

Noise Requirement for IMC QPDs

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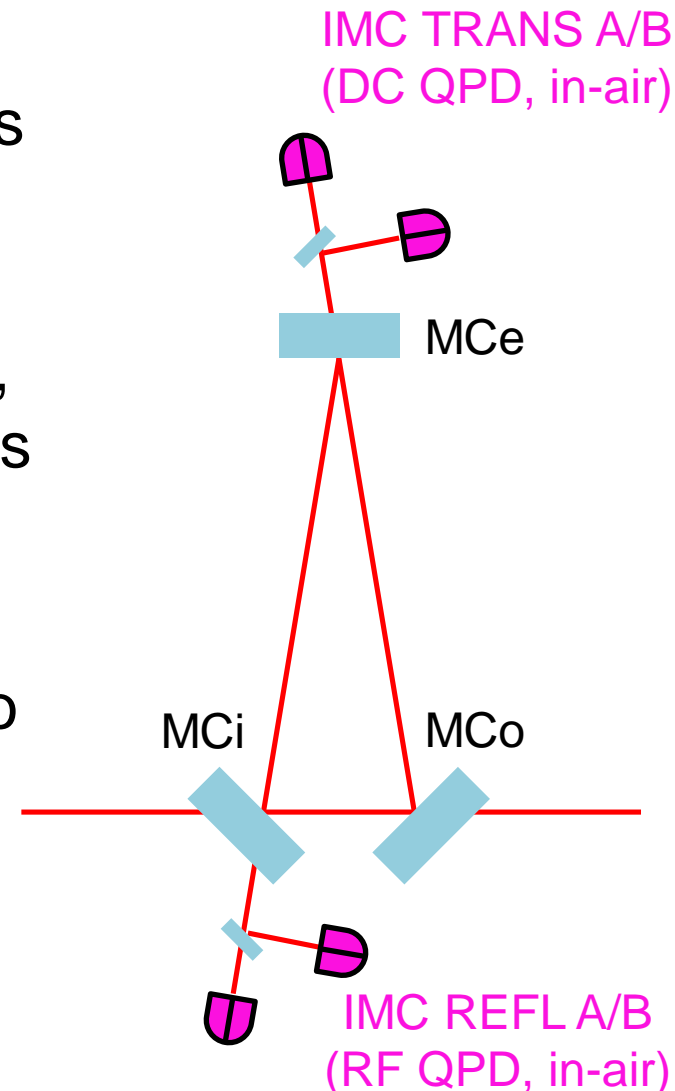
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Scope

- Derive noise requirements for QPDs used for IMC ASC
- Show that the current design meets the requirement
We don't have to put IMC TRANS DC QPDs on the isolated table in vacuum
- Related documents:
 - [JGW-T1402346](#) (requirement calculation for arm TMS)
 - [JGW-T1402481](#) (IMC alignment sensing matrix calculation)
 - [JGW-D1402411](#) (oplev QPD schematic)
 - [JGW-G1402375](#) (oplev QPD noise calculation)
 - [JGW-G1402961](#) (oplev QPD noise measurement)
 - [JGW-T1200913](#) (IMC length noise requirement from MIF; Fig. 4.6, 4.7)

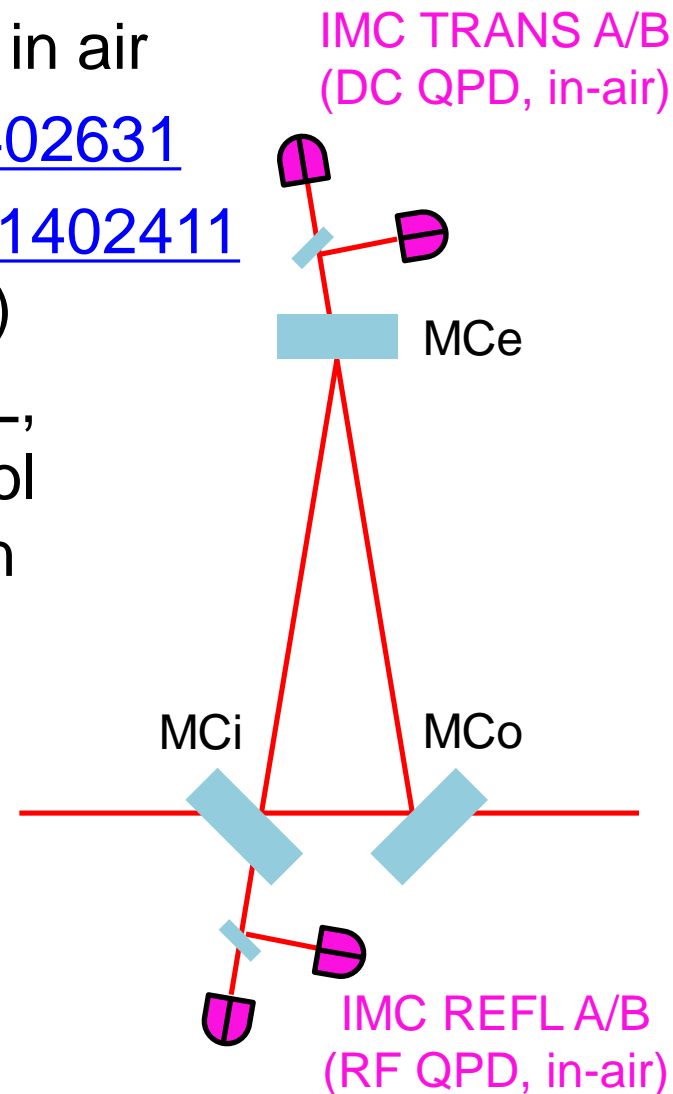
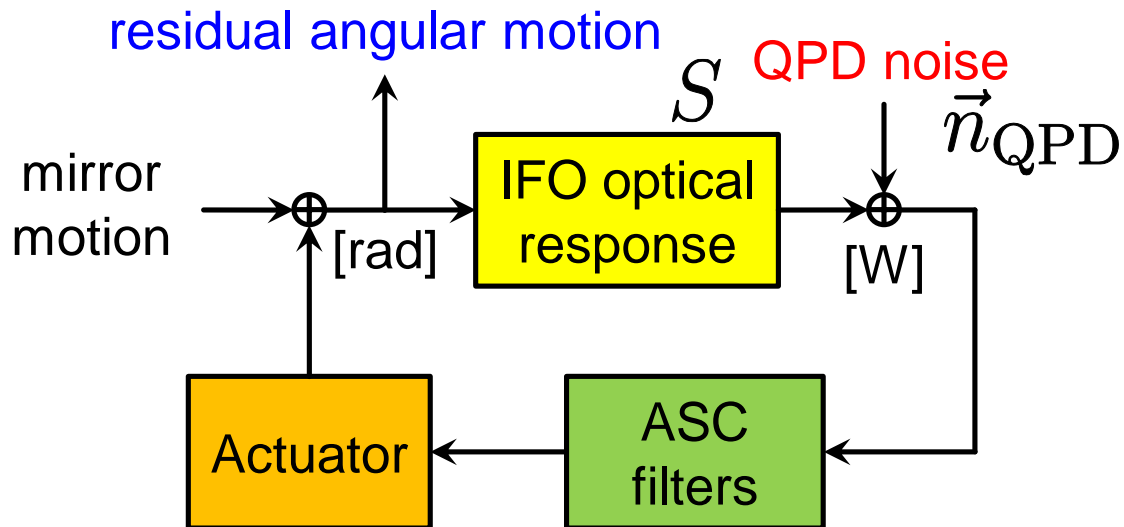
Requirement Derivation

- IMC is used for the laser frequency stabilization servo (FSS), and there is a requirement for IMC length noise
- Shot noise, seismic noise, etc. on QPDs will fake IMC alignment signal, and thus IMC ASC shakes the mirrors
- Angle to length (A2L) coupling result in the IMC length noise
- This noise should be small enough to meet the IMC length noise requirement
- Requirement derivation is similar to what we have done for the arms ([JGW-T1402346](#))



Current IMC ASC Design

- QPDs are put on non-isolated tables in air
- REFL RF QPD schematic: [JGW-D1402631](#)
- TRANS DC QPD schematic: [JGW-D1402411](#)
(same as the QPD used for oplevs)
- use two alignment signals from REFL, and one signal from TRANS to control three mirrors (we name two QPDs on each port as A and B)



Expression and Assumptions

- A2L from QPD noise should be smaller than the length noise requirement

$$\delta L(f) = \vec{k} \cdot d^{\text{RMS}} \frac{G(f)}{1 + G(f)} S^{-1} \vec{n}_{\text{QPD}}(f) < L_{\text{req}}(f)$$

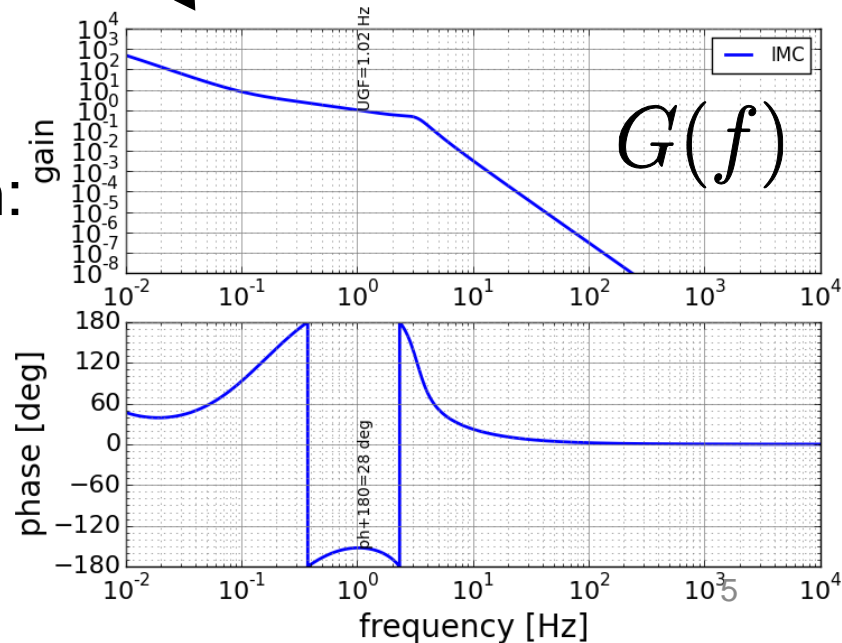
$\delta L(f)$ [m/rtHz] (A2L)
 \vec{k} (coupling for each mirror)
 d^{RMS} (beam mis-centering on mirrors [m])
 $\frac{G(f)}{1 + G(f)}$ (ASC OLTF)
 S^{-1} (sensing matrix [W/rad])
 $\vec{n}_{\text{QPD}}(f)$ (QPD noise [W/rtHz])
 $L_{\text{req}}(f)$ (length noise requirement [m/rtHz])

$$\vec{k} = 2 \cos \theta_i$$

θ_i (incident angle for each mirror)

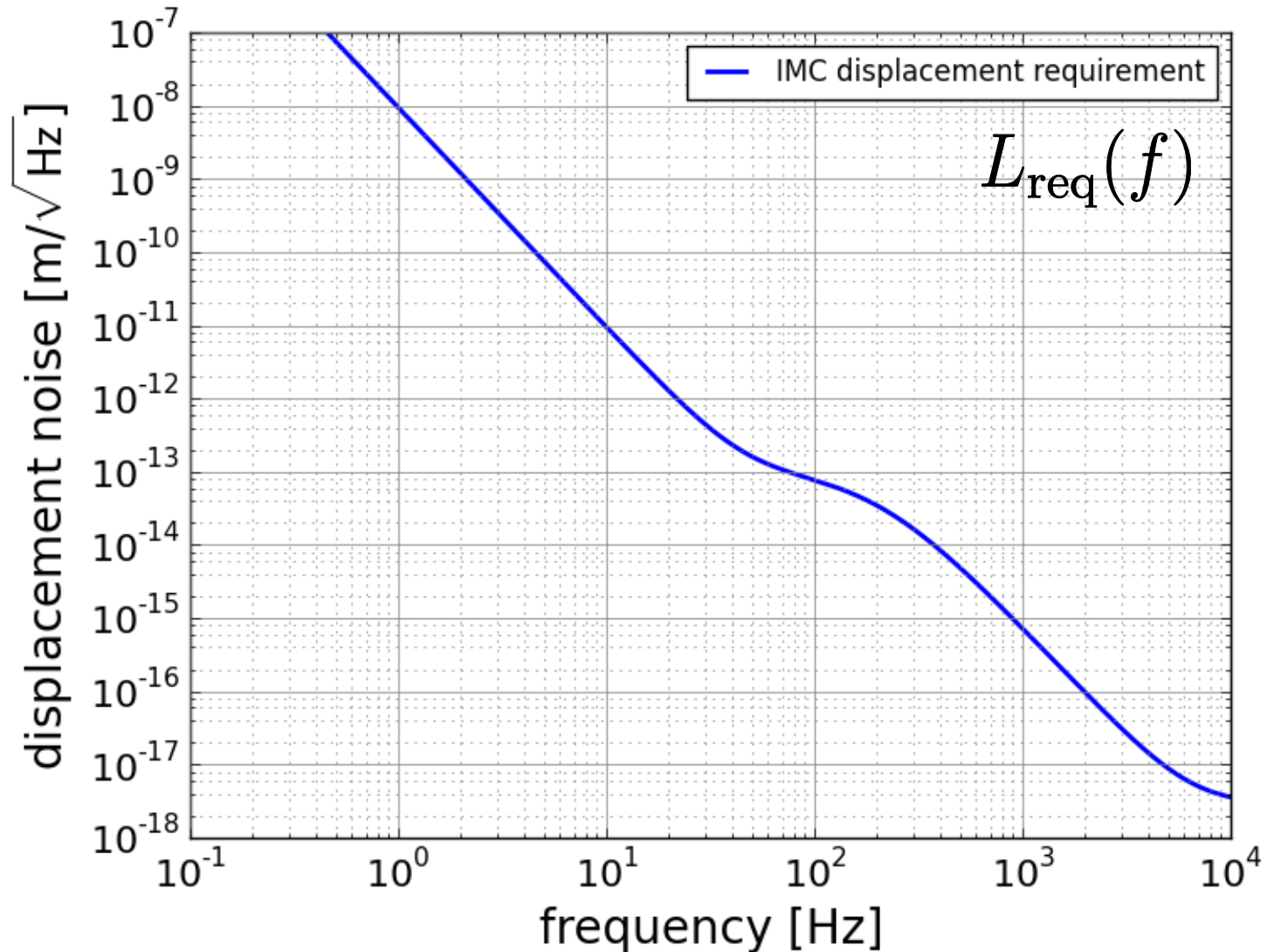
- Assumptions for the calculation:

- 1 mW on each QPD
- 0.2 mm beam radius on each QPD
- $d^{\text{RMS}} = 0.1$ mm
- IMC ASC UGF = 1 Hz



IMC Length Noise Requirement

- See MIF Design Document for the “real” spectrum



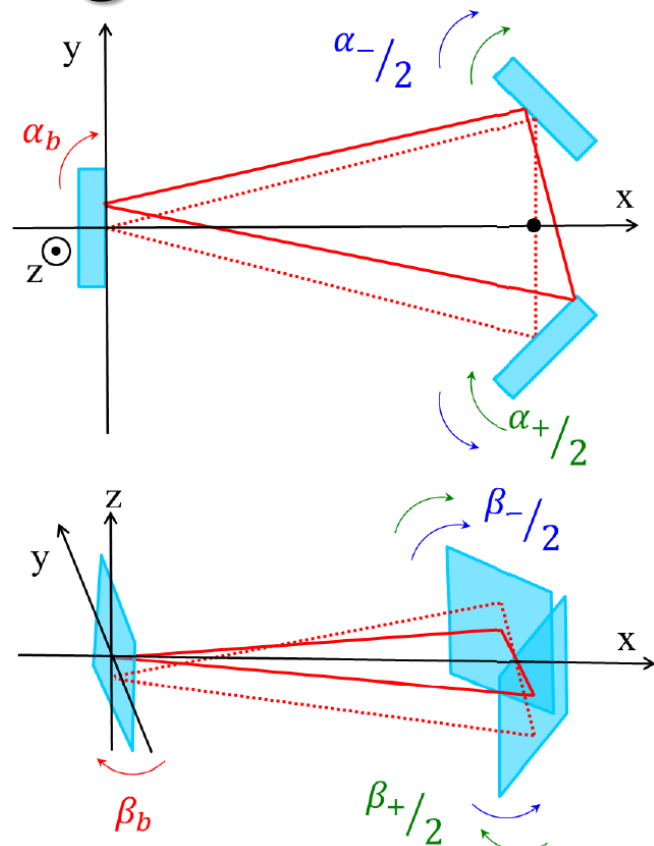
IMC Alignment Sensing Matrix

- DOF basis

	yaw			Pitch		
	α_b	α_+	α_-	Bb	β_+	β_-
REFL A	-39.2	-11.5	0	0	7.9	-7.9
REFL B	0	0	17.5	24.8	0	0
TRANS A	-12.6	0.32	0	-13.4	8.2	0
TRANS B	-14.3	0.26	-17.6	0	6.9	0.08

- Mirror basis

	yaw			pitch		
	MCi	MCo	MCE	MCi	MCo	MCE
REFL A	-11.5	-11.5	-39.2	15.8	0	0
REFL B	-17.5	17.5	0	0	0	24.8
TRANS A	0.32	0.32	-12.6	8.2	8.2	-13.4
TRANS B	17.8	-17.3	-14.3	6.8	7.0	0



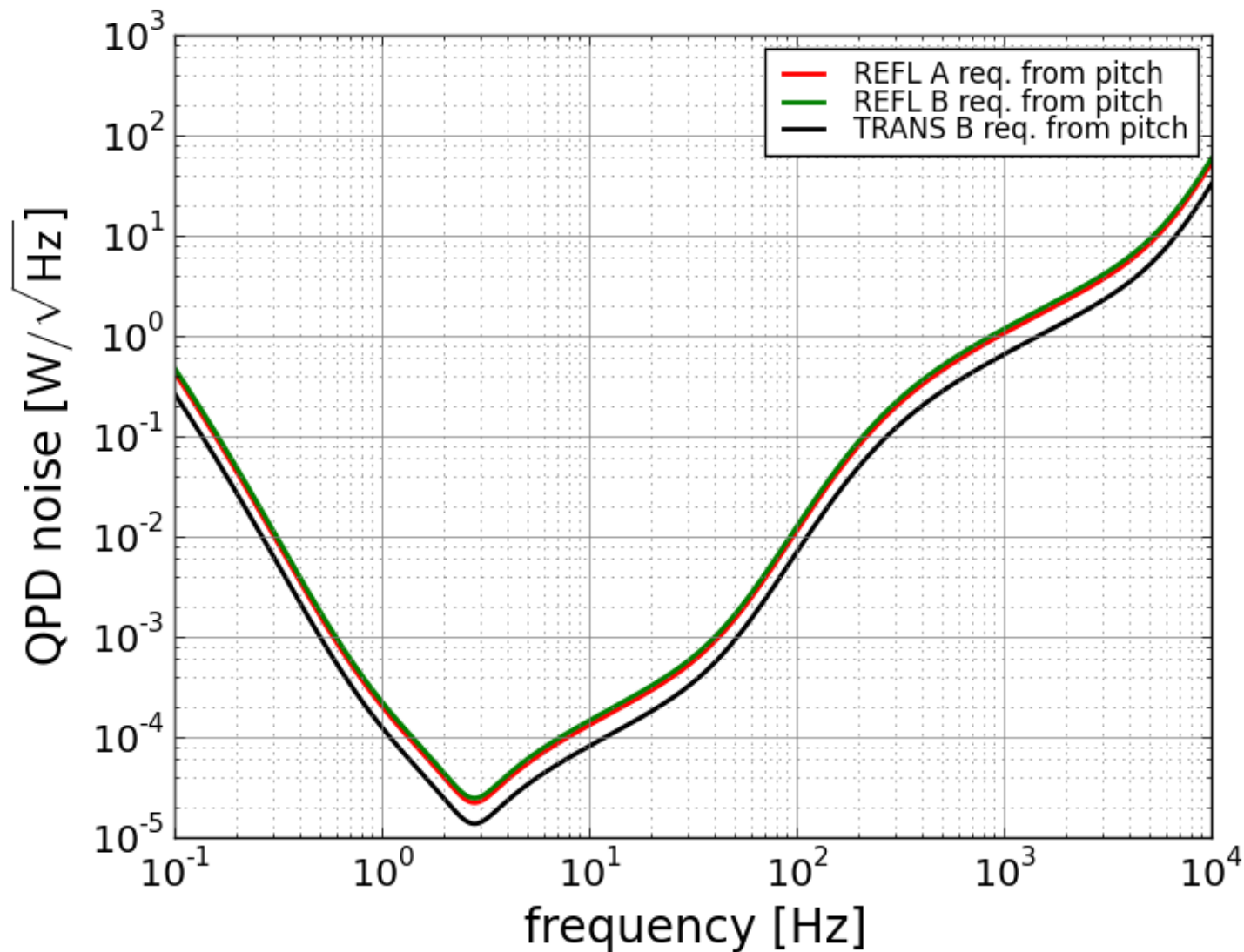
[JGW-T1402481](#)

← S in p.4

all in units of W/rad
modulation index = 0.1 7

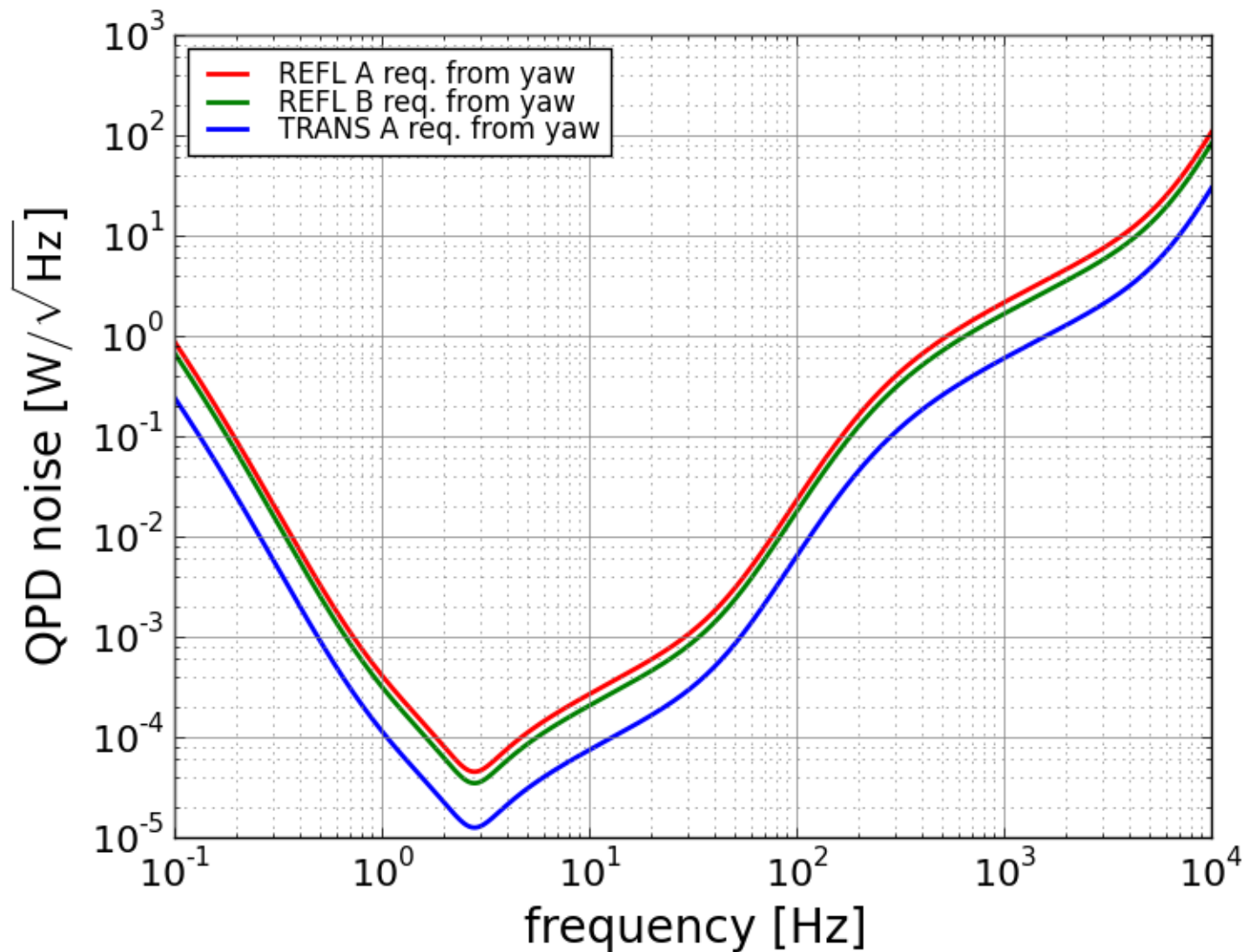
Noise Requirement for IMC QPDs

- requirement from pitch



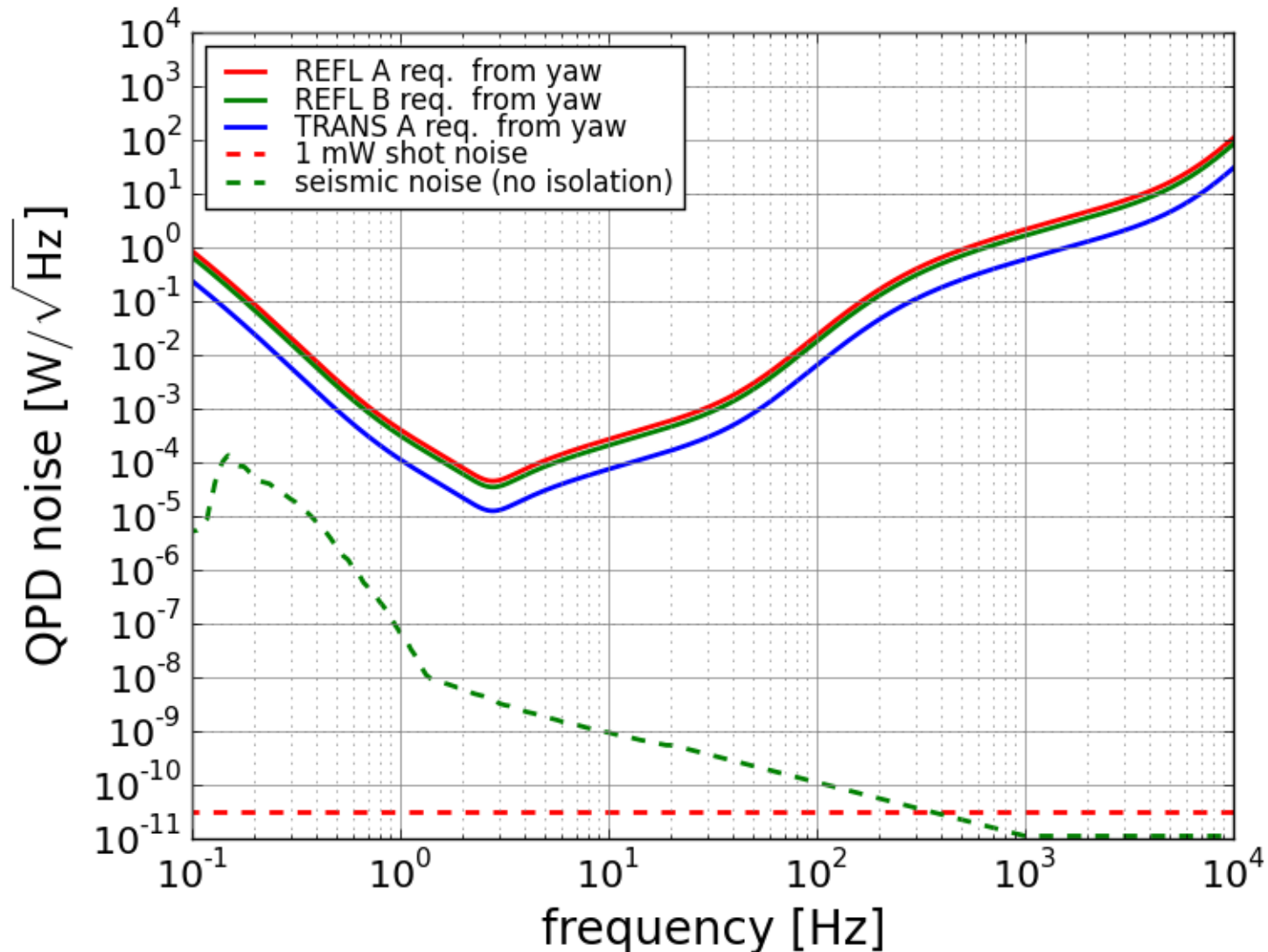
Noise Requirement for IMC QPDs

- requirement from yaw



Estimated QPD Noise

- DC QPD on non-isolated table work



Oplev QPD (ISC DC QPD in-air)

- Si diode, Hamamatsu [S5981](#)
 area 10 x 10 mm, gap 0.03 mm
 ~0.30 A/W @ 1064 nm (QE=36%)
 ~0.30 A/W @ 532 nm (QE=70%)
 ~0.47 A/W @ 680 nm (QE=85%)
 ↙ oplev wavelength
- transimpedance = 20 kΩ (or 100 kΩ)

