gains achieved between previous runs.

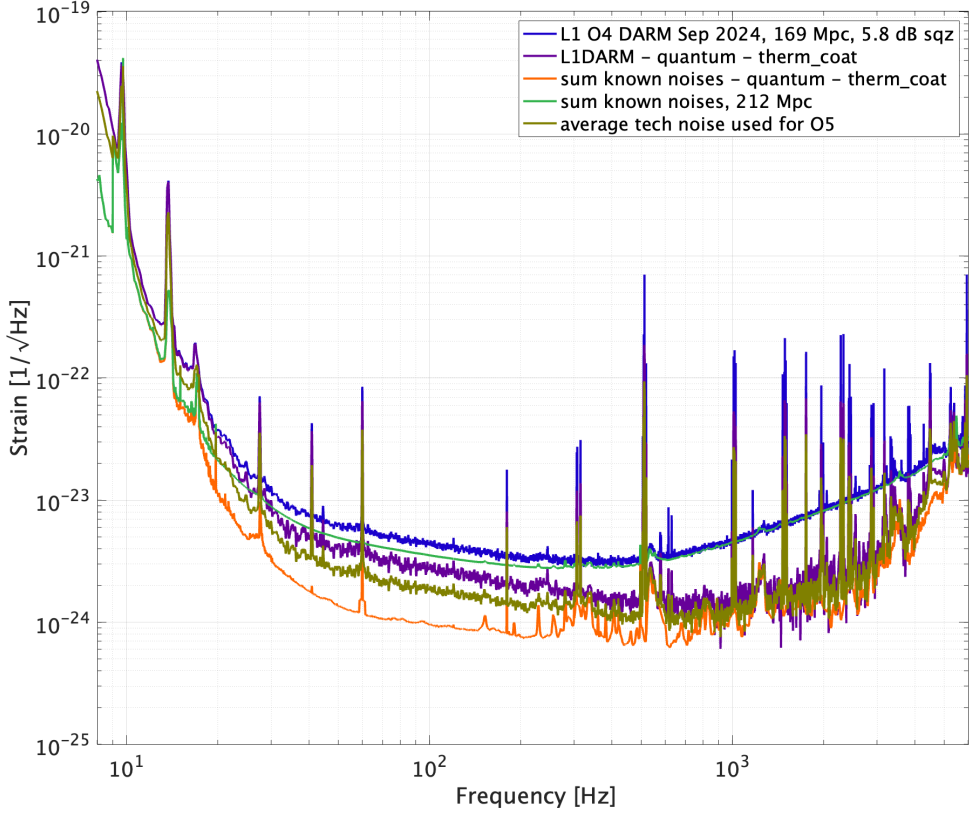


Figure 2: Technical noise model for O5. The dark purple curve is the observed spectrum of technical noise, derived from the measured strain noise by subtracting quantum and thermal noises. The orange curve contains the known technical noises (from the noise budget). The olive green curve is the average of these two curves, and is the assumed technical noise level at the beginning of O5.

### 3 O5 Projections

To make the final strain curves, we add the chosen quantum noise, the technical noise, and the remaining fundamental noises (thermal and residual gas). The results are shown in Fig. 3.

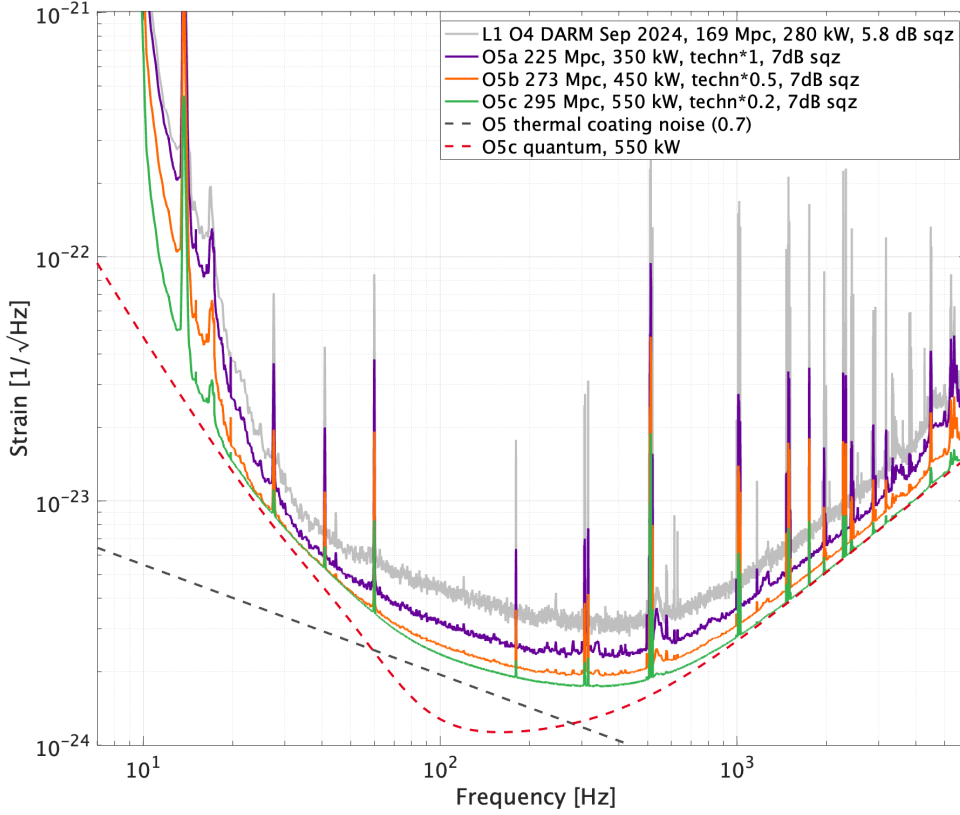


Figure 3: Strain noise projections for O5a, O5b, and O5c. In this progression, the arm stored power is increased from 350 kW to 450 kW to 550 kW, and the technical noise starts at the level shown in Fig. 2, and then is reduced by 50% and then by 80%. The maximum arm power is 550 kW (O5c), because the binary neutron star detection range starts to decrease for higher powers.

| O5 epoch | BNS range | Arm Power | Tech. noise @100 Hz                  | Squeezing @1 kHz |
|----------|-----------|-----------|--------------------------------------|------------------|
| O5a      | 225 Mpc   | 350 kW    | $2 \times 10^{-24}/\sqrt{\text{Hz}}$ | 7 dB             |
| O5b      | 273 Mpc   | 450 kW    | $1 \times 10^{-24}/\sqrt{\text{Hz}}$ | 7 dB             |
| O5c      | 295 Mpc   | 550 kW    | $4 \times 10^{-25}/\sqrt{\text{Hz}}$ | 7 dB             |

Table 1: Top level performance parameters for the 3 episodes of O5. The assumed technical noise spectrum for O5a is shown in Fig. 2.