



# 100 kg optic with upgraded suspension for LIGO A#

GWADW presentation

Brian Lantz, May 2023, drawing extensively from Heavy suspension subgroup of the LSC - esp. Edgard Bonilla, Calum Torrie, Eddie Sanchez, Betsy Weaver, Conor Mow-Lowry, Giles Hammond, Peter Fritschel

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2

• LIGO A<sup>#</sup> is the recommend path forward for upgrading the existing LIGO detectors after O5 (Kevin & Lisa on Monday)

LIGO A<sup>#</sup>

- Key upgrade is 100 kg optics & suspensions, see 'Post 05 report' LIGO-T2200287
- "workshop parameters" (T2300137)
  - same length as aLIGO
  - same aspect ratio
    - ~ 27 cm thick, 46 cm diam.
  - fibers at I.6 GPa (2x current)
  - 400 kg main chain
  - Set to "middle" of the ISI to remove the balancing masses
  - allowed a larger footprint
  - double reaction chain









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LIGO A#



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- CAD sketch by Eddie Sanchez, <u>D2300132</u>
- Keep the existing ISI
- Fit is an issue, esp. for transmon
- All install to be done "cartridge" style



#### why 100 kg?



- Larger suspensions possible because H2 is moving to India
- Heavier optics have lower thermal noise and better 'radiation pressure' noise
- Heavier optics (higher moment) have lower Sigg-Sidles frequencies - leads to lower ASC noise
- Hard to push above 100 kg AdvVirgo+ optics are  $\sim$  100 kg, and so the LMA fixturing in the coating machines is an issue
- ISI total payload is 1000-1100, so main chain limited to about 400 kg. If the test mass gets to be a larger fraction of the total chain mass, the 10 Hz isolation gets worse.



#### Thermal noise



Thermal noise at 10 Hz is about 5e-20 m/rtHz

Design target is 6e-20 m/rtHz (

Fibers stressed to 1.6 GPa (2x aLIGO), see Glasgow presentations

Higher stress fibers also puts bounce/ roll modes at 6.2 Hz & 8.7 Hz



### LSC Heavy Optic needs Heavy Chain

Test Mass should only be 1/3 to 1/4 of the total suspension chain mass, The top mass should be the heaviest.

Illustrate with simple model - 4 stage mass-spring system, Set mirror mass, total mass at 400 kg, and first mode at 0.6 Hz. Find springs and masses to get best 10 Hz isolation.

3 cases - final mass of 100 kg, 135 kg, & 200 kg

This optimization has more freedom than is realistic, but illustrates point that mass probably shouldn't be more than about 1/4 to 1/3 of the total suspension chain mass.

chain I:	chain 2:	chain 3:
(ml:148.0)	ml:121.5	m1:82.5
m2:93.2	m2: 84.6	m2: 65.5
m3: 58.8	m3: 58.9	m3: 52.0
(m4: 100)	m4: 135	m4: 200
calculated with T2100287		





#### Length Isolation



- Total is at the 6e-20 target @10 Hz
- Assumes OSEMs on the top stage (still the limit) & HoQIs (or some other IFO based sensor) on UIM





#### It's the controls



Noise budgets continue to show ASC noise significantly above quantum noise at low end of the detection band





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## Can we modify the suspension to reduce control noise?



- In particular reduce the ASC noise
- Heavy (High-moment) test mass to reduce the Sigg Sidles mode frequency damping this mode drives the ASC control.
- Reduce all the angular excitations of the mirror seismic, local damping, and cross coupling from LSC. Reduce the BW of the alignment control needed to achieve 1e-9 radians RMS.
- (Also reduce the ASC sensing noise, and coupling of ASC to length, but not in this talk)



#### Decouple Length & Pitch



- Current Quads have 2 wires at the top, so optic pitch is all from the control
- New "workshop parameters" have 4 wires at the top, more coupling from ground, less from length
- Puts all the wires vertical (OK if the springs take up big footprint on the ISI)
- Attach all the wires "at" the center of mass



#### Sigg-Sidles modes



 $\bullet\,at$  1.5 MW, Pitch and yaw modes set by Sigg-Sidles & optic I

 can damp with ASC, and keep the Ie-I7 rad/rtHz at I0 Hz,
only (probably) if the ASC rms control is well separated from the 2.6 Hz damping



Edgard Bonilla, <u>G2300771, T2300150</u> G2



#### RMS angle of the mirror





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#### Decouple Length & Pitch



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16

cross coupling is greatly reduced in design:

- Nominal is 0, because attachments, cg, and actuators aligned
- large moments lower compliance of pitch/ yaw





#### and so...



- High stress fibers improve the suspension thermal noise
- Bigger mass manages Sigg-Sidles modes
- Update to GEO/ aLIGO design, and addition of new sensors should improve the "control" noise so that we can appreciate better thermal noise
  - but -
- Just starting on the ASC modeling
- Should we put IFO sensors on the top mass? how to monitor the absolute position?
- Can we fit a top mass that big?
- Should we add other sensors?
- Double reaction chain? really?
- Where to put the transmon suspension? etc. etc.





