LIGO

Initial LIGO improvements & Advanced LIGO

P Fritschel

PAC Meeting

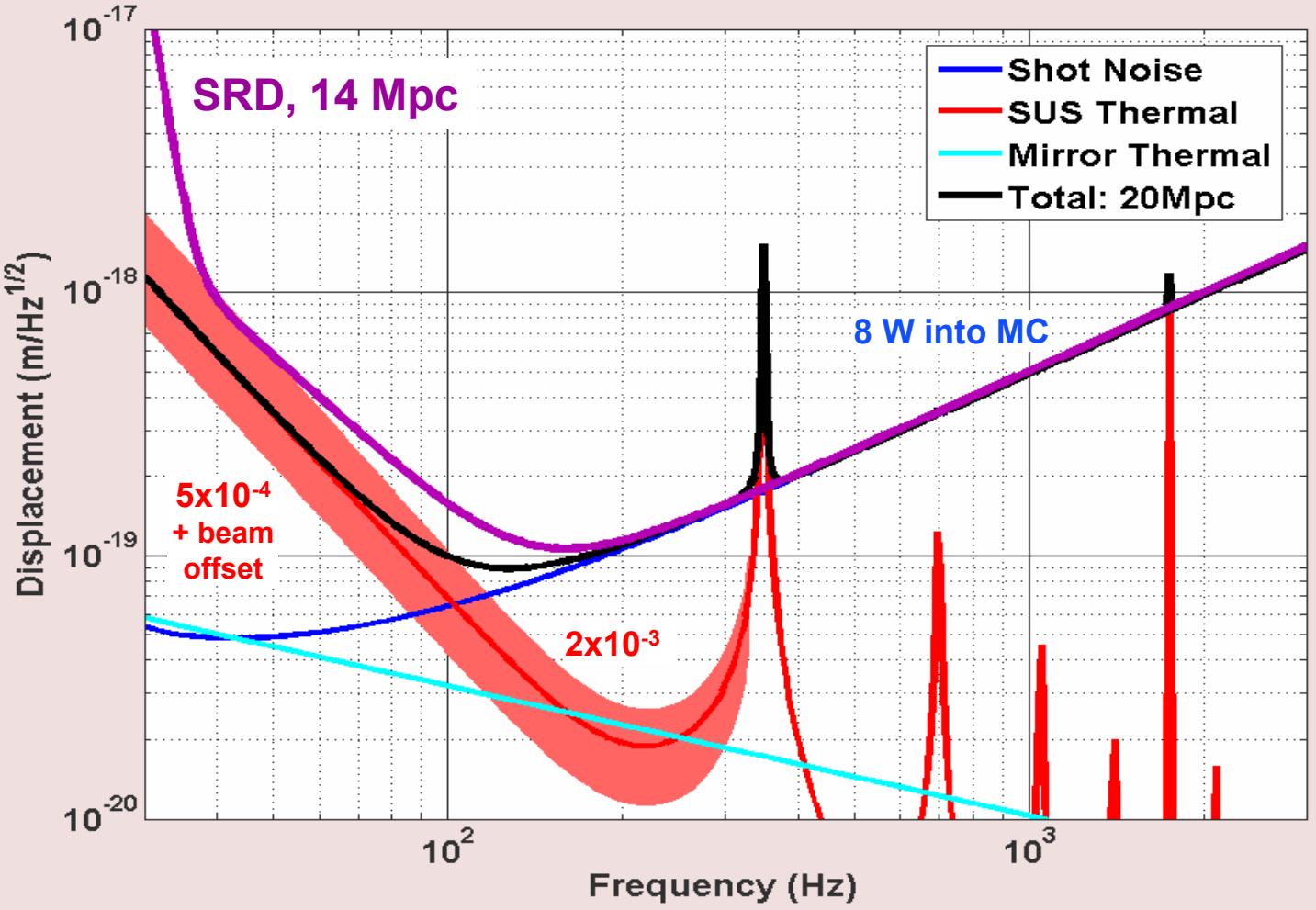
LLO, 18 May 2005

G050259-00-D

General considerations

- Any upgrade must account for time to install and fully commission it, plus time for running!
- Plan should favor technologies, techniques, subsystems that are part of Advanced LIGO
- Plan should consider contingency options for potential AdLIGO delays
- Initial LIGO components/features that are not candidates for upgrade
  - Core Optics (except possible spare replacements)
  - Isolation stacks
  - IFO beam path (e.g., no suspension change that moves the optic)

Initial LIGO fundamental noises

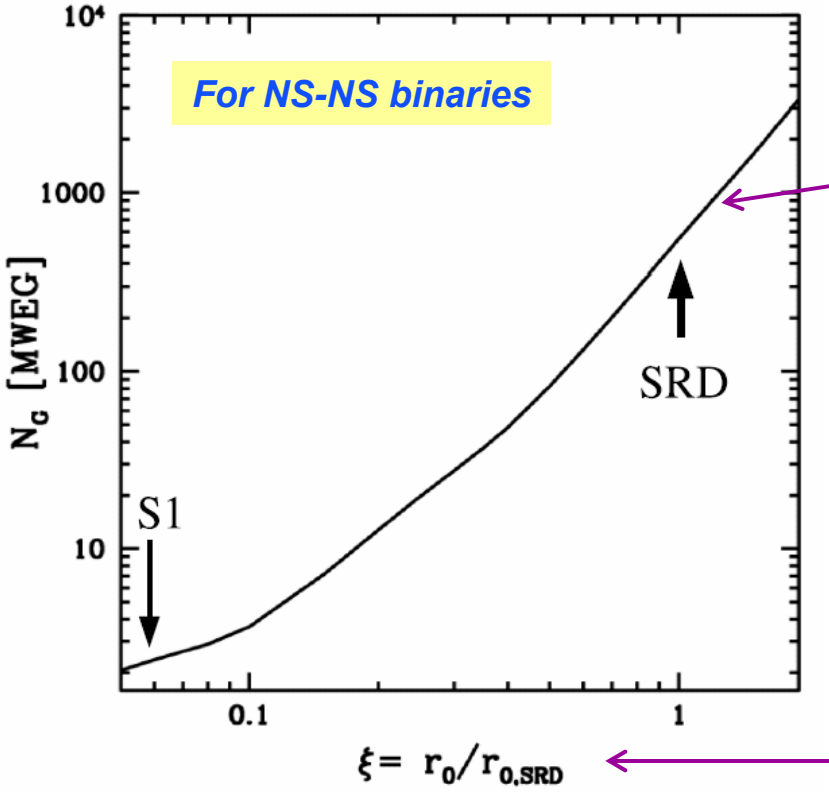


See also Rana Adhikari's thesis

Astrophysical impact of a modest improvement

- How does the number of surveyed galaxies increase as the sensitivity is improved?

From astro-ph/0402091, Nutzman et al., "Gravitational Waves from Extragalactic Inspiraling Binaries: Selection Effects and Expected Detection Rates"



Power law: 2.7

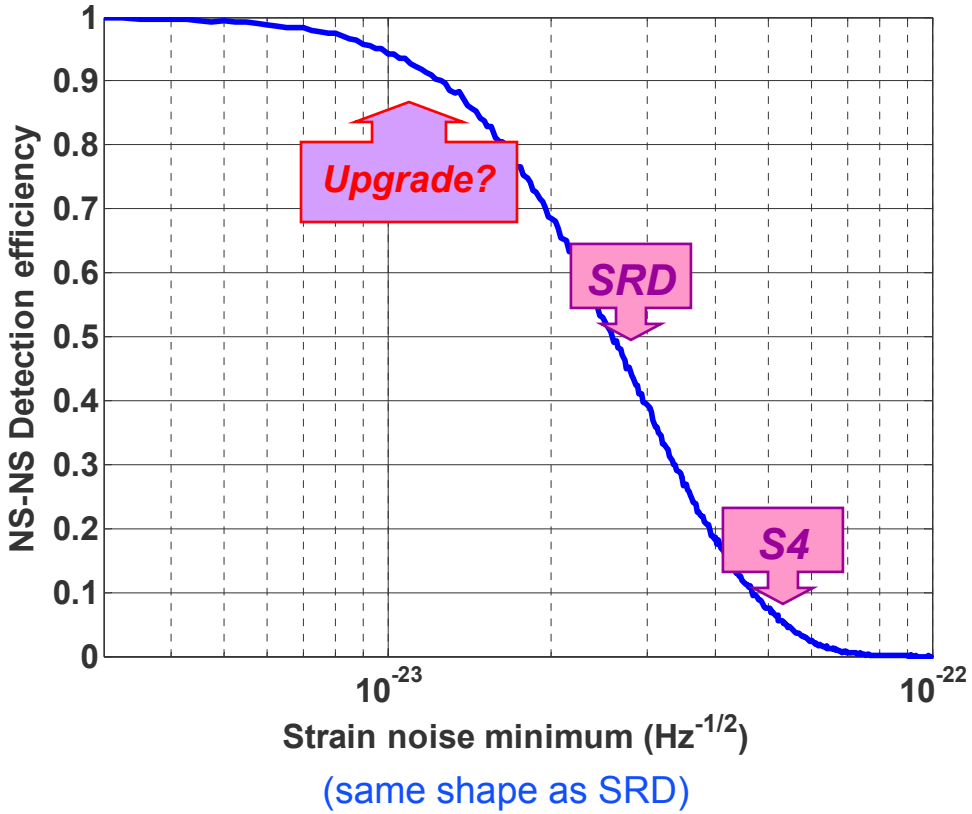
Factor of 2 reduction in strain noise,

⇨factor of 6.5 increase in MWEG

Prop. to inspiral range

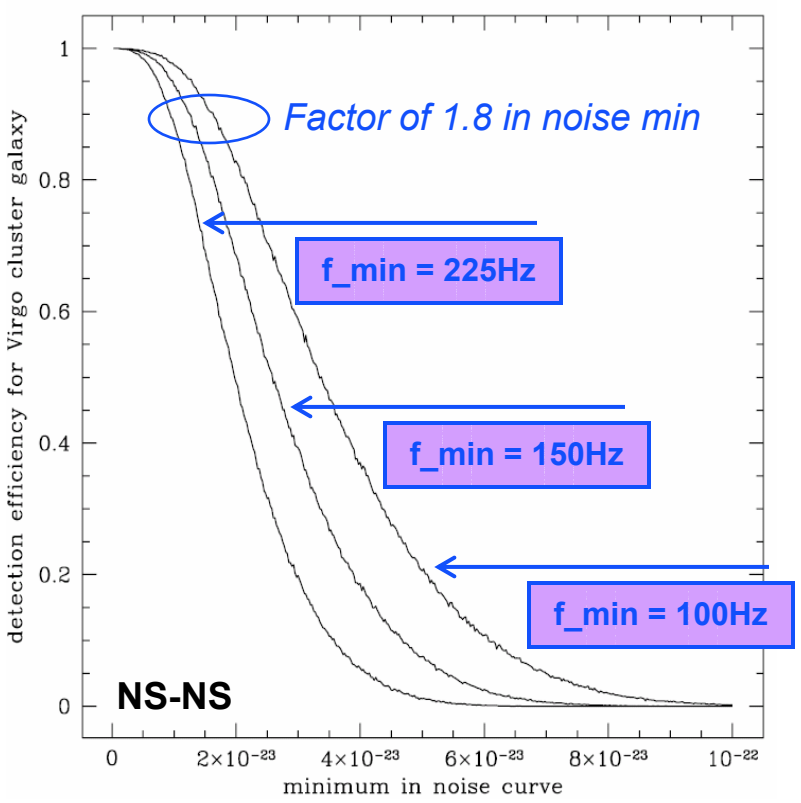
Sensitivity to Virgo cluster

Effect of reducing noise floor:



(same shape as SRD)

Effect of reducing min freq:



Data courtesy of Philip Nutzman

Detection rate estimates

Assuming factor of 6 increase in surveyed volume:

Source	***Initial LIGO***	***Improved***
NS-NS	~1 / 3000 yrs to **~1 / 3 yrs**	~1 / 500 yrs to **~2 / yr**
NS-BH	~1 / 5000 yrs to **~1 / 3 yrs**	~1 / 800 yrs to **~2 / yr**
BH-BH	~1 / 250 yrs to **~2 / yr**	~1 / 40 yrs to **~12 / yr**

Suspension options

- Find that current wire suspensions operate at wire-loss limit
  - Optimize with beam position shift (1 cm down from center)
- Find that current wire suspensions have excess loss
  - Design new clamping systems for the ends

Factor of 2-3 lower noise than SRD at 100 Hz

Beyond current wire suspensions: more than 3x below SRD

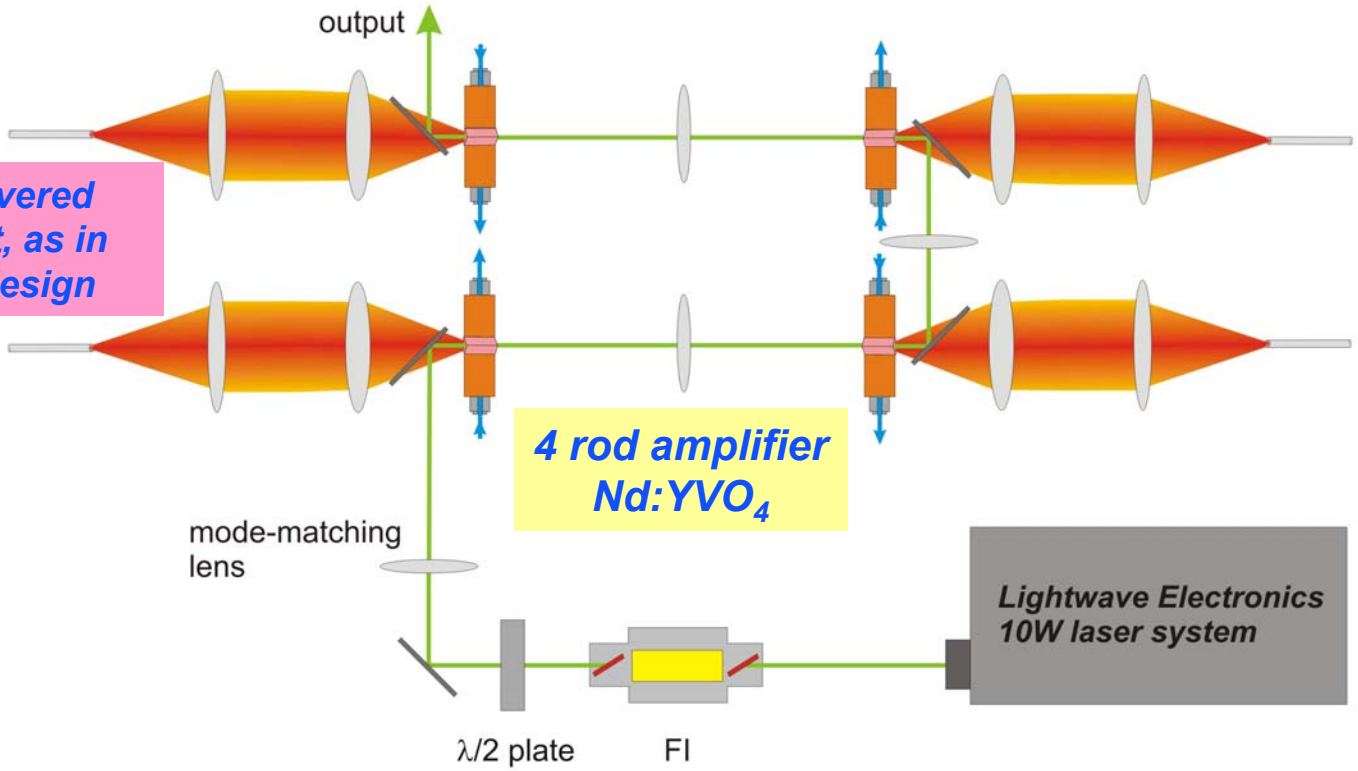
- Two wire loops
- Low-loss flexures
- Cradle for optic, suspended by silica fibers
  - See G020241 & G020242

***Research needed**: In-vacuum test suspension, to investigate violin mode Q's of current wire suspension, and potential variants*

Power increase: 4x more laser power

- Higher power laser
  - Amplify current Lightwave Electronics laser with commercial amp
  - Amplifier from Laser-Zentrum Hanover (LZH)

Fiber-delivered pump light, as in AdLIGO design

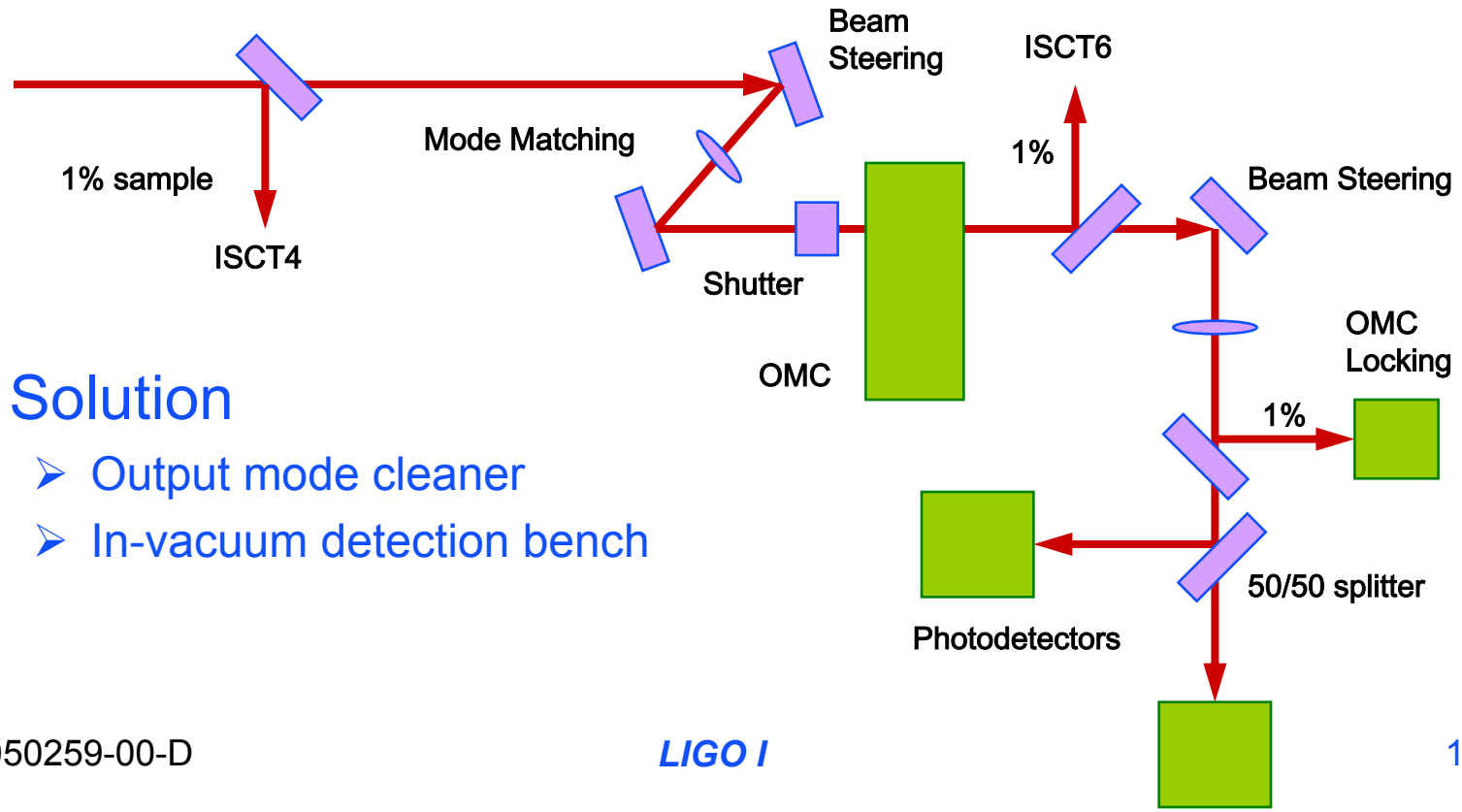


Input Optics to handle it

- New electro-optic modulators
  - Thermal lensing in current modulators (LiNbO3) would be too high
  - Use modulators developed at UFI for Advanced LIGO
  - RTP & RTA, 4 mm x 4 mm aperture, negligible thermal lensing at 100 W
- New in-vacuum Faraday isolator
  - Current isolators produce beam drift, would lens too much at higher power
  - Use AdLIGO Faraday isolator, developed at UFI
  - Design uses birefringence & thermal lensing compensation; different polarizer type
- Replace or clean mode cleaner optics ?
  - MC transmission only ~75%

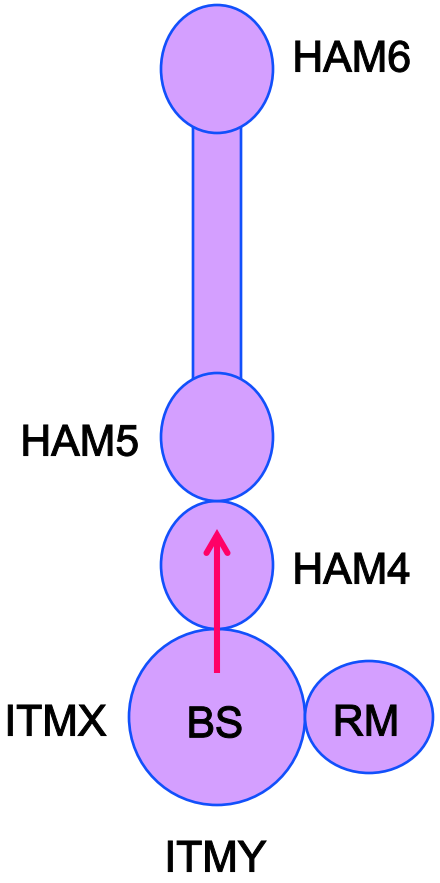
Output mode cleaner to handle the output power

- Basic motivations
  - Quadruple the photodetectors: 4 ⇨ 16 !
  - Acoustic noise: close to limiting sensitivity now (jitter on detection tables); H1-H2 stochastic sensitivity limited by it
- Solution
  - Output mode cleaner
  - In-vacuum detection bench



OMC design options

- Monolithic spacer cavity
  - Triangular or 4 mirror zig-zag
  - Low finesse
  - Sidebands pass on same FSR
  - Easier design, HAM5 or HAM6
  - Could test DC readout with a higher finesse version
- Suspended
  - Same design as input mode cleaner
  - High finesse
  - Sidebands pass on next over FSR
  - More complicated design, more expensive, HAM5 and HAM6
- Seismic isolation
  - Initial LIGO stack
  - Advanced LIGO HAM isolation



Thermal compensation

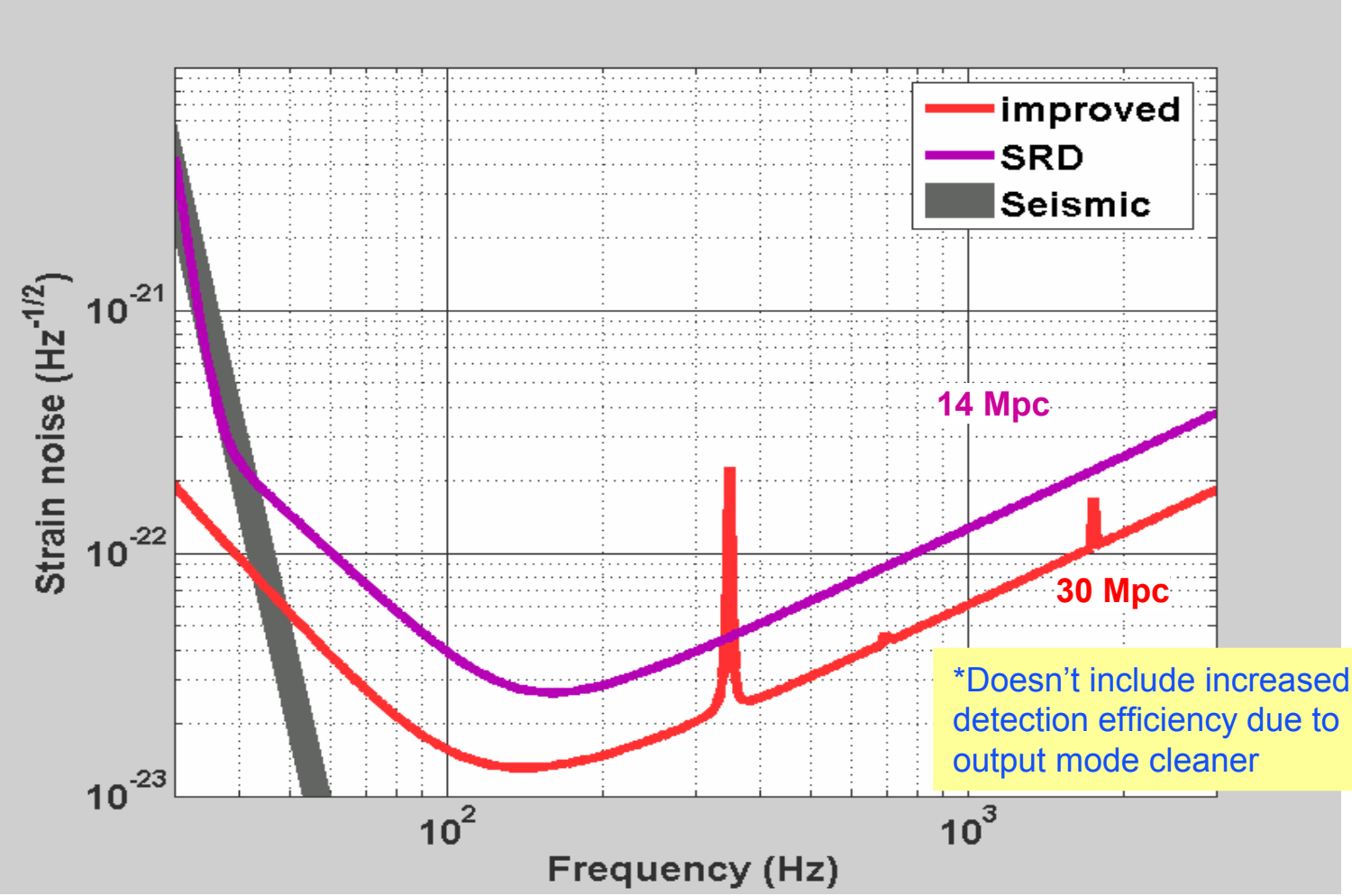
- Current thermal compensation system (TCS) on H1 compensates for 100 mW absorbed power
  - Working to extend this with a higher power CO2 laser
- If optics absorb at their expected level

$$0.1\,\mathrm{W} = (P_{bs}/2)(4\,\mathrm{ppm/cm} \times 20\mathrm{cm} + 0.6\,\mathrm{ppm} \times 130)$$

$$\Rightarrow P_{bs} = 1.3\,\mathrm{kW}$$

- Initial LIGO estimate: P_bs = 8W*0.65*40 = 200 W:
  - *factor of 6 headroom*
- Potential that extra-absorbant core optics would be replaced

4x more power* & good wire suspensions + beam offset



Other possibilities

- Add PEPI to the LHO test masses
  - Sensors (large part of cost) would be useable in AdLIGO
  - Could help with up-conversion
- Dealing with wind noise (both sites)
  - Adding good tilt sensing to HEPI
- Miscellaneous
  - AdLIGO electronics improvements: lower noise ADCs; new architectures for controls and monitoring
  - Detection table seismic isolation
  - Acoustic mitigation at LHO