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Noise Requirement for QPDs on TMS

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2016 Update

- Requirement below 1 Hz was wrong
  - I was using wrong seismic noise data
  - replaced with Type A seismic noise in normal seismic
- Requirement on RMS motion was added

Scope

- Derive noise requirements for QPDs on TMS from ASC point of view

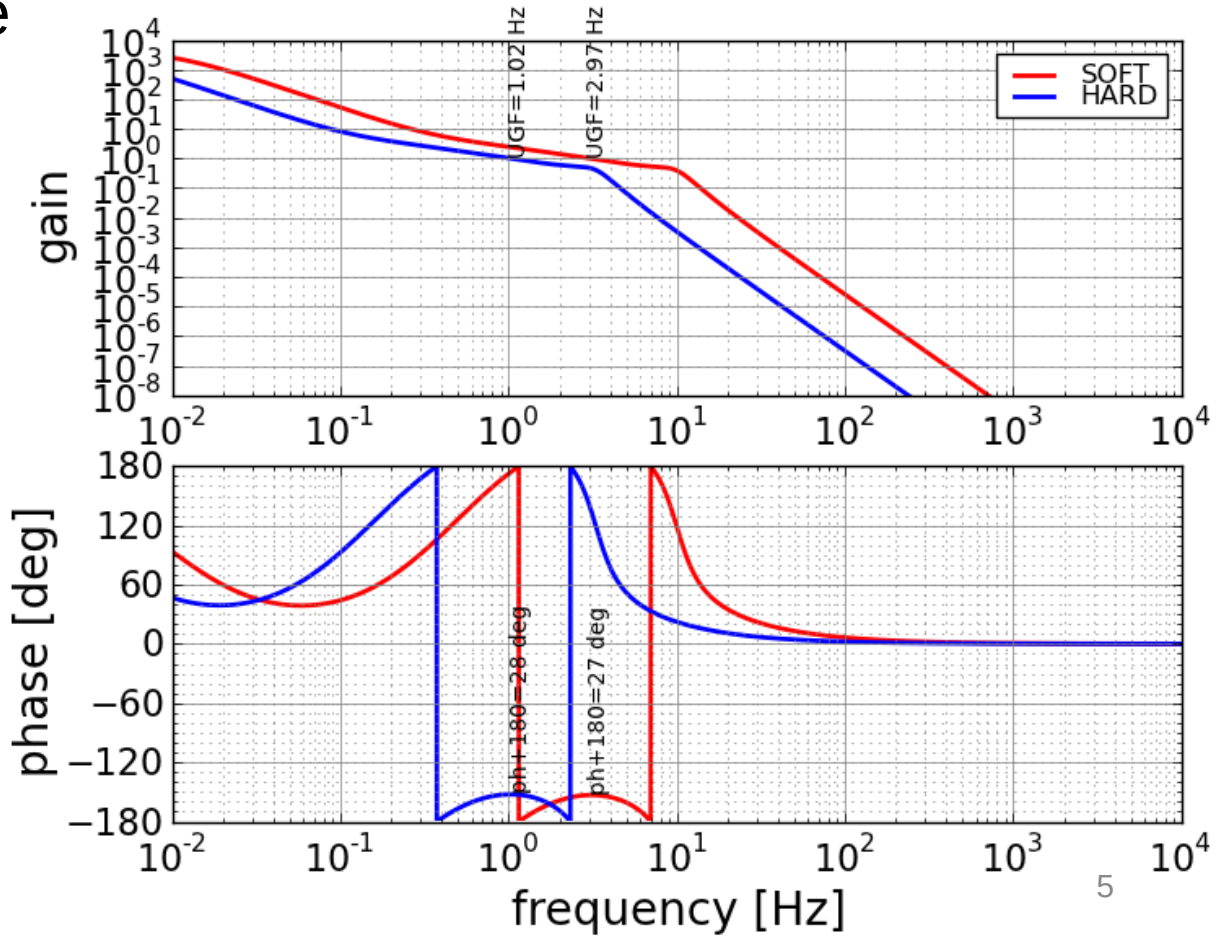
- References:
  - JGW-T1301878 (B=0 idea)
  - JGW-G1301664 (WFS shot noise requirement calculation described in detail in Japanese)
  - JGW-G1301779, Phys. Rev. D 88, 043007 (2013) (WFS shot noise requirement calculation; final version)
  - JGW-G1402171 (calculation method for noise coupling from TMS motion; note that conclusions are somewhat wrong; making B=0 does help)
  - JGW-G1402223 (TMS QPD noise calculation based on actual TMS design)

Requirement Derivation

- Derivation method is the same as the one done when deriving WFS shot noise requirement described in documents JGW-G1301664, JGW-G1301779, and Phys. Rev. D 88, 043007 (2013).
- WFS noise requirement calculation was already done by simulating ASC sensing matrix, assuming servo filters, and assuming beam mis-centering.
- WFS shot noise requirement is set to satisfy above requirement above 10 Hz.
- I redid the same calculation but in SOFT/HARD basis

Assumptions

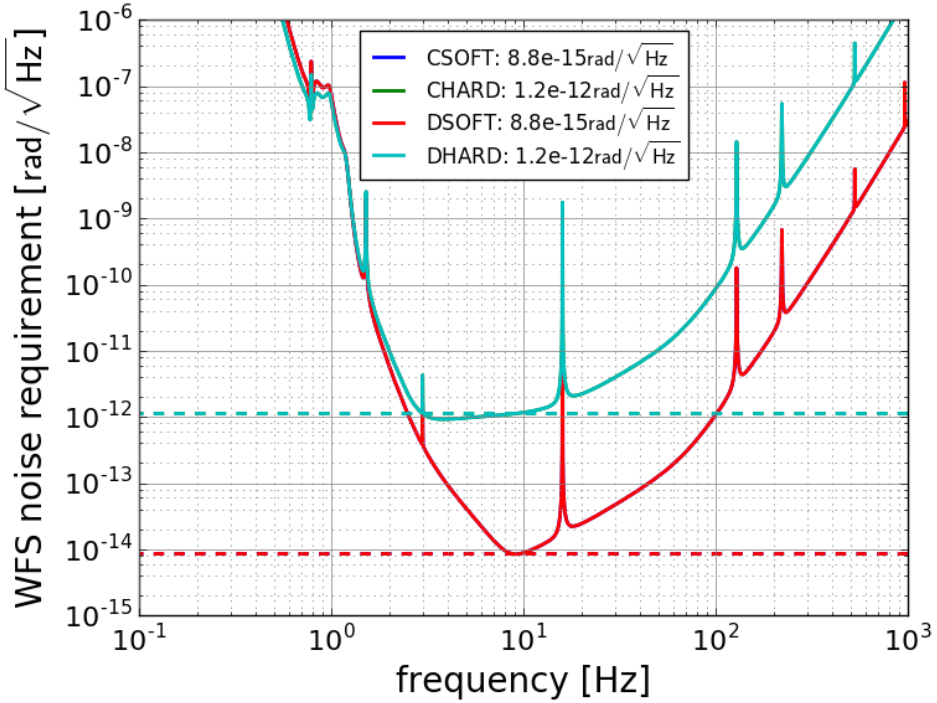
- mis-centering at ITMs, ETMs: 0.1 mm
- servo filters shown below (higher UGF for SOFT mode since it's unstable pole is at around 1 Hz)



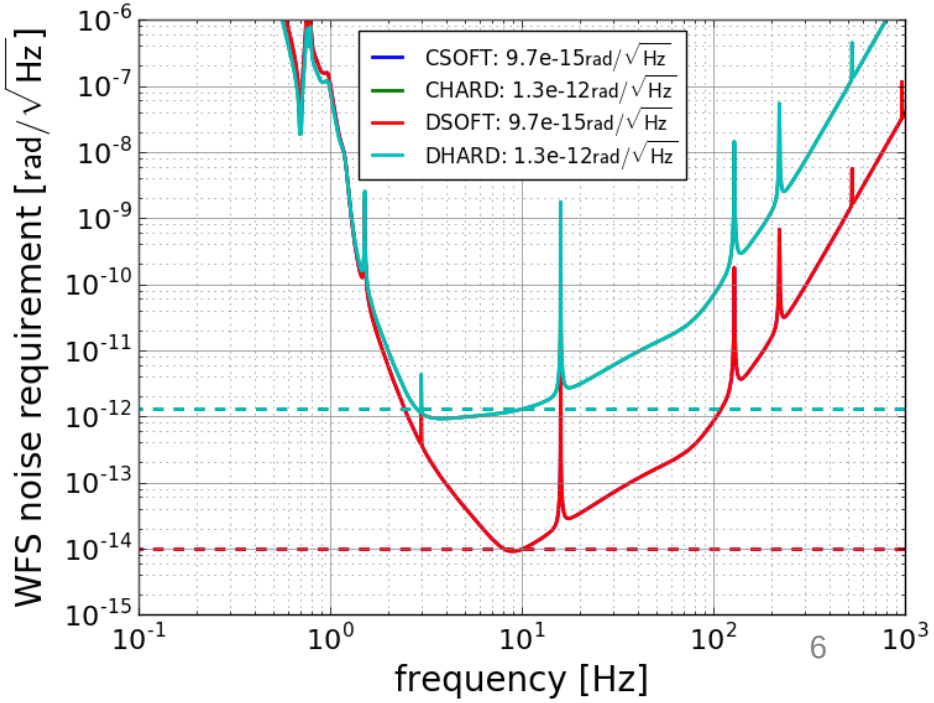
Requirement

- in terms of SOFT/HARD motion equivalent noise in rad/rtHz
- safety factor = sqrt(22) for 11 mirrors, pitch/yaw
- 1e-7 rad/rtHz @ 1 Hz, 1e-14 rad/rtHz @ 10 Hz for SOFT
- 1e-7 rad/rtHz @ 1 Hz, 1e-12 rad/rtHz @ 10 Hz for HARD
- requirement for SOFT is more severe because of higher UGF

BRSE



DRSE

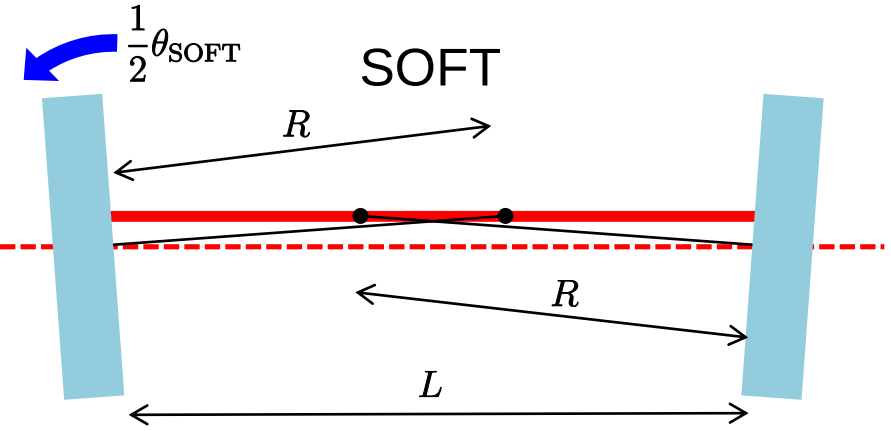


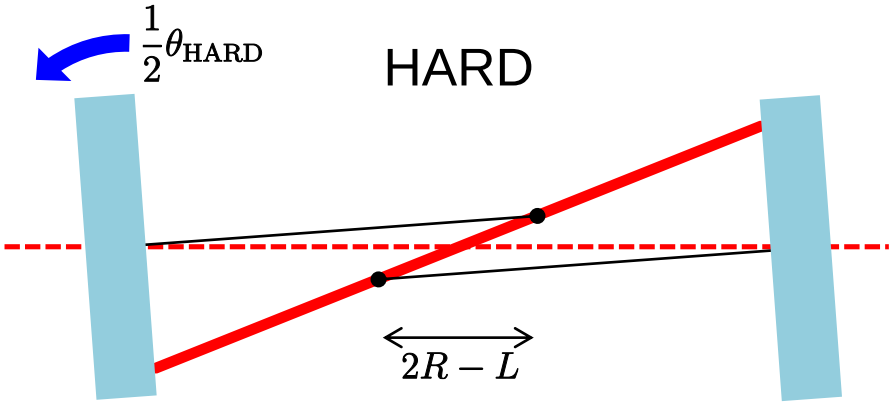
Requirement on RMS

- the requirement spectra in p.6 was derived assuming beam spot motion on mirror to be less than 0.1 mm RMS
- but there is also requirement on mirror angular motion to achieve 0.1 mm RMS beam spot motion
- Requirement on RMS

SOFT: $$\theta_{\mathrm{SOFT}} < \frac{2d}{R} = \frac{2 \times 0.1\ \mathrm{mm}}{1.9\ \mathrm{km}} = 0.1\ \mathrm{urad}$$

HARD: $$\theta_{\mathrm{HARD}} < \frac{2d}{RL/(2R-L)} = \frac{2 \times 0.1\ \mathrm{mm}}{7.125\ \mathrm{km}} = 0.03\ \mathrm{urad}$$





To Do (as of Apr 2016)

- we don’t want to do much vibration isolation for TMS
- requirement on angular motion for TMS could be very strict
- take combination of SOFT and HARD signal using TMS QPDs which is insensitive to TMS angular motion
- orthogonal combination of SOFT and HARD signal will be taken at REFL/AS WFS

To Do (as of Apr 2014)

- design TMS (beam reducing telescope, Gouy phase telescope) that satisfy the requirement
- if sensitivity for SOFT meets the requirement, use TMS QPDs to sense SOFT
- if sensitivity for HARD meets the requirement, but not SOFT, use TMS QPDs to sense HARD
- if TMS QPDs don't satisfy the requirement above 1 Hz because of TMS motion, we need suspended TMS (according to Daniel's calculation JGW-G1402223, it is likely that we have to suspend)
- if TMS QPDs don't satisfy the requirement below 1 Hz, we have to re-think ASC scheme (use B=0 method at TMS and use REFL/AS QPDs also to diagonalize SOFT/HARD)