An Advanced Interferometer

dhs Aspen Feb ‘00

G000013-00-R

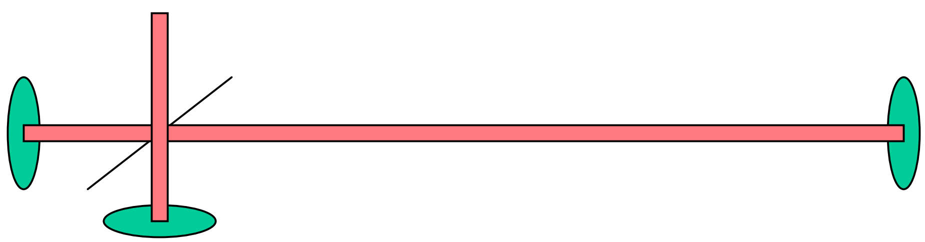
- Guess at what one would like to build, knowing what we think we know now
- attempt only incremental changes (e.g., no QND)
- work to get back to completely quantum limited configuration
- Configuration:
  - RSE, Fabry-Perot arms
  - Cooled larger Sapphire test masses
  - slightly lower loss optics, lower scatter optics
  - same suspension thermal noise performance as LIGO II
  - same isolation system performance as LIGO II
  - rough doubling of input power

Parameters

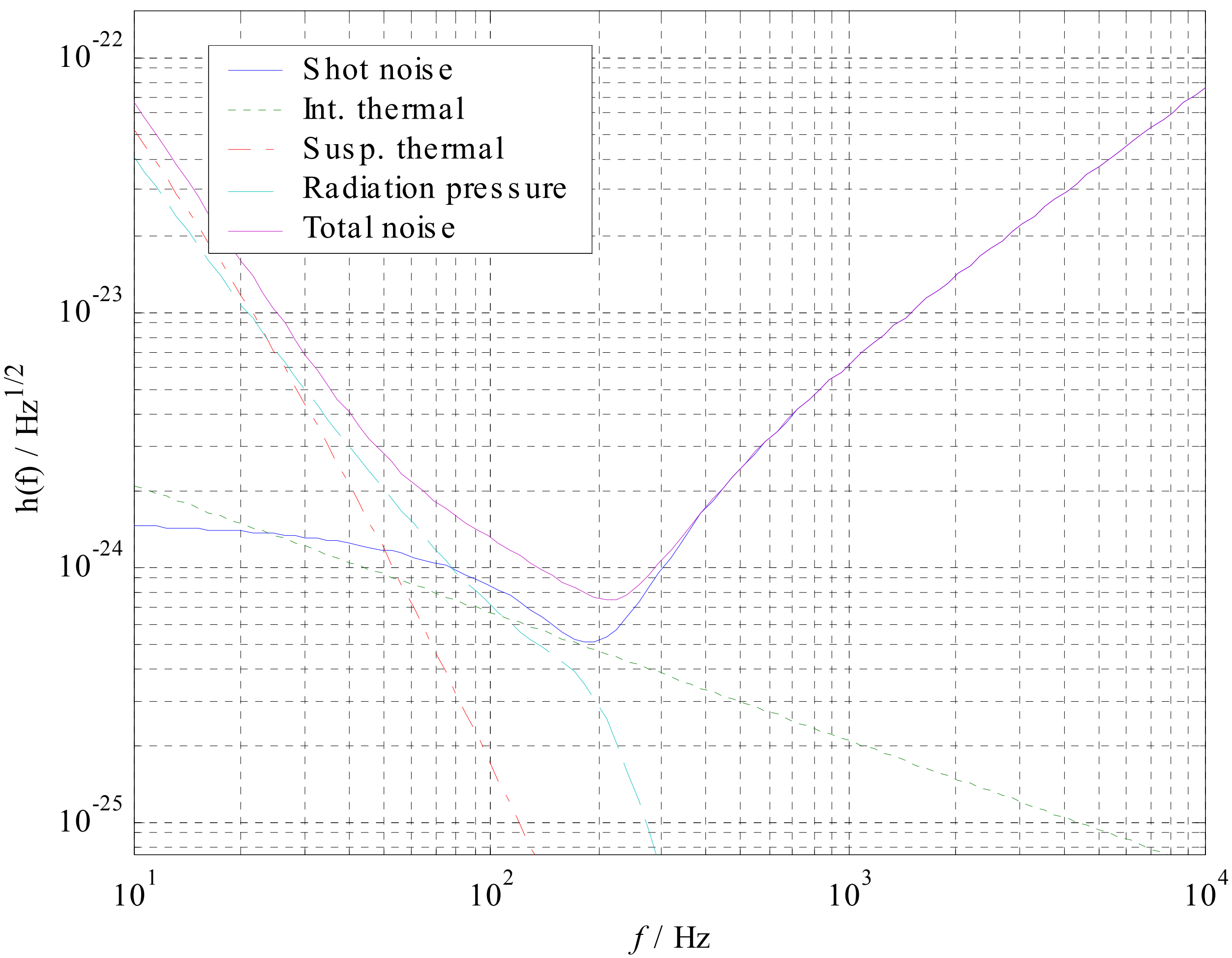
Subsystem and Parameters	White Paper LIGO II Reference Design	Advanced IFO Aspen, Feb ‘00
Strain Sensitivity (rms, 100 Hz band)	2×10^{-23}	$7\text{x}10^{-24}$
Displacement Sensitivity (rms, 100 Hz band)	8×10^{-20} m	3×10^{-20} m
Fabry-Perot Arm Length	4000 m	4000 m
Beam Tube Vacuum Level (Chambers)	$< 10^{-6}$ torr, ($<10^{-7}$)	$< 10^{-7}$ torr
Laser Wavelength	1064 nm	1064 nm
Optical Power at Laser Output	180 W	300 W
Optical Power at Interferometer Input	125 W	200 W
Power Recycling Factor	80 x	61 x
Input Mirror Transmission	3%	1%
End Mirror Transmission	15 ppm	15 ppm
Arm Cavity Power Loss on Reflection	1%	0.5 %
Light Storage Time in Arms	0.84 ms	ms
Test Masses	sapphire, 30 kg	20 K Sapphire, 120 kg
Mirror Diameter	28 cm	44 cm
Test Mass Pendulum Period	1 sec	1 sec
Seismic Isolation System	Active/Passive, 6 stage	Active/Passive, 6 s.
Seismic Isolation System Attenuation	10^{-8} (10 Hz)	10^{-8} (10 Hz)

A few technical points

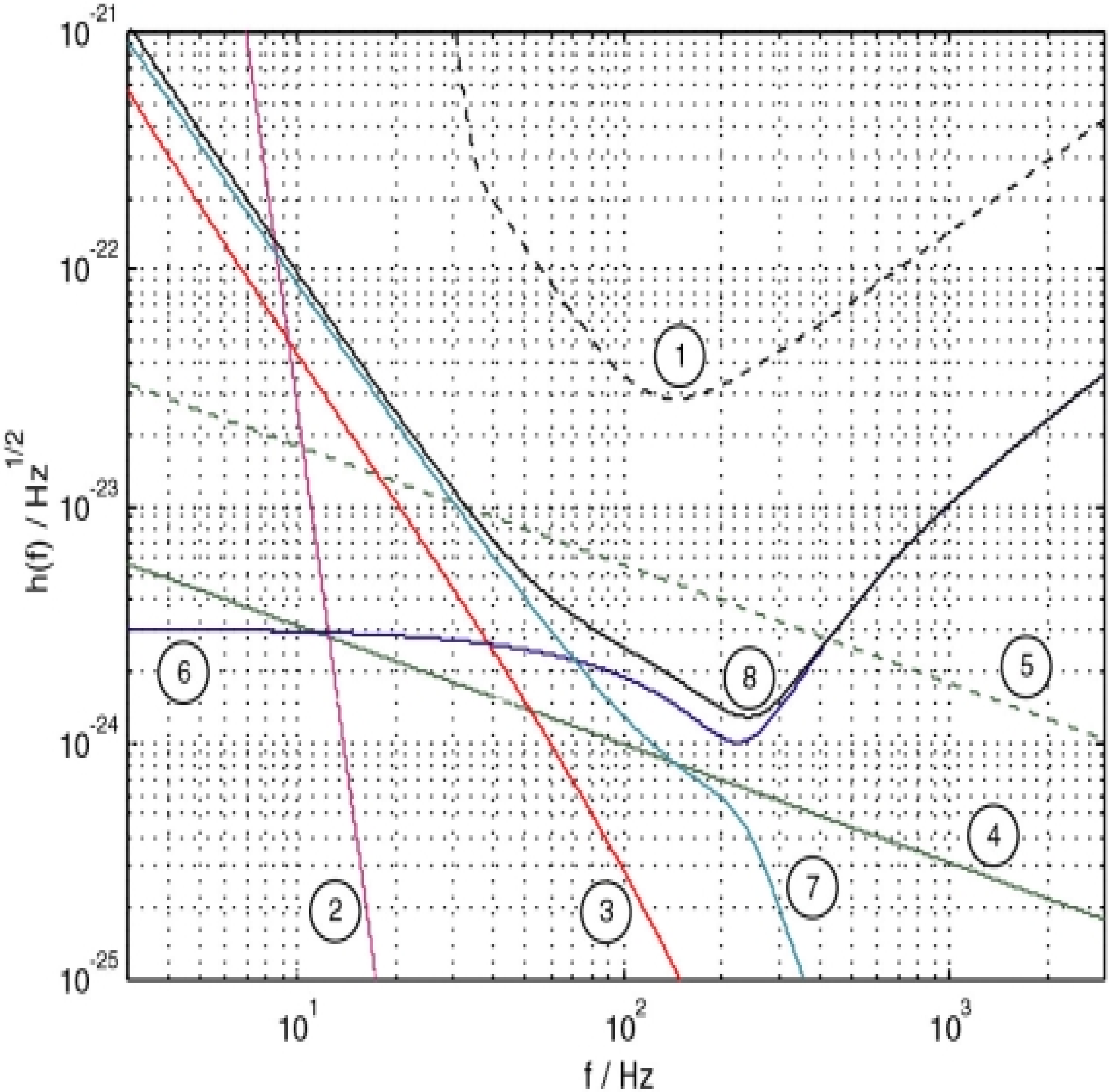
- Assumed cooled sapphire mirrors to 20K, result as per Sheila's plot; gets us just about back to where we were 6 months ago (modulo root 2).
  - Assumed no significant noise due to bulk 'shimmering'…
- probably a little underpowered, but Bench would not let me go further!
- Ended up with 2 MW on arm mirrors, so ask for
  - ~0.5 ppm absorption per bounce or 1 W
  - another 1 W to correct thermal lensing
  - another 1 W due to 4ppm/cm substrate absorption in ITM
  - 3 W input to mirror - how to get this out????
- Or…are the mirrors Silicon, 140 K, with light coupled in using a pellicle? Room temperature, sensed (at lower power) with a pair of cooled optics?



Noise Anatomy as per Bench



White Paper LIGO II



Performance as per Bench

- For NS-NS, can see 1.6 times further out than White Paper system
  - I.e., from 450 Mpc to 750 (!) Mpc; (750/450)^3 = 4.6
  - can see ~3-4x further than present best guess LIGO II system
    - you can cube it for yourselves
- Finn: best guess 2-3 NS-NS inspirals/yr inside 450 Mpc
  - numbers are down by roughly a factor of 4 from earlier estimates
  - but the ‘Advanced Ifo’ should see ~9-14 per year, one per month
- So: NS-NS becomes a relatively ‘assured’ source;
  - NS-BH and NH-BH in any event (LIGO II present best guess also)
  - are you scared, Lisa?
- For stochastic background, 3 times better upper limit
  - was 1.5e-9, becomes 5.4e-10

What else…

- Our ‘Advanced Interferometer’
  - Is part of world-wide ‘web’ of detectors, of course, with LCGT, EURO and ACIGA among others
  - DR, RSE configurations represented -- probably some QND schemes too!
  - some transmissive optics, some diffractive, some with virtual Mach-Zehnders, some ‘cooled’ by interferometric sensing
  - some ideal combination of ‘stiff’ and ‘soft’ isolation systems
  - probably some suspension point interferometers in there, too
  - ideas all tested on the 18 (or certainly by then even more) suspended prototypes around the world
  - bars, spheres near each interferometric detector
  - in fierce competition (or was that collaboration?) with LISA

  - …and with everyone distracted thinking about how to make a 4-letter acronym (no not word) followed by the Roman numeral ‘IV’