Quantum Noise Output Filtering

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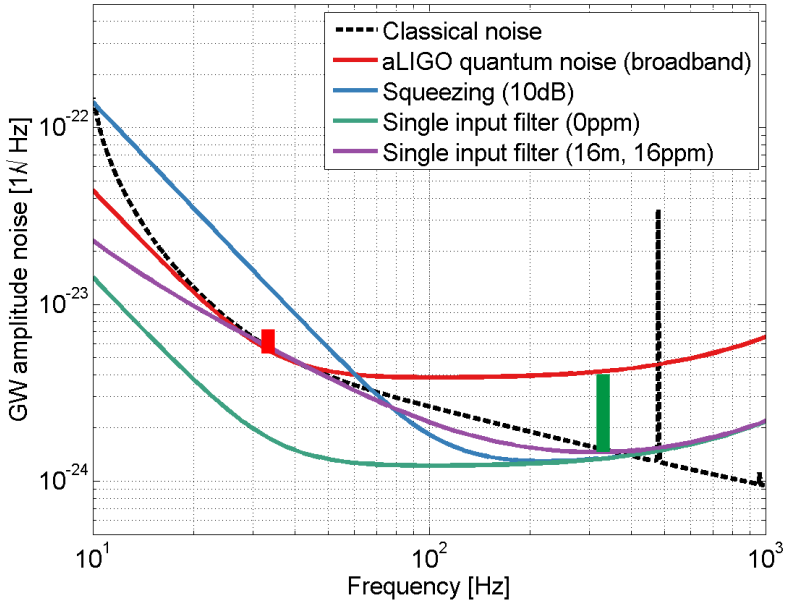
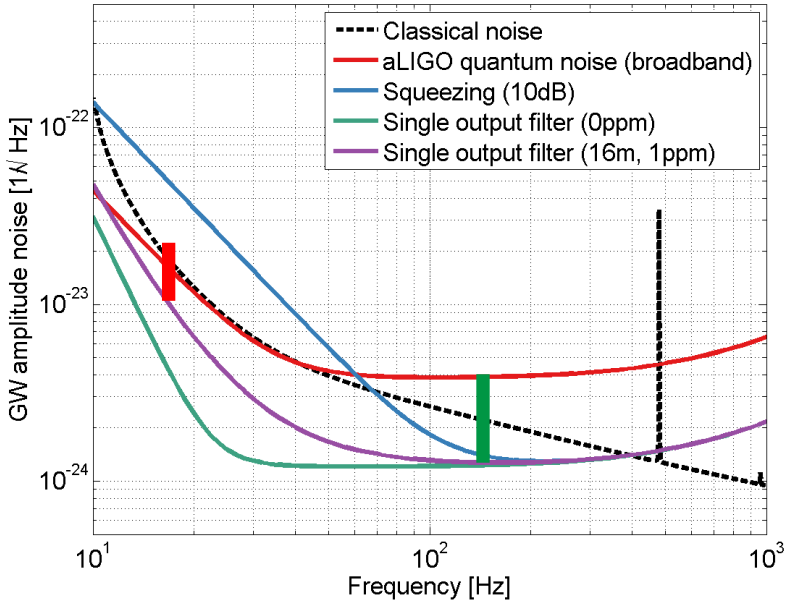
Squeezing/Loss FOMs

In the two plots below, SEC roundtrip loss: 1000ppm

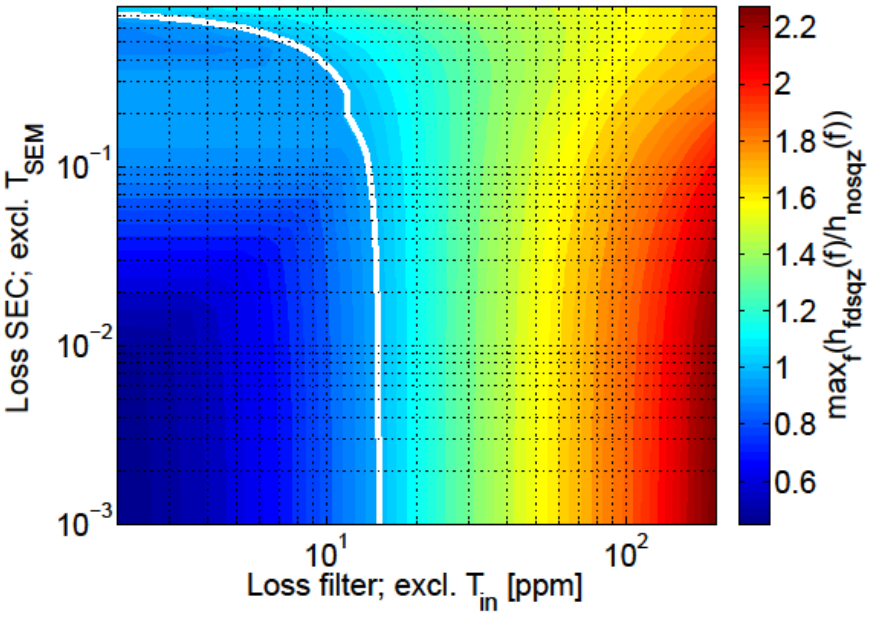


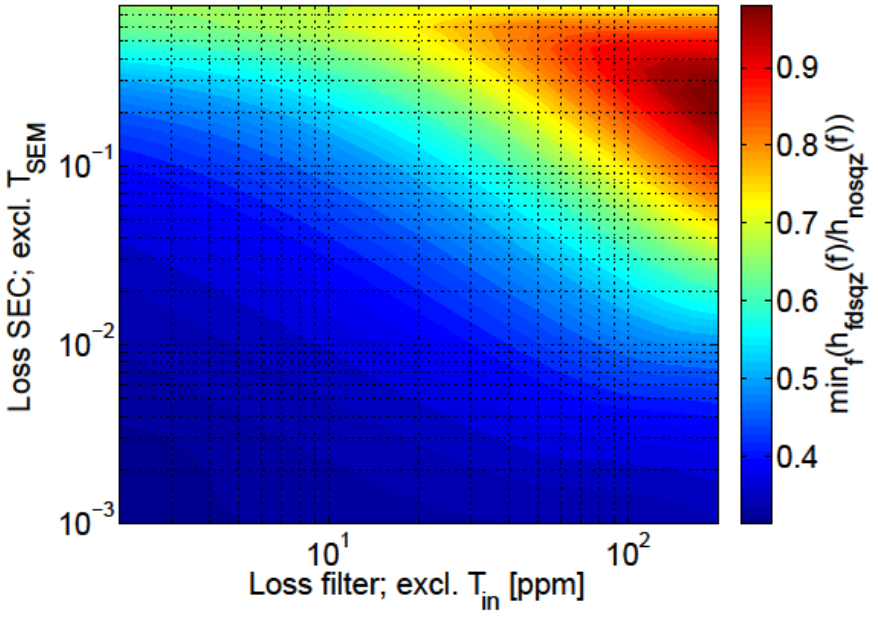


As a function of SEC and filter round-trip loss, collect **smallest** and **highest** ratio of quantum noise relative to broadband aLIGO (full instrumental noise).

Input Filters

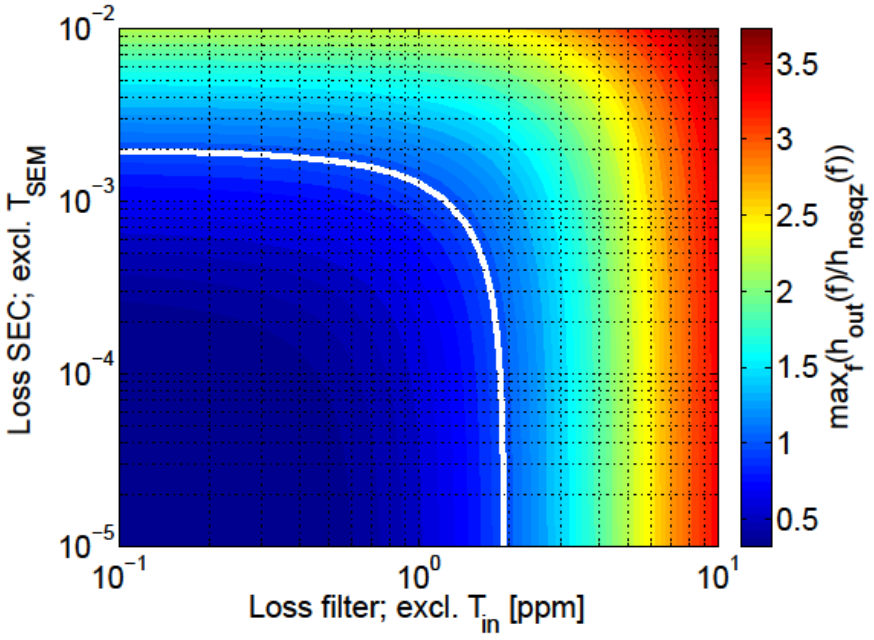
Filter cavity length: 16m

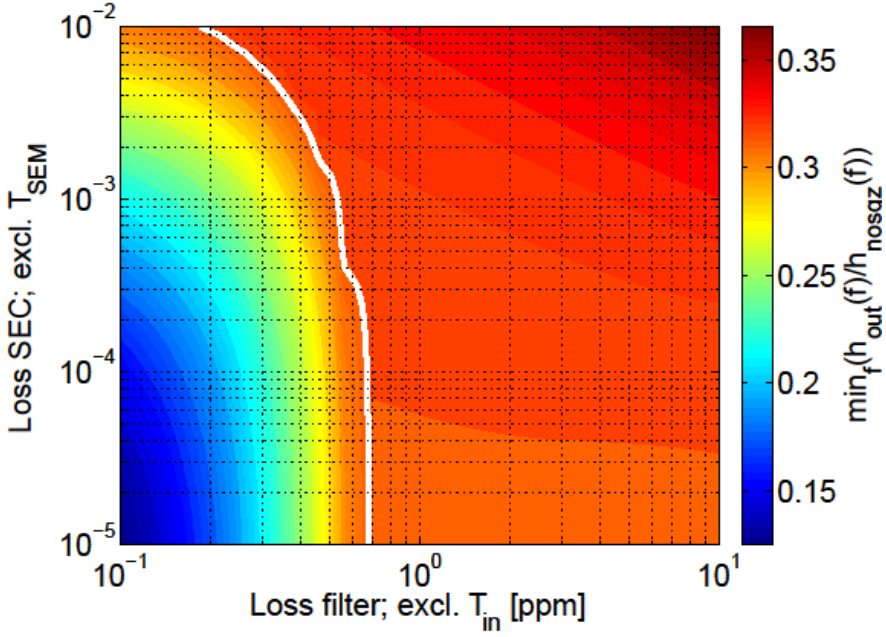




Output Filters

Filter cavity length: 16m





Lower-Order Mode Clipping

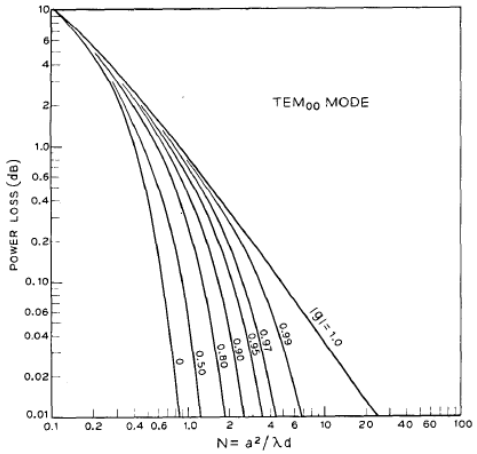


Fig. 22. Diffraction loss per transit (in decibels) for the TEM_{00} mode of a stable resonator with circular mirrors.

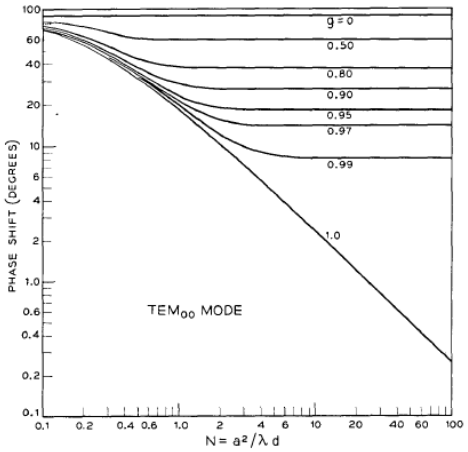


Fig. 24. Phase shift per transit for the TEM_{01} mode of a stable resonator with circular mirrors.

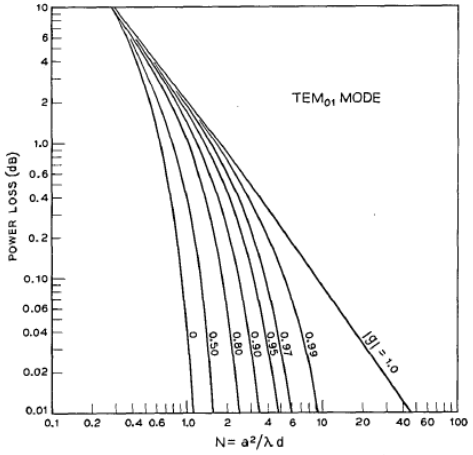


Fig. 23. Diffraction loss per transit (in decibels) for the TEM_{01} mode of a stable resonator with circular mirrors.

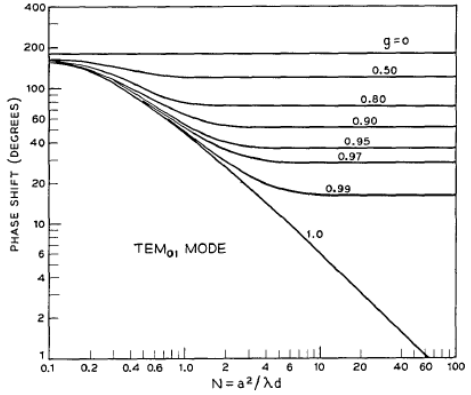
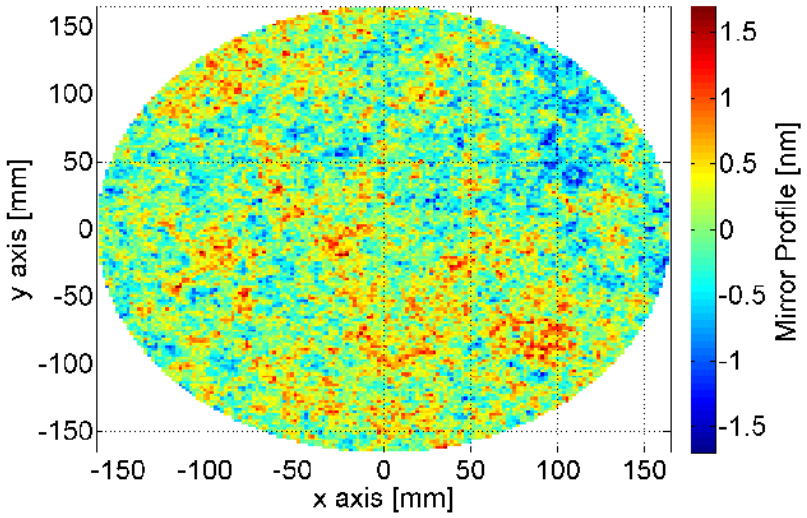


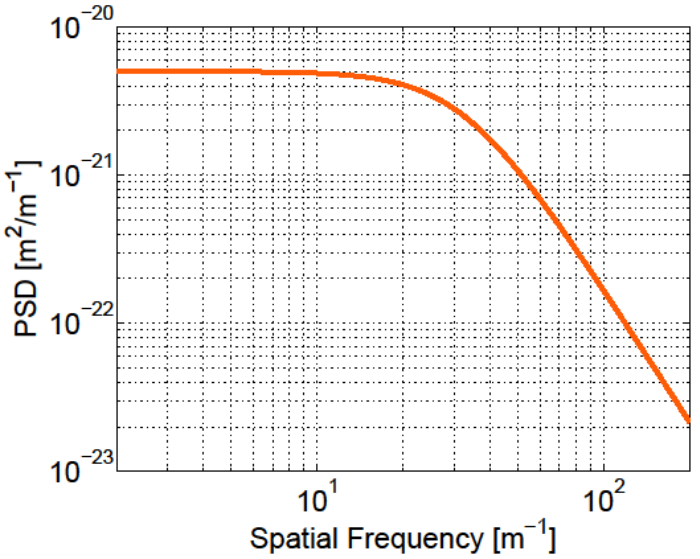
Fig. 25. Phase shift per transit for the TEM_{01} mode of a stable resonator with circular mirrors.

Additional factors:

- Transverse mode spacing
- Cavity finesse
- Mode matching

Surface-Roughness Scattering





Golden Rule

$$\delta_r = \left(\frac{4\pi\sigma}{\lambda}\right)^2$$

Advanced Virgo grade: 22ppm

Point Defect Scattering

Loss per mirror in 3.3m cavity (excluding transmission): 1.7ppm; Opt Expr 22, 11570 (2014)

Super-polished optics: rms = 0.1nm
Golden Rule: 1.4ppm surface roughness scatter

Golden Rule prediction and measured loss agree very well. Absorption and point-defect scatter can explain the small discrepancy.

Conclusion: point-defect scattering may already be negligible in current highest-quality optics (however, effective rms in cited experiment may have been smaller than 0.1nm).

R&D Strategy

Assume that point defects can be reduced by coating manufacturers.

Design cavity (Fresnel number, g-parameters) to minimize lower-order clipping loss.

Concerning surface roughness, hope for the best, and/or do R&D for high-resolution, adaptive optics.