BS Actuator Design

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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 0.0744 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 λ/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

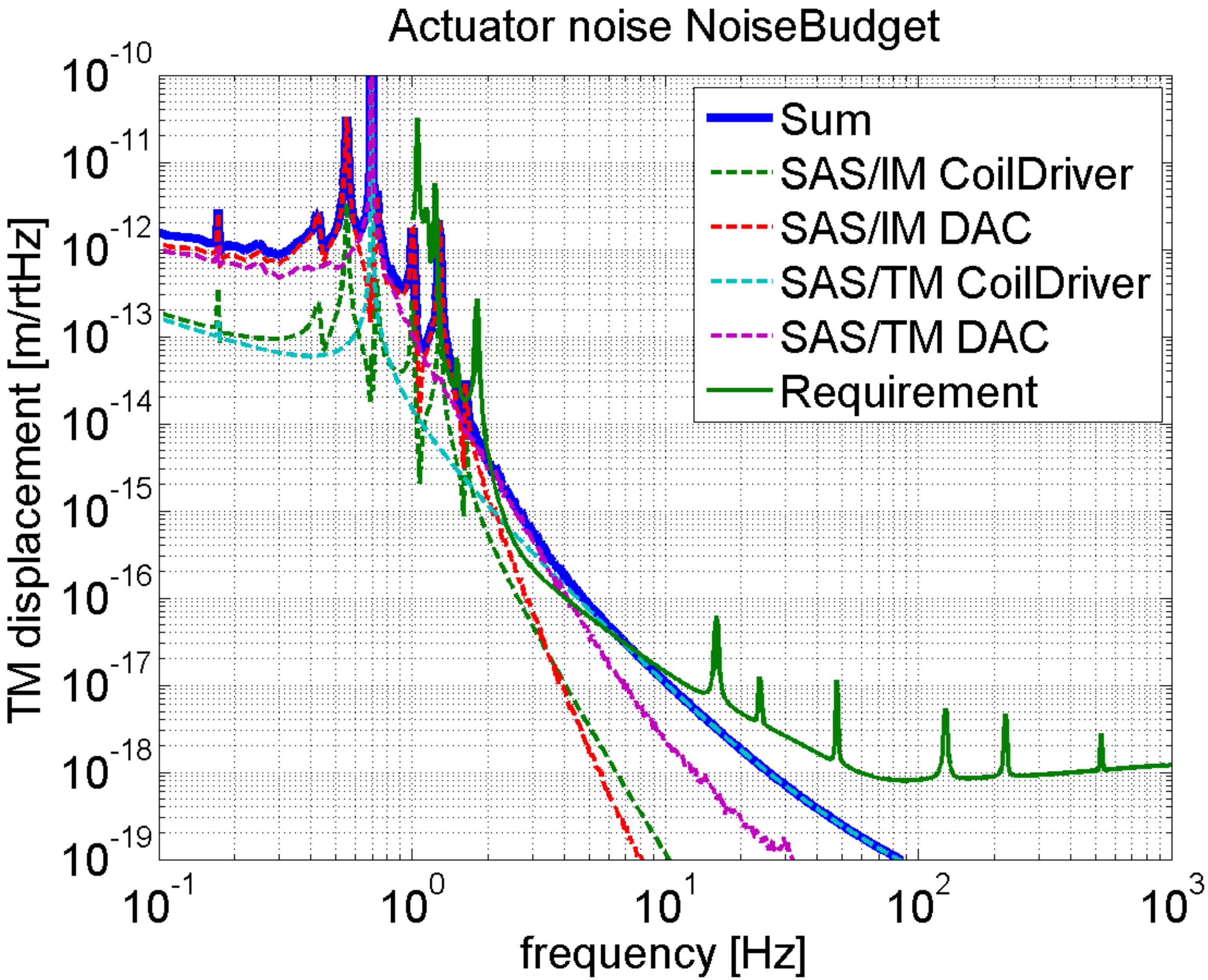
  -> no saturation at all (we can reduce actuation efficiency
  by factor of ~1/930)

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

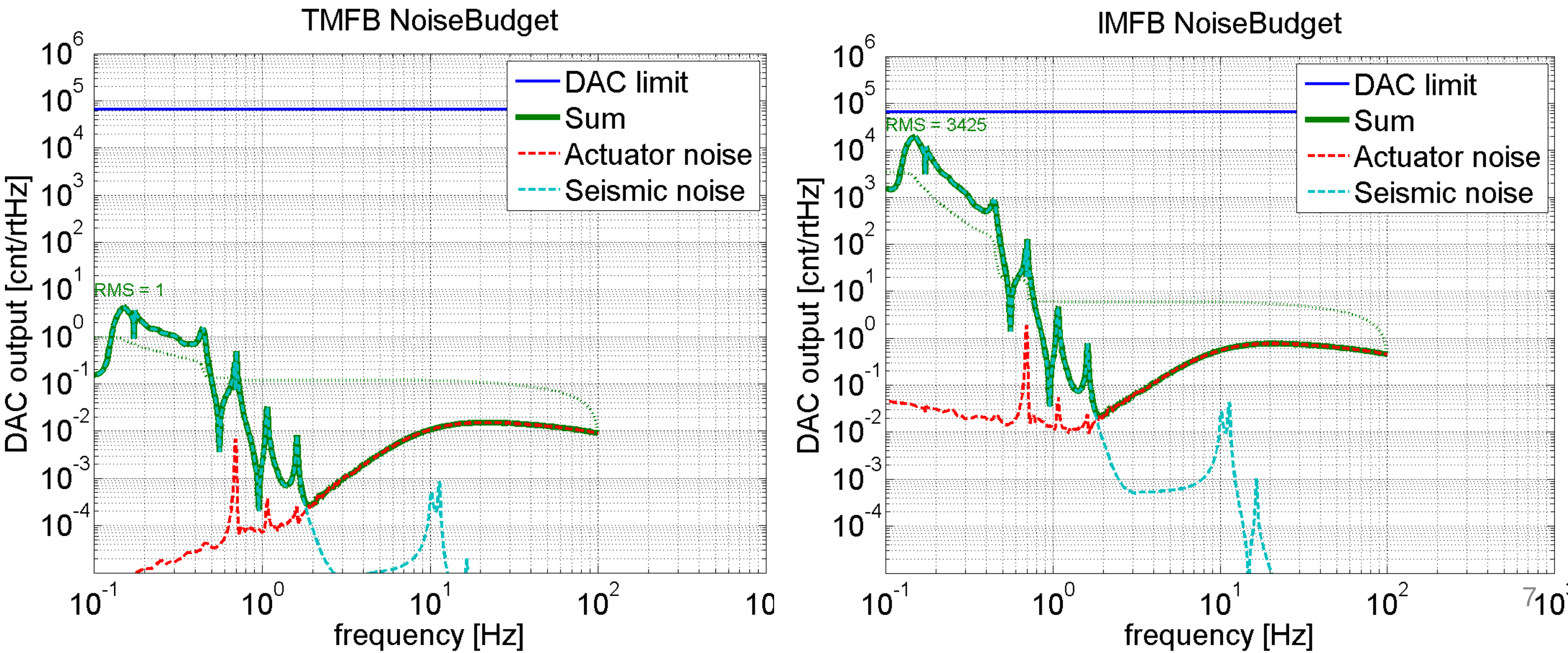
Simulated Actuator Noise

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



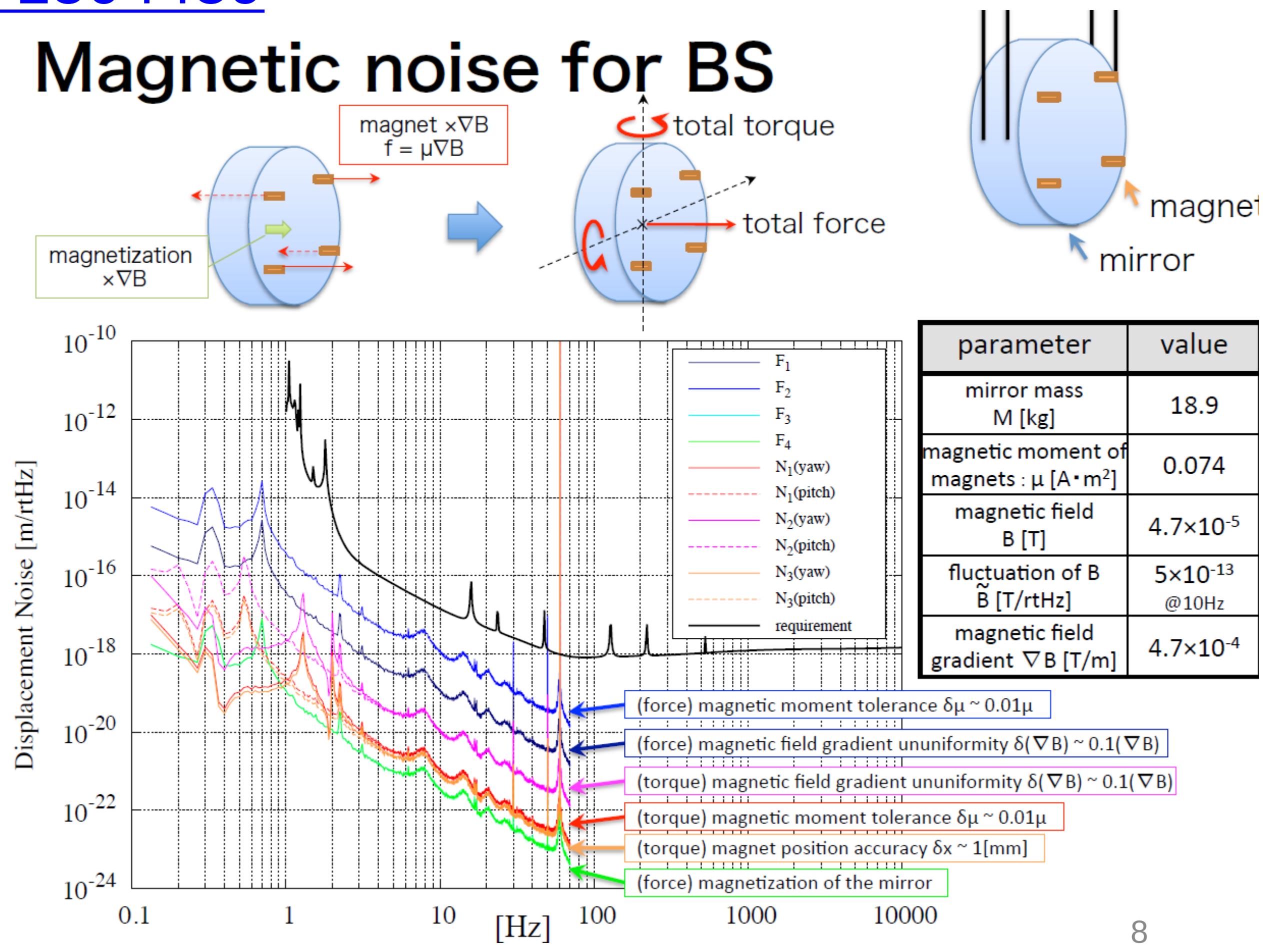
Simulated Feedback During Lock

- 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



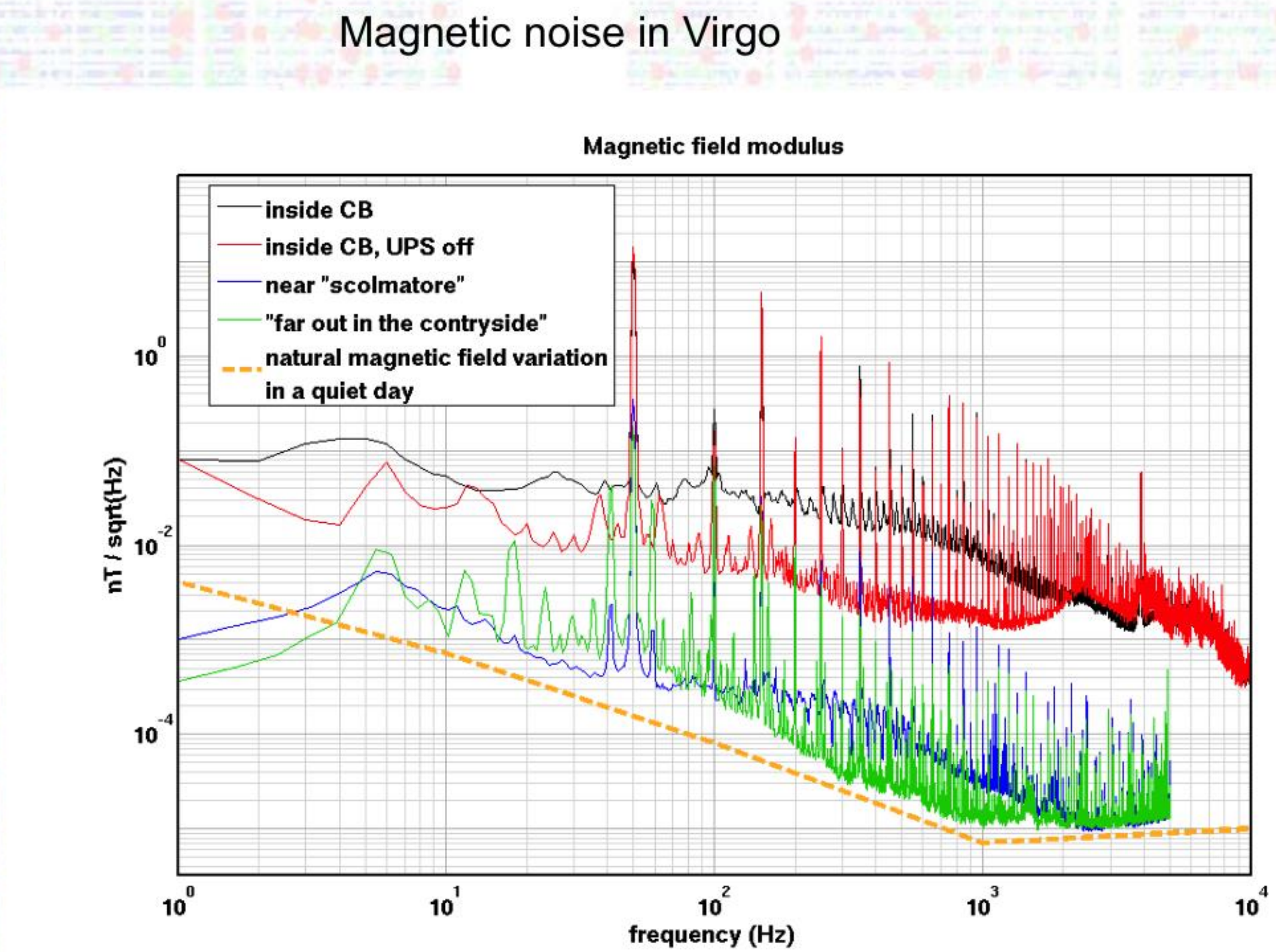
Simulated Magnetic Noise

- Magnetic noise is below requirement according to calculation done by Shimoda-kun
- Details in [JGW-T1504459]
- OSEM design: [JGW-D1504353]
- Magnetic noise with machines could be much larger (~ x50 from Virgo measurement)



parameter	value
mirror mass M [kg]	18.9
magnetic moment of magnets : μ [A･m²]	0.074
magnetic field B [T]	4.7×10^{-5}
fluctuation of B $\tilde{B}$ [T/rtHz]	5×10^{-13} @10Hz
magnetic field gradient ∇B [T/m]	4.7×10^{-4}

Magnetic Noise in Virgo



NdFeB or SmCo

- SmCo is better considering the Barkhausen noise, but a little fragile compared with NdFeB
- Magnetic moment/volume
  NdFeB: 8.78e5 A/m
  SmCo: 4.3e5 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?

- 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).

For Other Mirrors

- Use smaller magnets for SRM/SR2/SR3 TMs by factor of 1/40 to reduce actuator/magnetic noise.
- Use slightly smaller resistance for PRM/PR2/PR3 IM (maybe 7800 Ohm to 3800 Ohm for example). In the current design, it could saturate the DAC after locking.
- Use coil drivers with higher power for PRM/PR2/PR3 TM (resistance of less than 440 Ohm, output current of more than 45 mA). Since Type-Bp mirrors move too much (4.4 um/sec RMS after local damping), strong force is needed on lock acquisition.
- Slightly increase the number of coil turns (now 40 turns) or use bigger magnets (now 1mm dia, 5mm long) for IMC. It could saturate the DAC and the coil drivers on lock acquisition. Maybe not now since they are already installed.
- See JGW-T1503453 for detail