WFS Shot Noise Requirement

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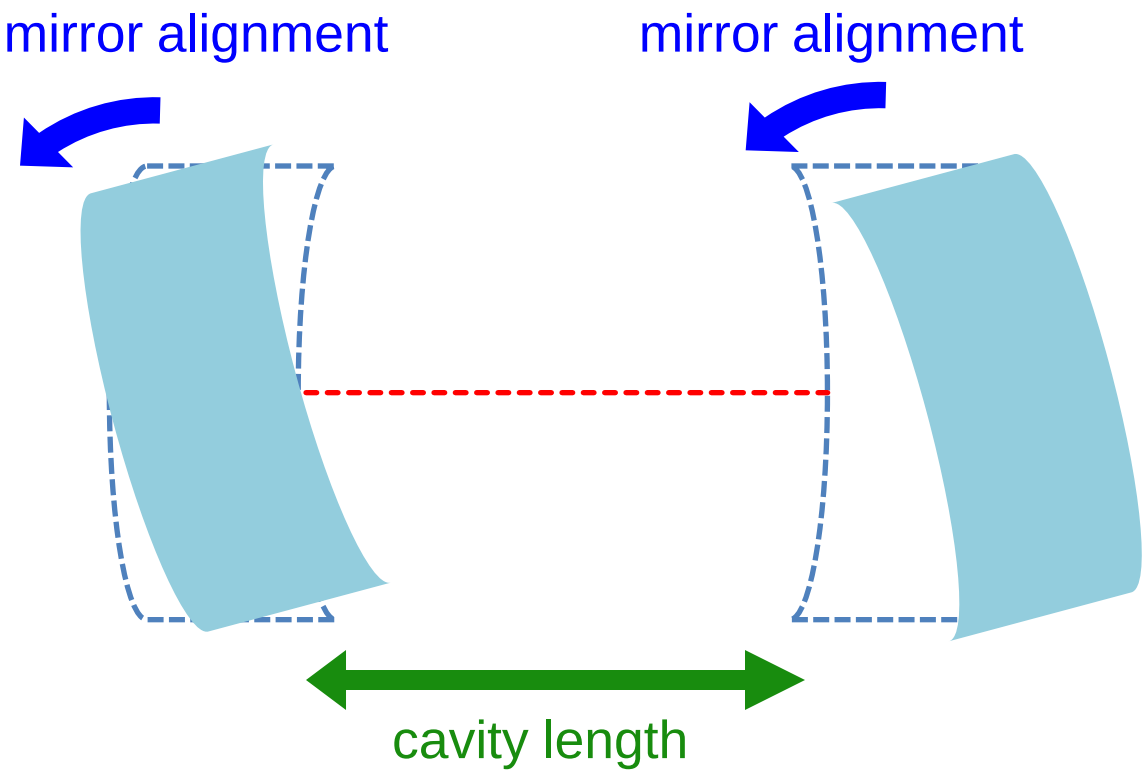
What is ASC

- Alignment Sensing and Control
- essential for high sensitivity interferometers(IFO)



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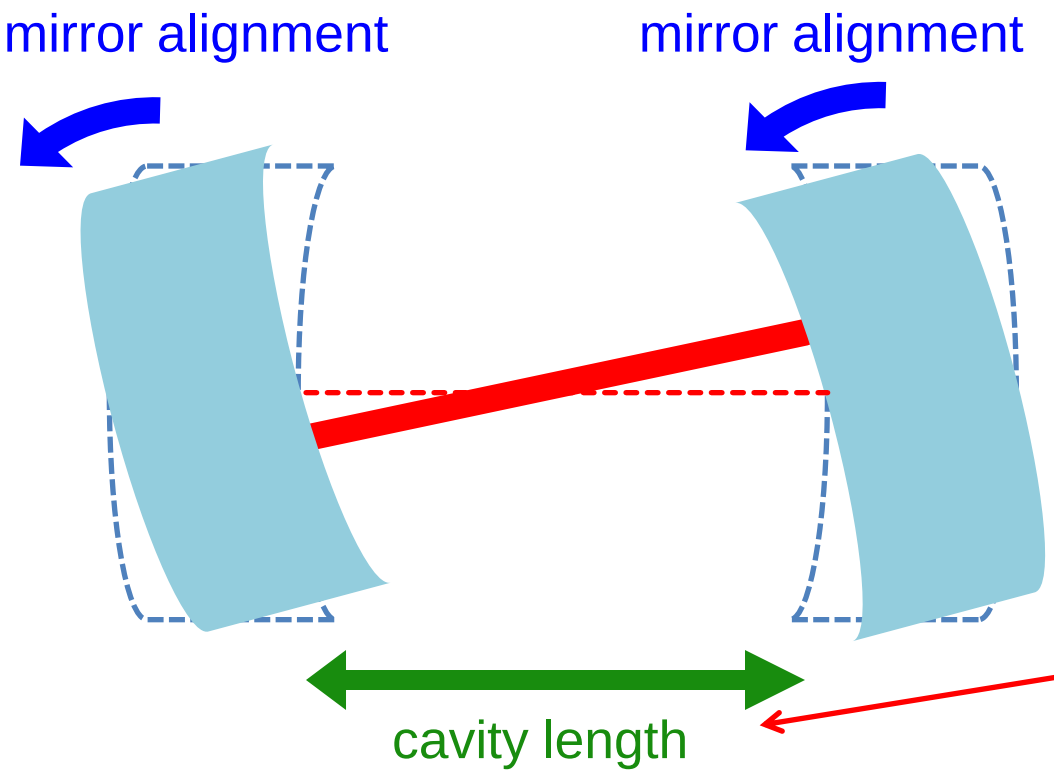
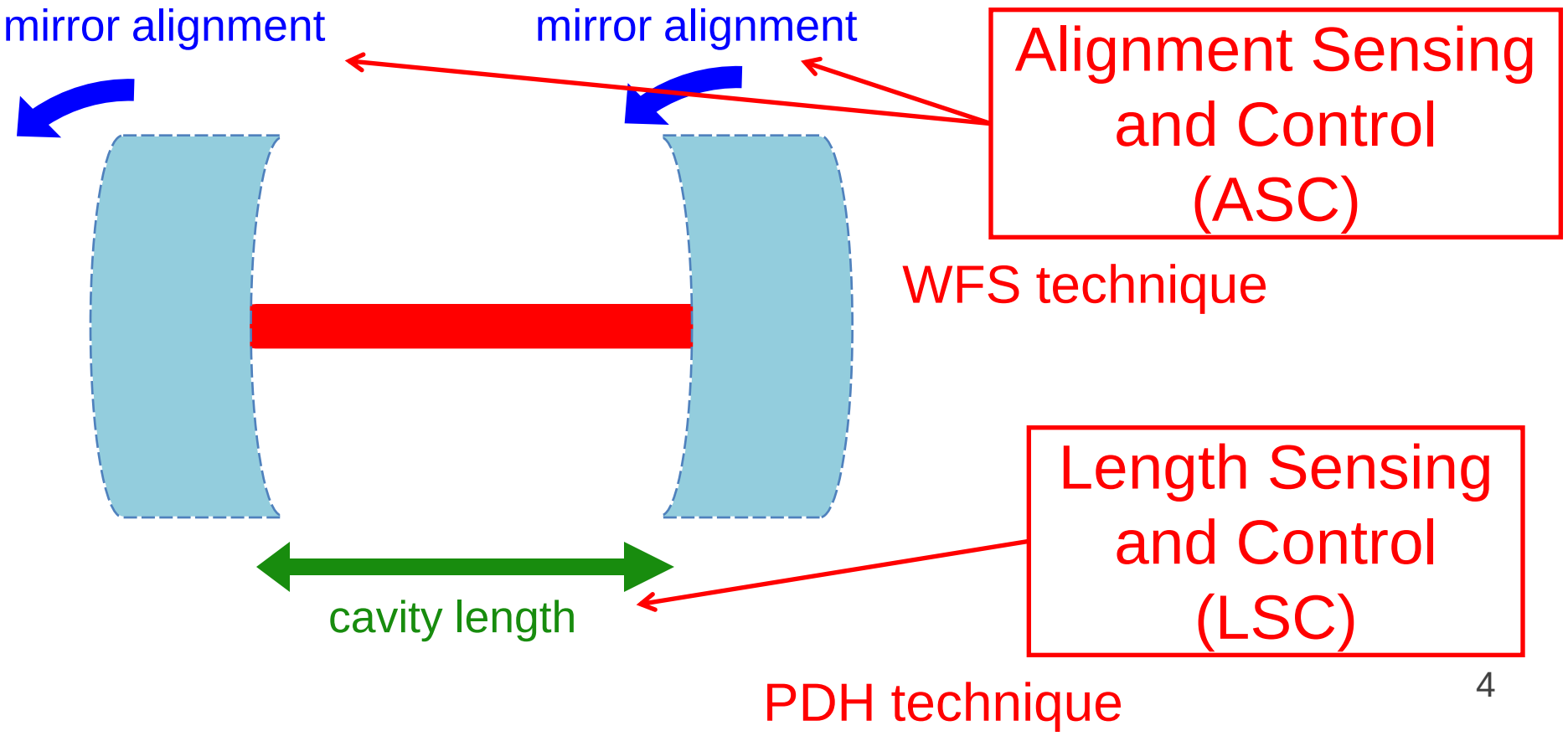


Length Sensing and Control (LSC)

PDH technique

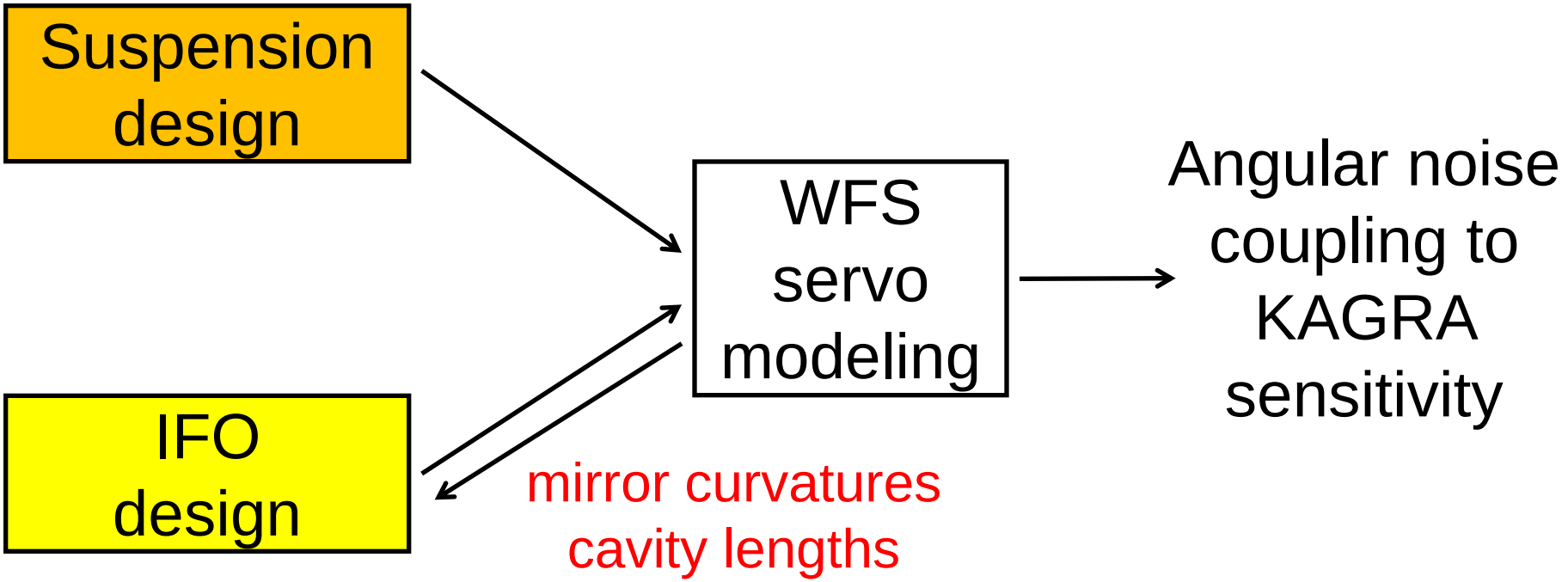
What is ASC

- Alignment Sensing and Control
- essential for high sensitivity interferometers(IFO)



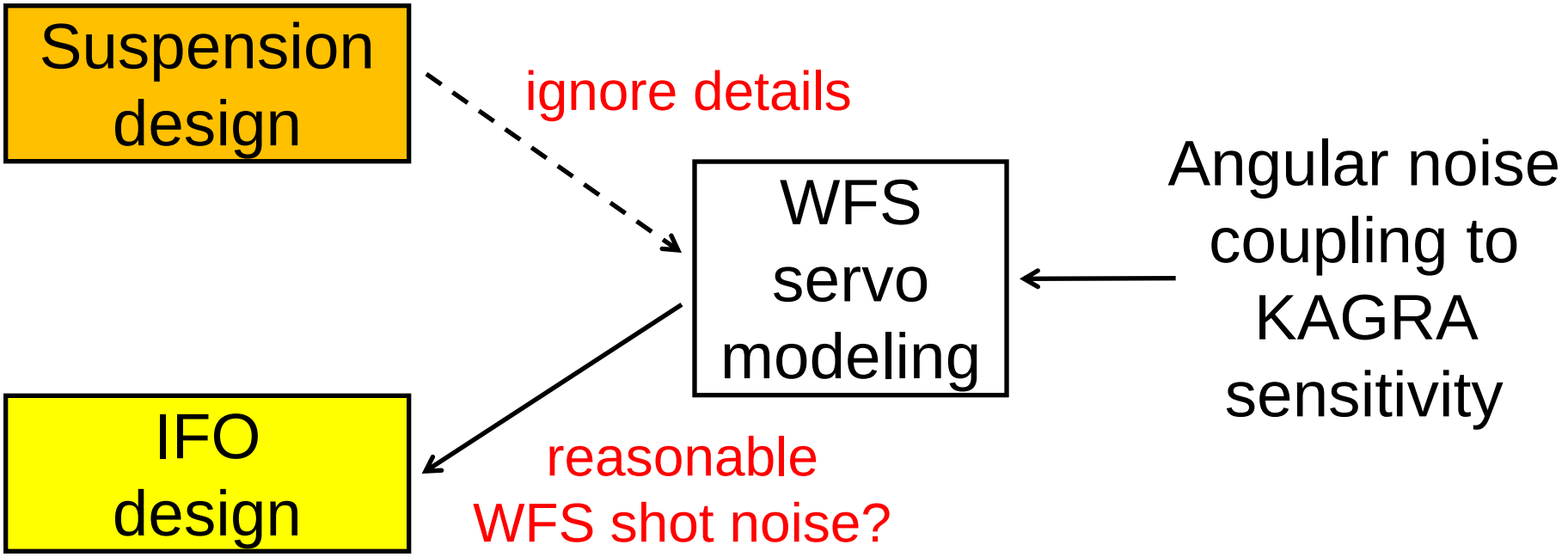
What have done previously

- developed WFS servo model
- finalized IFO design



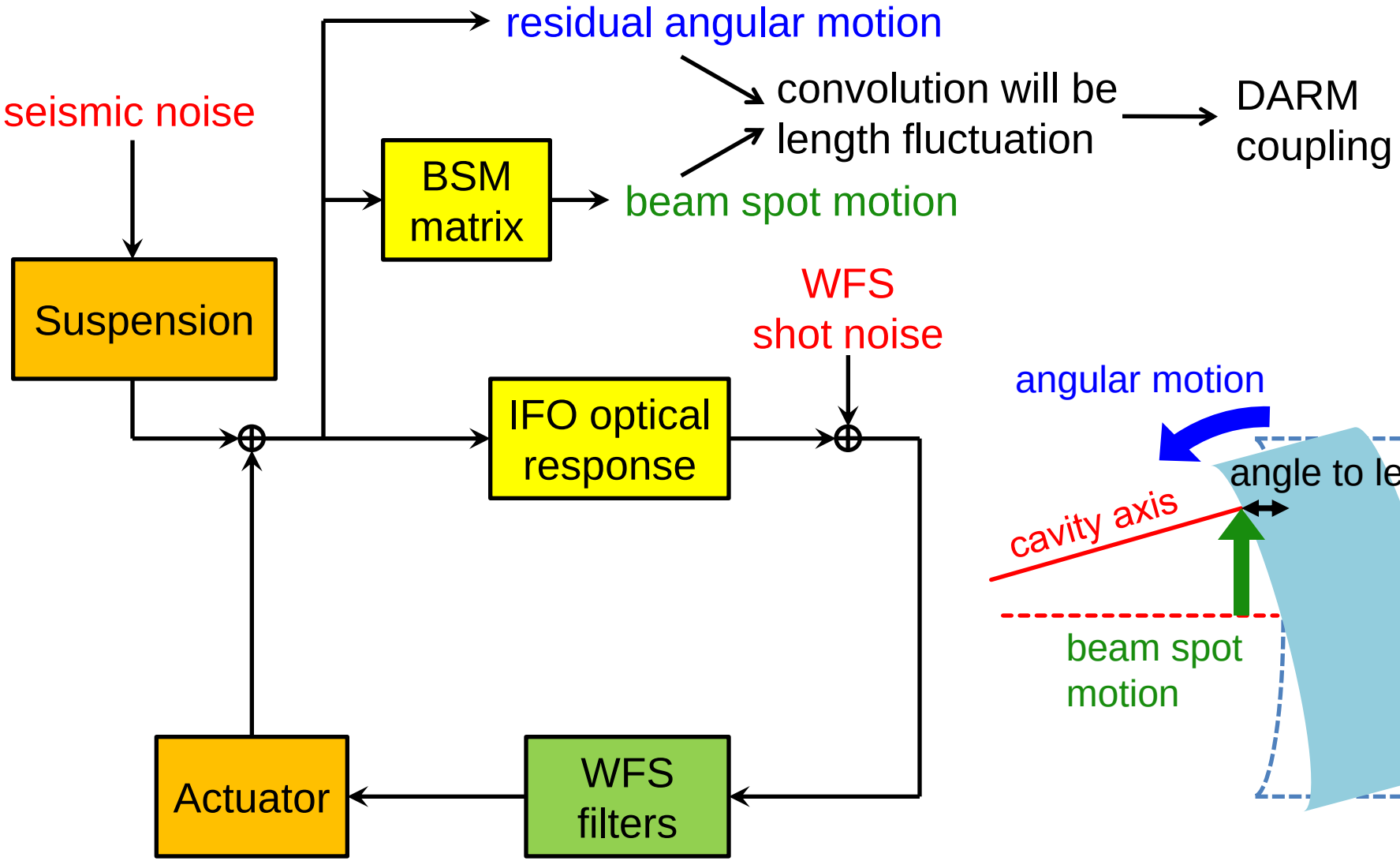
This time

- check IFO design from ASC point of view
- ignore suspension details

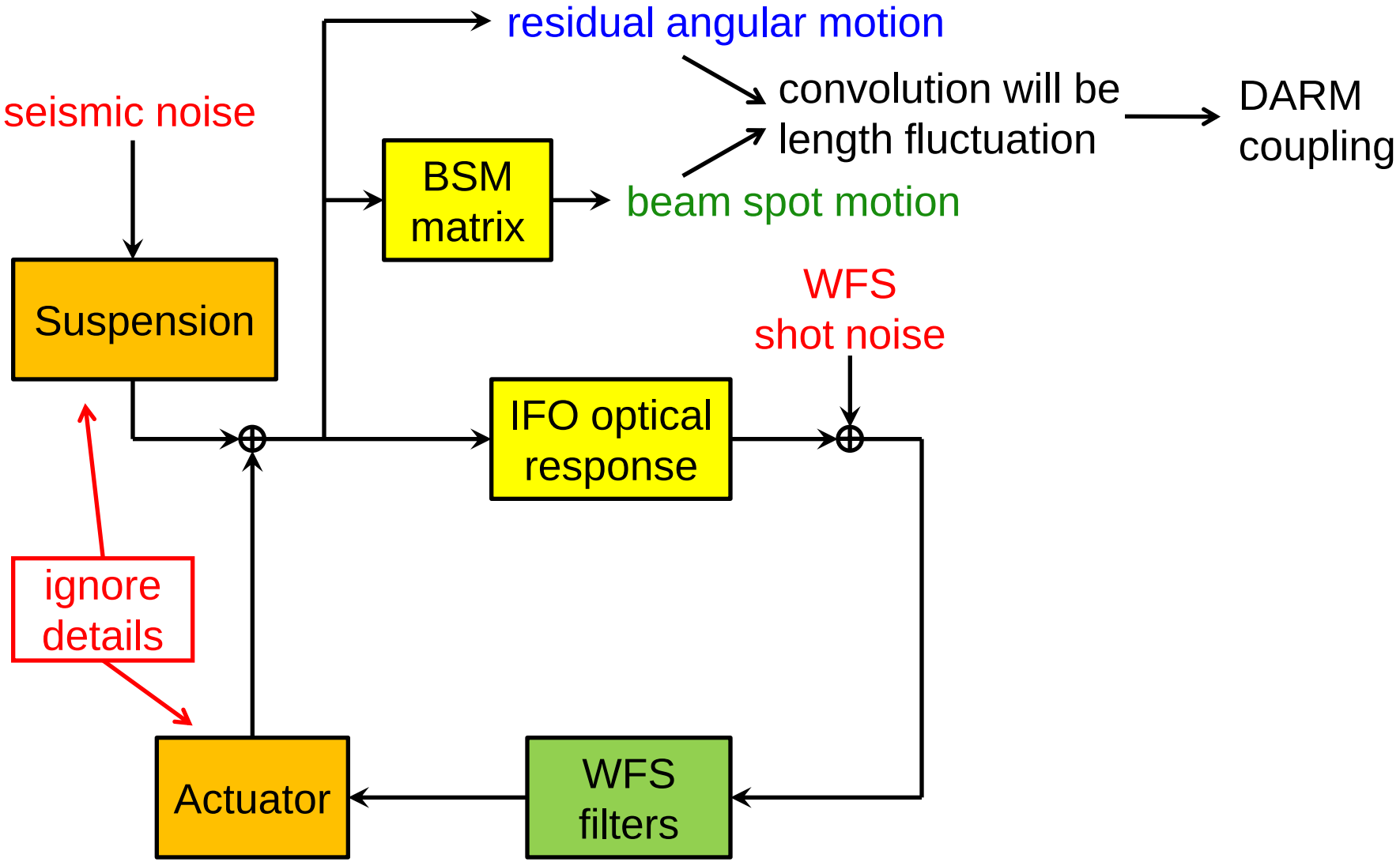


For details, see
- Y. Aso, Y. Michimura, K. Somiya *et al.*: arXiv:1360.6747 (PRD accepted)
- Y. Michimura: JGW-G1301664 (Japanese)

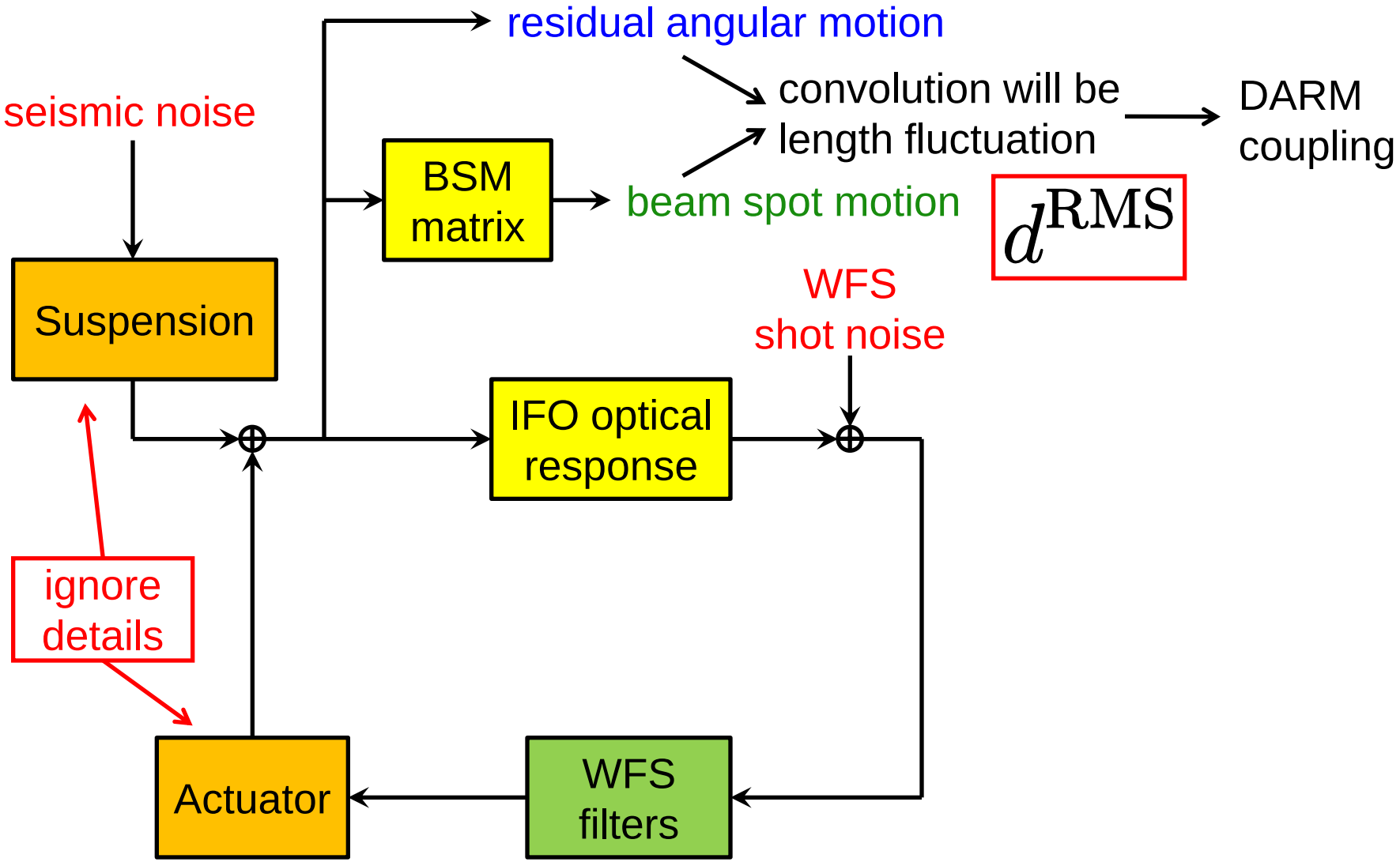
WFS servo model



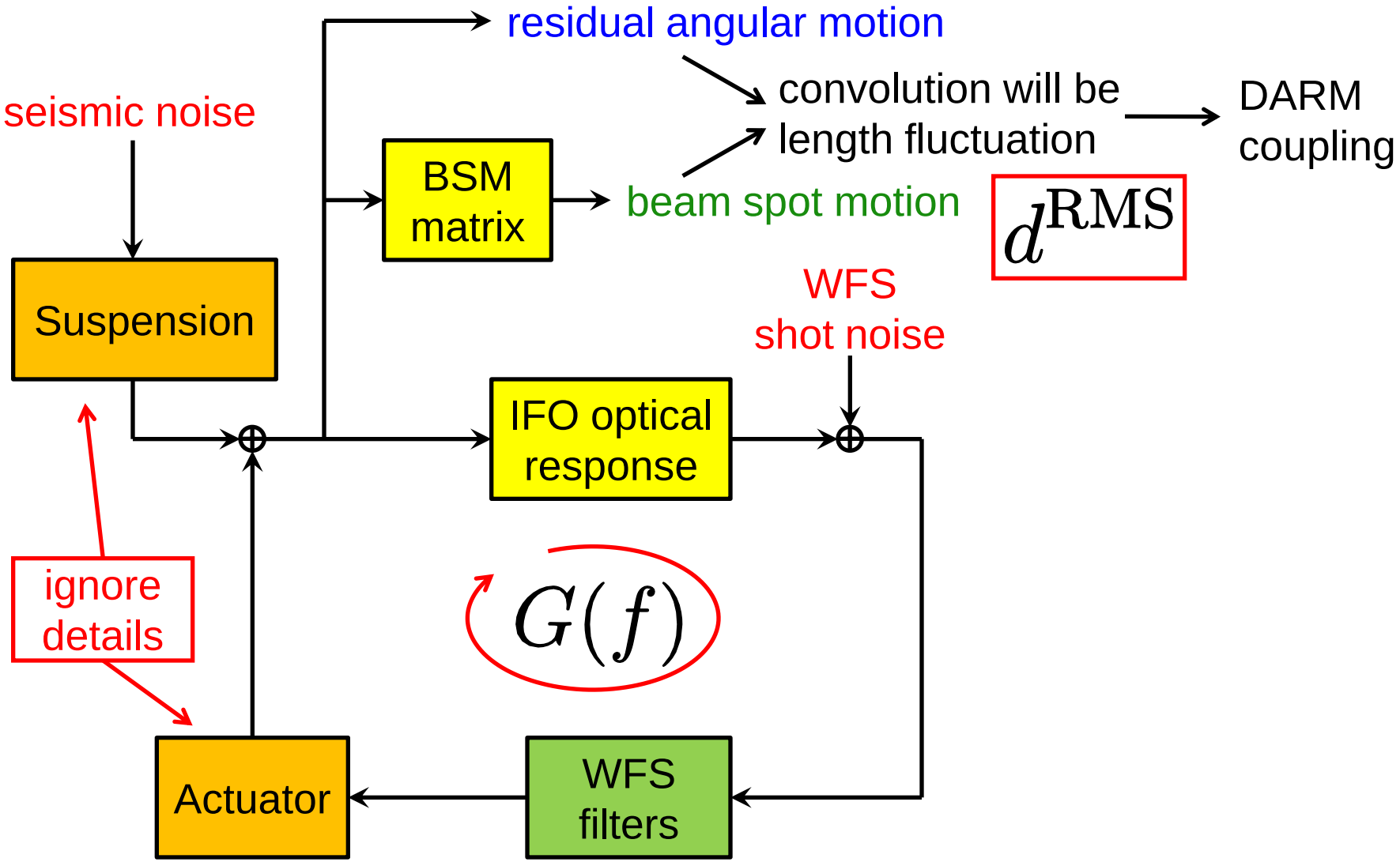
1. Ignore suspension details



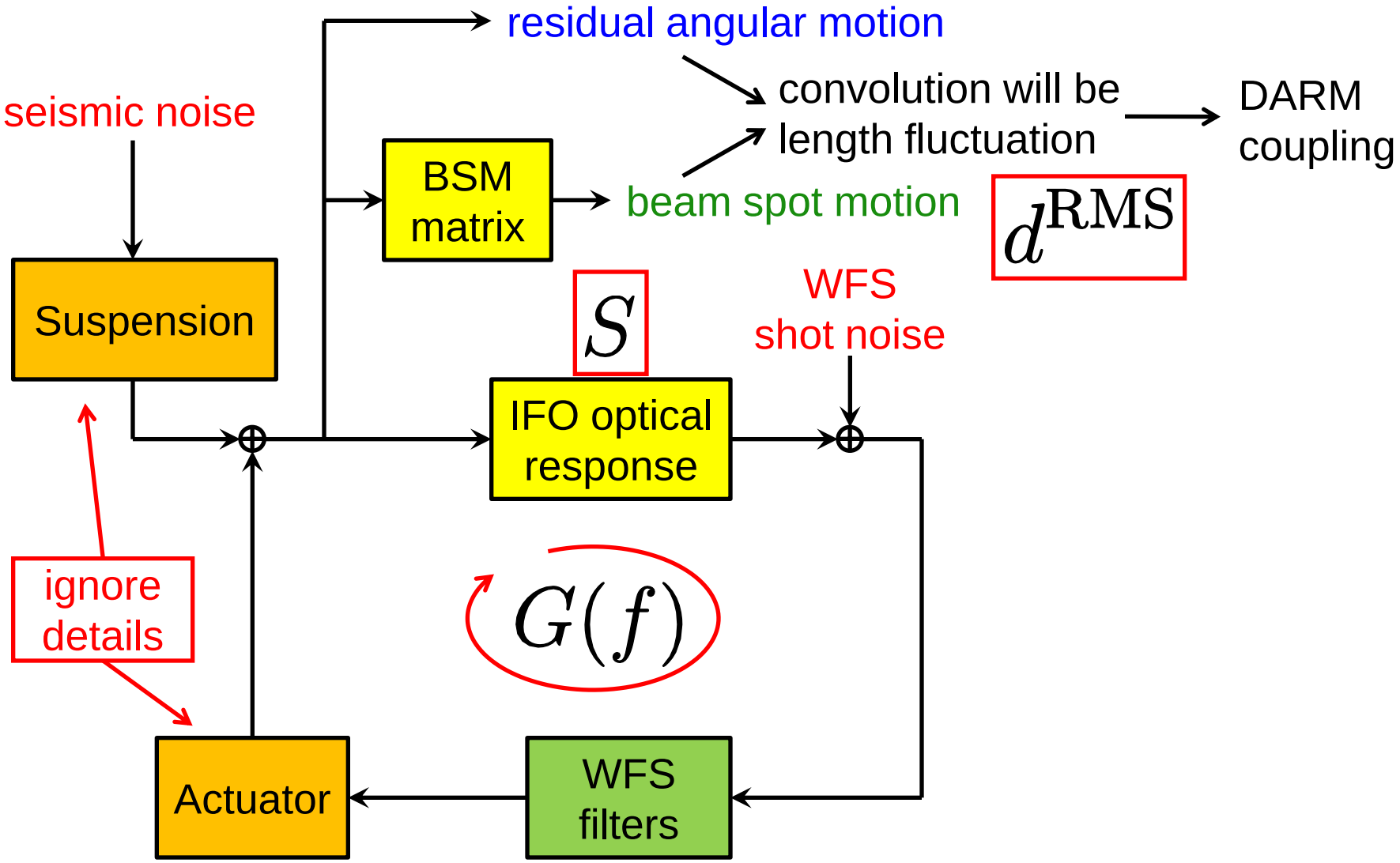
2. Suppose RMS of BSMs



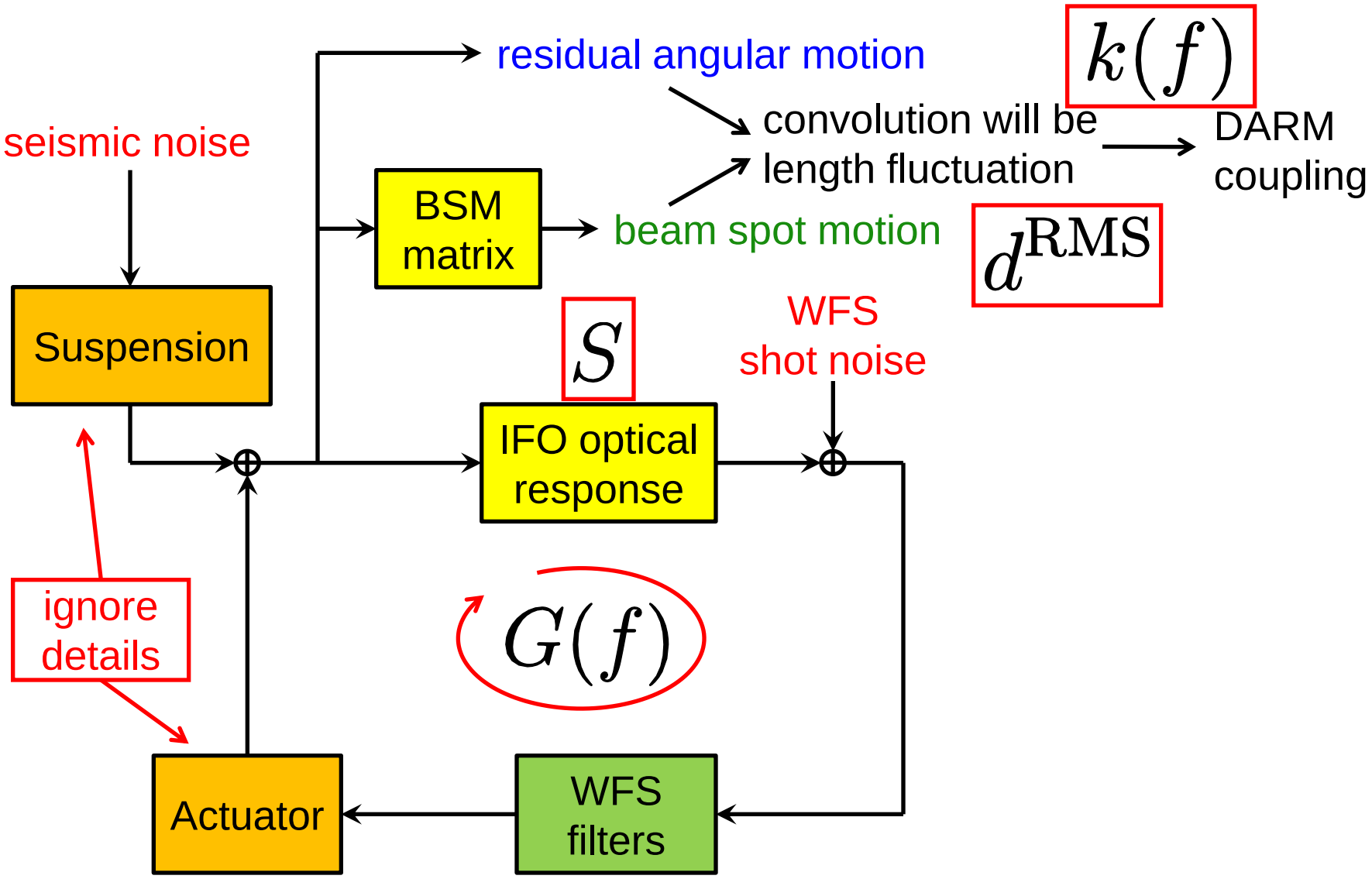
3. Suppose WFS OLTFs



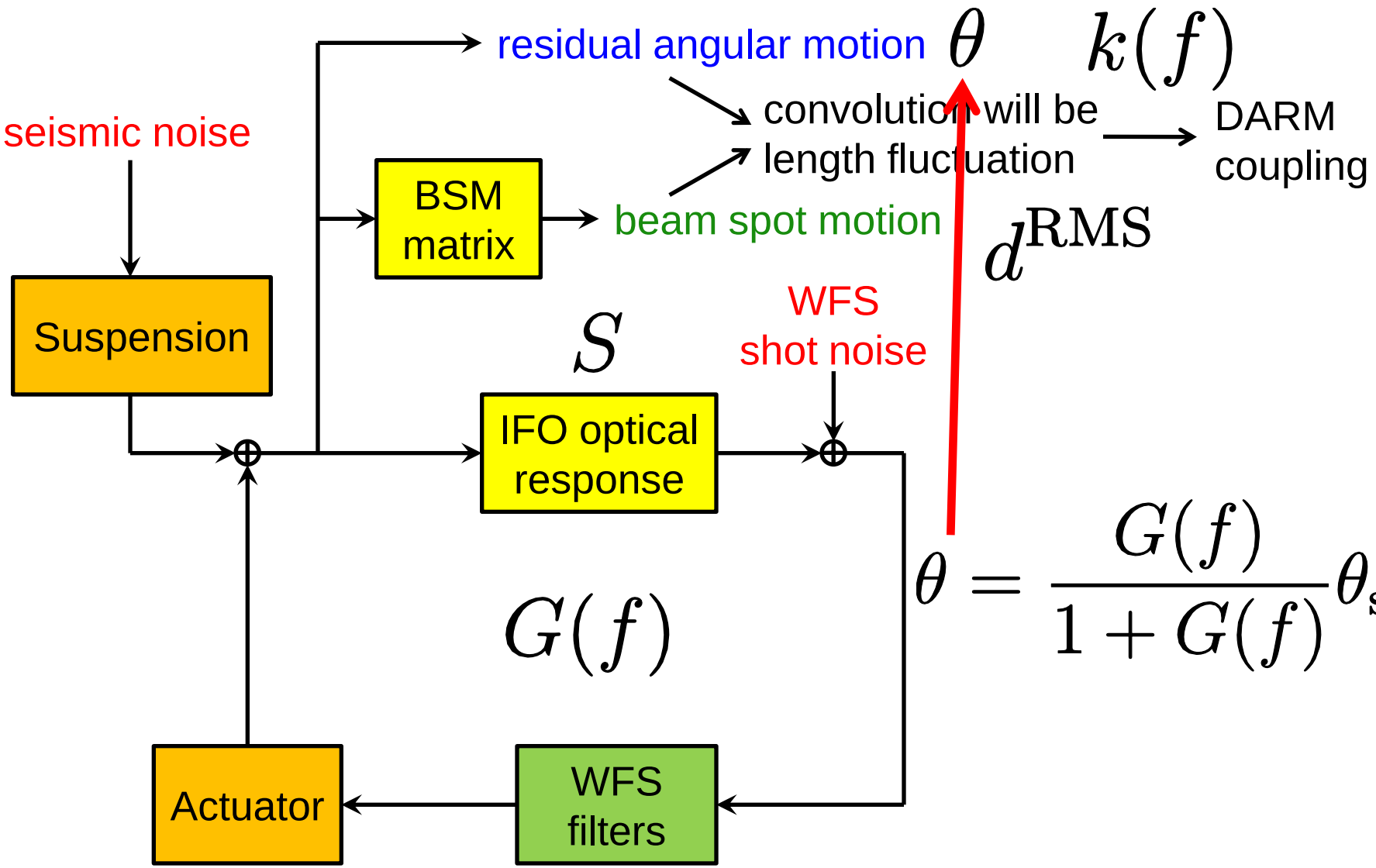
4. Simulate IFO response



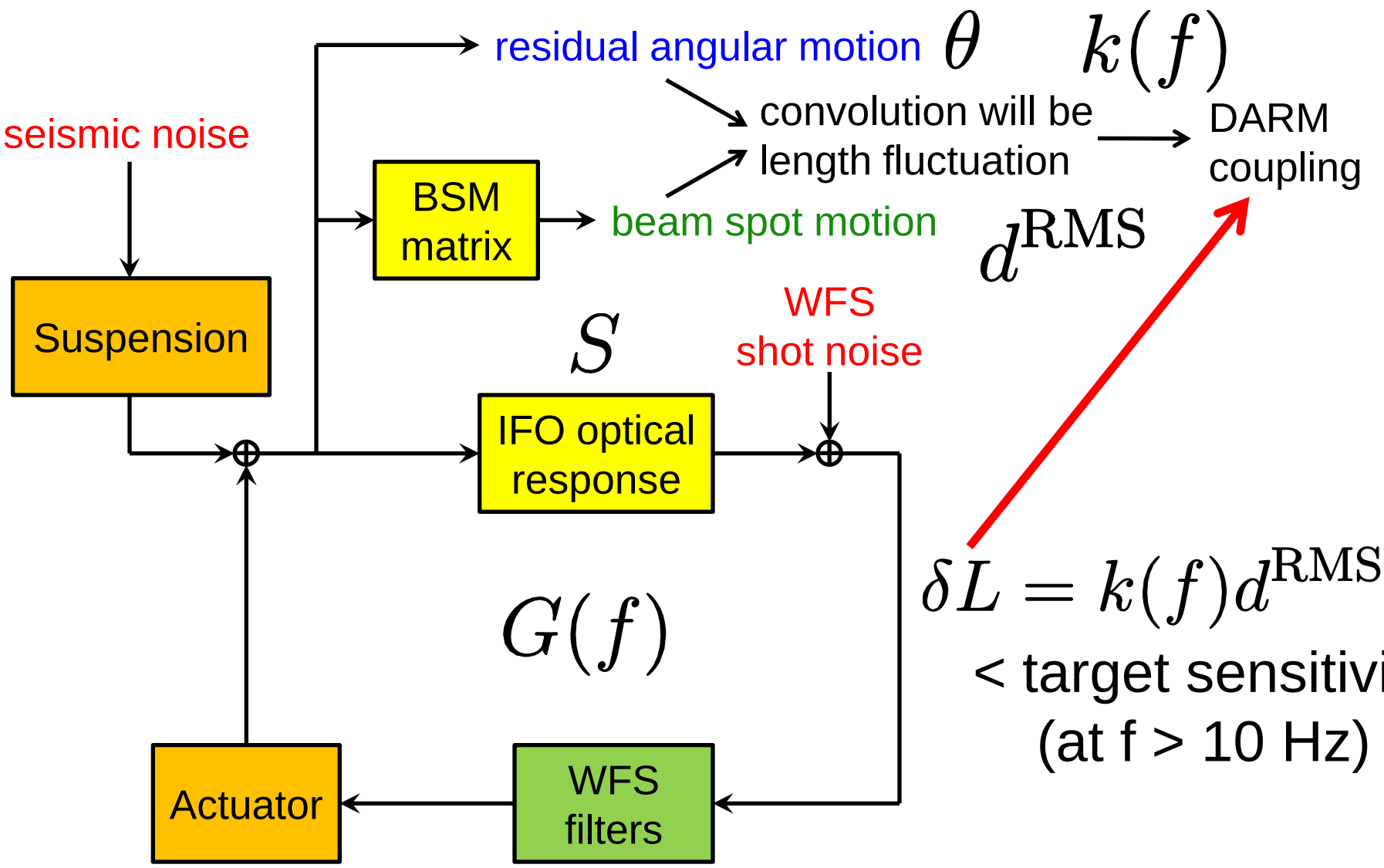
5. Simulate DARM coupling



Residual angular motion



Angle to DARM coupling



$$\delta L = k(f) d^{\mathrm{RMS}} \theta$$

< target sensitivity
(at f > 10 Hz)

Assumptions

- beam spot motion

$$d^{\mathrm{RMS}} < 0.1\ \mathrm{mm} \quad \text{for TMs}$$

$$d^{\mathrm{RMS}} < 1\ \mathrm{mm} \quad \text{for others}$$

  - comes from beam jitter requirement by Yoichi

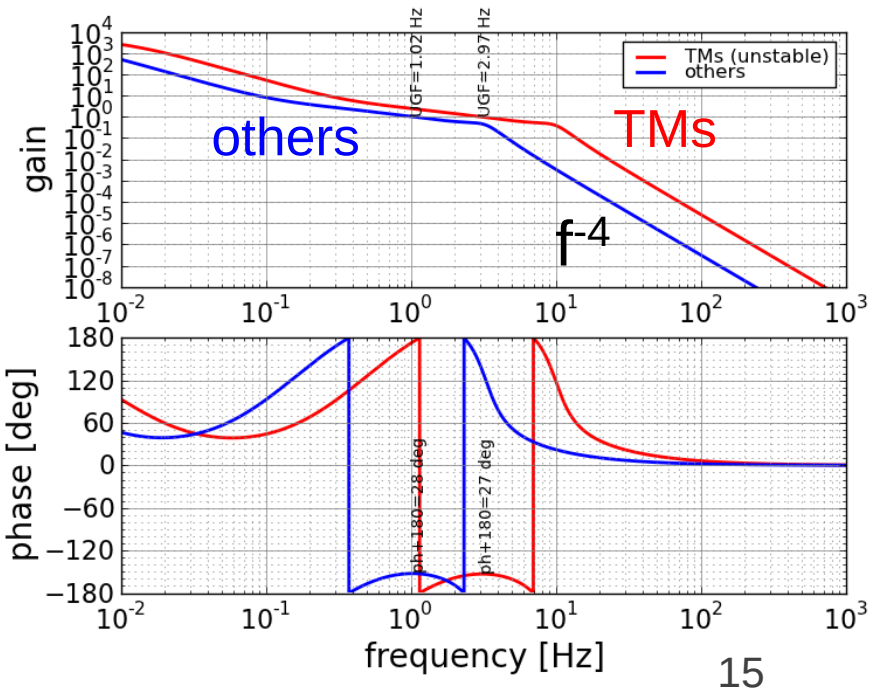
$$\theta^{\mathrm{RMS}} < 10^{-8}\ \mathrm{rad}$$

- WFS OLTFs

  UGF 3 Hz for TMs

  UGF 1 Hz for others

  - comes from Sidles-Sigg instability and mirco seismic peak ~0.5 Hz



Required/simulated WFS shot noise

- simulation done using Optickle
- not all meet the requirement

TABLE VIII. WFS shot noise requirements and the simulated shot noises. All values are in the unit of $\mathrm{rad}/\sqrt{\mathrm{Hz}}$.

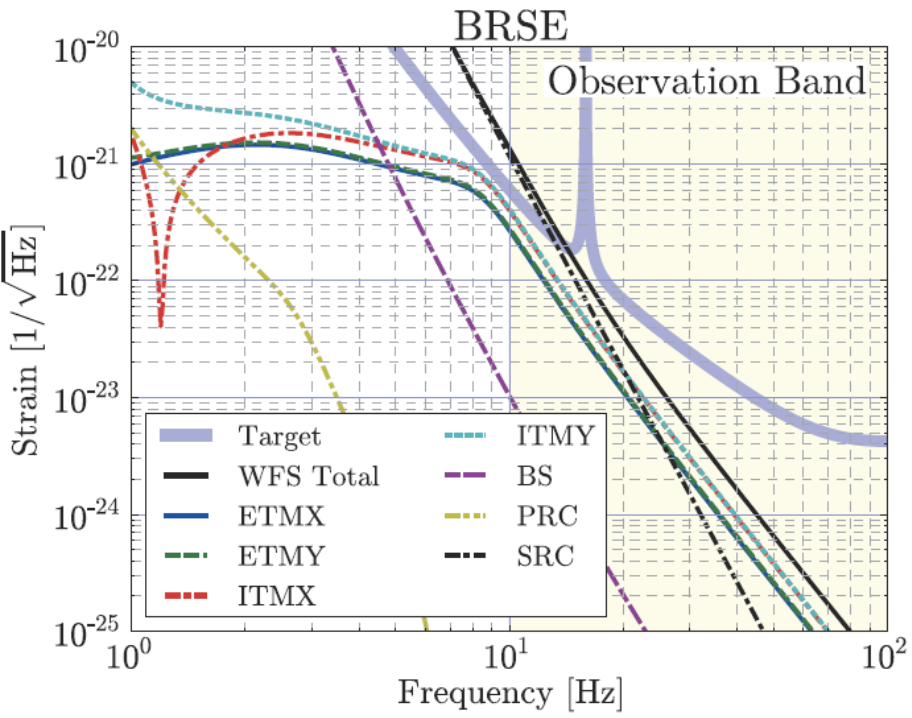
	BRSE		DRSE	
	Requirement	Simulated	Requirement	Simulated
ETMX	8.8×10^{-15}	1.9×10^{-14}	9.7×10^{-15}	2.9×10^{-14}
ETMY	8.8×10^{-15}	1.9×10^{-14}	9.7×10^{-15}	1.9×10^{-14}
ITMX	8.8×10^{-15}	2.8×10^{-14}	9.7×10^{-15}	3.7×10^{-14}
ITMY	8.8×10^{-15}	2.8×10^{-14}	9.7×10^{-15}	2.8×10^{-14}
BS	9.2×10^{-12}	7.4×10^{-13}	1.5×10^{-11}	3.1×10^{-12}
PR3	3.2×10^{-09}	2.7×10^{-13}	1.4×10^{-09}	1.1×10^{-12}
PR2	3.2×10^{-09}	1.0×10^{-13}	1.4×10^{-09}	3.1×10^{-13}
PRM	3.2×10^{-09}	8.9×10^{-14}	1.4×10^{-09}	6.1×10^{-13}
SR3	7.4×10^{-12}	7.7×10^{-12}	1.3×10^{-11}	1.3×10^{-11}
SR2	7.4×10^{-12}	6.6×10^{-11}	1.3×10^{-11}	1.2×10^{-10}
SRM	7.4×10^{-12}	1.4×10^{-12}	1.3×10^{-11}	6.8×10^{-12}

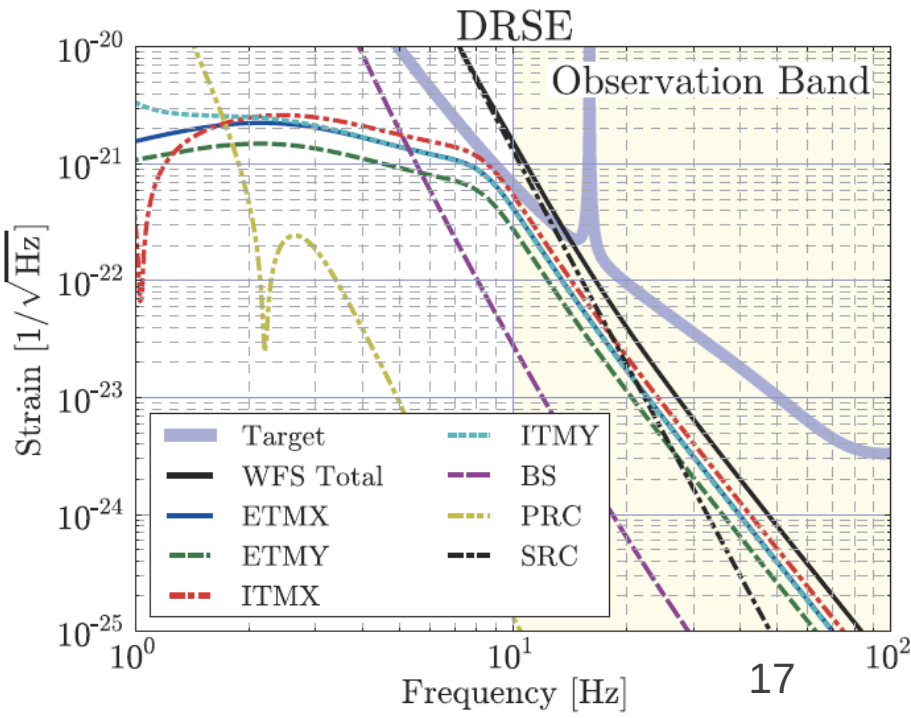
TMs
2x to 4x larger

SR2
~10x larger

DARM coupling of WFS shot noise

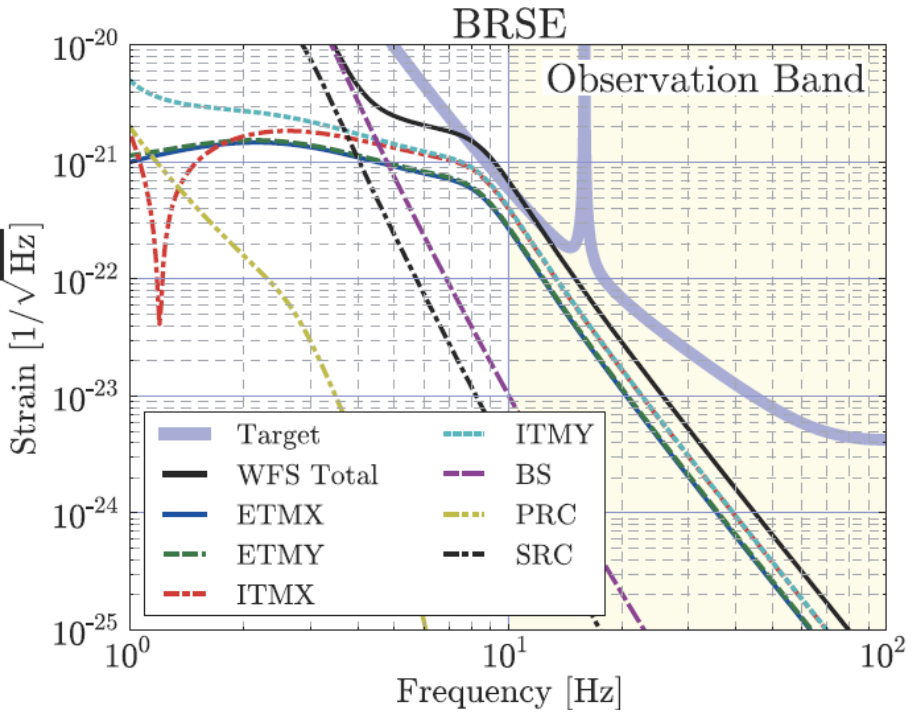
- WFS shot noise of SR2 contributes too much
  → may be we should not control SR2 by WFS

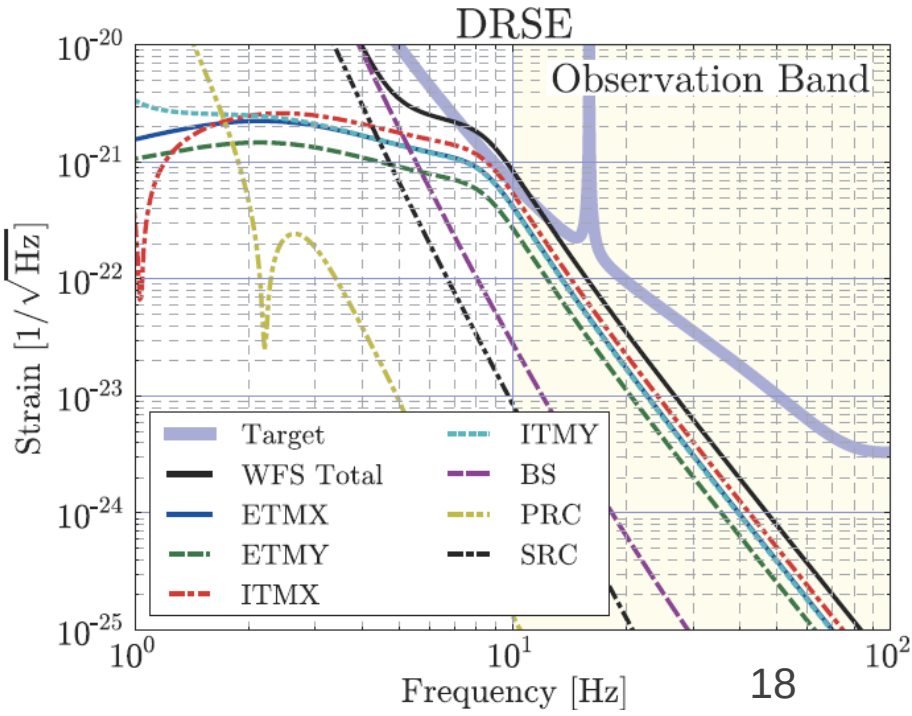




DARM coupling of WFS shot noise

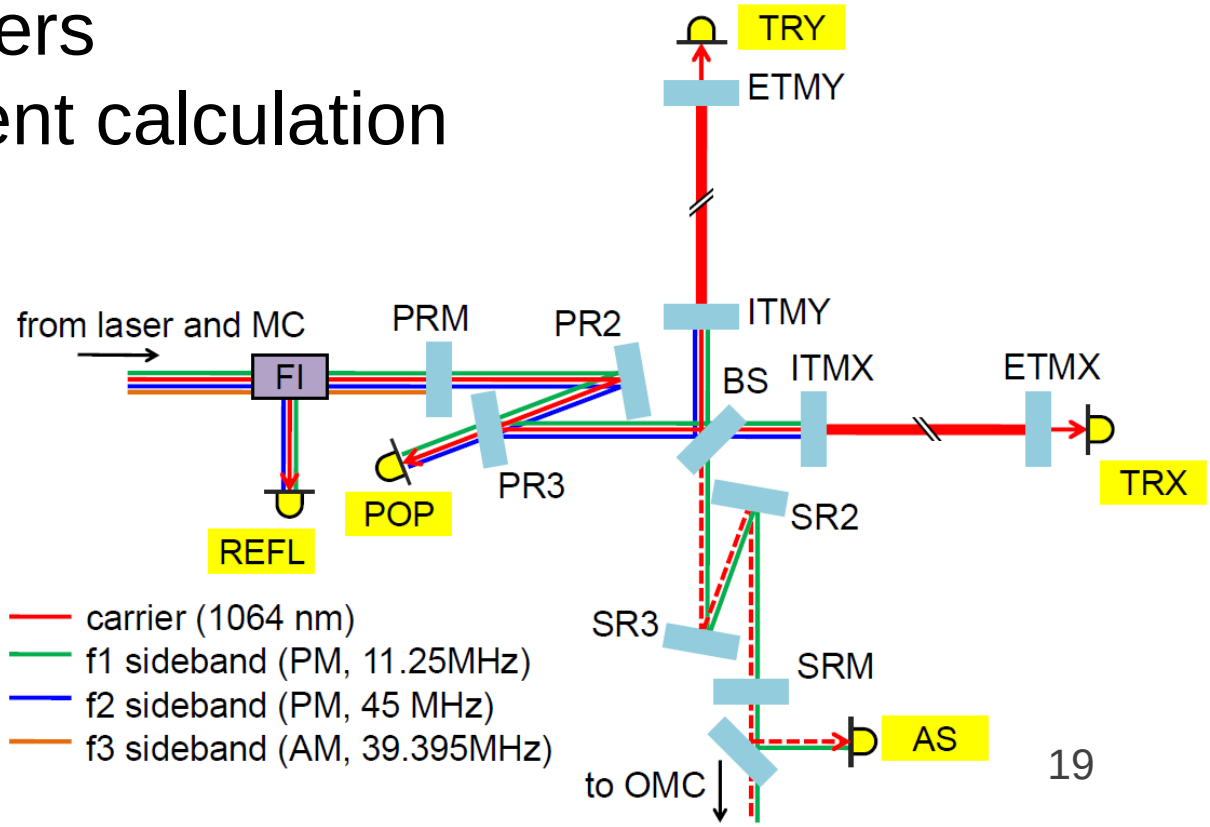
- turning off SR2 WFS servo helps
- not perfect, but OK
  BRSE IR 217.6 Mpc → 217.0 Mpc
  DRSE IR 237.6 Mpc → 237.4 Mpc





Further concerns

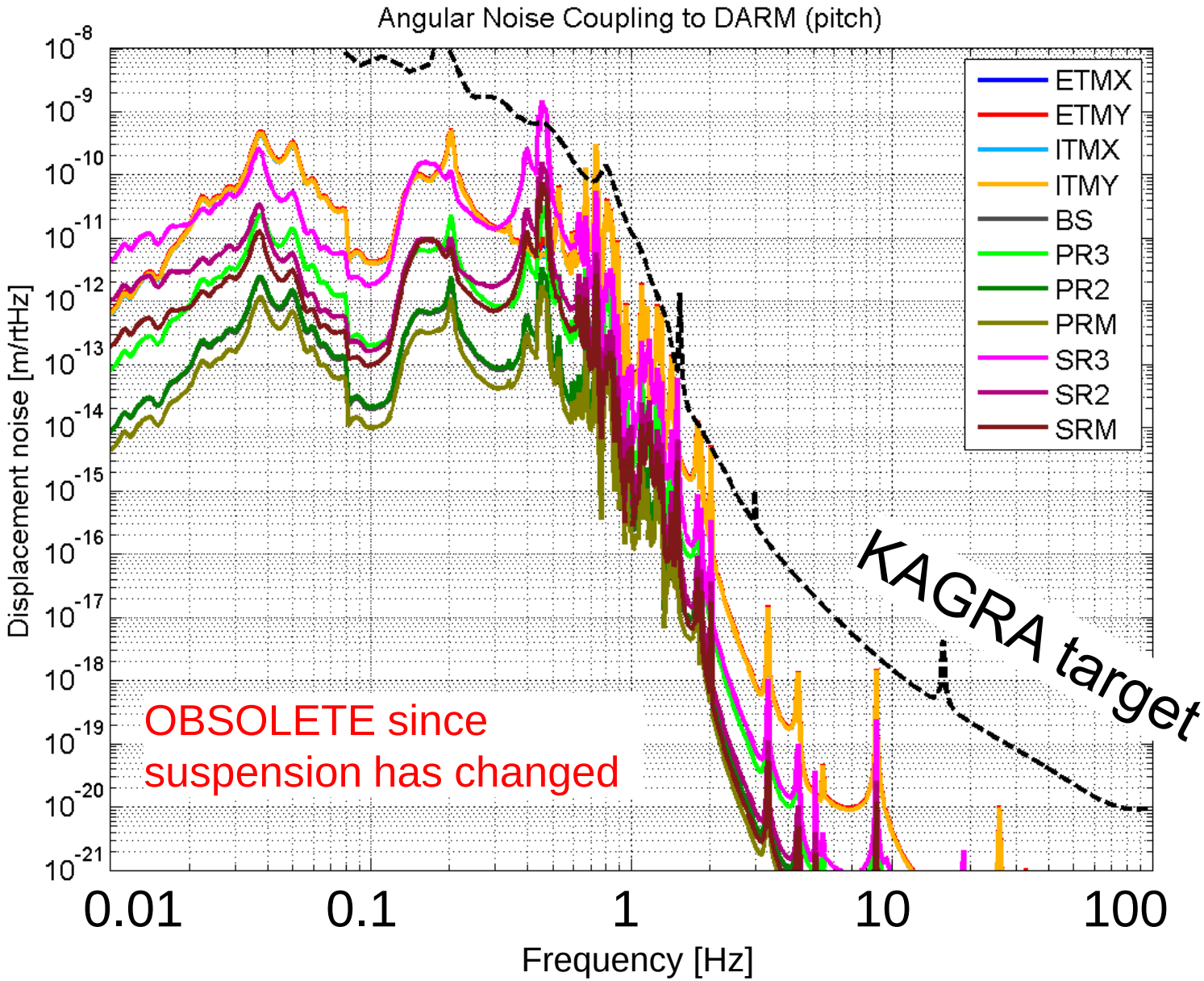
- no safety margin
  - WFS shot noise may be higher than calculation
- no QPD motion included
  - motion of beam reducing telescope(BRT) probably matters
    → requirement calculation on going
- suspension modeling with local damping
  → on going



Summary

- IFO design finalized
  mirror RoCs, lengths
- confirmed they are reasonable from ASC (and many other things)
- mirrors being fabricated
- WFS shot noise touches the target at 10 Hz
- there's no safety factor
- detailed simulation together with suspension modeling needed

Angular noise coupling (pitch)



Angular noise coupling (yaw)