Reducing the mirrors coating noise in laser gravitational-wave antennae by means of double mirrors (gr-qc/0406071)

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1. Introduction

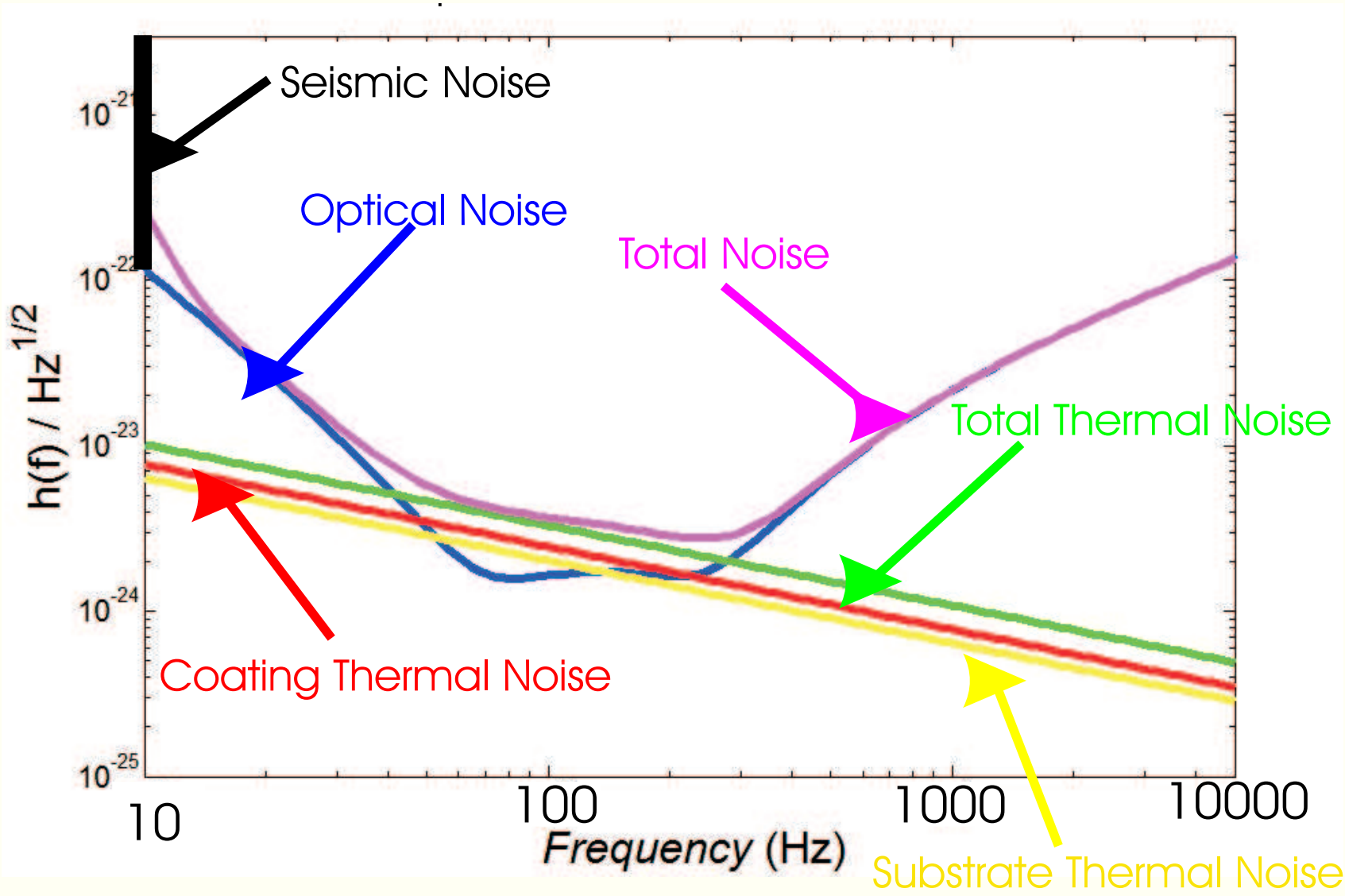
2. Double mirror reflector

3. Equation and Estimates

4. On the EETM mirror design

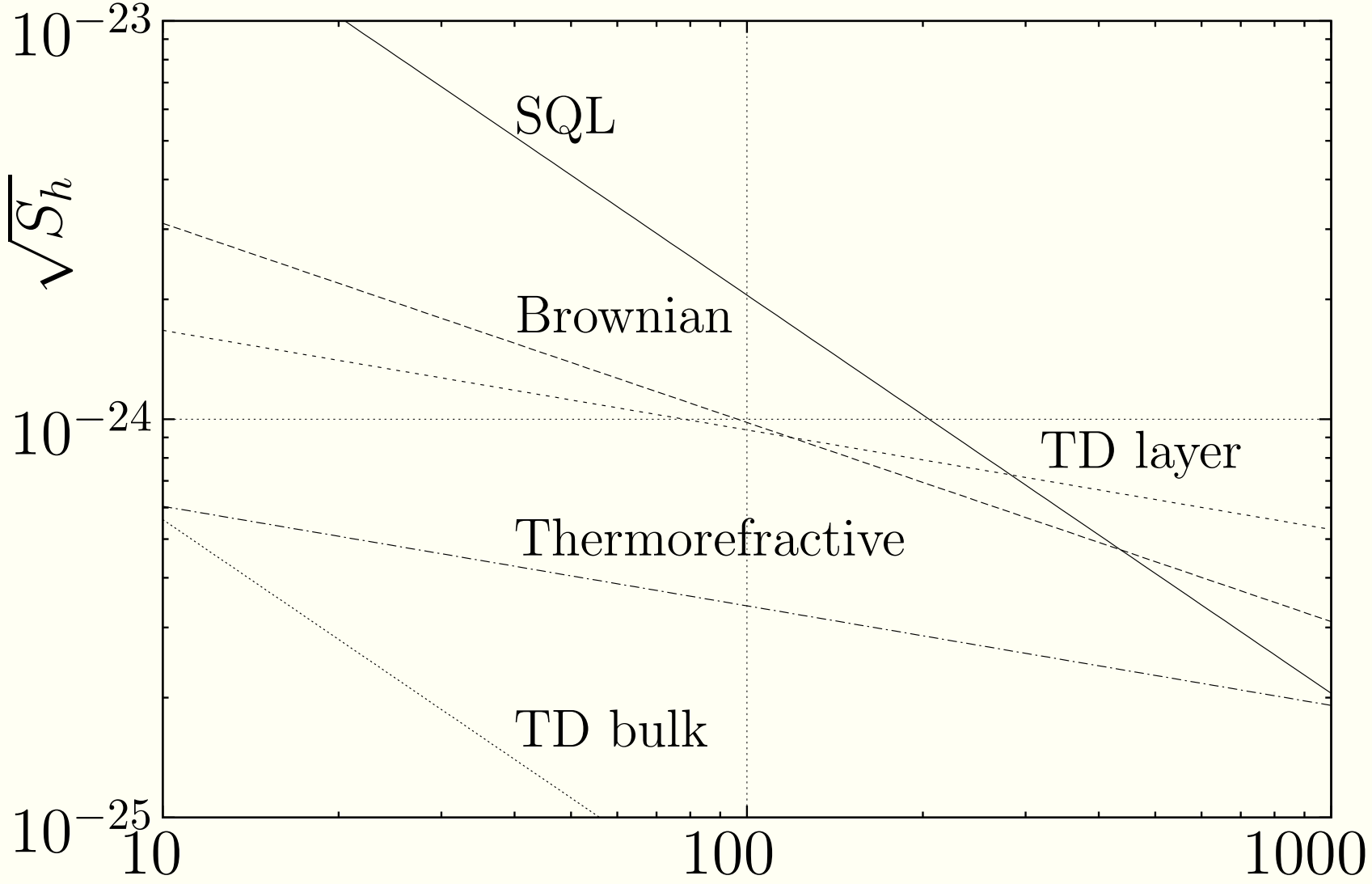
5. Conclusion

Coating thermal noise in AdvLIGO



G.M.Harry *et al*, www.ligo.caltech.edu/docs/P/P040023-00

TD noise, fused silica with $Ta_2O_5 + SiO_2$



V.B.Braginsky, S.P.Vyatchanin, Phys. Lett. A **312**, 169 (2003).

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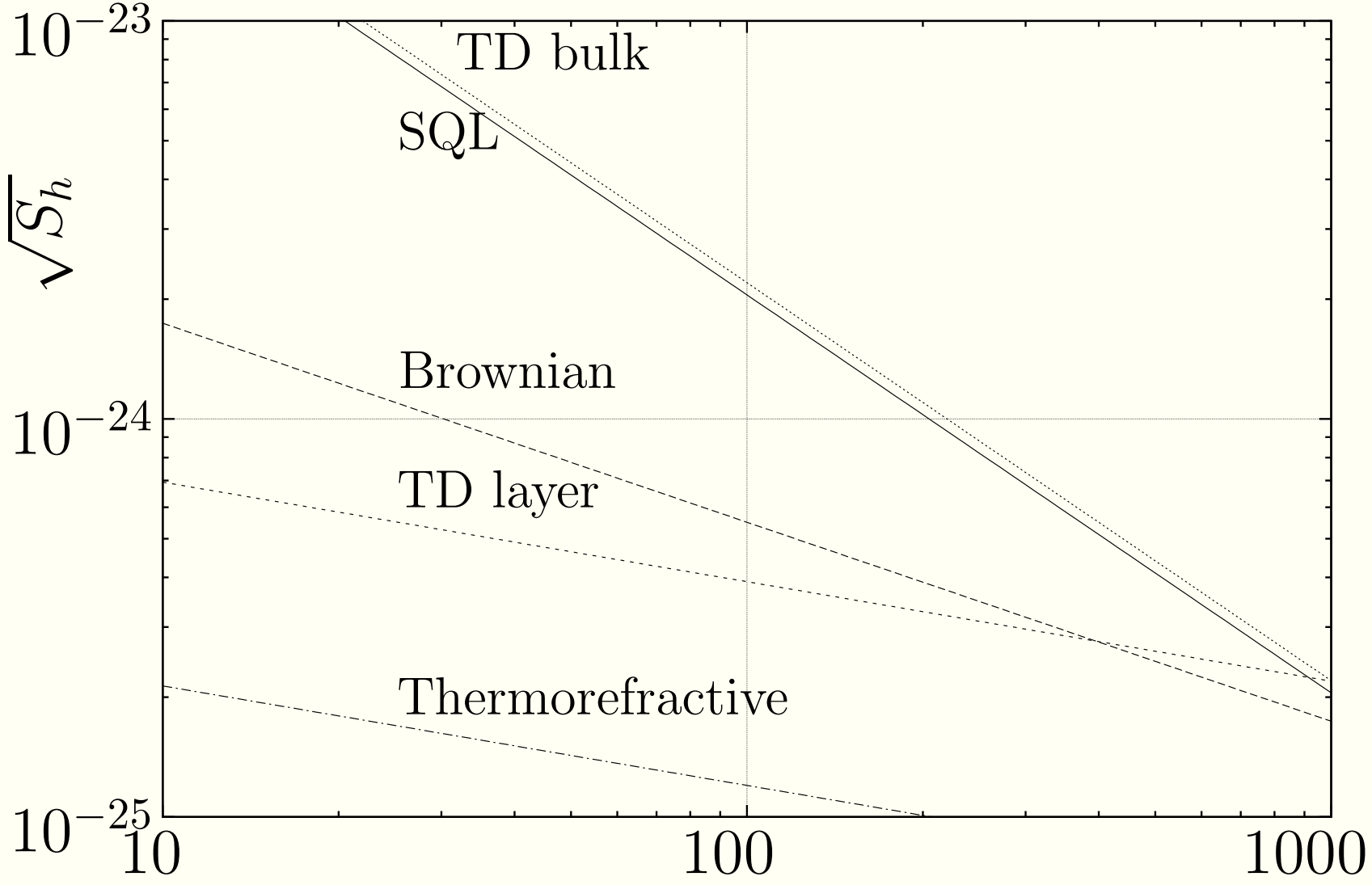

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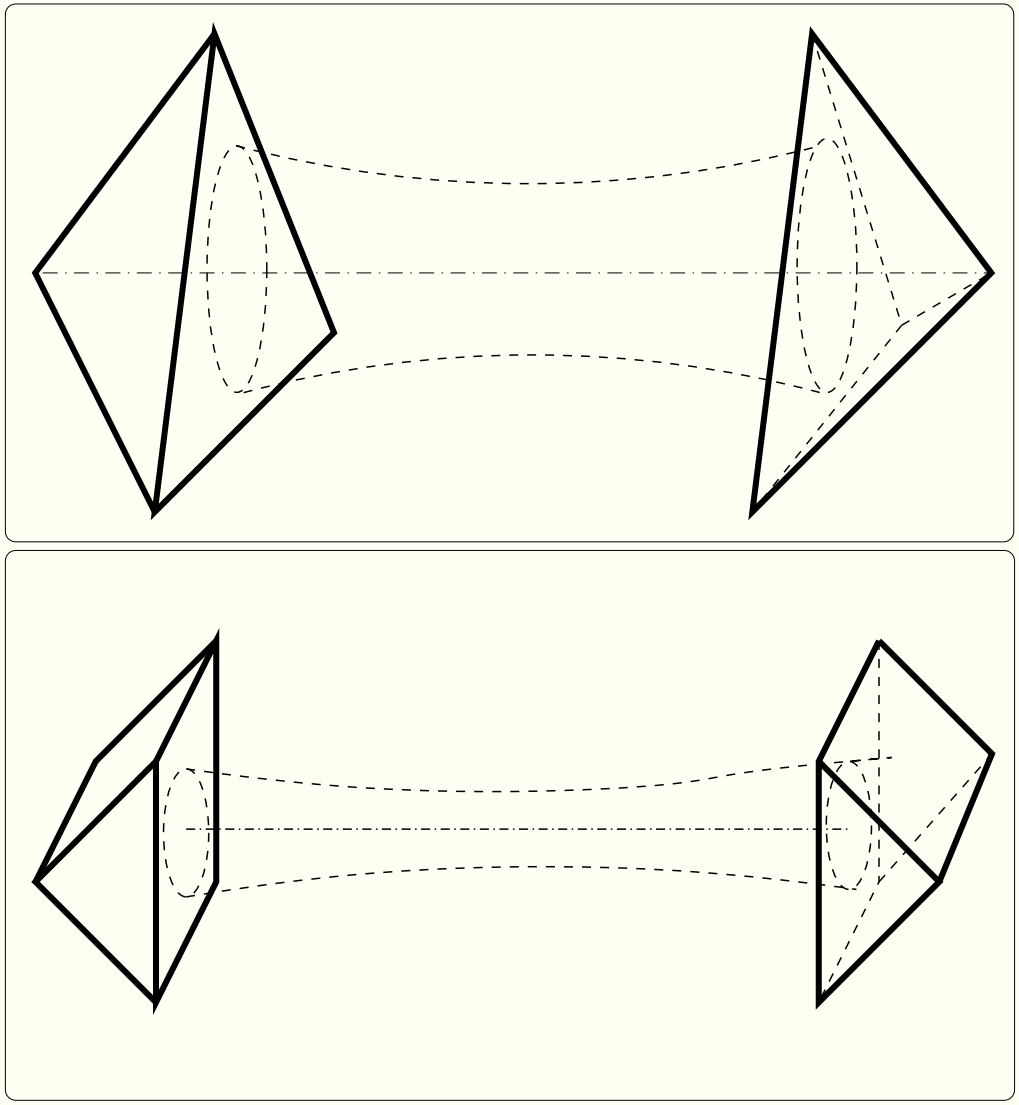
Coatingless corner reflectors



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Most of the light is reflected from the first couple of layers;
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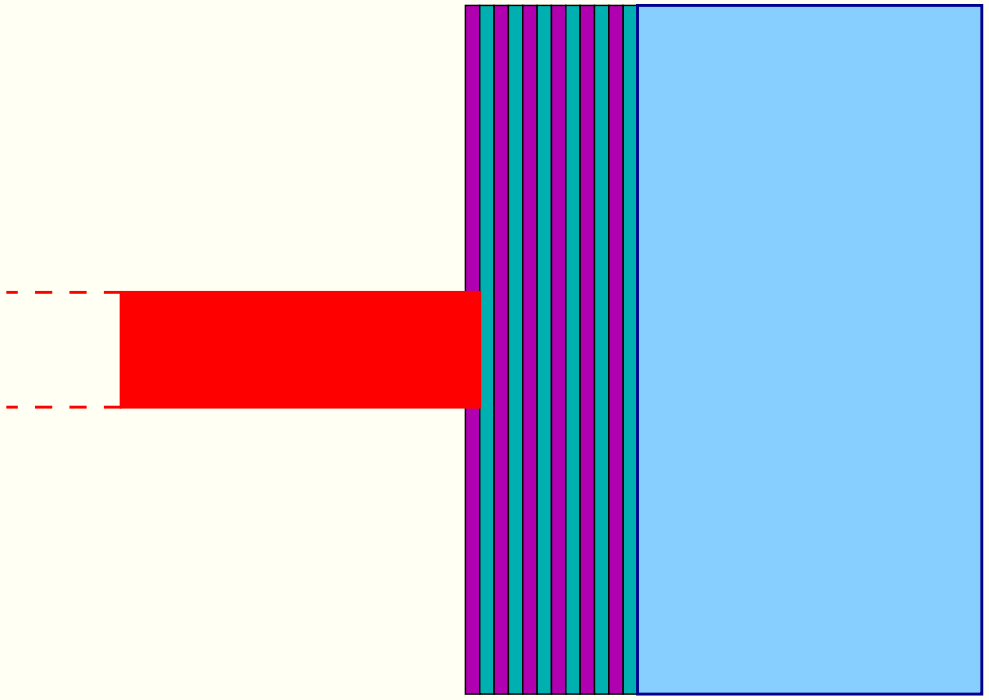
The surface fluctuations are relatively small for the input mirrors (ITM) and is considerably larger for the end mirrors (ETM).

The idea of double mirror reflector:

mechanically isolate most of the layers from the mirror surface by replacing one of the layers by an air gap:



$$l = \frac{\lambda}{4}$$

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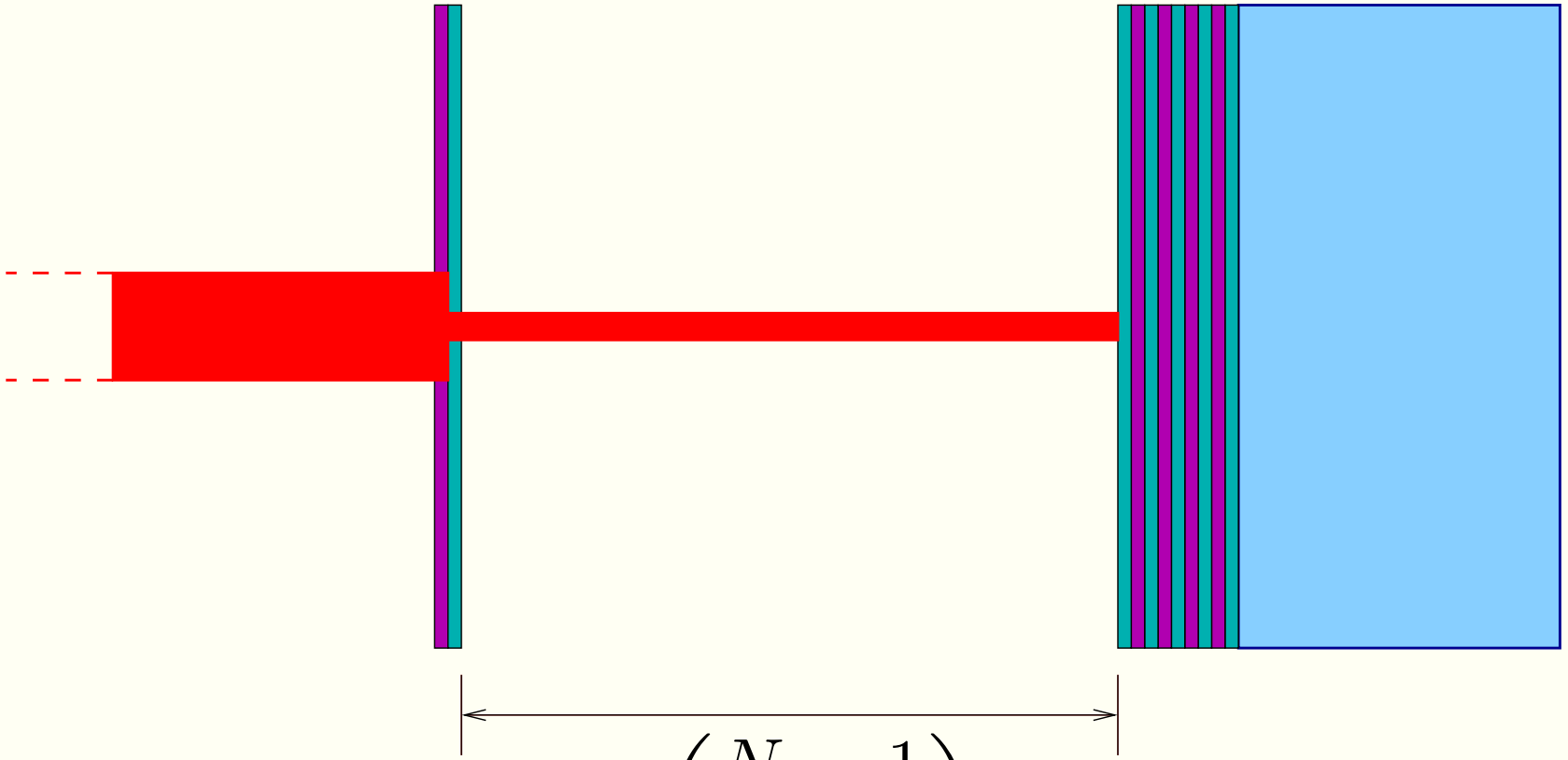

$$l = \left(\frac{N}{2} + \frac{1}{4}\right)\lambda$$

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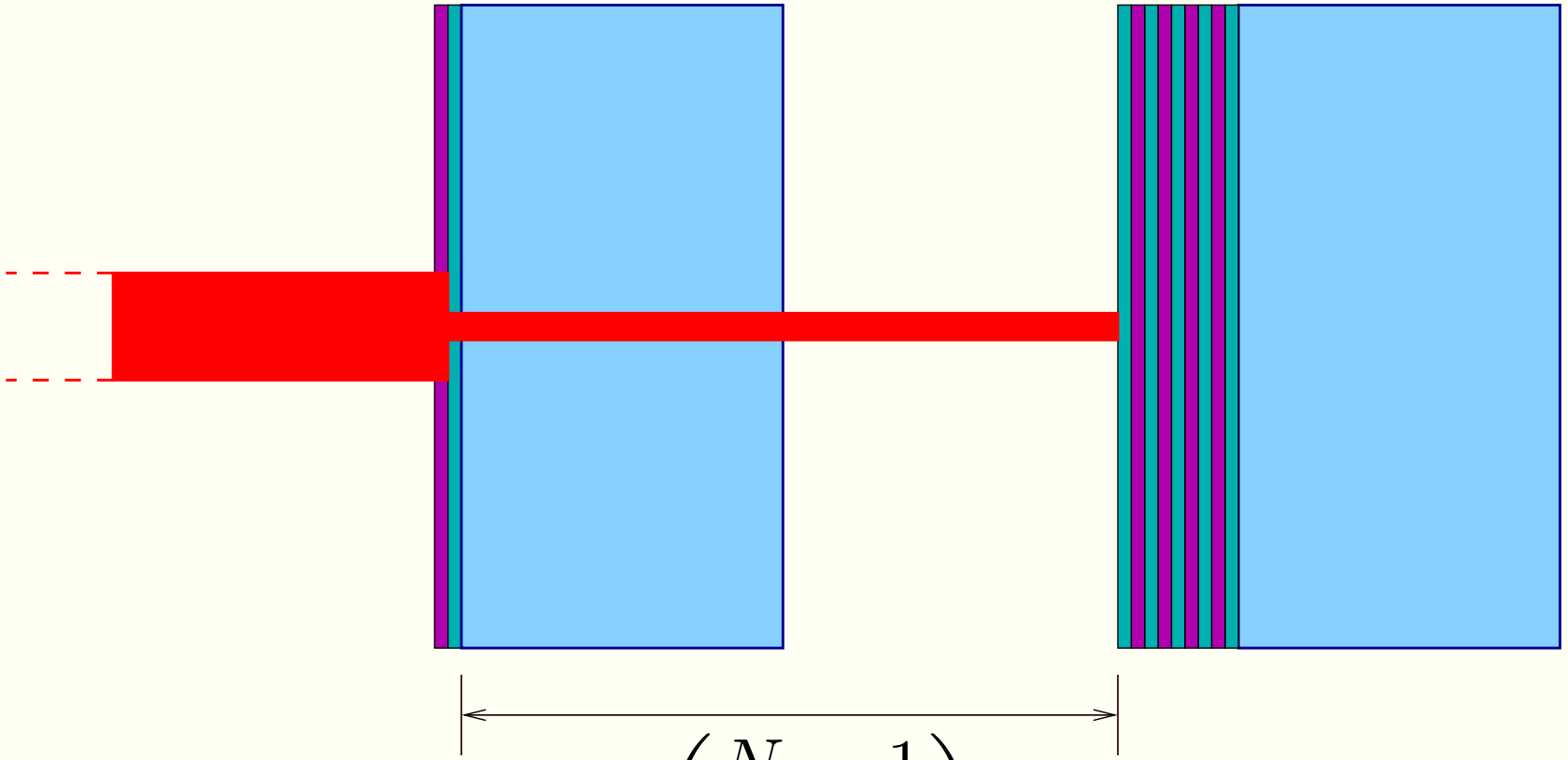

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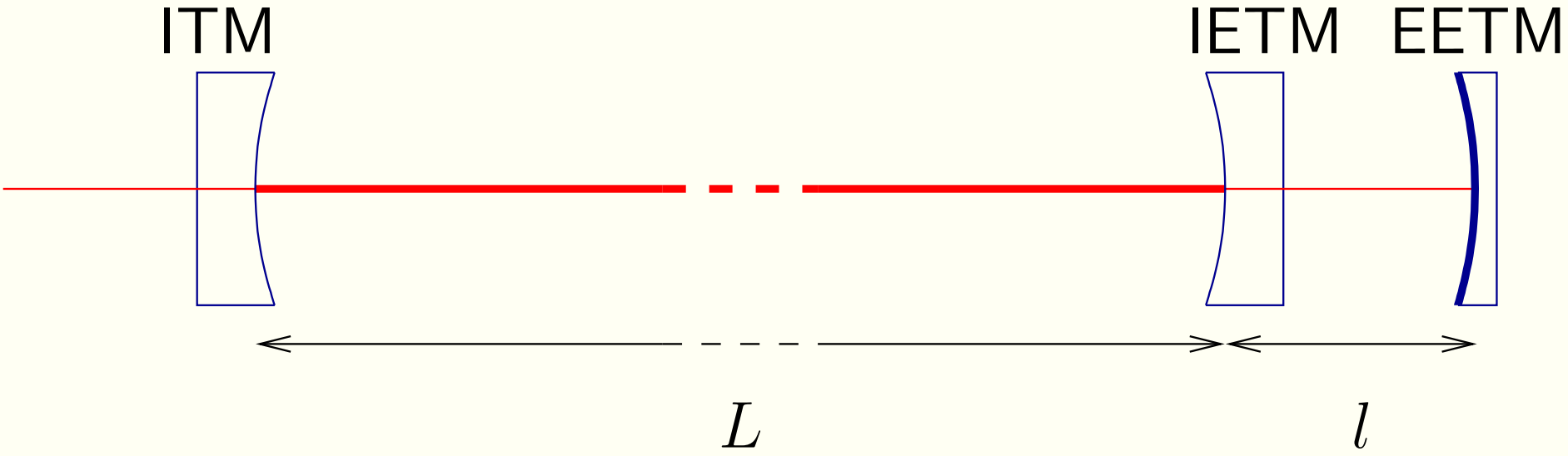
Layout of the interferometer arm

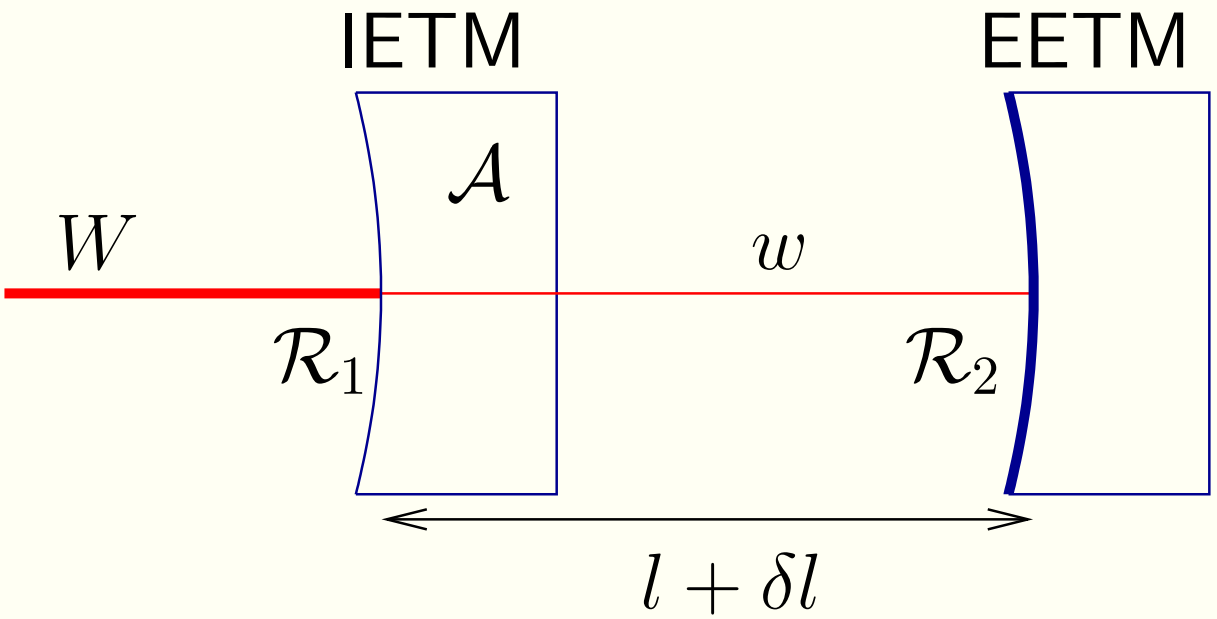


$$L = \frac{N_1 \lambda}{2} \approx 4\,\mathrm{Km}\,,$$

$$l = \left(\frac{N}{2} + \frac{1}{4}\right)\lambda \lesssim 10\,\mathrm{m}\,.$$

ITM, IETM are similar thin-coating mirrors;
EETM is a thick-coating one.

Combined reflection



$$1 - \mathcal{R}_1 \approx 5 \times 10^{-2}, \quad 1 - \mathcal{R}_2 \lesssim 10^{-5}, \quad \mathcal{A} \lesssim 10^{-5}.$$

$$1 - \mathcal{R} \approx \frac{1 - \mathcal{R}_1}{4} (1 - \mathcal{R}_2 + 2\mathcal{A})$$

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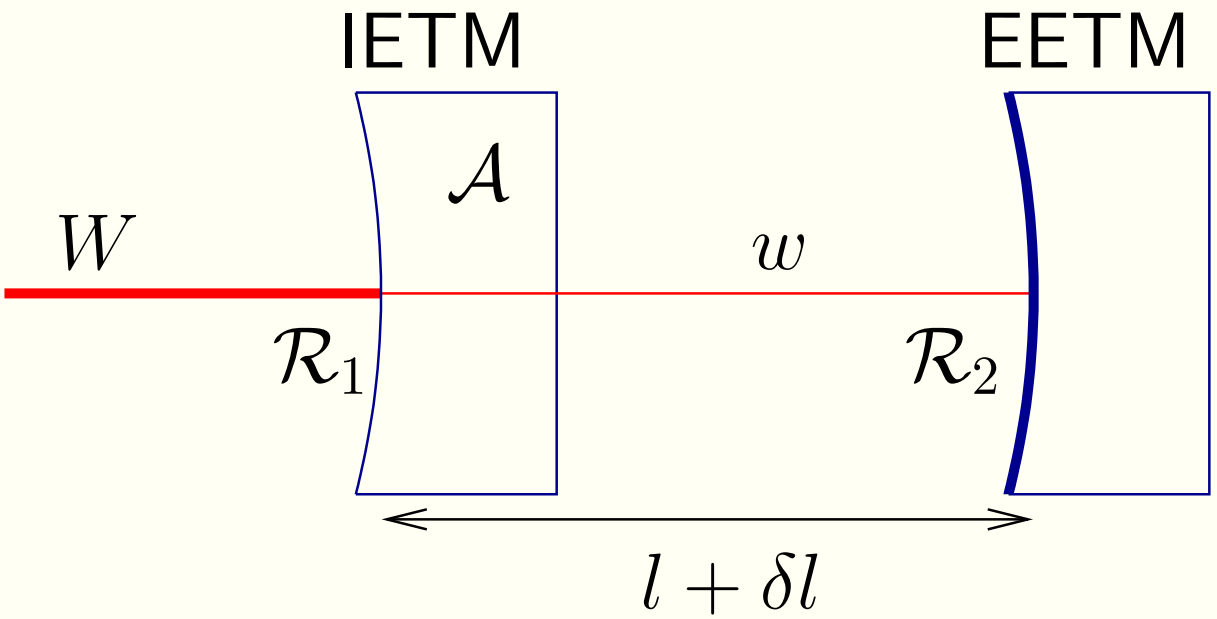

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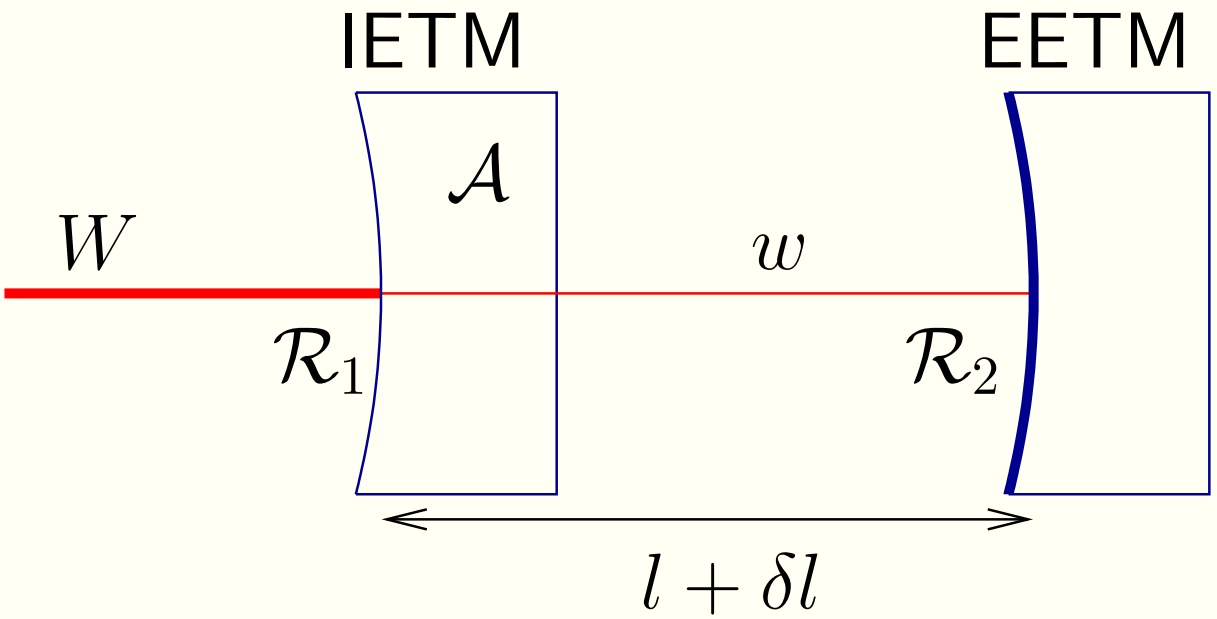
Combined reflection

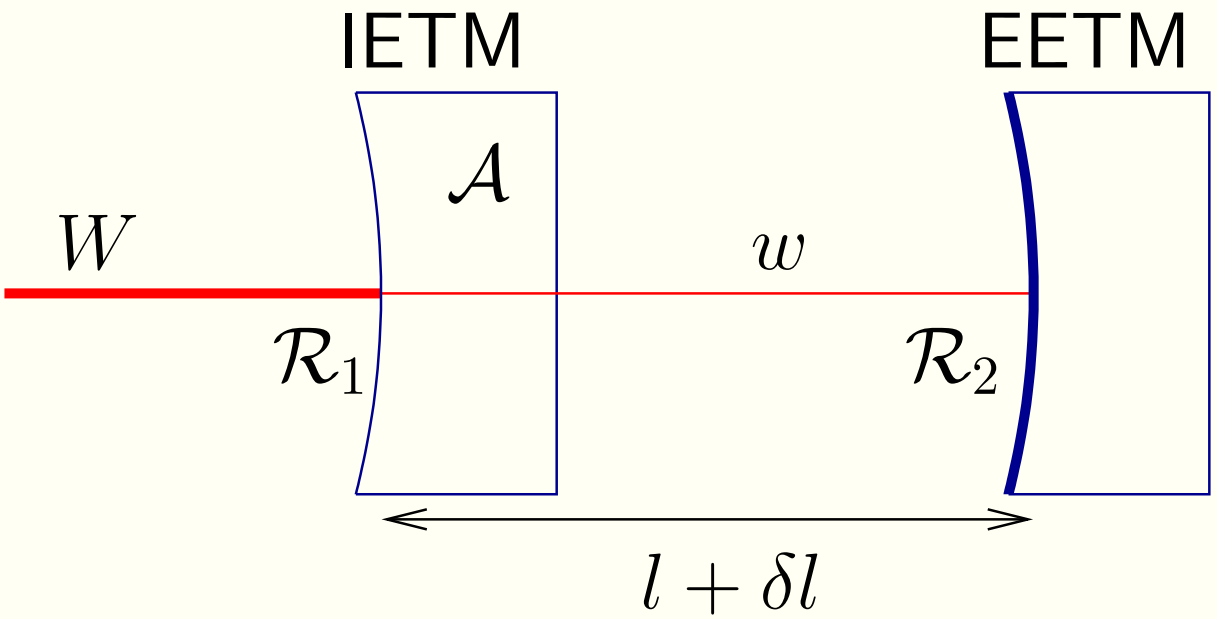


$$1 - \mathcal{R}_1 \approx 5 \times 10^{-2}, \quad 1 - \mathcal{R}_2 \lesssim 10^{-5}, \quad \mathcal{A} \lesssim 10^{-5}.$$

$$1 - \mathcal{R} \approx \underline{\frac{1}{4}} \, (1 - \mathcal{R}_2 + 2\mathcal{A}) \lesssim 10^{-6}$$

Note this factor

The reflected light beam phase shift



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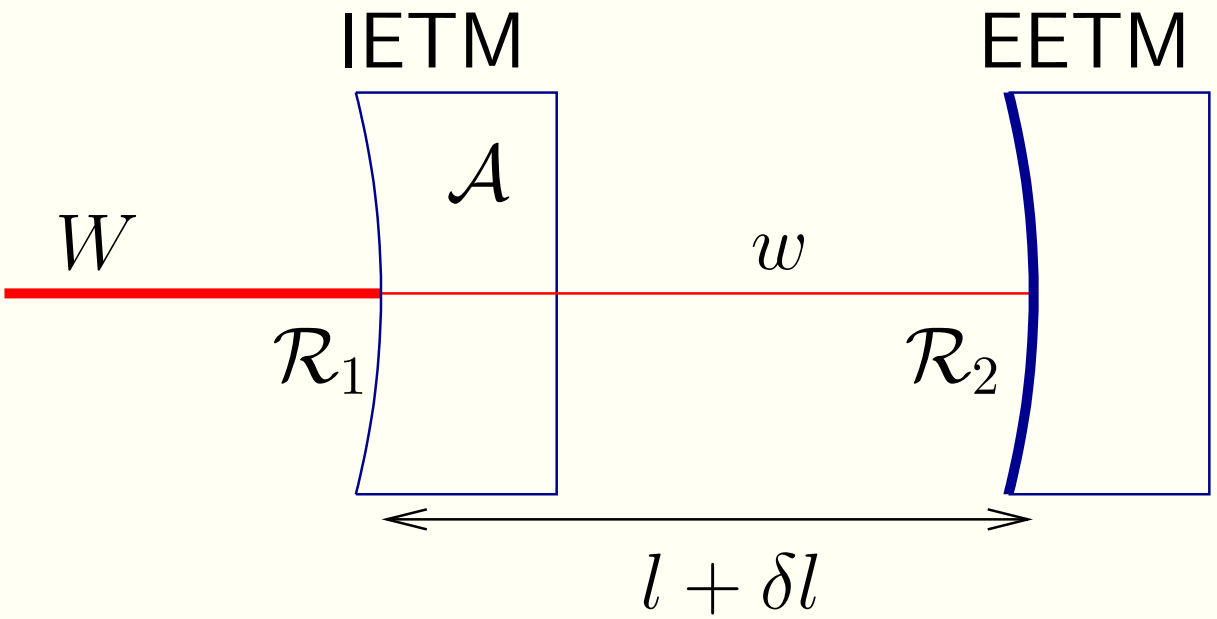

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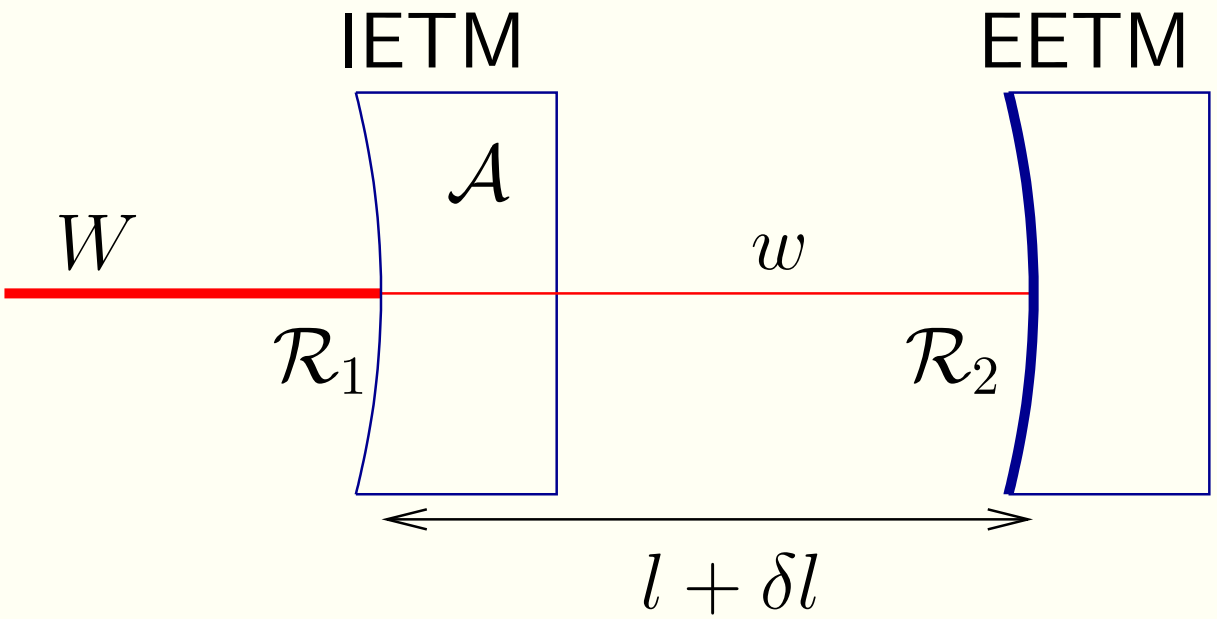
Circulating optical power



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$$w \approx \frac{1 - \mathcal{R}_1}{4} W$$

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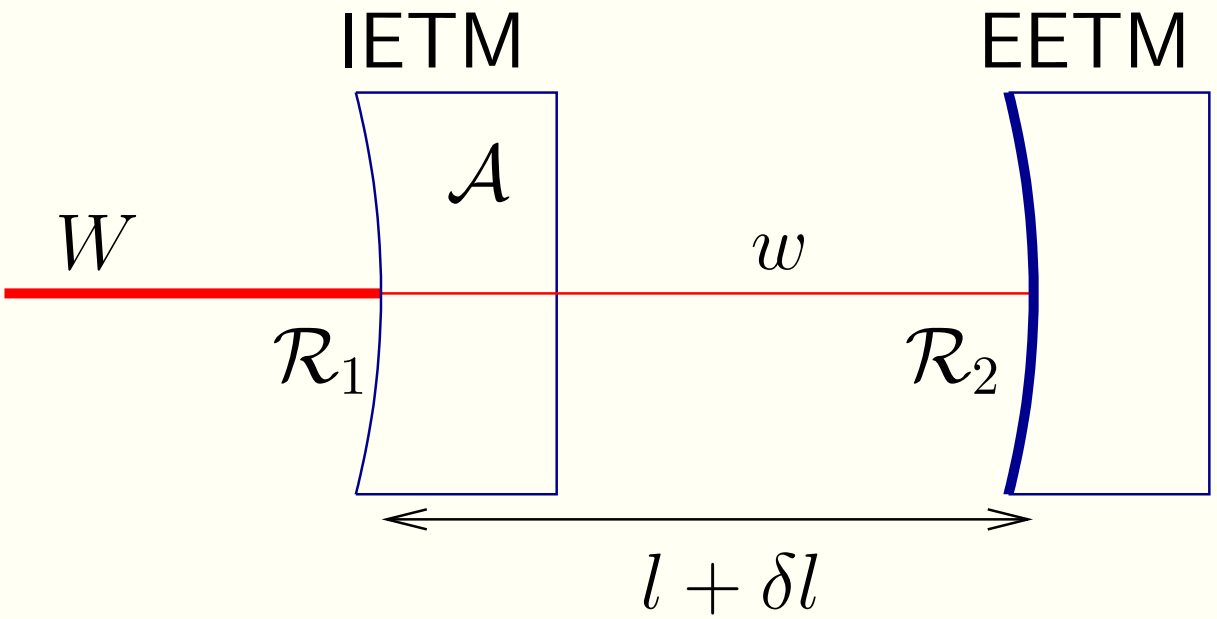

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$$w \approx \frac{1 - \mathcal{R}_1}{4}\, W \approx 10^{-2} W \approx 10\,\mathrm{KW}$$

On the EETM mirror design

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This includes:

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the mirror quantum fluctuations $\Rightarrow$ its mass can be as small as

$$m \gtrsim \left(\frac{1 - \mathcal{R}_1}{4}\right)^2 M \sim 5\,\mathrm{gr}$$

Conclusion

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2. It allows to reduce the coating thermoelastic noise spectral density by factor
$$\left(\frac{n_{\mathsf{ETM}}}{n_{\mathsf{ITM}}}\right)^2 \sim 10^2\,.$$
3. Its implementation does not looks as a very difficult one because small EETM mirror with simplified suspension system can be used.

Acknowledgments

I am grateful to V.B.Braginsky, S.L.Danilishin, G.Harry, D.Ottaway and S.P.Vyatchanin who have helped me in this new for me area of non-quantum noises.