ASC simulations for O3 SRM transmission, SRC Gouy phase shift, and ITM transmission asymmetry

Yuta Michimura

Department of Physics, University of Tokyo

Scope

- Shot noise coupling from ASC has been calculated with Optickle and reported in
  Y. Aso *et al*, PRD 88, 043007 (2013)
- We want to see the effect of
  - T_SRM = 30% (for O3 low power operation)
  - SRC Gouy phase shift (from nominal one-way 17.5 deg to measured 24 deg; see klog #9246)
  - ITM transmission asymmetry (JGW-T1910352) to ASC shot noise
- Optickle simulations were done using codes in https://granite.phys.s.u-tokyo.ac.jp/svn/LCGT/trunk/mif/ASC-Optickle

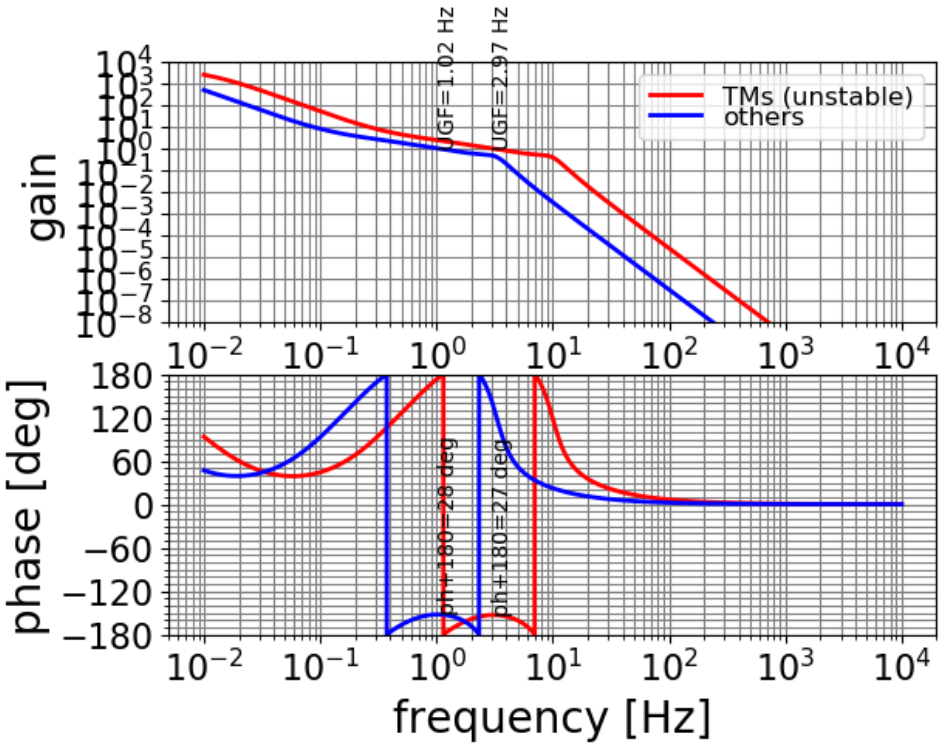
Configurations

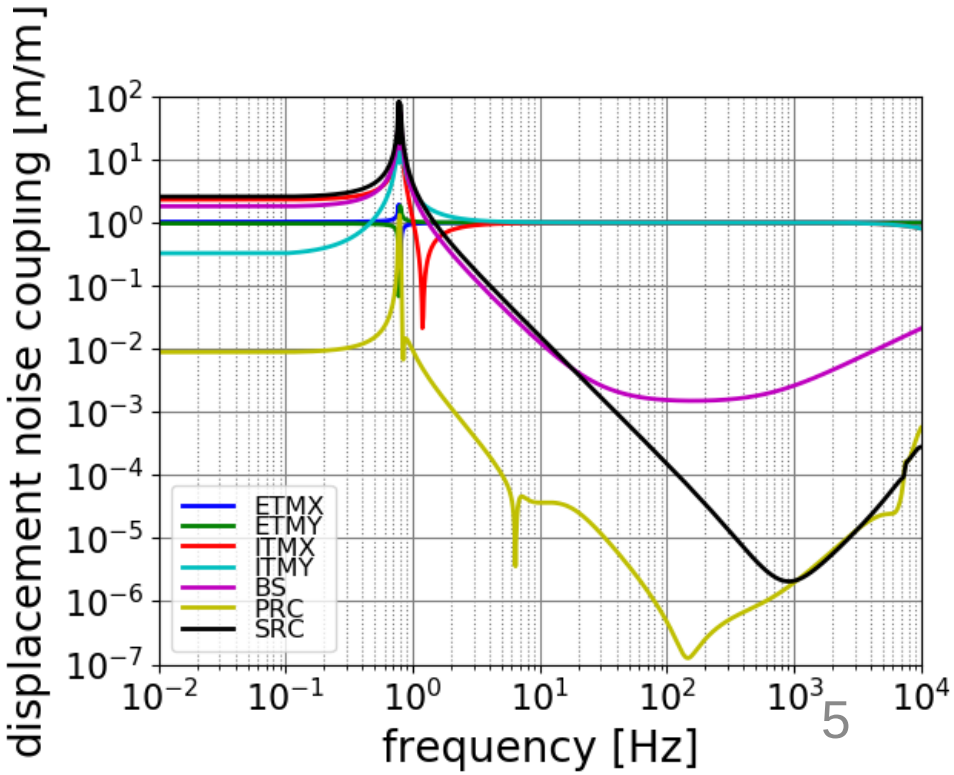
- Nominal BRSE at the time of Aso 2013 (PRM input power 77.5 W), but with T_PRM = 10.35% (see JGW-L1605744)
- Nominal BRSE with updated PRM input power to 65 W (670 W at BS)
- BRSE with T_SRM=30%, PRM input power 1 W (O3 SRM transmission, 10 W at BS)
- BRSE with T_SRM=30%, PRM input power 1 W, SRC one-way Gouy phase 48deg/2 (by changing SR2-SR3 length by +4 cm)
- BRSE with T_SRM=30%, PRM input power 1 W, SRC one-way Gouy phase 48deg/2, T_ITMX=0.444%, T_ITMY=0.479%

Methods

- Method based on JGW-G1301664
- ASC shot noise is calculated with Optickle
- For ASC open loop transfer functions, UGF of 3 Hz for TMs and 1 Hz for other mirrors are assumed (could be too optimistic for O3)
- For DARM coupling, DisplacementNoiseCouplingFF.dat (available from the link below) calculated with nominal configuration was used for all the interferometer configurations for simplicity
  https://granite.phys.s.u-tokyo.ac.jp/svn/LCGT/trunk/mif/doc/DesignDocument/data/DisplacementNoise/BRSE/DisplacementNoiseCouplingFF.dat

ASC Loops and Displacement Noise Coupling



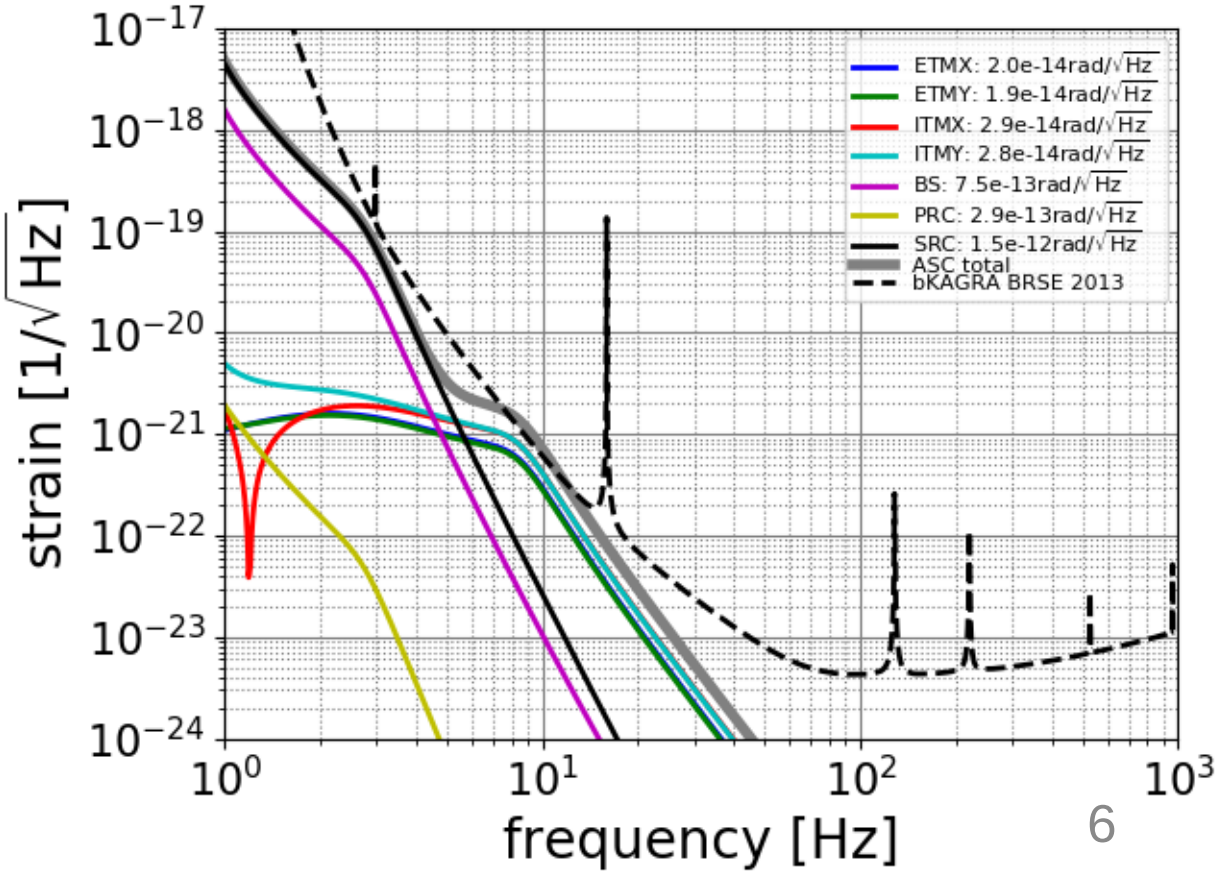


Nominal BRSE 2013

WFS Sensing Matrix [W/mrad]

phases at POP A:-8.0, POP B:-76.4 REFL A:13.3, REFL B:-88.4, AS A:6.7, AS B:-83.7, TR A:

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
$TRX_A DC$	-9.22	0.40	-9.22	0.38	0.00	-0.01	-0.00	-0.00	0.00	0.00	0.00
$REFL_A 2I$	-11.01	36.58	-0.13	0.22	0.61	2.49	0.41	9.69	-0.00	-0.00	-0.00
$TRY_A DC$	-9.22	0.40	9.22	-0.38	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
$AS_A 1Q$	-0.21	-0.21	6.86	25.69	0.11	-0.17	-0.02	-0.01	-0.28	-0.03	-0.01
$POP_A 1Q$	-0.02	-0.00	0.35	-0.36	0.25	-0.02	-0.00	-0.00	-0.01	-0.00	-0.00
$POP_A 2Q$	-1.53	0.73	-0.00	0.00	0.98	2.83	0.35	0.17	-0.00	-0.00	-0.00
$POP_B DC$	-0.17	-0.02	0.00	0.00	-0.12	-0.30	-2.08	-1.02	0.01	0.00	0.00
$REFL_B DC$	-3.43	-2.42	-0.01	0.04	1.35	4.38	0.55	7.93	0.24	0.03	0.02
$POP_B 1I$	-1.93	-0.68	0.00	-0.00	-0.46	-2.40	-0.29	-0.15	-1.07	-0.13	-0.07
$AS_B DC$	-0.01	0.00	-0.10	-0.05	-0.06	-0.00	-0.00	-0.00	0.02	0.00	-0.04



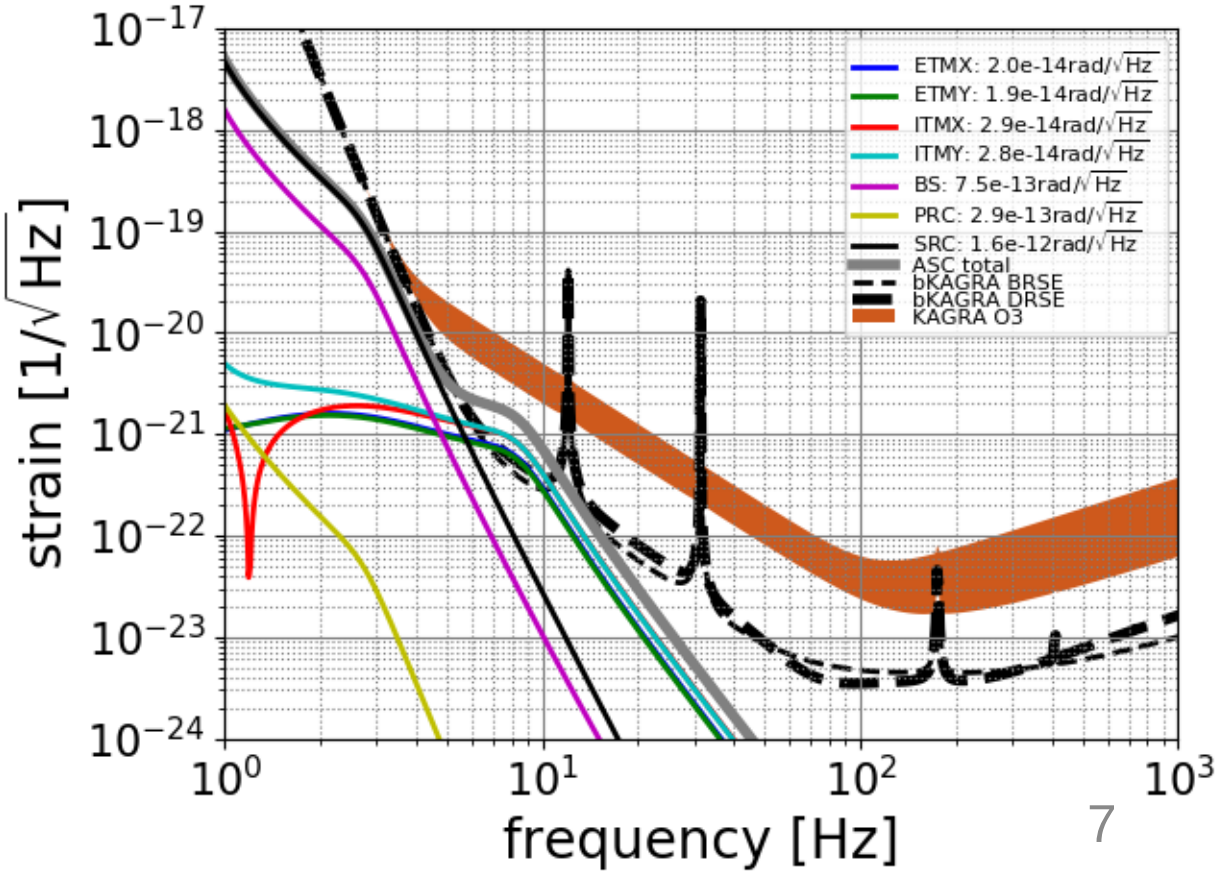
Nominal BRSE with PRM input 67 W

WFS Sensing Matrix [W/mrad]

phases at POP A:-8.0, POP B:-76.4 REFL A:13.3, REFL B:-88.4, AS A:6.7, AS B:-83.7, TR A:

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
$TRX_A DC$	-9.22	0.40	-9.22	0.38	0.00	-0.01	-0.00	-0.00	0.00	0.00	0.00
$REFL_A 2I$	-11.01	36.58	-0.13	0.22	0.61	2.49	0.41	9.69	-0.00	-0.00	-0.00
$TRY_A DC$	-9.22	0.40	9.22	-0.38	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
$AS_A 1Q$	-0.17	-0.17	5.75	21.54	0.09	-0.14	-0.02	-0.01	-0.23	-0.03	-0.01
$POP_A 1Q$	-0.02	-0.00	0.35	-0.36	0.25	-0.02	-0.00	-0.00	-0.01	-0.00	-0.00
$POP_A 2Q$	-1.53	0.73	-0.00	0.00	0.98	2.83	0.35	0.17	-0.00	-0.00	-0.00
$POP_B DC$	-0.17	-0.02	0.00	0.00	-0.12	-0.30	-2.08	-1.02	0.01	0.00	0.00
$REFL_B DC$	-3.43	-2.42	-0.01	0.04	1.35	4.38	0.55	7.93	0.24	0.03	0.02
$POP_B 1I$	-1.93	-0.68	0.00	-0.00	-0.46	-2.40	-0.29	-0.15	-1.07	-0.13	-0.07
$AS_B DC$	-0.00	0.00	-0.08	-0.04	-0.05	-0.00	-0.00	-0.00	0.01	0.00	-0.03

Input power change do not change ASC shot noise much since power on QPD is limited to 50 mW anyway

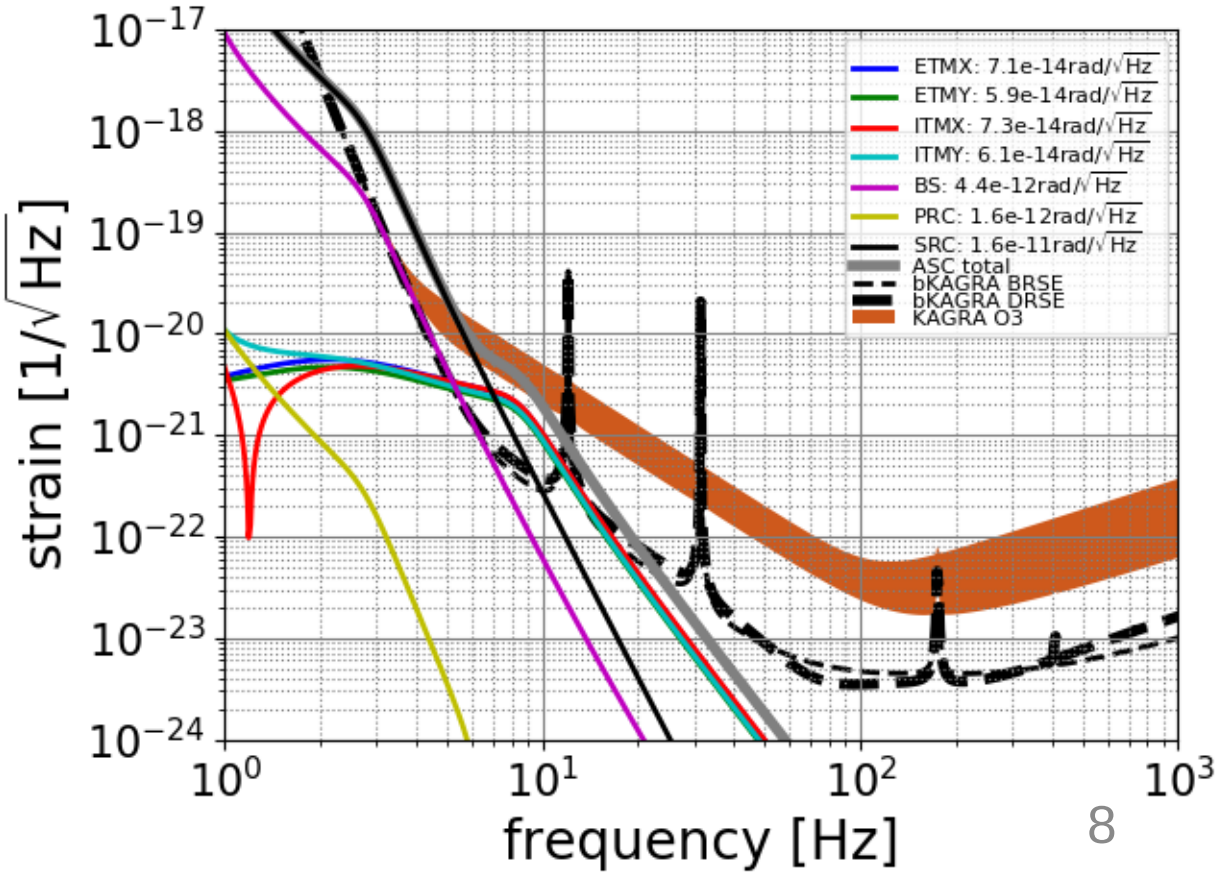


BRSE with T_SRM = 30% PRM input 1W

WFS Sensing Matrix [W/mrad]

phases at POP A:-8.0, POP B:-76.4 REFL A:13.3, REFL B:-88.4, AS A:6.7, AS B:-83.7, TR A:

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
$TRX_A DC$	-4.57	0.20	-4.57	0.19	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
$REFL_A 2I$	-0.59	-1.97	-0.01	0.01	0.03	0.13	0.02	0.52	0.00	0.00	0.00
$TRY_A DC$	-4.57	0.20	4.57	-0.19	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$AS_A 1Q$	-0.00	-0.00	0.12	0.47	0.00	-0.00	-0.00	-0.00	-0.01	-0.00	-0.00
$POP_A 1Q$	-0.00	-0.00	0.01	-0.01	0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$POP_A 2Q$	-0.07	0.03	-0.00	0.00	0.05	0.14	0.02	0.01	-0.00	-0.00	-0.00
$POP_B DC$	-0.01	-0.00	0.00	0.00	-0.01	-0.02	-0.10	-0.05	0.00	0.00	0.00
$REFL_B DC$	-0.14	-0.18	-0.00	0.00	0.06	0.16	0.02	0.40	-0.01	-0.00	-0.00
$POP_B 1I$	-0.06	-0.02	0.00	-0.00	-0.01	-0.08	-0.01	-0.00	-0.03	-0.00	-0.00
$AS_B DC$	-0.00	0.00	-0.01	-0.02	-0.00	0.00	0.00	0.00	0.00	0.00	-0.00



No attenuation before QPDs since input power is low (thus shot noise is much worse)

Gouy phase and demod phase re-tuning not done

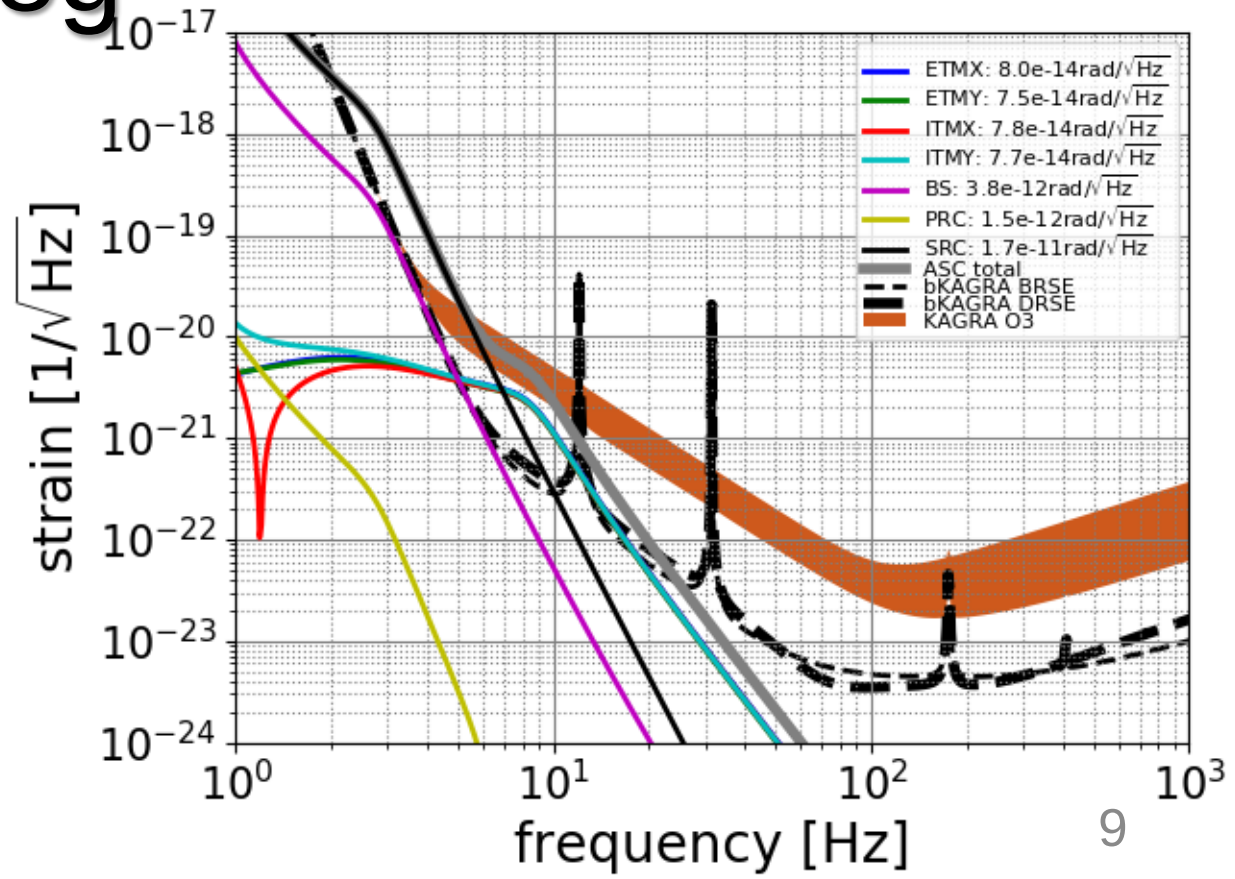
OK for O3

BRSE with T_SRM = 30% PRM input 1W SRC 24 deg

WFS Sensing Matrix [W/mrad]

phases at POP A:-8.0, POP B:-76.4 REFL A:13.3, REFL B:-88.4, AS A:6.7, AS B:-83.7, TR A:

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
$TRX_A DC$	-4.57	0.20	-4.57	0.19	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
$REFL_A 2I$	-0.59	-1.97	-0.01	0.01	0.03	0.13	0.02	0.52	-0.00	-0.00	-0.00
$TRY_A DC$	-4.57	0.20	4.57	-0.19	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$AS_A 1Q$	-0.00	-0.00	0.09	0.35	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$POP_A 1Q$	-0.00	-0.00	0.02	-0.02	0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$POP_A 2Q$	-0.07	0.03	-0.00	0.00	0.05	0.14	0.02	0.01	-0.00	-0.00	-0.00
$POP_B DC$	-0.01	-0.00	0.00	0.00	-0.01	-0.02	-0.10	-0.05	0.00	0.00	0.00
$REFL_B DC$	-0.14	-0.17	-0.03	0.03	0.04	0.17	0.02	0.40	-0.01	-0.00	-0.00
$POP_B 1I$	0.06	-0.02	0.00	-0.00	-0.01	-0.07	-0.01	-0.00	-0.03	-0.00	-0.00
$AS_B DC$	-0.00	0.00	-0.00	-0.01	-0.00	0.00	0.00	-0.00	0.00	0.00	-0.00



~10% increase of shot noise probably due to slight mis-tuning of Gouy phase and demod phase

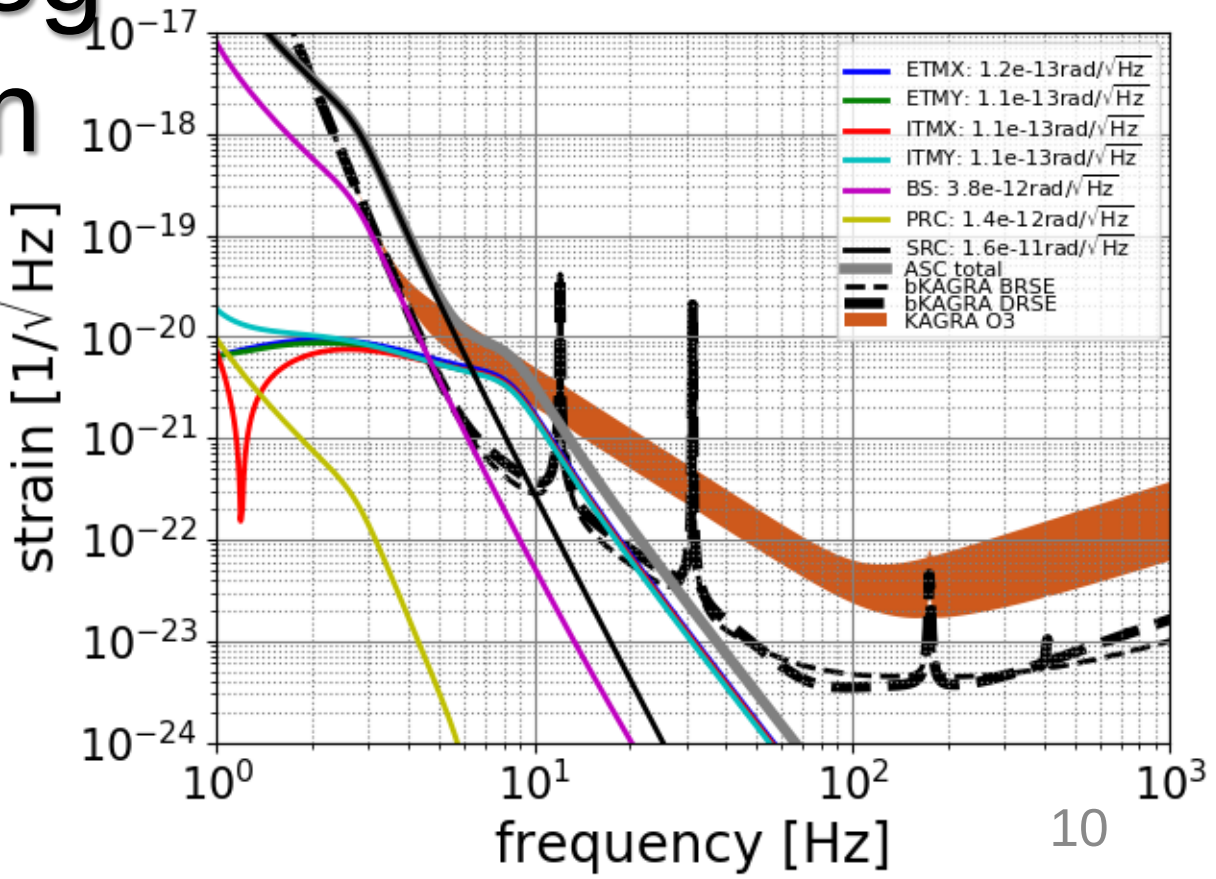
OK for O3

BRSE with T_SRM = 30% PRM input 1W SRC 24 deg ITM asym

WFS Sensing Matrix [W/mrad]

/ phases at POP A:-8.0, POP B:-76.4 REFL A:4.1, REFL B:83.6, AS A:6.7, AS B:-83.7, TR A:-

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
$TRX_A DC$	-4.69	0.20	-4.69	0.20	0.00	-0.01	-0.00	-0.00	0.00	0.00	0.00
$REFL_A 2I$	-0.18	-0.68	0.00	0.00	-0.00	0.00	0.00	0.47	0.00	0.00	0.00
$TRY_A DC$	-4.35	0.19	4.35	-0.18	-0.00	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
$AS_A 1Q$	-0.00	-0.00	0.10	0.37	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$POP_A 1Q$	-0.00	-0.00	0.02	-0.02	0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
$POP_A 2Q$	-0.08	0.04	-0.00	0.00	0.05	0.14	0.02	0.01	-0.00	-0.00	-0.00
$POP_B DC$	0.01	-0.00	0.00	-0.00	-0.01	-0.02	-0.11	-0.06	0.00	0.00	0.00
$REFL_B DC$	-0.00	-1.43	0.02	-0.03	-0.21	-0.64	-0.07	-1.02	0.03	0.00	0.00
$POP_B 1I$	0.06	-0.02	0.00	-0.00	-0.01	-0.07	-0.01	-0.00	-0.03	-0.00	-0.00
$AS_B DC$	-0.00	0.00	-0.00	0.00	-0.00	0.00	0.00	-0.00	0.00	0.00	-0.00



~50% increase of shot noise due to larger degeneracy between CH and PRM/PR3

REFL A and B Gouy phases retuned

OK for O3

Conclusions

- O3 SRM transmission, SRC Gouy phase shift, ITM transmission asymmetry seems to be OK for O3

- ITM transmission asymmetry is troublesome since it creates larger degeneracy between CH mode and PRC modes
- More study necessary including the effect of ITM inhomogeneity