LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO –
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Study on the sensitivity of a possible Low Frequency Gravitational Wave Interferometric Detector

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This work aims to analyze the optimal parameters for a new Low Frequency Interferometer within the LIGO facility.

We have started some simple analysis on the main dependence of the sensitivity curve w.r.t. some parameters.

The analysis uses "*bench*", a MatLab file made by Samuel Finn, from the Pennsylvania state University.

All values in the figures of this report should be taken as a study of "relative" effects of the different parameters. The absolute values of the curves are not guaranteed.

In the following table there is an extract of the most important parameters of a "baseline" LF-ITF as well as those of ADV LIGO.

	LF ITF	ADV-LIGO
Mirror diameter	430 mm	340 mm
Mirror subst. Limiting factor	200 M Q-factor	Thermoelastic
Coating loss angle	5×10^{-5}	5×10^{-5}
Coating Y modulus	95 G Pa	95 G Pa
Beam spot radius	12 cm	5.5 cm
Last stage susp. Length	1.5 m	0.6

Table1

The "baseline" LF ITF is represented in all drawings with the THICK red curve, the different parameters are varied around the "baseline" value. In all drawings a "Mexican hat", rectangular profile beam is assumed for the LF ITF.

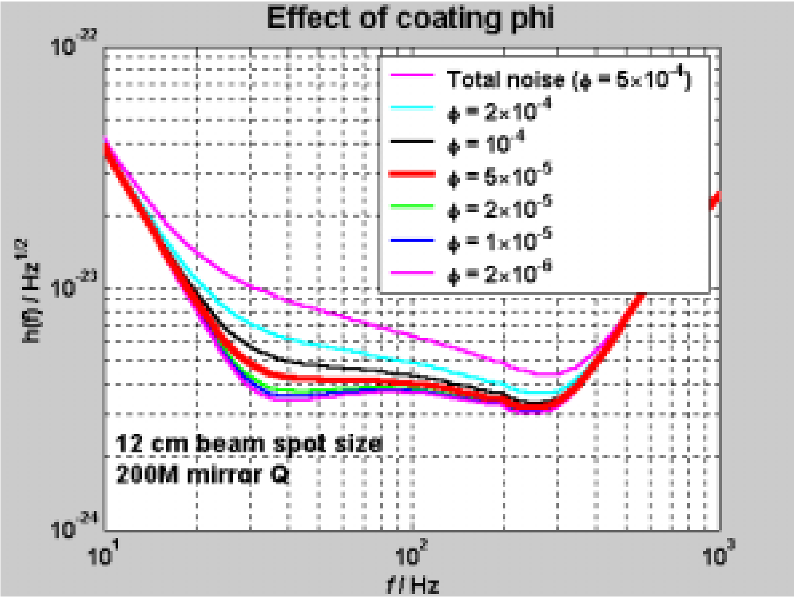

Figure 1

Fig.1 shows the relative effect of the mirror coating loss angle (ϕ) changes on the overall sensitivity of the interferometer in the range between 10 Hz and 1 kHz. All the parameters are the "baseline" except ϕ.

It is easy to see that the gain in sensitivity saturates between $2\ 10^{-5}$ and 10^{-5}.
We do the same thing varying the quality factor of the mirror substrate in fig. 2. The gain due to the increasing substrate Q factor has a saturation at a Q-factor value of about 100M (note that the black and green lines are covered by the red one).

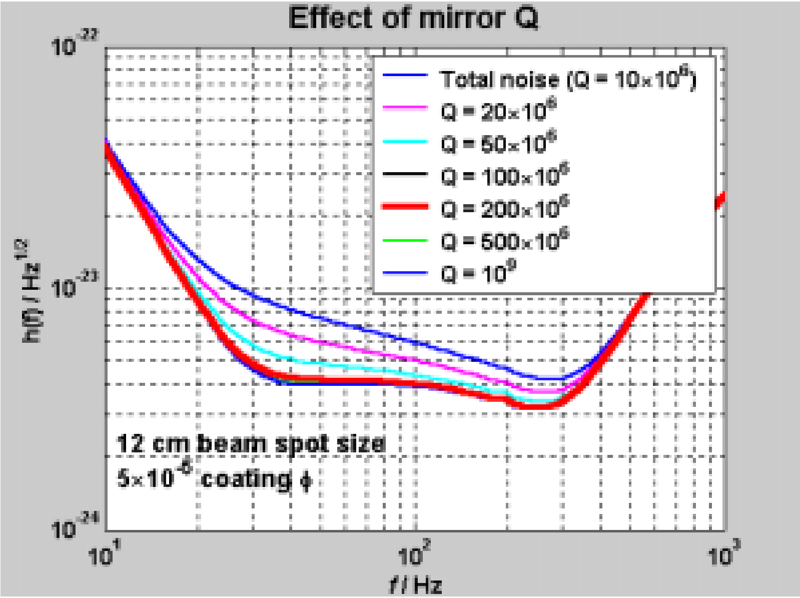

Figure 2

It is evident that the coating ϕ plays a dominant role: although the mirror Q-factor may actually be higher, any sensitivity improvement can be reaped only after an improvement (decreasing) in the coating loss angle ϕ. This is illustrated redoing the plot of fig.2 with a lower value for the coating. The result is the following (fig.3).

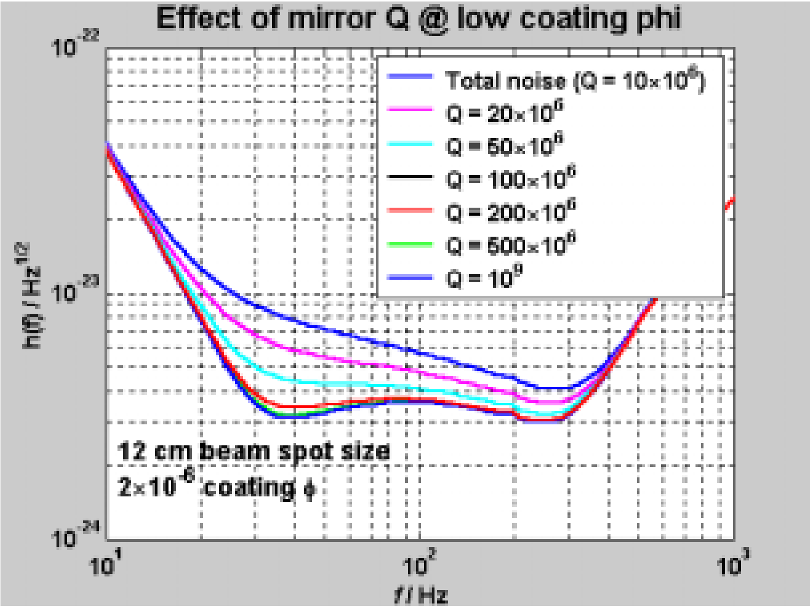

Figure 3

At 3-4 Hz there is a 4/3 factor improvement for mirror substrate Q of 200 M and a saturation beyond that value.
It is also worthwhile to study the dependence of the sensitivity curve w.r.t. the beam spot radius (fig.4).

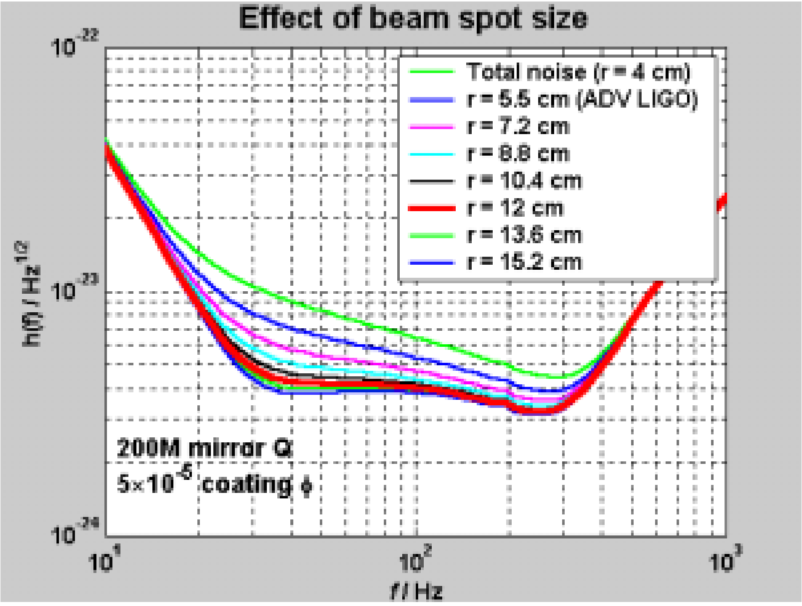

Figure 4

In this plot the saturation effect is slower but it is possible to say that a beam spot radius of about 12 cm is sufficient to reap most of the available sensitivity with “presently achievable” coatings and substrates. As a cross check we have seen (fig.5) that the effect of the spot size disappears when the Q of coating and substrate is driven to higher values.

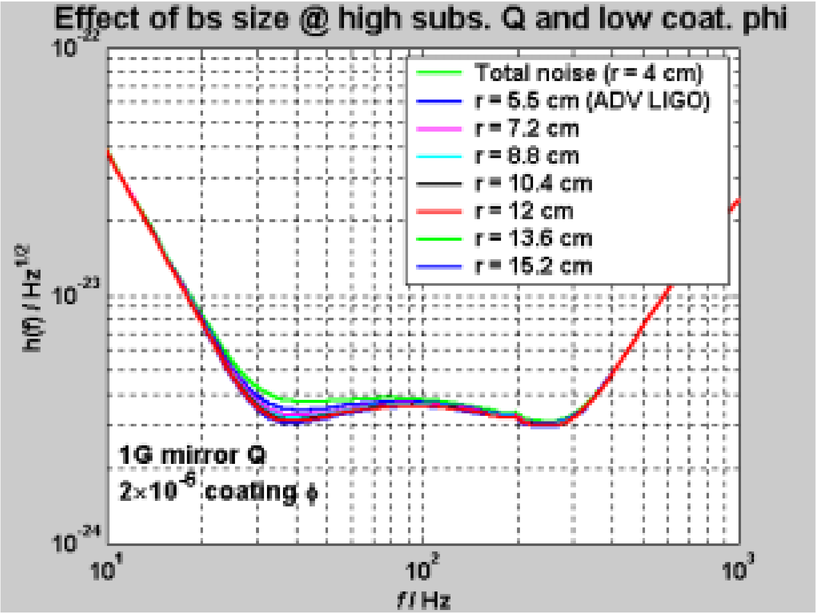

Figure 5