

# BS Actuator Design

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# Scope

- Motivations
  - magnets for the BS might be too 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**
  - 600 turns Ref. [JGW-T1503239](#)
  - 6 mm dia, 3 mm long
  - NdFeB ( $8.78e5$  A/m)
  - mag. moment  $0.744$  Am<sup>2</sup>
  - 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<sup>2</sup>
  - 1.12 N/A at max
  - ~100 mA at max
  - 1 coil in longitudinal
- **DAC**
  - +/- 10V, 16 bit (65536 counts)

# Saturation on Lock Acquisition

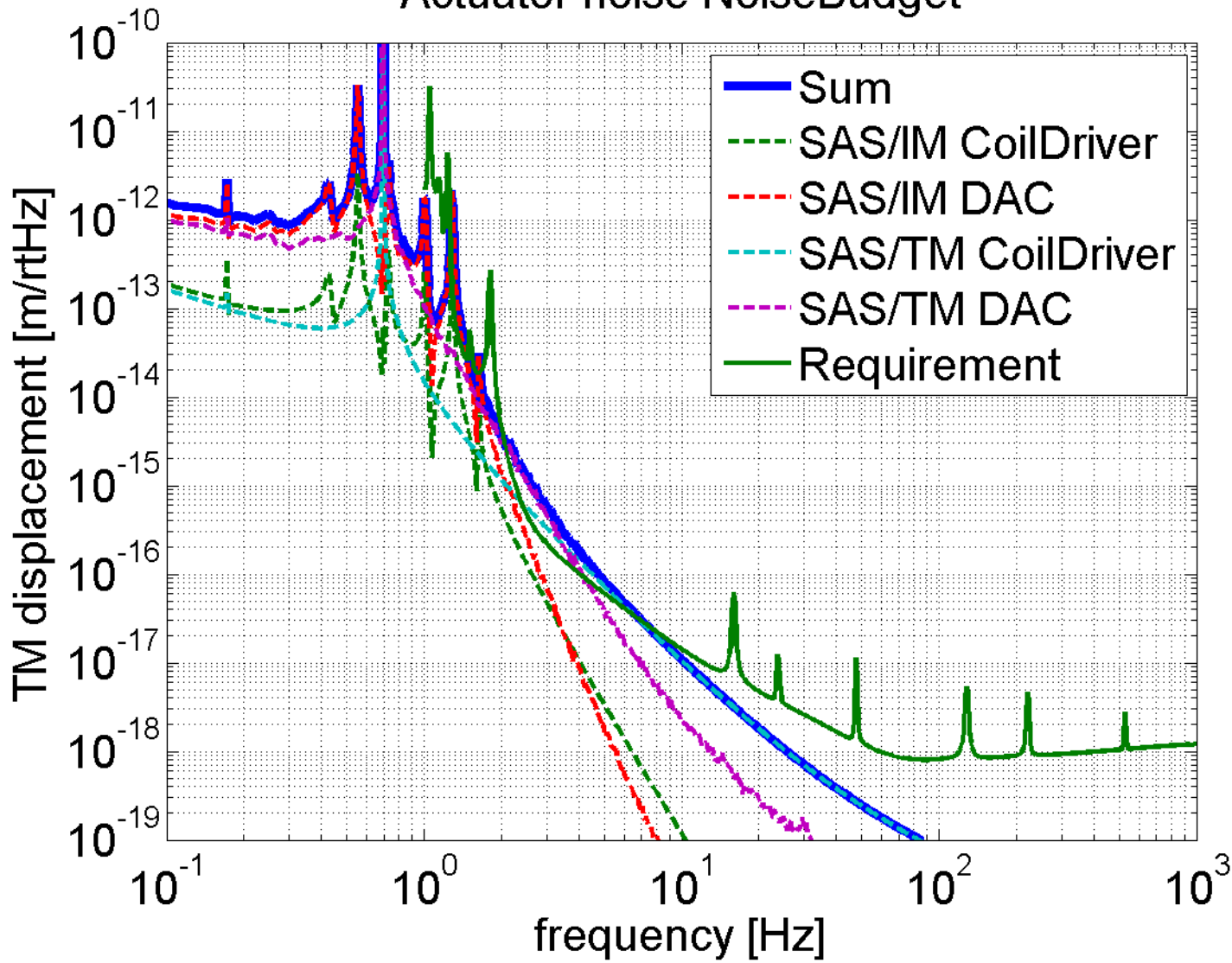
- RMS velocity after local damping is simulated to be  
 $v = 0.2 \text{ um/sec}$   
(according to e-mail from Shoda-san on Jul 22, 2015)
  - The linewidth for MICH error signal is roughly  $\lambda/2 = 532 \text{ nm}$
  - So, the time it takes to pass the linewidth is  
 $dt = 532 \text{ nm} / (0.2 \text{ um/sec}) \sim 2.7 \text{ sec}$
  - The force we need to stop BS is  
 $F = m v / dt = 18.9 \text{ kg} * 0.2 \text{ um/sec} / 2.7 \text{ sec} = 1.4\text{e-}6 \text{ N}$
  - 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  $\sim 1/930$ )

# 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
$$50 \text{ counts} * 400/0.128 * 1.6/1.12 = 2.2e5 \text{ counts}$$
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
$$50 \text{ counts} / 2^{16} \text{ counts} * 20 \text{ V} * 400 \text{ mA/V} = 6 \text{ mA}$$
  - > it won't saturate the low power coil driver

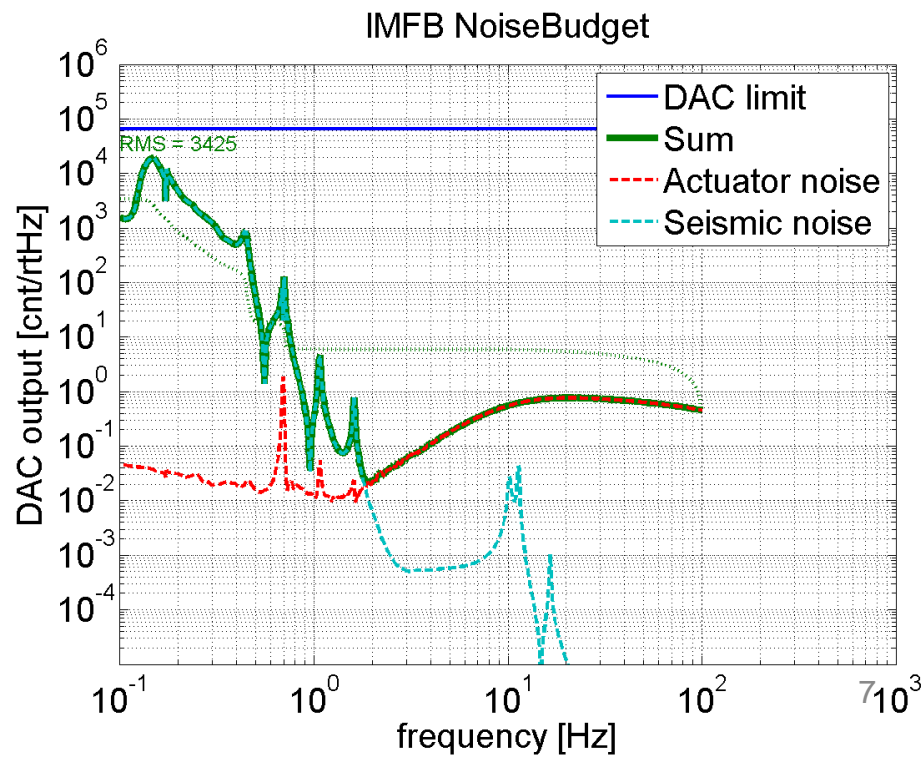
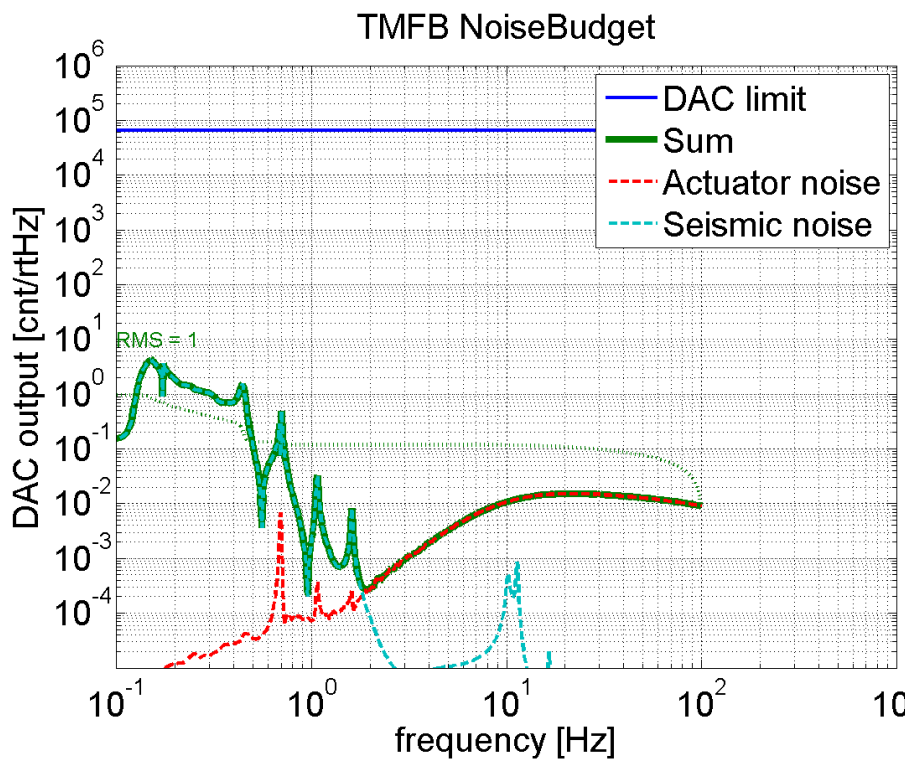
# Simulated Actuator Noise

- Barely meet the requirement (see [JGW-T1503453](#) for details)
- Actuator noise NoiseBudget



# 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

- SmCo is better considering the Barkhausen noise, but a little fragile compared with NdFeB
- Magnetic moment/volume
  - NdFeB:  $8.78 \times 10^5$  A/m
  - SmCo:  $4.3 \times 10^5$  A/m

# 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?
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- 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).