BS Actuator Design

Yuta Michimura
Department of Physics, University of Tokyo

Scope

- Motivations
  - magnets for the BS might be to large
    (compared with Virgo experience)
  - not sure if the Low Power Coil Drivers do not saturate

- Summarize the current BS actuator design
- Summarize prototype Type-B experiment at TAMA for re-thinking the current actuator design
- Come up with the new design based on
  - DAC, OSEM saturation on lock acquisition
  - actuator noise
  - magnetic noise

Current BS Actuator Design

- **TM mirror**
  - 370mm dia, 80 mm thick
  - 18.9 kg
  - Fused Silica
  - magnetic susceptibility 1.37e-5
- **IM** Ref. JGW-T1100571
  - 36.5 kg
- **Coil drivers**
  - low power (JGW-D1503507)
    * 7.8 kOhm at DC, 1.3kOhm above 312 Hz
    * 0.128 mA/V at DC
    * 10 mA at max (AD8671)
    * for TM/IM OSEMs
  - high power (JGW-D1503503)
    * 73 Ohm
    * 13.6 mA/V
    * 3 A at max (OPA548)
    * for LVDTs
- **TM coil-magnet** Ref. JGW-T1503239
  - 600 turns
  - 6 mm dia, 3 mm long
  - NdFeB (8.78e5 A/m)
  - mag. moment 0.744 Am^2
  - 0.129 N/A at max
  - ~100 mA at max
  - 4 coils in longitudinal
- **IM coil-magnet**
  - 600 turns
  - 10 mm dia, 10 mm long
  - NdFeB (8.78e5 A/m)
  - mag. moment 0.690 Am^2
  - 1.12 N/A at max
  - ~100 mA at max
  - 1 coil in longitudinal
- **DAC**
  - +/- 10V, 16 bit (65536 counts)

Saturation on Lock Acquisition

- RMS velocity after local damping is simulated to be
  v = 0.2 um/sec
  (according to e-mail from Shoda-san on Jul 22, 2015)
- The linewidth for MICH error signal is roughly $\lambda/2$ = 532 nm
- So, the time it takes to pass the linewidth is
  dt = 532 nm / (0.2 um/sec) ~ 2.7 sec
- The force we need to stop BS is
  F = m v / dt = 18.9 kg * 0.2 um/sec / 2.7 sec = 1.4e-6 N
- This corresponds to
  2.8e-6 A to each coil, 0.022 V to low power coil drivers,
  70 counts at DAC output

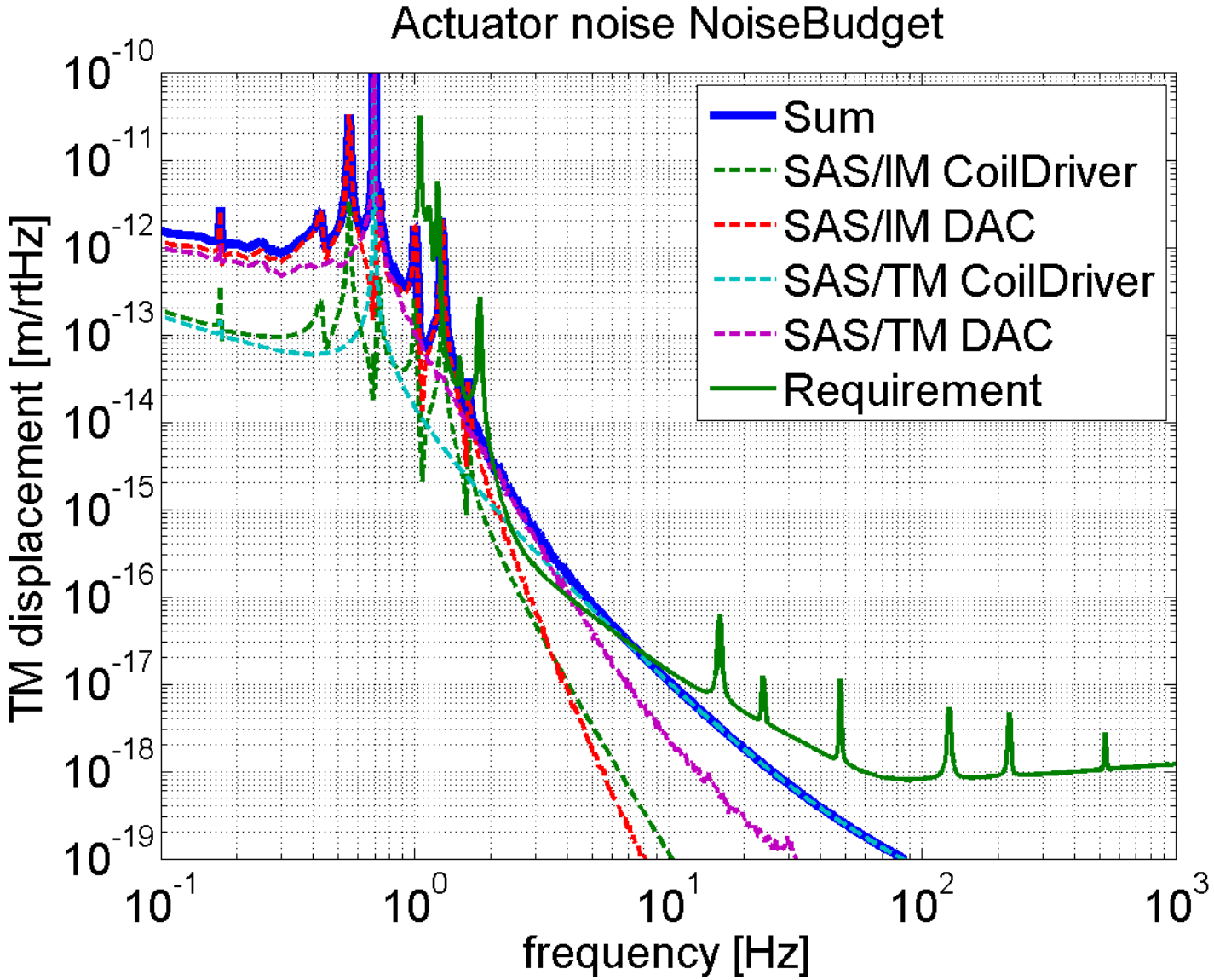
  -> no saturation at all (we can reduce actuation efficiency
  by factor of ~1/930)

Saturation on Earthquakes

- In Prototype Type-B experiment at TAMA, DAC output was ~50 counts at max during the earthquake (see [kagra-seis 00847])
- In this prototype,
  - coil driver: 400 mA/V instead of 0.128 mA/V
  - actuation efficiency: 1.6 N/A instead of 1.12 N/A
- So, 50 counts in the prototype corresponds to
  50 counts * 400/0.128 * 1.6/1.12 = 2.2e5 counts
  in KAGRA Type-B
  -> it will saturate the DAC
  (but do we have to keep it locked even in earthquakes?)
- In coil current, this corresponds to
  50 counts / 2^16 counts * 20 V * 400 mA/V = 6 mA
  -> it won't saturate the low power coil driver

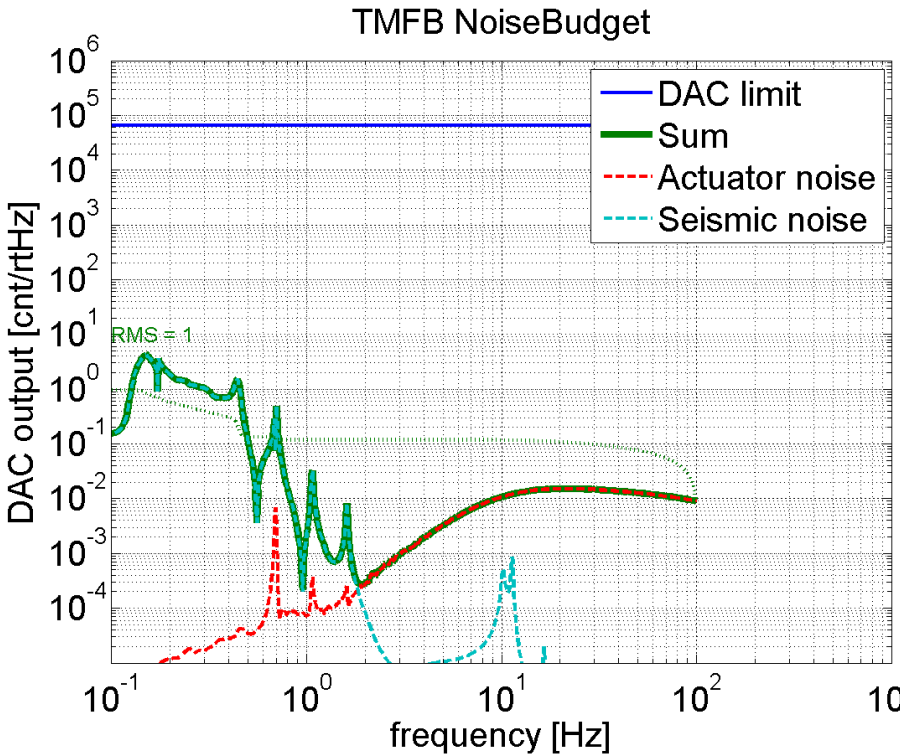
Simulated Actuator Noise

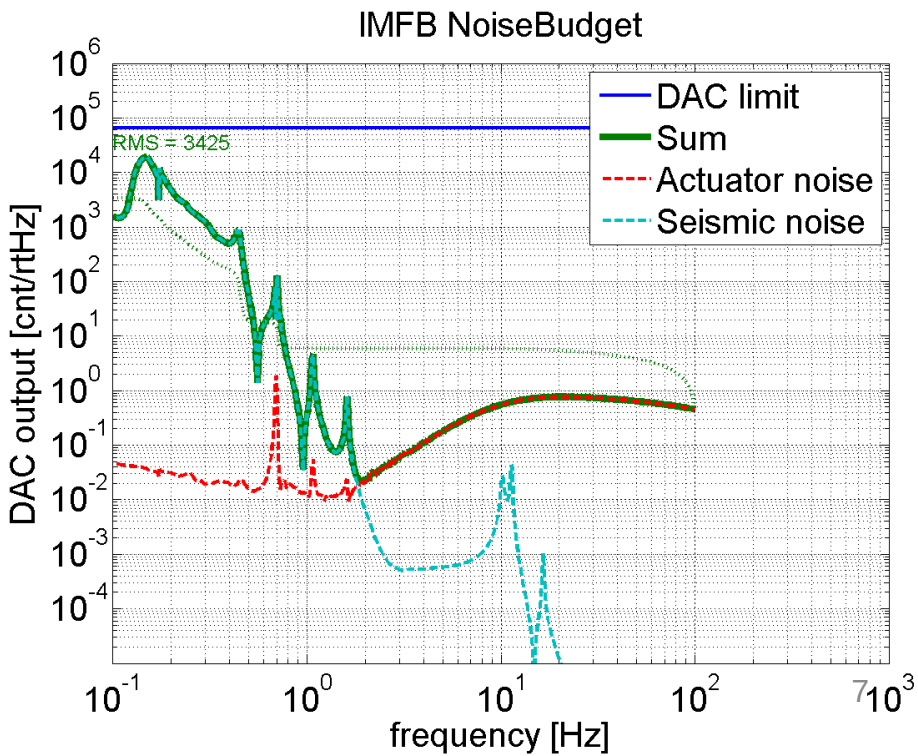
- Barely meet the requirement (see JGW-T1503453 for details)



Simulated Feedback During Lock

- Don’t saturate the DAC (see JGW-T1503453 for details)
- But RMS too small for TM
  -> we can reduce actuation efficiency by upto 1/65000





Simulated Magnetic Noise

- Calculation on going by Shimoda

NdFeB or SmCo

- TBD

Proposed Actuator Design

- Reduce magnetic moment of the magnets on BS TM by factor of 1/900 (or 1/90 to be safe in the range?)
- In this case;
  - 2.5 mA to each coil, 19 V to low power coil drivers, 63000 counts at DAC output on lock acquisition
    -> won't saturate
  - reduced actuator/magnetic noise by factor of 1/900
    -> actuator noise meet the requirement by 3 orders of magnitude
  - 900 counts RMS to TM coils during lock
    -> won't saturate

- Do we have to change the suspension / jigs design to adopt this proposed actuator?
  (e.g. flags, gluing jigs, etc)

Magnet Replacing?

- If we are going to use the same type of bonding as LIGO, we can remove the magnets afterwards (according to Hirose-san)
- Removing can be done by soaking it in acetone
- Are we going to use the same type of bonding?

- By the way, the bonding used for IMC mirrors were the different type, and so we couldn't remove them (we could remove them by heat, but it might damage the mirror).