

2011年7月5日

# LCGT ASC現状報告

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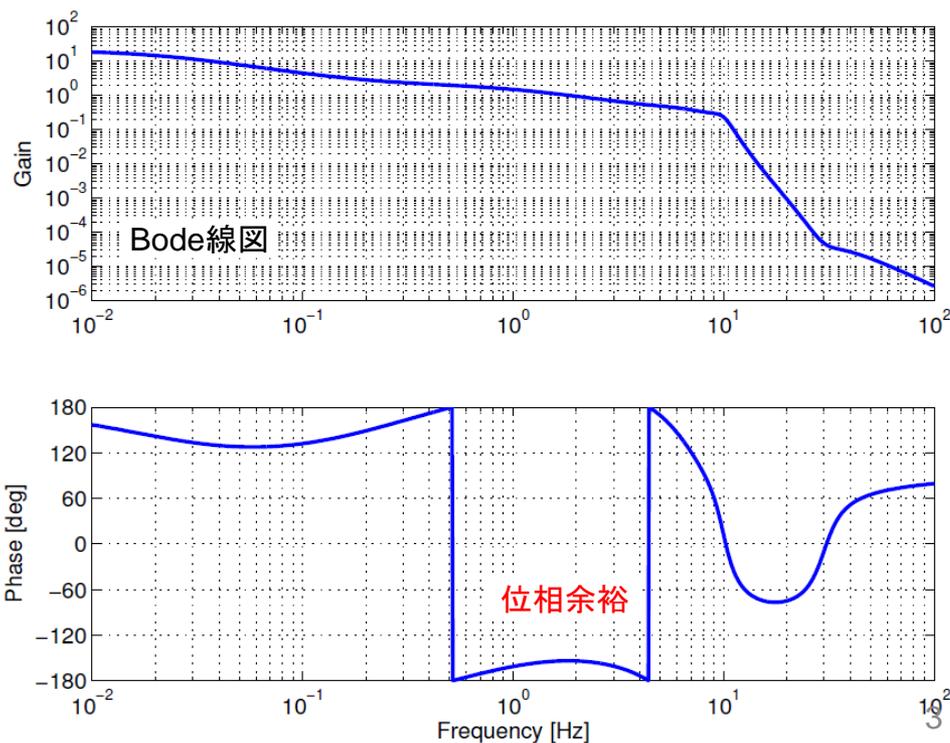
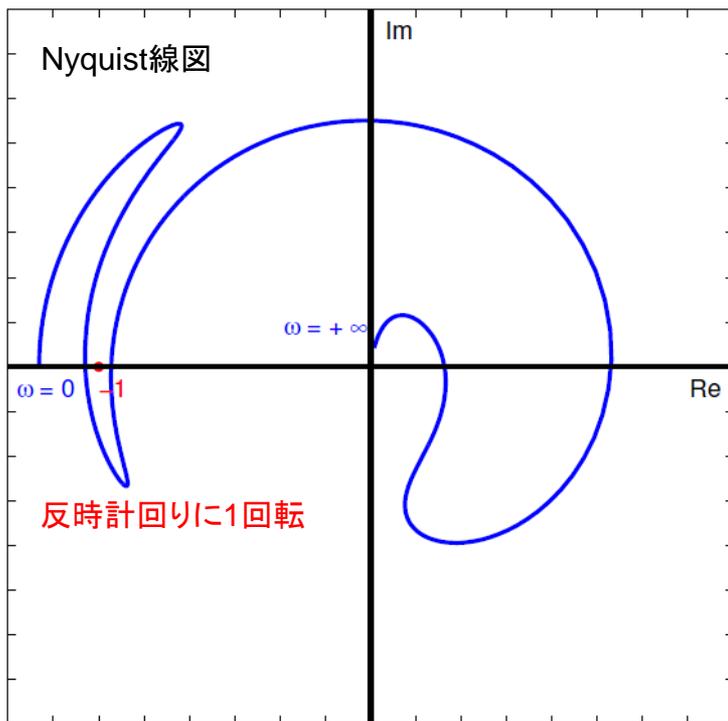
東京大学大学院理学系研究科物理学専攻 坪野研究室 修士課程2年

# 前回のmeetingからのA/I

- unstable SOFTモードの制御法について検討  
→そんなに面倒じゃなさそう
- bLCGTで制御後の方がノイズが大きいのは計算ミス？  
→解決、再計算
- 不確定要素は多いが、bLCGT ASCはbLCGTのサスペンションモデルを用いて計算
- ローカルダンピング込みでのサスペンション伝達関数、角度揺れを用いたASC計算 →まだ
- TAMAの実測データを用いてのASC計算の正しさ確認  
→難しそう。SASモデルの比較検証はできそう。WFSの雑音は正体不明の雑音をどうするか。複雑な制御の計算はaLIGOとクロスチェックした方が良さそう。
- DC readout等に対応 →まだ(ASのショットノイズ良  
いまま)

# Unstableモードの制御

- unstableモードは共振周波数、Q値が純虚数  
→実数の2つのpole、一方が負で安定、他方が正で不安定
- Nyquist線図で-1を反時計回りに1回転すればよい
- Bode線図で見れば、(簡単にいえば)UGFで位相余裕を持つこと  
→stableモードと同様！



# 前回のbLCGT計算は何かダメ？

- sensing matrixが悪かった  
POP\_A2IとREFL\_BDCがほぼ同じ情報で対角化困難  
→BSはPOP\_B1Qから取ることにする positive g-factorの時の話

WFS Sensing Matrix [W/mrad/sqrt(2/pi)]

(Gouy phases at POP A:70.6, POP B:-72.9 REFL A:-89.9, REFL B:-0.1, AS A:89.5, AS B:73.1, TR A:64.4 deg)

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
REFL_A2I	163.97	19.39	0.02	0.01	-4.76	-13.95	-2.03	-2.74	0.00	0.00	0.00
TRX_ADC	-0.03	10.88	0.03	10.88	0.00	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
AS_A1Q	0.00	0.00	1.51	0.25	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
TRY_ADC	-0.03	10.88	-0.03	-10.88	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
POP_A2I	-5.07	2.27	0.00	-0.00	1.94	5.49	0.66	0.33	-0.00	-0.00	-0.00
REFL_BDC	-46.95	-40.43	-0.04	0.03	-20.30	-57.30	-6.63	-2.18	-0.19	-0.02	-0.01
POP_ADC	-0.03	0.24	0.00	0.00	0.15	0.43	-2.28	-1.14	0.00	0.00	0.00
REFL_B1I	-0.27	-1.81	-0.00	-0.00	-0.88	-2.88	-0.34	5.96	-0.38	-0.05	-0.02
POP_B1I	-0.00	-0.09	0.00	-0.00	0.02	-0.05	-0.01	0.00	-0.11	-0.01	-0.01
AS_BDC	-0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00

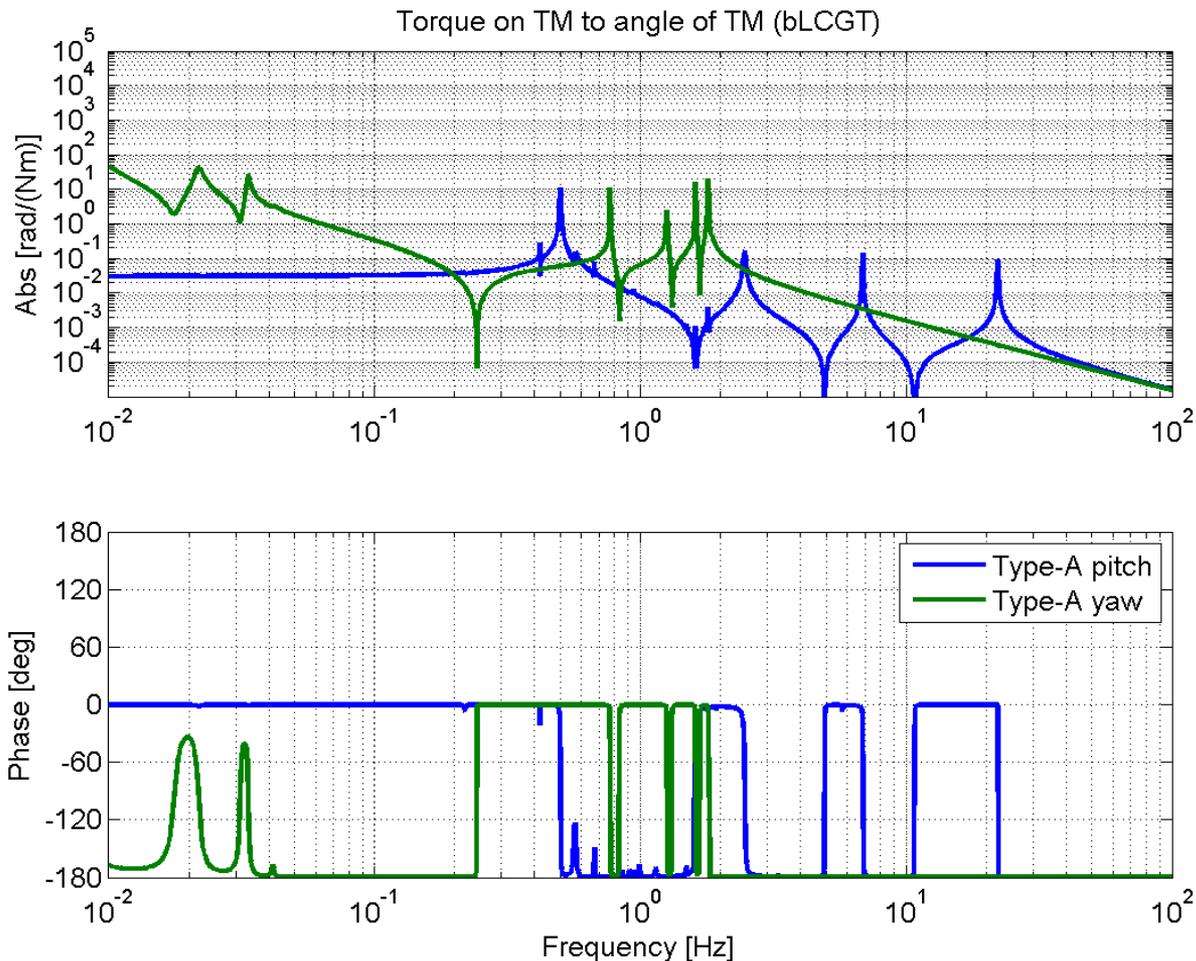
↑ 前回のbLCGT sensing matrix

iLCGT ASC  
(省略)

bLCGT ASC

# bLCGT Suspension

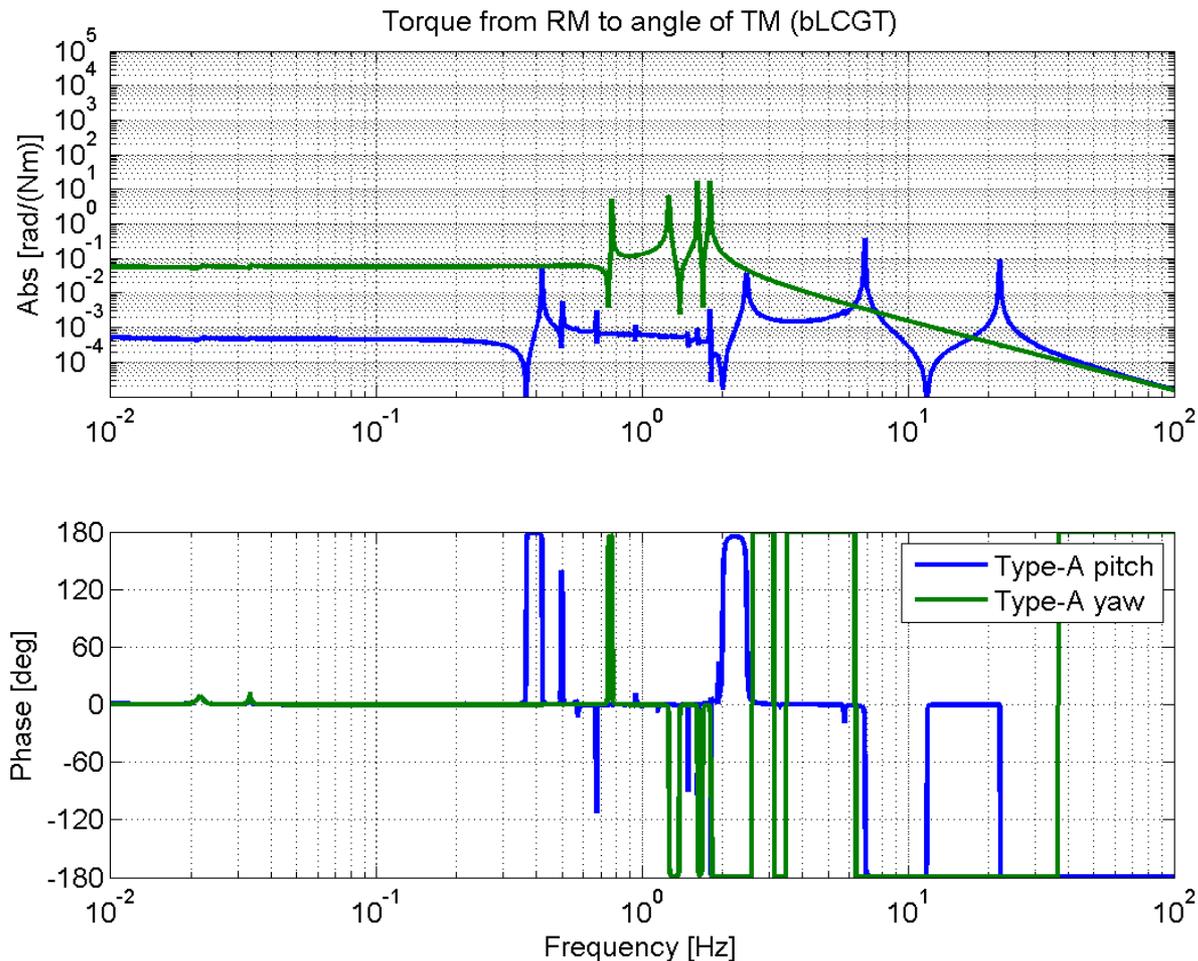
- 鏡に加えたトルクから鏡の角度へのTF (Hrad)



関口くん提供  
(2011/5/23版)

# bLCGT Suspension

- リコイルマスで加えたトルクから鏡の角度へのTF (Hact)



関口くん提供  
(2011/5/23版)

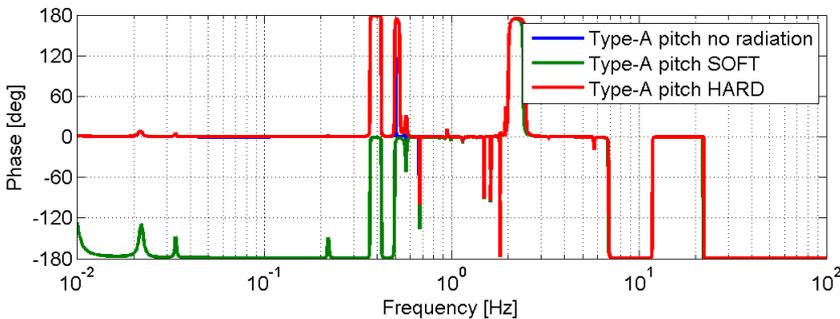
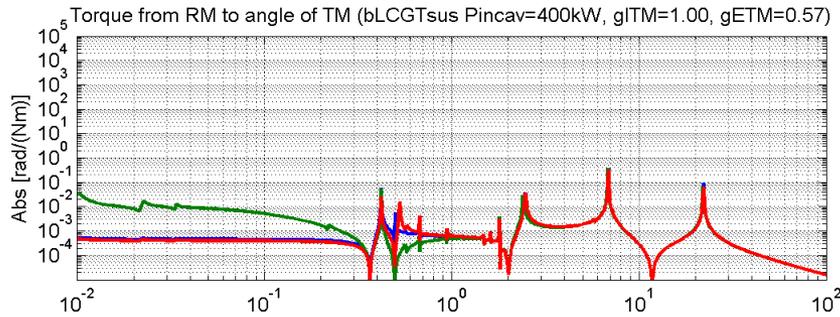
# Opto-mechanical TF

- 輻射圧トルクによってunstableになる可能性がある
- unstableかstableかは時に微妙
  - 例えば、腕内パワー400 kWとするか、379kWとするかで変わってくる(後者の方がより正確な値)
- 重要なのは「unstableになりすぎないこと」  
stableになりすぎるのはLCGTのサスペンションではあまり関係ない(そもそも固すぎ)
- 以下の4ページは
  - positive g-factor, 400 kWの場合
  - negative g-factor, 400 kWの場合
  - positive g-factor, 379 kWの場合
  - negative g-factor, 379 kWの場合

# Opto-mechanical TF

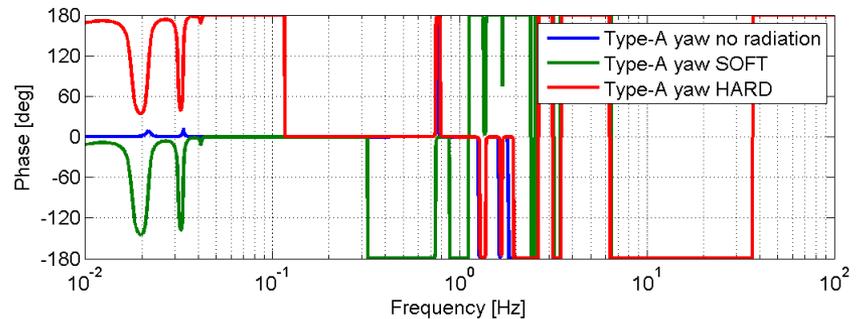
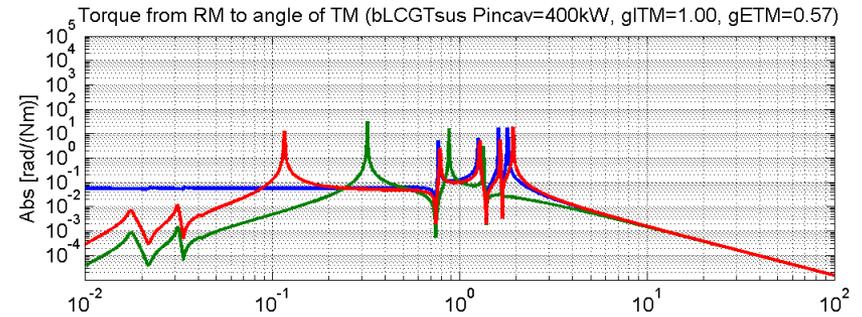
- $g_{ITM}=1.00$ ,  $g_{ETM}=0.57$  (flat-7km)
- $k_{SOFT}=-33.8$  Nm,  $k_{HARD}=4.4$  Nm (400 kW)

pitch



pitchのSOFTはunstable

yaw



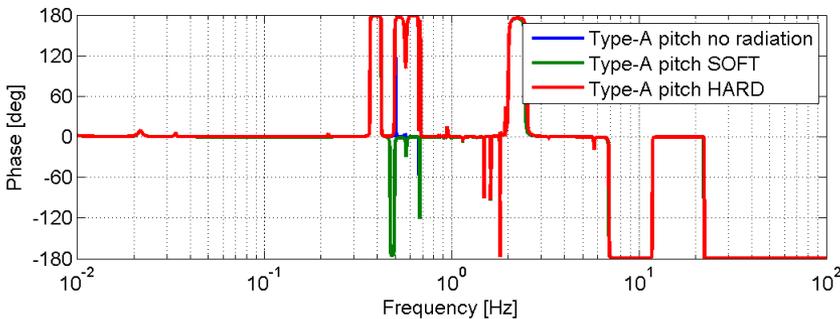
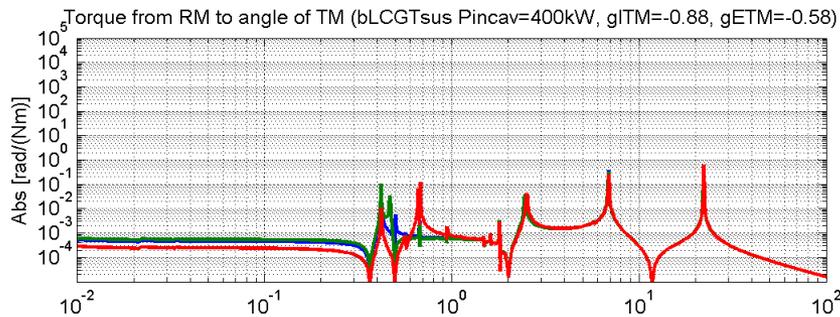
yawのSOFTはunstable

0.01 Hz以下にもう1つ共振があることに注意  
(1本吊りのSAS)

# Opto-mechanical TF

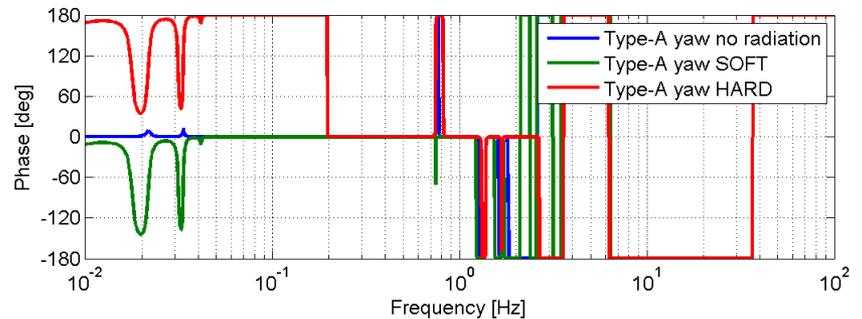
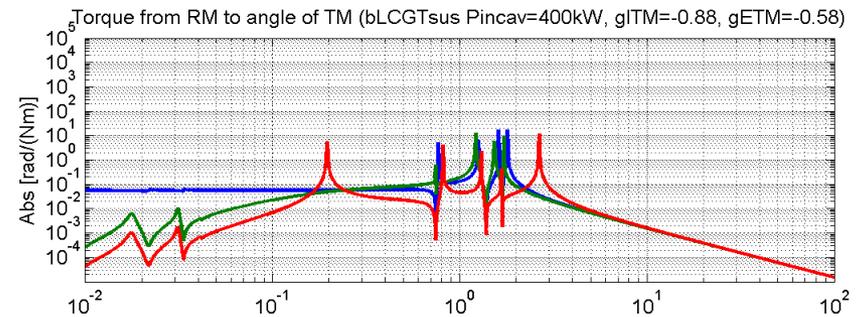
- $g_{ITM} = -0.88$ ,  $g_{ETM} = -0.58$  (1.6km-1.9km)
- $k_{SOFT} = -4.6$  Nm,  $k_{HARD} = 28.2$  Nm (400 kW)

pitch



pitchのSOFTはstable

yaw



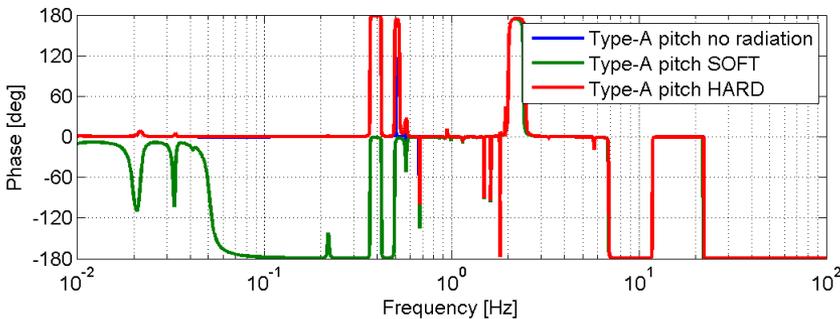
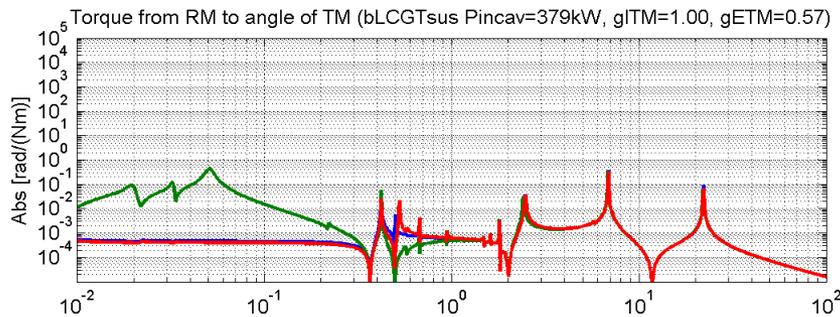
yawのSOFTはunstable

0.01 Hz以下にもう1つ共振があることに注意 (1本吊りのSAS)

# Opto-mechanical TF

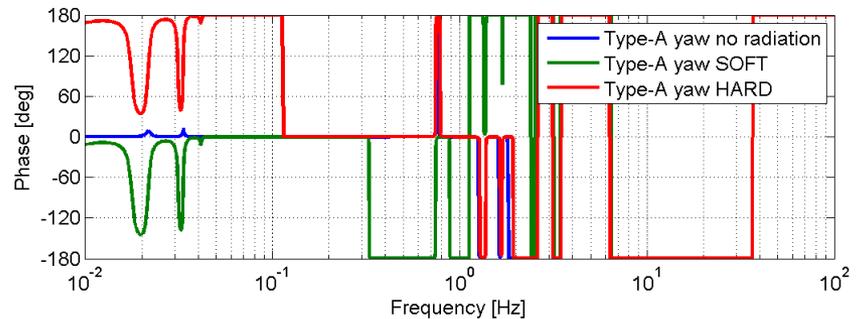
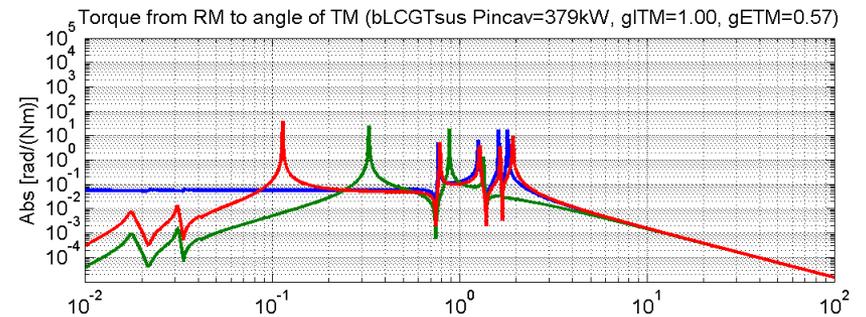
- $g_{ITM}=1.00$ ,  $g_{ETM}=0.57$  (flat-7km)
- $k_{SOFT}=-33.8$  Nm,  $k_{HARD}=4.4$  Nm (379 kW)

pitch



pitchのSOFTはstable(0.5HzあたりにあるのはSOFTモードのピーク)

yaw



yawのSOFTはunstable  
0.01 Hz以下にもう1つ共振があることに注意  
(1本吊りのSAS)

# Opto-mechanical TF

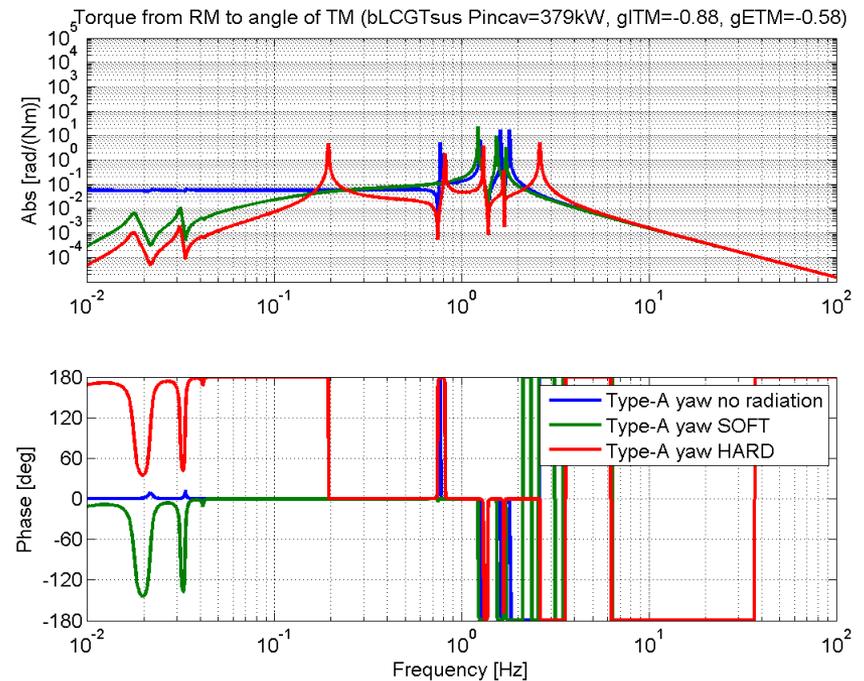
- $g_{ITM} = -0.88$ ,  $g_{ETM} = -0.58$  (1.6km-1.9km)
- $k_{SOFT} = -4.6$  Nm,  $k_{HARD} = 28.2$  Nm (379 kW)

pitch



pitchのSOFTはstable

yaw



yawのSOFTはunstable

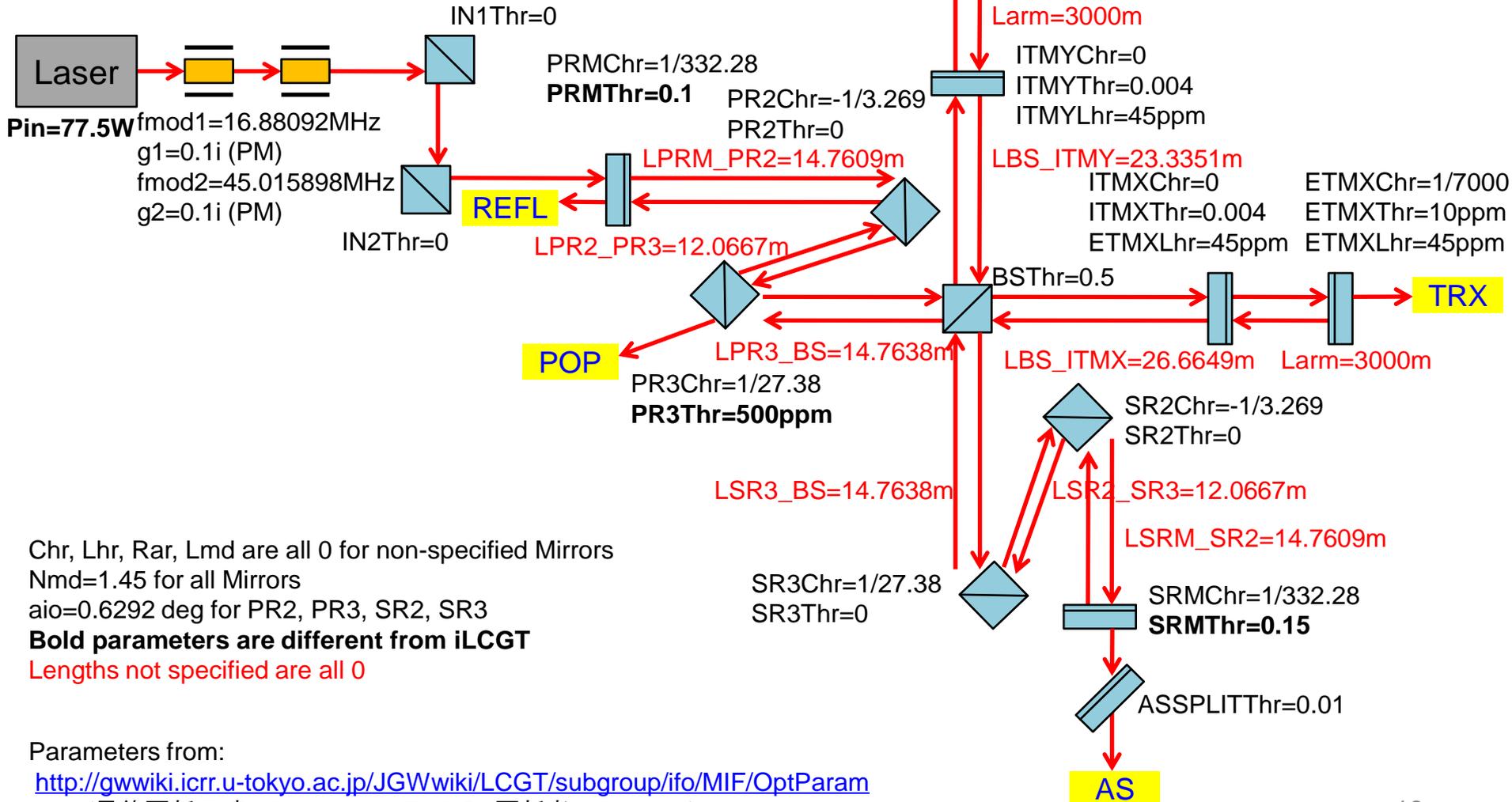
0.01 Hz以下にもう1つ共振があることに注意  
(1本吊りのSAS)

bLCGT ASC  
(positive  $g$ -factorの場合)

# bLCGT ASC計算時の仮定

- 制御したい鏡  
ETMX, ETMY, ITMX, ITMY, BS, PR3, PR2, PRM, SR3, SR2, SRM
- 制御自由度  
CS, CH, DS, DH, BS, PR3, PR2, PRM, SR3, SR2, SRM
- SR2はWFSでは制御しない
- bLCGTのサスペンションモデルを使用  
古いパラメータだが、とりあえず0次近似として
- 全てリコイルマスから制御
- 全てpitchの計算
- SRCLのDARMへのカップリングはとりあえず今回は  
1/100とした

# Optickle Model of bLCGT ASC



Chr, Lhr, Rar, Lmd are all 0 for non-specified Mirrors  
 Nmd=1.45 for all Mirrors  
 aio=0.6292 deg for PR2, PR3, SR2, SR3  
**Bold parameters are different from iLCGT**  
 Lengths not specified are all 0

Parameters from:

<http://gwwiki.icrr.u-tokyo.ac.jp/JGW/wiki/LCGT/subgroup/ifo/MIF/OptParam>

(最終更新日時 2011-04-19 17:43:58 更新者 YoichiAso)

[http://gwwiki.icrr.u-tokyo.ac.jp/JGW/wiki/LCGT/subgroup/OCG/parametermeeting?action=AttachFile&do=view&target=interface\\_parameter\\_%28selected%29.pdf](http://gwwiki.icrr.u-tokyo.ac.jp/JGW/wiki/LCGT/subgroup/OCG/parametermeeting?action=AttachFile&do=view&target=interface_parameter_%28selected%29.pdf)



# 各所でのDC光量

- Laser: 77.5 W
- from PR3 to BS: 799 W
- intra-cavity: 379 kW
- 各ポート
  - POP: 50.9 mW
  - REFL: 51.1 mW
  - AS: 0.018 mW
  - TRX/Y: 49.3 mW

キャリアのみのDC光量

各ポートに関しては、  
サイドバンドも含めた全DC光量  
ASはサイドバンドしか出ないこと  
になってる(DC readoutに対応し  
ていないし、腕の非対称性を導入  
していない)

AS以外、大体50mWになるように調整

# ポートの選択と位相の最適化

min XXはXXの信号を最初にするようにGouy phaseを決めるということ

何も条件が書いていないのは他でGouyを決められてしまったもの(Gouyをどう頑張っても分離できないもの)

POP DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-19.4	-22.0	-24.7	-81.4	-44.3	-46.9	88.1	87.0	64.5	64.5	64.5
max ampli	<b>-42003.1</b>	-7661.3	-8.2	-0.5	-507.3	-1310.5	<b>-3375.0</b>	-1680.9	1.3	0.2	0.1
Gouy	-2	-2	NaN	NaN	71	71	70	70	NaN	NaN	NaN
ampli	-28338.6	-5091.0	NaN	NaN	153.3	433.5	<b>-2268.6</b>	-1136.5	NaN	NaN	NaN
contami	1.2	6.8	NaN	NaN	29.4	10.4	2.0	3.9	NaN	NaN	NaN
N big sig	1	2	NaN	NaN	6	3	1	2	NaN	NaN	NaN

POP\_ADC (min CS)

POP f1 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-17.1	-32.9	51.8	51.8	39.3	-28.6	-27.3	19.6	-25.5	-25.5	-25.5
max demod	0.1	0.1	-89.9	-89.9	-71.0	-0.1	-0.1	0.5	<b>-0.0</b>	-0.0	-0.0
max ampli	<b>-118.7</b>	<b>-119.7</b>	<b>53.4</b>	<b>-65.5</b>	<b>48.4</b>	<b>-70.7</b>	<b>-8.2</b>	<b>-8.3</b>	<b>-164.2</b>	<b>-19.7</b>	<b>-10.3</b>
Gouy	64	-73	-81	-81	-82	-73	-73	-38	-73	-73	-73
demod	0	-2	-89	-89	-89	-2	-2	0.1	-2	-2	-2
ampli	-81.1	-91.5	-36.3	44.5	<b>-32.3</b>	-50.5	-5.7	0.1	<b>-110.7</b>	<b>-13.3</b>	<b>-7.0</b>
contami	1.3	3.3	3.1	2.5	3.6	6.0	5.9	13.1	2.7	22.7	43.2
N big sig	1	2	3	1	3	3	2	5	1	5	6

POP\_B1Q

POP\_B1I (min CS)

POP f2 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-72.6	76.6	81.8	79.5	75.5	75.5	75.5	75.4	81.5	81.5	81.5
max demod	0.1	0.1	-26.9	-23.0	0.0	0.1	0.1	0.1	-90.0	-90.0	-90.0
max ampli	<b>-5076.6</b>	<b>2282.9</b>	2.8	-4.0	<b>1947.9</b>	<b>5511.2</b>	660.5	335.8	0.0	0.0	0.0
Gouy	-17	-20	70	70	68	-20	-20	-14	NaN	NaN	NaN
demod	-70	-70	90	90	90	-70	-70	75	NaN	NaN	NaN
ampli	-90.6	-55.7	-1.3	1.6	-2.6	-98.2	-11.6	-4.2	NaN	NaN	NaN
contami	1.2	3.7	6.7	5.6	4.9	2.1	17.8	36.2	NaN	NaN	NaN
N big sig	1	2	4	2	2	1	4	5	NaN	NaN	NaN

REFL DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-3.5	3.8	-0.8	-16.8	2.1	3.9	4.0	36.0	83.8	83.8	83.8
max ampli	<b>-66522.5</b>	<b>-57318.2</b>	-57.7	43.8	<b>-28726.4</b>	<b>-81234.2</b>	<b>-9402.2</b>	<b>-3818.7</b>	<b>-2485.2</b>	<b>-297.9</b>	<b>-156.4</b>
Gouy	-86	86	NaN	NaN	-6	86	86	-87	-86	-86	-86
ampli	-6172.3	-5533.9	NaN	NaN	-20108.3	-7887.1	-923.3	1472.1	1729.5	207.3	108.9
contami	1.7	3.7	NaN	NaN	8.6	2.6	22.4	7.3	6.1	50.9	96.9
N big sig	1	2	NaN	NaN	4	1	6	3	2	5	6

REFL f1 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-89.9	85.9	71.8	71.1	-13.8	-22.3	-57.0	19.2	-6.2	-6.2	-6.2
max demod	0.0	0.0	77.6	-88.3	0.6	0.0	0.0	0.0	-0.1	-0.1	-0.1
max ampli	<b>-16121.3</b>	<b>226218.0</b>	-128.0	-153.4	<b>-909.2</b>	<b>-3111.6</b>	<b>-620.1</b>	<b>6313.7</b>	<b>-384.4</b>	<b>-46.1</b>	<b>-24.2</b>
Gouy	-71	0	0	0	0	-3	0	0	0	NaN	NaN
demod	-71	0	-90	-90	-90	-3	-3	0	-4	NaN	NaN
ampli	<b>-152357.5</b>	<b>-1858.0</b>	40.5	-49.7	35.9	<b>-2876.0</b>	<b>-337.4</b>	<b>5954.7</b>	<b>-381.3</b>	NaN	NaN
contami	1.2	6.3	3.3	2.7	3.7	4.4	37.1	2.1	32.8	NaN	NaN
N big sig	1	3	2	1	3	2	4	1	5	NaN	NaN

REFL\_B1I (min CS)

REFL f2 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-89.9	84.0	76.4	-86.7	-74.9	-75.4	-78.1	26.3	-79.3	-79.3	-79.3
max demod	0.1	0.2	8.5	-16.5	0.0	0.0	-0.0	-0.0	89.8	89.8	89.8
max ampli	<b>-163972.4</b>	<b>19501.2</b>	-21.6	13.3	<b>-4926.0</b>	<b>-14407.0</b>	<b>-2073.0</b>	<b>6213.0</b>	0.0	0.0	0.0
Gouy	-78	40	NaN	-79	40	40	40	-1	NaN	NaN	NaN
demod	-90	-90	NaN	-90	-90	-90	-90	-87	NaN	NaN	NaN
ampli	265.0	105.4	NaN	3.7	67.6	185.4	21.8	291.7	NaN	NaN	NaN
contami	1.2	3.7	NaN	87.6	5.7	2.1	17.8	1.2	NaN	NaN	NaN
N big sig	1	2	NaN	3	3	1	4	1	NaN	NaN	NaN

REFL\_A2I (max CS)

AS DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-16.9	-16.9	-87.3	-30.2	-6.2	-24.9	-26.6	83.7	-13.3	-12.9	23.8
max ampli	<b>-7.5</b>	<b>9.2</b>	-0.2	0.3	-2.7	<b>5.7</b>	0.6	0.9	<b>12.7</b>	1.6	<b>1.1</b>
Gouy	-66	-66	74	77	73	77	77	73	64	65	<b>73</b>
ampli	-3.5	4.3	0.1	-0.1	-0.4	-0.8	-0.1	0.6	2.0	0.2	0.5
contami	5.5	4.5	22.3	53.4	8.4	3.9	31.1	4.9	3.1	24.5	5.9
N big sig	3	2	6	9	5	1	8	1	1	7	<b>4</b>

AS\_BDC (min CS/CH)

AS f1 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-84.8	81.4	<b>89.5</b>	86.2	-13.4	89.6	89.5	88.6	76.8	77.1	-67.5
max demod	-90.0	-90.0	<b>-90.0</b>	-90.0	-90.0	-90.0	-90.0	-90.0	-90.0	-90.0	89.3
max ampli	-0.3	-0.0	<b>-1511.0</b>	-245.9	9.2	0.5	0.1	0.0	-0.0	-0.0	-0.0
Gouy	NaN	NaN	-4	0	-1	NaN	NaN	NaN	NaN	NaN	NaN
demod	NaN	NaN	0	0	0	NaN	NaN	NaN	NaN	NaN	NaN
ampli	NaN	NaN	0.0	-0.0	0.0	NaN	NaN	NaN	NaN	NaN	NaN
contami	NaN	NaN	1.1	2.3	3.9	NaN	NaN	NaN	NaN	NaN	NaN
N big sig	NaN	NaN	1	1	3	NaN	NaN	NaN	NaN	NaN	NaN

AS\_A1Q (max DS)

TRX DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-25.6	74.8	-25.6	74.8	-10.4	0.5	0.4	-0.6	-36.3	-36.3	-36.3
max ampli	<b>-43183.8</b>	<b>15641.0</b>	<b>-43183.3</b>	<b>15640.8</b>	0.0	-43.4	-5.2	-2.6	0.0	0.0	0.0
Gouy	-15	64	-15	64	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ampli	<b>30013.6</b>	<b>10865.5</b>	<b>-30013.4</b>	<b>10865.4</b>	NaN	NaN	NaN	NaN	NaN	NaN	NaN
contami	2.0	2.0	2.0	2.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN
N big sig	1	1	2	2	NaN	NaN	NaN	NaN	NaN	NaN	NaN

TRX\_ADC (min CS/DS)

TRY DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-25.6	74.8	-25.6	74.8	0.5	0.5	0.4	-0.6	-23.9	-23.9	-23.9
max ampli	<b>-43183.8</b>	<b>15641.0</b>	<b>-43183.4</b>	<b>15640.8</b>	-30.6	-43.4	-5.2	-2.6	-0.0	-0.0	-0.0
Gouy	-15	64	-15	64	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ampli	<b>30013.7</b>	<b>10865.5</b>	<b>30013.5</b>	<b>10865.4</b>	NaN	NaN	NaN	NaN	NaN	NaN	NaN
contami	2.0	2.0	2.0	2.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN
N big sig	1	1	2	2	NaN	NaN	NaN	NaN	NaN	NaN	NaN

TRY\_ADC (min CS/DS)

# 全Sensing Matrix

## WFS Sensing Matrix [W/mrad/sqrt(2/pi)]

(Gouy phases at POP A:70.6, POP B:-72.9 REFL A:-89.9, REFL B:-0.1, AS A:89.5, AS B:73.1, TR A:64.4 deg)

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
POP_ADC	0.03	0.24	0.00	0.00	0.15	0.43	-2.28	-1.14	0.00	0.00	0.00
POP_BDC	-17.67	-3.42	-0.00	-0.00	-0.31	-0.83	2.26	1.12	-0.00	-0.00	-0.00
POP_A1I	0.07	0.03	-0.00	0.00	-0.00	0.01	0.00	-0.01	0.02	0.00	0.00
POP_A1Q	0.00	0.00	-0.05	0.06	-0.04	0.00	0.00	0.00	0.00	0.00	0.00
POP_B1I	-0.00	-0.09	0.00	-0.00	0.02	-0.05	-0.01	0.00	-0.11	-0.01	-0.01
POP_B1Q	-0.00	-0.00	0.03	-0.04	0.03	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
POP_A2I	-5.07	2.27	0.00	-0.00	1.94	5.49	0.66	0.33	-0.00	-0.00	-0.00
POP_A2Q	-0.00	-0.00	-0.00	0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00
POP_B2I	4.18	-1.97	-0.00	0.00	-1.66	-4.69	-0.56	-0.29	-0.00	-0.00	-0.00
POP_B2Q	0.05	-0.02	0.00	-0.00	-0.02	-0.05	-0.01	-0.00	0.00	0.00	0.00
REFL_ADC	-2.99	2.65	-0.00	0.01	0.72	3.80	0.45	1.58	1.75	0.21	0.11
REFL_BDC	-46.95	-40.43	-0.04	0.03	-20.30	-57.30	-6.63	-2.18	-0.19	-0.02	-0.01
REFL_A1I	161.21	26.15	0.03	0.00	-0.22	-1.18	-0.52	-2.06	-0.04	-0.01	-0.00
REFL_A1Q	0.08	0.01	0.12	-0.14	0.10	-0.00	-0.00	-0.00	-0.01	-0.00	-0.00
REFL_B1I	0.27	-1.81	-0.00	-0.00	-0.88	-2.88	-0.34	5.96	-0.38	-0.05	-0.02
REFL_B1Q	-0.00	0.00	-0.04	0.05	-0.04	-0.00	-0.00	0.00	0.00	0.00	0.00
REFL_A2I	163.97	19.39	0.02	0.01	-4.76	-13.95	-2.03	-2.74	0.00	0.00	0.00
REFL_A2Q	-0.23	0.06	0.00	-0.00	0.02	0.04	0.00	-0.00	0.00	0.00	0.00
REFL_B2I	0.42	-2.01	-0.01	0.00	-1.30	-3.66	-0.43	5.57	-0.00	-0.00	-0.00
REFL_B2Q	-0.19	-0.09	-0.00	0.00	-0.07	-0.21	-0.02	-0.00	0.00	0.00	0.00
AS_ADC	0.00	-0.00	0.00	-0.00	0.00	-0.00	-0.00	0.00	-0.00	-0.00	0.00
AS_BDC	-0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00
AS_A1I	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00
AS_A1Q	0.00	0.00	1.51	0.25	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
AS_B1I	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00
AS_B1Q	0.00	0.00	1.45	0.24	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
TRX_ADC	0.03	10.88	0.03	10.88	0.00	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
TRX_BDC	30.54	1.99	30.54	1.99	-0.00	0.03	0.00	0.00	-0.00	-0.00	-0.00
TRY_ADC	0.03	10.88	-0.03	-10.88	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
TRY_BDC	30.54	1.99	-30.54	-1.99	0.02	0.03	0.00	0.00	0.00	0.00	0.00

SR2はWFSでは  
制御しない

# 選択後のSensing Matrix

WFS Sensing Matrix [W/mrad/sqrt(2/pi)]

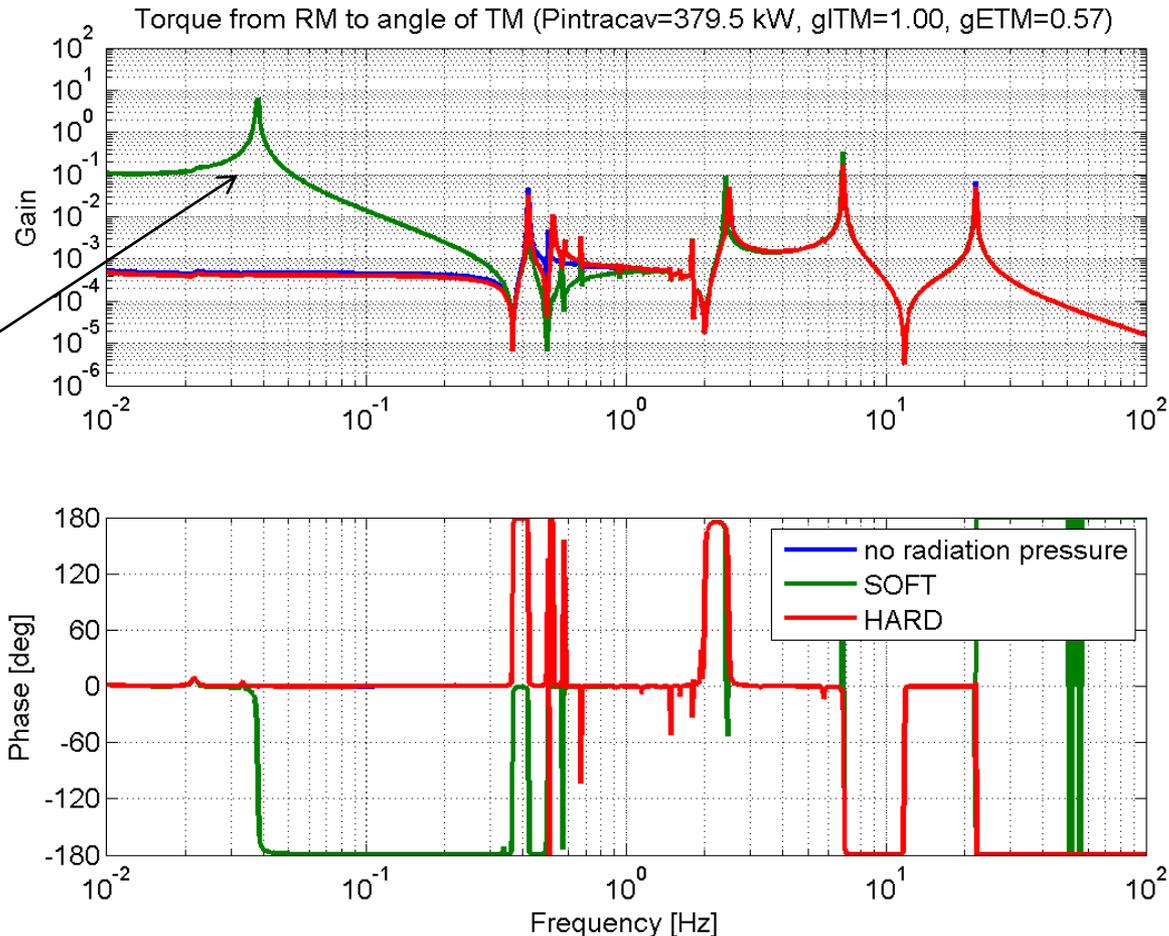
(Gouy phases at POP A:70.6, POP B:-72.9 REFL A:-89.9, REFL B:-0.1, AS A:89.5, AS B:73.1, TR A:64.4 deg)

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
REFL_A2I	163.97	19.39	0.02	0.01	-4.76	-13.95	-2.03	-2.74	0.00	0.00	0.00
TRX_ADC	0.03	10.88	0.03	10.88	0.00	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
AS_A1Q	0.00	0.00	1.51	0.25	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
TRY_ADC	0.03	10.88	-0.03	-10.88	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
POP_B1Q	-0.00	-0.00	0.03	-0.04	0.03	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
REFL_BDC	-46.95	-40.43	-0.04	0.03	-20.30	-57.30	-6.63	-2.18	-0.19	-0.02	-0.01
POP_ADC	0.03	0.24	0.00	0.00	0.15	0.43	-2.28	-1.14	0.00	0.00	0.00
REFL_B1I	0.27	-1.81	-0.00	-0.00	-0.88	-2.88	-0.34	5.96	-0.38	-0.05	-0.02
POP_B1I	-0.00	-0.09	0.00	-0.00	0.02	-0.05	-0.01	0.00	-0.11	-0.01	-0.01
AS_BDC	-0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00

SR2はWFSでは  
制御しない

# Opto-mechanical TF

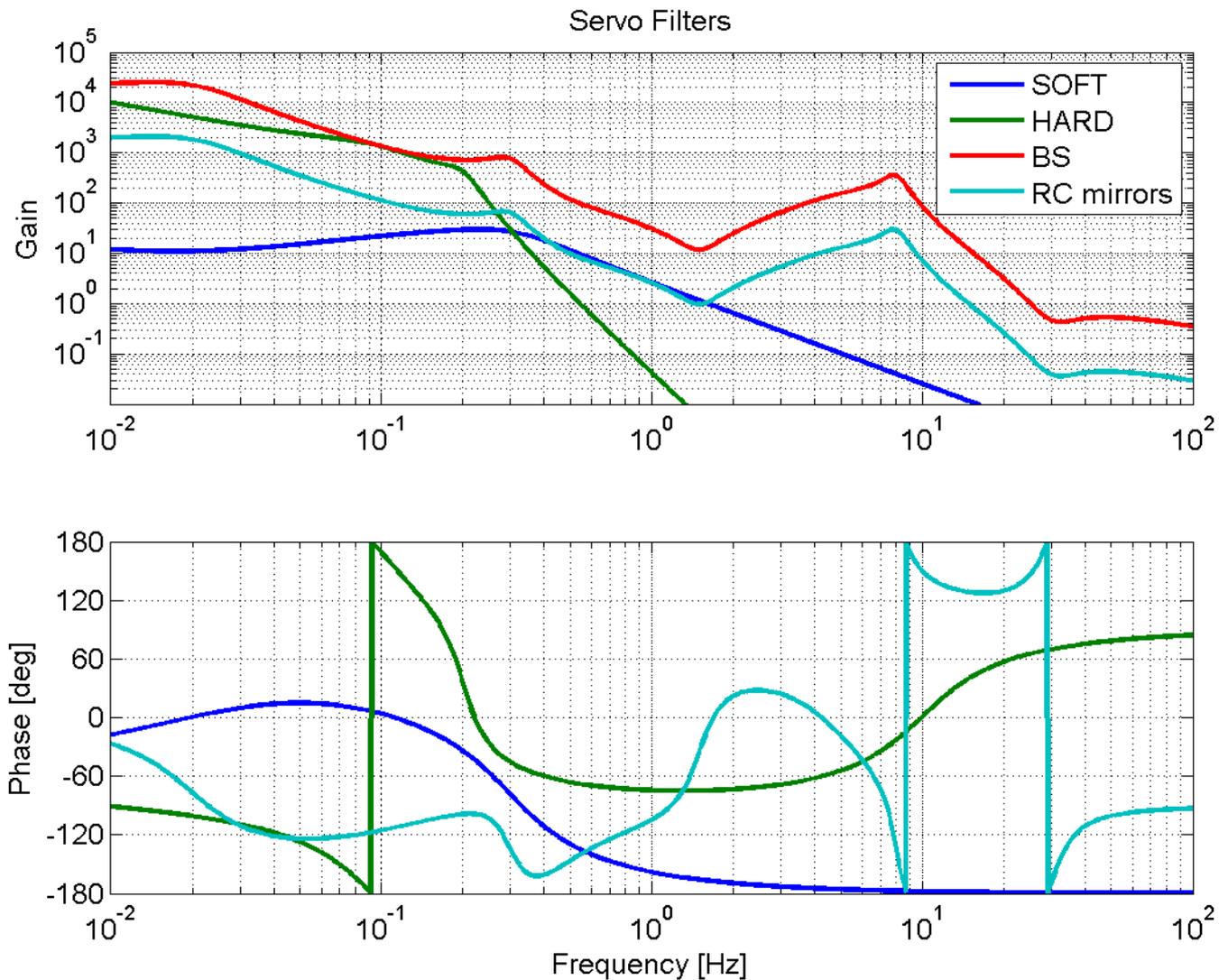
- リコイルマスに加えたトルクから鏡の角度へのTF (pitch)  
青が輻射圧 ( $P_{incav}=379kW$ ) 下で緑と赤に



SOFTモードもぎりぎりstableだが、かえってこのピークが悪さをする(少しのトルクで鏡が大きく揺れることになる)

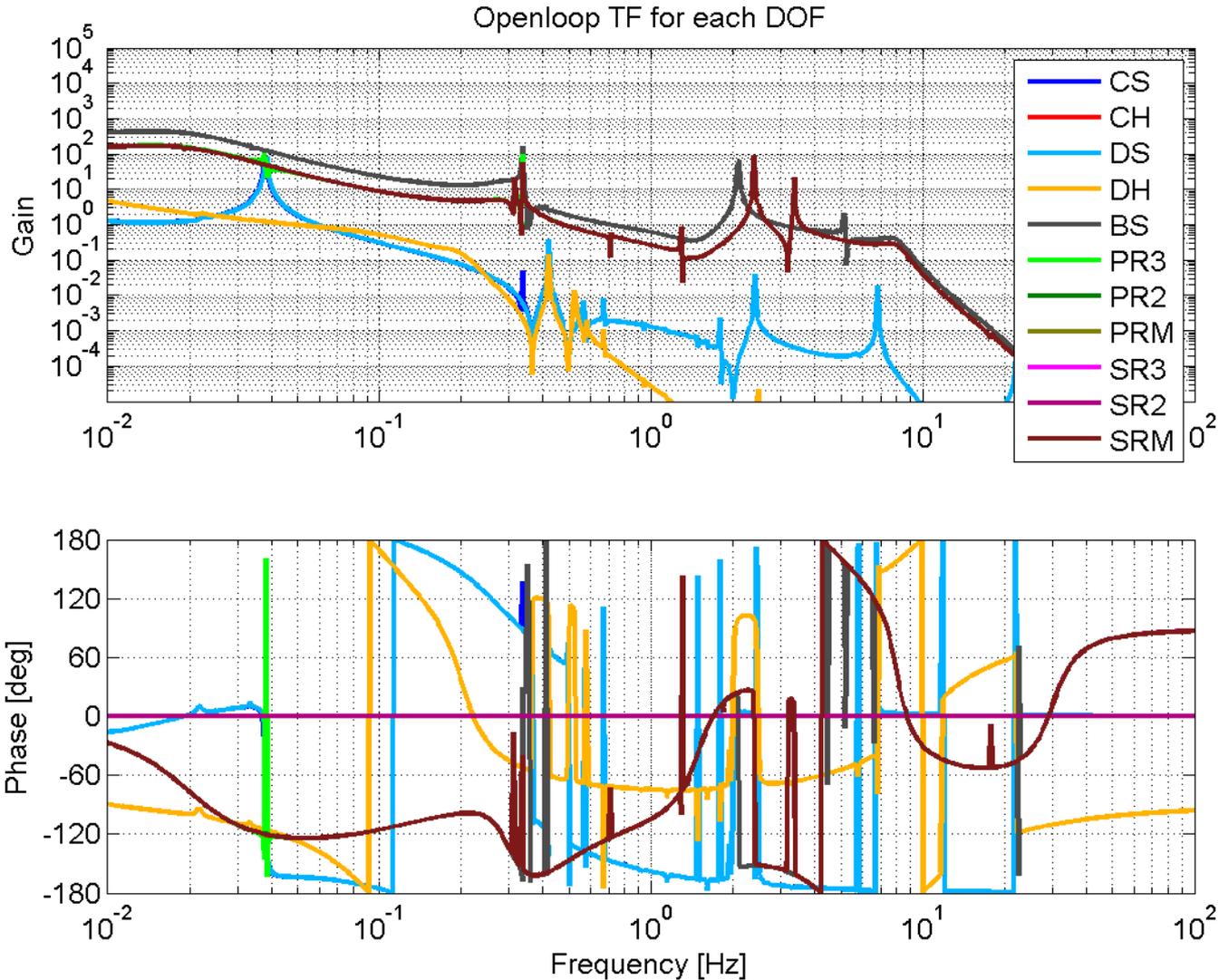
p12にある低周波側の構造(ヒートリンクのピーク)が無いのはOpticelに与えているデータはフィッティングで求めたzpk関数だから。

# 制御フィルタ

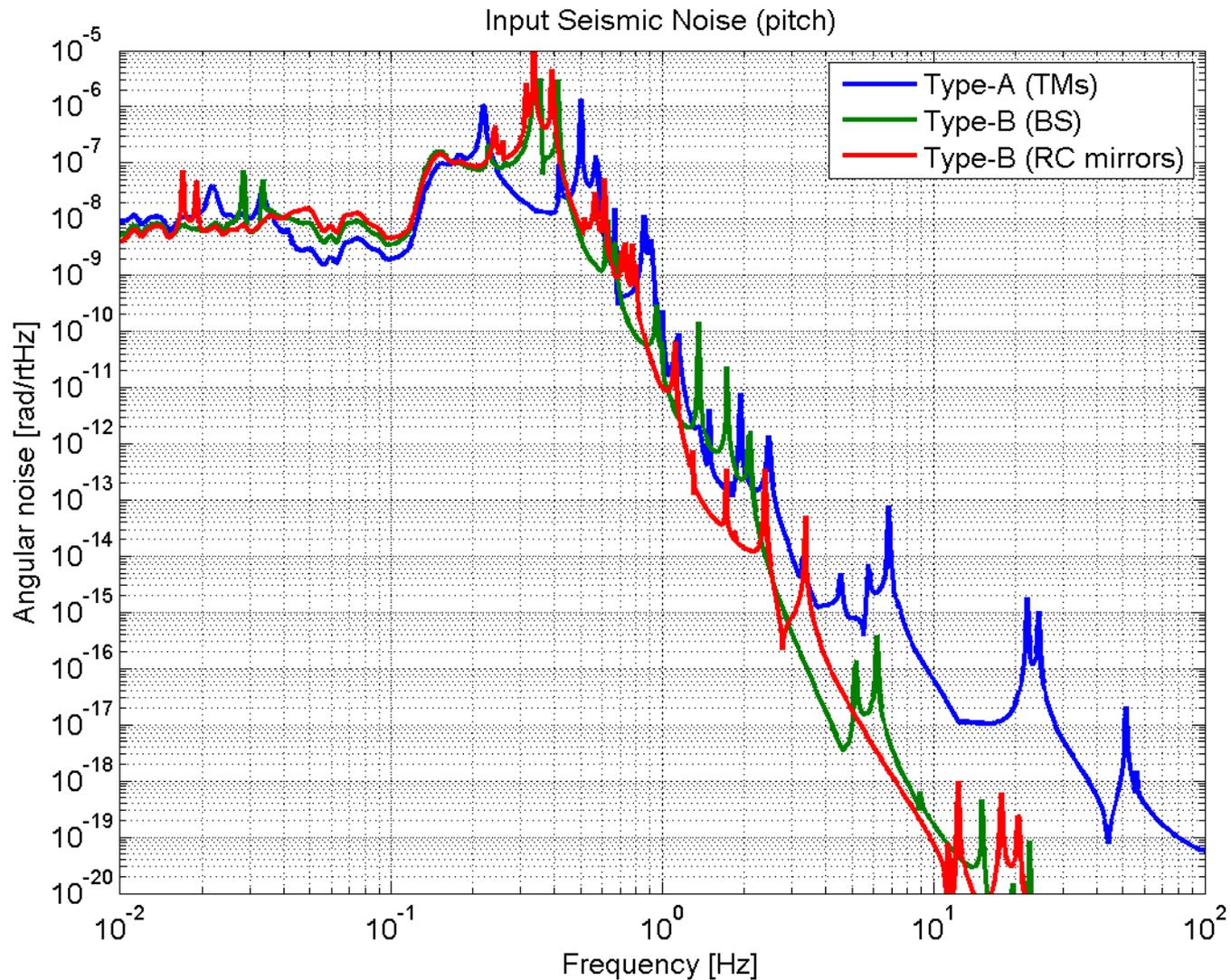


TMの制御は低周波 (<0.06Hz)だけにする

# オープンループ伝達関数



# 地面振動による角度揺れ

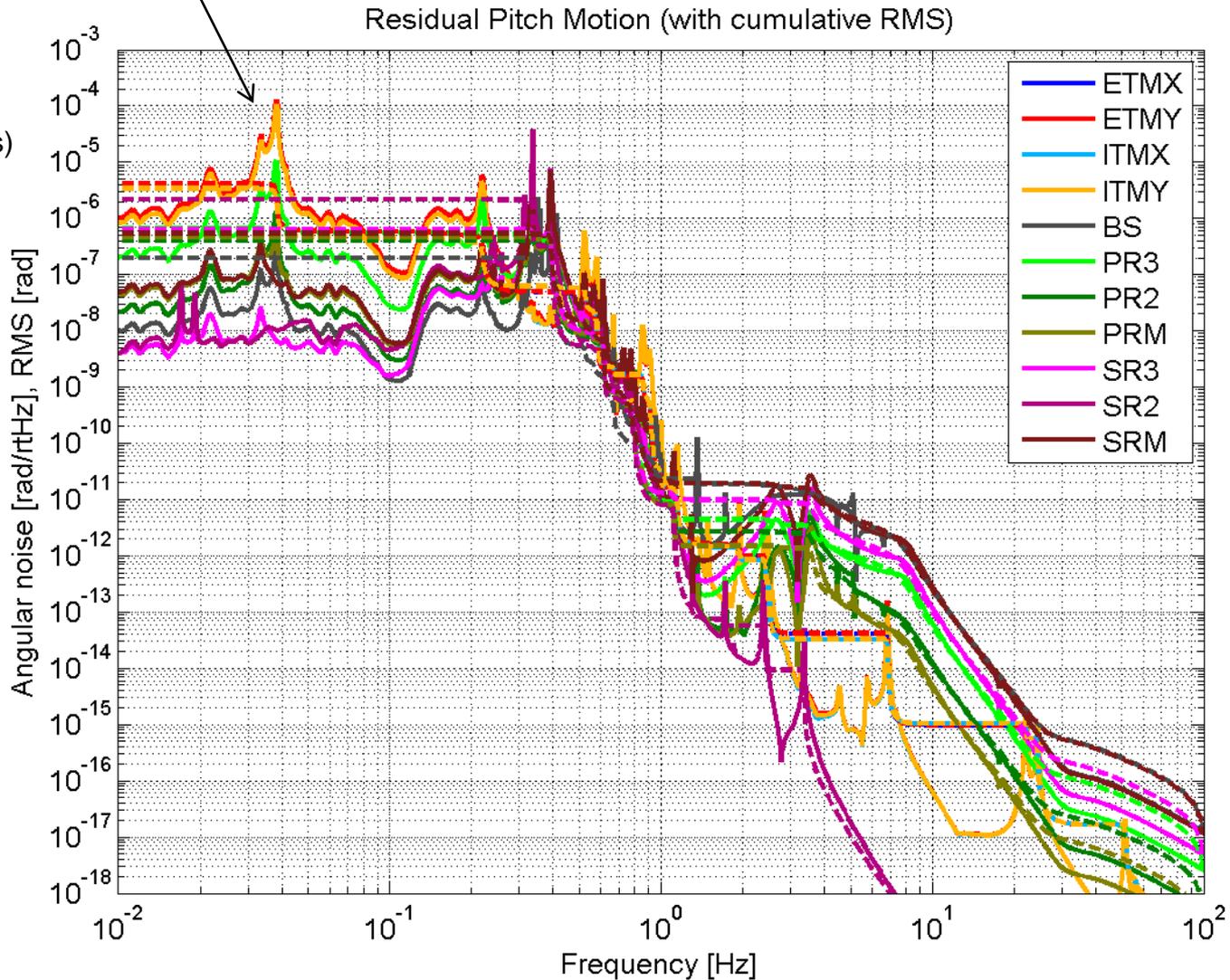


関口くん提供  
(2011/5/23版)  
“Noisy day”

# 残留角度揺れ

SOFTモードのピーク  
(RMSを増やす元凶)

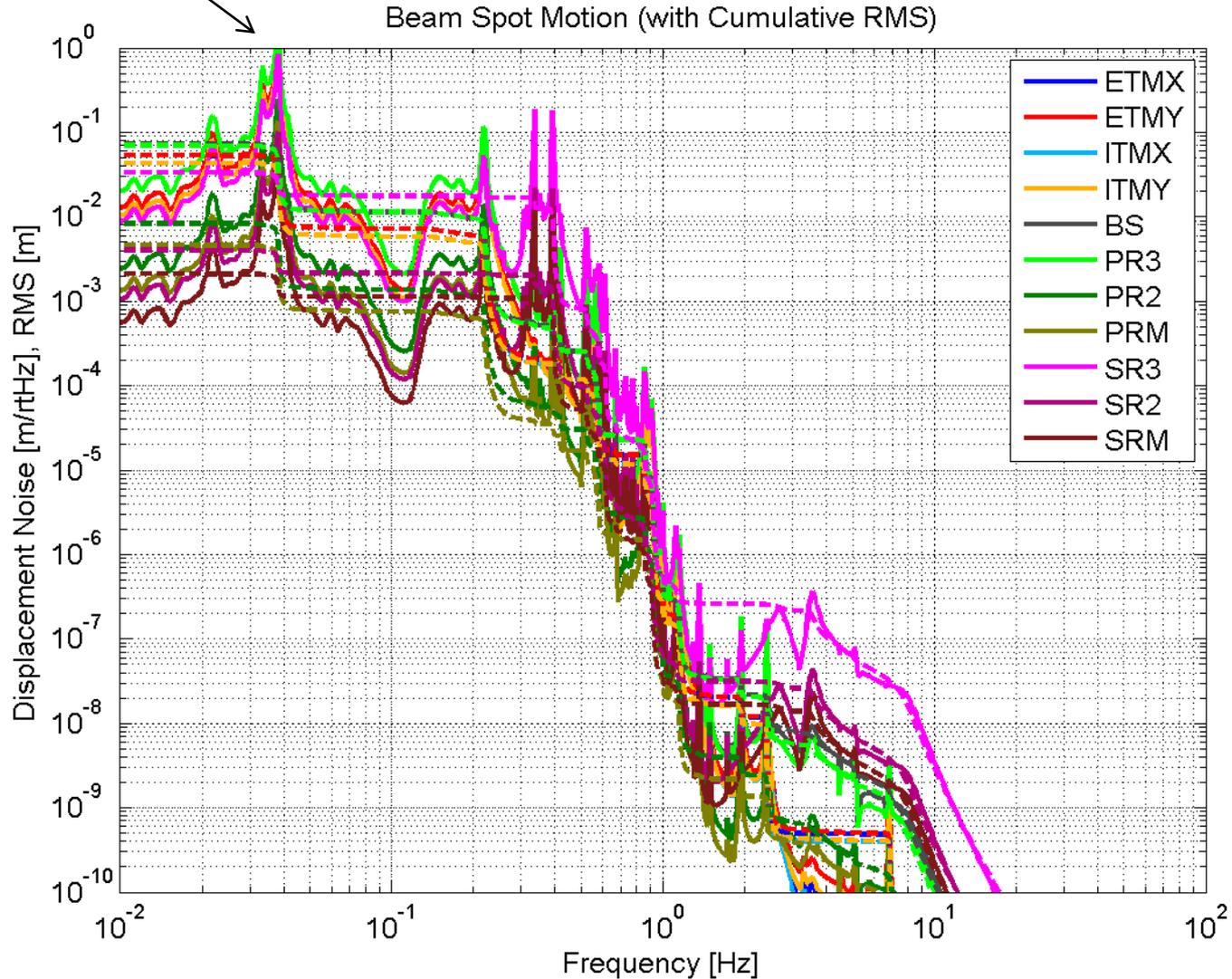
累積RMS  
~4e-6 rad(TMs)



# ビームスポットの動き

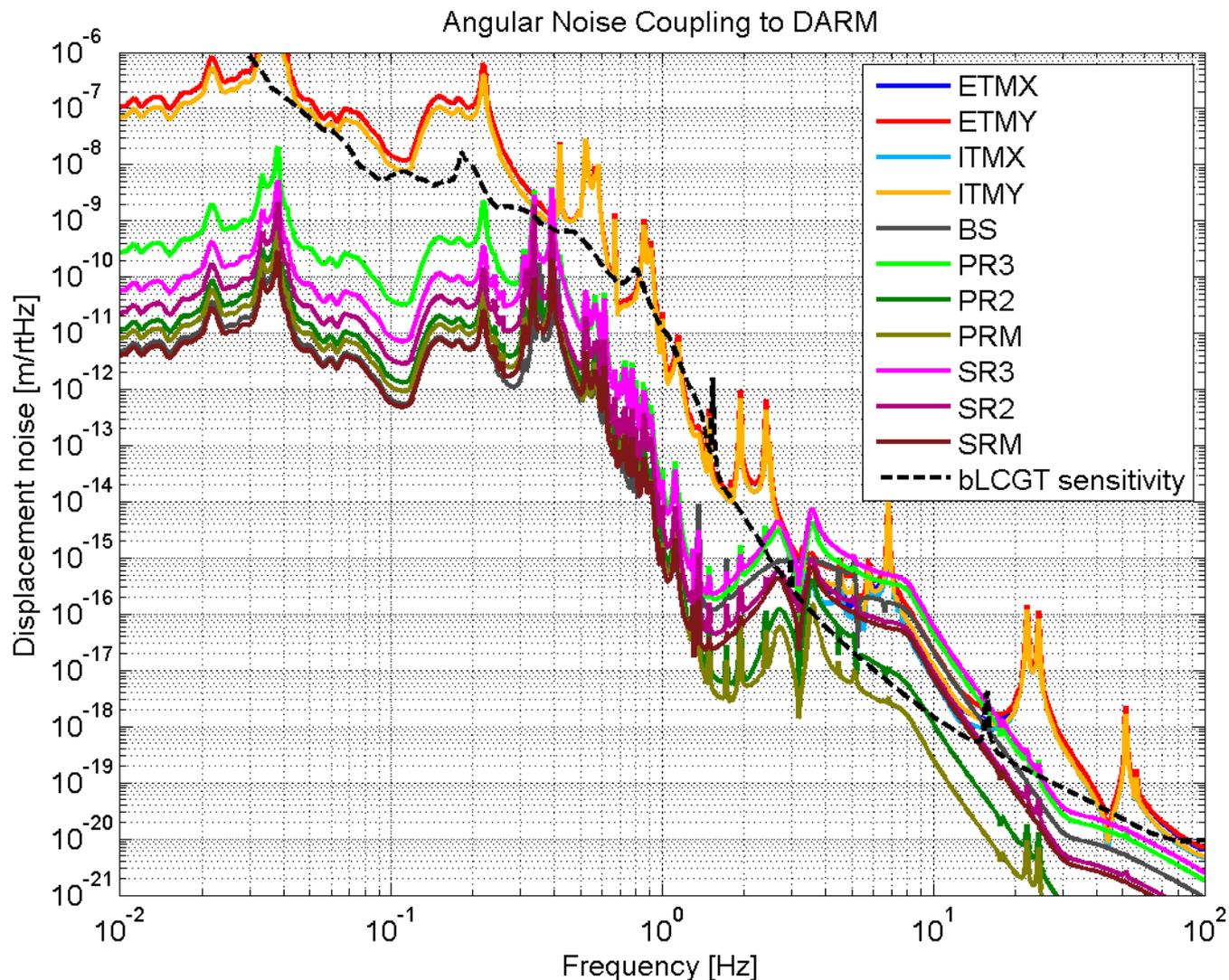
SOFTモードのピーク  
(RMSを増やす元凶)

累積RMS  
~4e-2 m (TM)



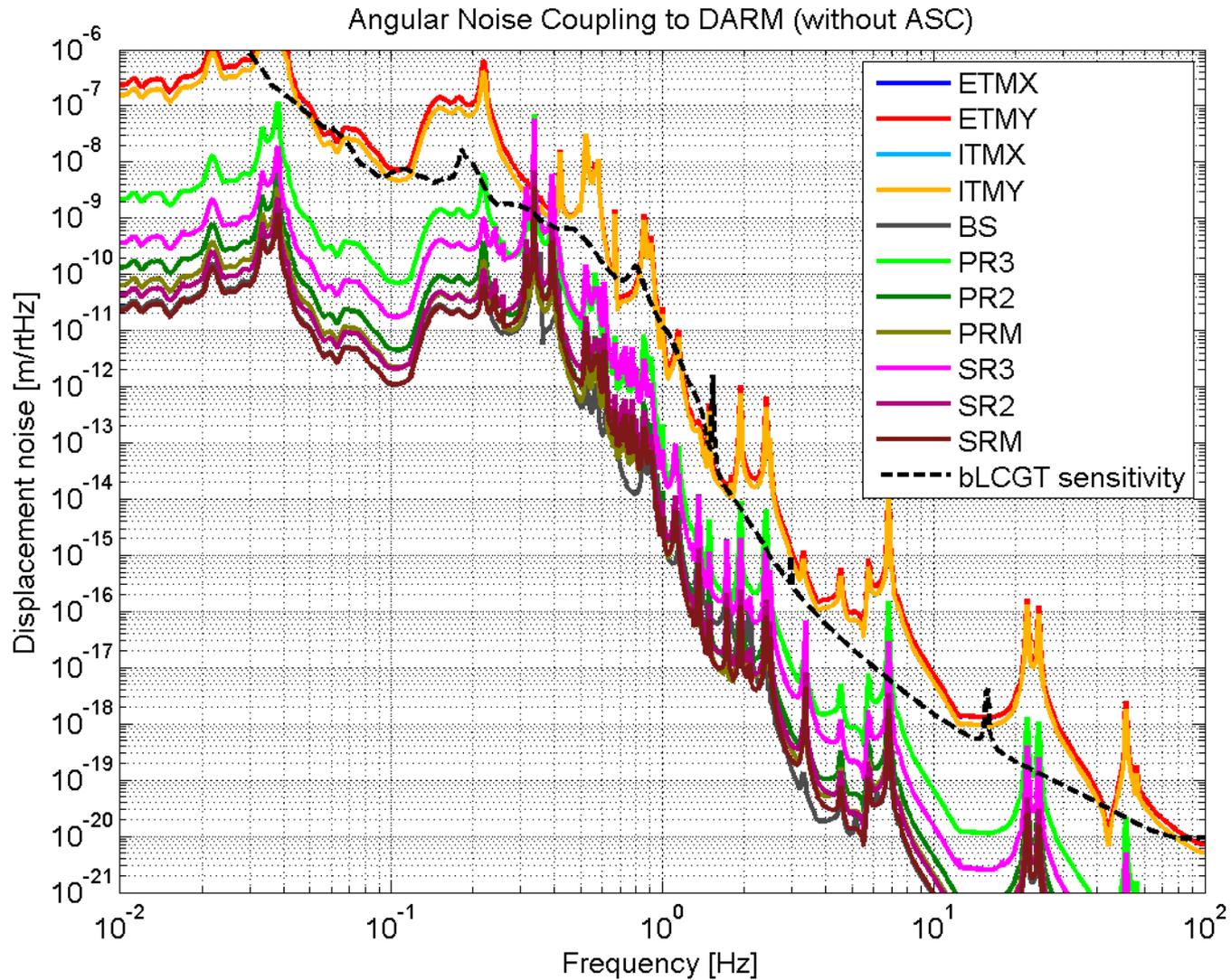
# DARMへのカップリング

$$\Delta L(f) = c \cdot d_{\text{spot}}(f) * \theta_{\text{Mirror}}(f)$$

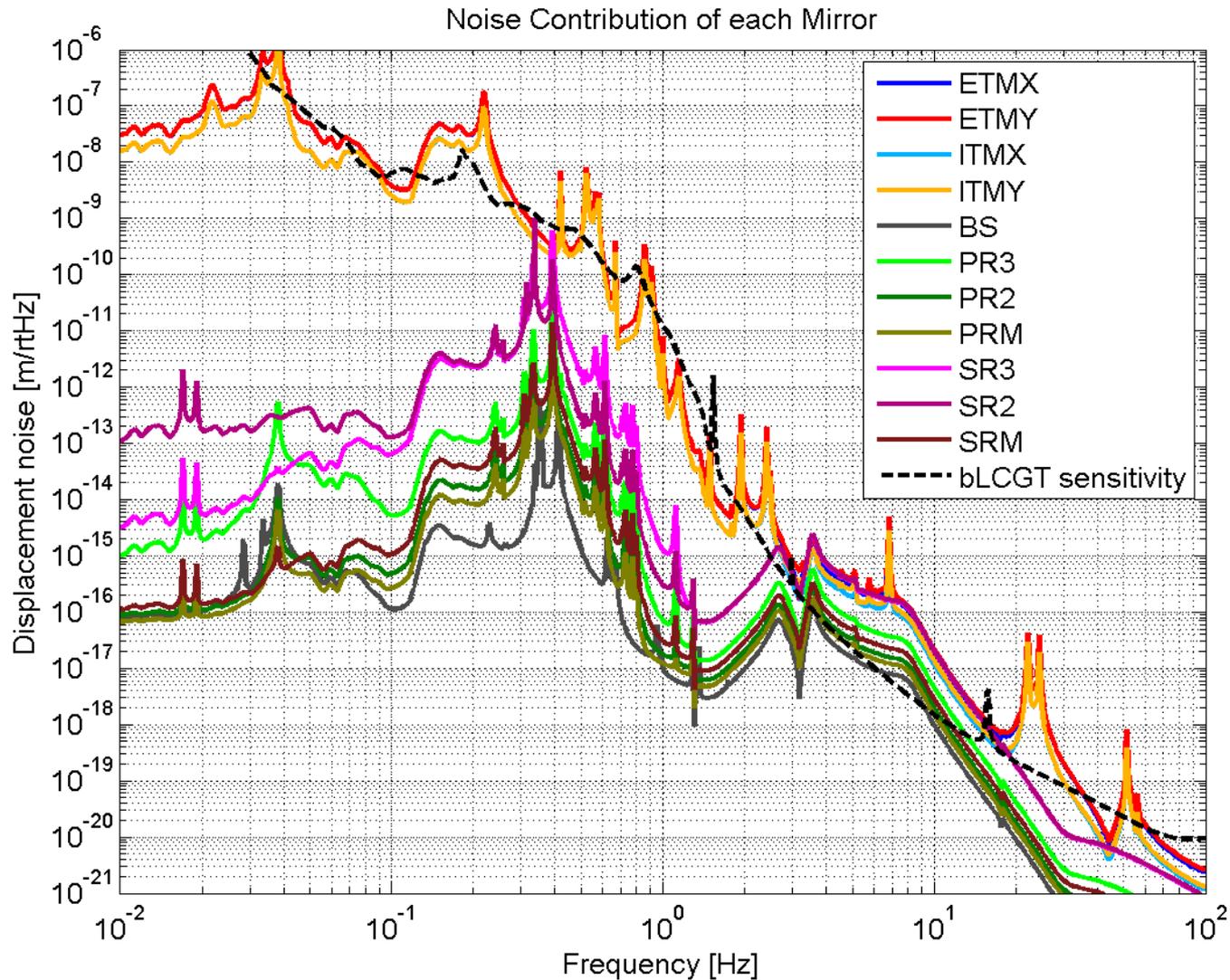


SOFTモードのピーク  
によってTMがひどく  
揺れている

# 制御しないと.....



# 各鏡の揺れの寄与



1つの鏡だけを地面振動で揺らすとDARMIに合計どれだけのノイズが出るか。

どの鏡の揺れが実際に悪さをしているか、もっと揺れを抑えなければいけないかがわかる。

やはりTMの寄与が大きい

bLCGT ASC  
(negative g-factorの場合)

# negative g-factor

- ITM曲率を1.6 km、ETM曲率を1.9 kmに変えただけで、同じ計算をする。
- でも信号の出方は変わってくるのでポート選択、sensing matrixからやり直し

# ポートの選択と位相の最適化

min XXはXXの信号を最初にするようにGouy phaseを決めるということ

何も条件が書いていないのは他でGouyを決められてしまったもの(Gouyをどう頑張っても分離できないもの)

POP DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-8.8	-9.4	5.8	56.8	-14.6	-14.0	84.9	84.4	78.8	78.8	78.8
max ampli	-11670.6	34918.5	-4.0	2.4	-984.2	-2686.2	-3851.9	-3333.6	1.0	0.1	0.1
Gouy	-5	-5	NaN	NaN	-6	-6	81	81	NaN	NaN	NaN
ampli	-8234.5	24619.0	NaN	NaN	-688.2	-1880.9	-2717.4	-2353.2	NaN	NaN	NaN
contami	4.3	1.4	NaN	NaN	51.6	18.9	2.0	2.3	NaN	NaN	NaN
N big sig	2	1	NaN	NaN	4	3	1	2	NaN	NaN	NaN

POP\_ADC (min CH)

POP f1 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	8.4	-47.8	53.3	53.3	4.8	-12.2	-10.7	9.6	-11.2	-11.2	-11.2
max demod	0.0	0.4	-89.5	-89.5	-25.8	0.0	0.0	0.4	0.1	0.1	0.1
max ampli	-72.4	-110.0	19.8	-24.6	27.0	-53.4	-6.8	-13.0	-124.4	-16.1	-14.7
Gouy	43	79	2	2	3	42	42	42	42	42	42
demod	1	0	-90	-90	90	4	4	4	4	4	4
ampli	-59.6	65.9	12.4	-15.4	-11.3	-31.2	-4.1	-10.8	-74.5	-9.7	-8.8
contami	3.6	1.5	3.2	2.5	3.5	52.1	19.6	1.5	2.9	22.3	24.4
N big sig	2	1	2	1	3	3	5	6	1	6	7

POP\_B1I (min CS)

POP f2 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-88.7	-83.5	-77.6	-78.1	-89.8	-89.8	-89.8	-89.8	-76.6	-76.6	-76.6
max demod	-0.2	-0.1	-12.7	-12.6	-0.2	-0.1	-0.1	-0.1	89.5	89.5	89.5
max ampli	-5302.3	-3335.6	-12.0	15.1	-4001.9	-11467.8	-1486.6	-1318.2	0.0	0.0	0.0
Gouy	-3	-4	66	66	-6	4	4	-51	NaN	NaN	NaN
demod	-60	-66	89	89	-82	-54	-54	-89	NaN	NaN	NaN
ampli	-72.4	-153.5	-3.1	3.7	67.7	751.5	98.1	6.7	NaN	NaN	NaN
contami	3.7	1.4	8.9	7.5	6.2	2.2	16.6	18.6	NaN	NaN	NaN
N big sig	2	1	4	3	3	1	4	5	NaN	NaN	NaN

POP\_A2I

AS DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-23.8	-23.8	-63.3	-32.4	-10.1	-38.9	-43.9	87.8	-16.6	-15.7	56.3
max ampli	-2.7	3.4	-0.4	0.4	-1.1	2.3	0.3	1.2	4.8	0.7	1.3
Gouy	-33	-33	73	-34	51	74	74	67	-2	-2	66
ampli	-1.9	2.4	0.2	0.2	-0.4	-0.6	-0.1	0.8	3.3	0.5	0.9
contami	6.0	4.8	18.0	45.7	12.5	5.4	38.5	3.9	3.3	24.0	3.4
N big sig	3	2	6	8	6	3	7	2	1	7	1

AS\_ADC

AS\_A1Q (max DH)

AS f1 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-81.7	79.8	-89.2	89.0	-16.4	89.8	89.7	89.3	73.8	74.6	-34.9
max demod	-90.0	-90.0	-90.0	-90.0	-90.0	-90.0	-90.0	-90.0	-89.6	-89.7	89.3
max ampli	-0.0	-0.1	455.7	-1186.6	9.7	0.5	0.1	0.1	-0.0	-0.0	-0.0
Gouy	NaN	NaN	-1	1	-1	NaN	NaN	NaN	NaN	NaN	NaN
demod	NaN	NaN	0	0	0	NaN	NaN	NaN	NaN	NaN	NaN
ampli	NaN	NaN	0.0	-0.0	0.0	NaN	NaN	NaN	NaN	NaN	NaN
contami	NaN	NaN	1.7	1.3	2.6	NaN	NaN	NaN	NaN	NaN	NaN
N big sig	NaN	NaN	1	1	2	NaN	NaN	NaN	NaN	NaN	NaN

AS\_B1Q(min DH)

REFL DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-17.0	4.6	21.3	21.7	8.0	8.7	8.8	21.3	87.7	87.7	87.7
max ampli	37117.5	160219.7	-174.6	205.1	-59212.6	169542.6	21685.7	18870.1	-1882.9	-244.2	-222.6
Gouy	-85	-81	NaN	NaN	-68	-86	-82	-82	NaN	NaN	NaN
ampli	-5444.3	-8645.6	NaN	NaN	-10095.6	9794.9	1275.8	3064.4	1310.1	NaN	NaN
contami	4.2	2.1	NaN	NaN	7.8	2.7	21.0	5.6	13.1	NaN	NaN
N big sig	2	1	NaN	NaN	3	1	6	3	5	NaN	NaN

REFL f1 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-88.8	89.1	62.4	62.4	-17.2	-25.2	-55.1	9.4	-2.3	-2.3	-2.3
max demod	0.0	0.0	85.8	-79.9	0.5	0.0	0.0	0.0	-0.0	-0.0	-0.0
max ampli	48630.4	126604.3	-46.4	-58.6	-981.7	-3118.1	-634.4	12312.2	-291.2	-37.8	-34.4
Gouy	-81	-81	0	0	-1	-1	-1	-1	-1	-1	-1
demod	1	10	-90	-90	0	0	0	0	0	0	0
ampli	47296.5	22818.6	21.5	-26.8	19.8	-2845.2	-371.9	12111.9	-291.1	NaN	NaN
contami	3.6	1.4	3.5	2.9	3.9	6.5	50.0	1.5	63.9	NaN	NaN
N big sig	2	1	2	2	3	2	5	1	6	NaN	NaN

REFL\_A1I (min PRM)

REFL\_B1I (min CH)

REFL f2 demodulation

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	-87.6	88.0	-64.2	-76.2	-75.7	-76.2	-77.4	24.2	-67.6	-67.6	-67.6
max demod	-0.0	0.2	-13.5	-11.1	-0.2	-0.2	-0.2	-0.4	89.3	89.3	89.3
max ampli	58223.3	111998.4	-25.2	43.2	-9828.7	-28554.6	-4022.9	12046.5	0.0	0.0	0.0
Gouy	-66	79	-71	-71	-7	-36	-36	-1	NaN	NaN	NaN
demod	80	89	-90	-90	89	-90	-90	-83	NaN	NaN	NaN
ampli	-9514.1	-2286.3	-6.4	7.9	-342.8	509.1	66.4	1404.2	NaN	NaN	NaN
contami	3.6	1.4	5.2	4.2	6.2	2.1	16.5	1.1	NaN	NaN	NaN
N big sig	2	1	5	4	3	1	4	1	NaN	NaN	NaN

TRX DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	85.5	22.2	85.5	22.2	-15.8	0.2	0.1	-0.3	-45.1	-45.1	-45.1
max ampli	17425.5	37097.6	17425.3	37097.4	0.0	-42.0	-5.4	-4.7	0.0	0.0	0.0
Gouy	-68	-4	-68	-4	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ampli	-11029.7	23528.3	-11029.5	23528.4	NaN	NaN	NaN	NaN	NaN	NaN	NaN
contami	2.0	2.0	2.0	2.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN
N big sig	1	2	2	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN

TRX\_ADC (min CH/DH)

TRY DC

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
max Gouy	85.5	22.2	85.5	22.2	0.2	0.2	0.1	-0.3	-51.0	-51.0	-51.0
max ampli	17425.5	37097.6	17425.3	37097.4	-29.2	-41.9	-5.4	-4.7	-0.0	-0.0	-0.0
Gouy	-68	-4	-68	-4	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ampli	-11029.7	23528.3	-11029.5	23528.4	NaN	NaN	NaN	NaN	NaN	NaN	NaN
contami	2.0	2.0	2.0	2.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN
N big sig	1	2	2	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN

TRY\_ADC (min CH/DH)

# 全Sensing Matrix

## WFS Sensing Matrix [W/mrad/sqrt(2/pi)]

(Gouy phases at POP A:80.8, POP B:42.2 REFL A:80.6, REFL B:-0.9, AS A:89.0, AS B:-1.0, TR A:-67.8 deg)

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
POP_ADC	-0.06	0.08	-0.00	0.00	0.07	0.16	-2.72	-2.35	0.00	0.00	0.00
POP_BDC	-5.20	-15.34	-0.00	0.00	-0.38	-1.06	-2.00	-1.75	0.00	0.00	0.00
POP_A1I	0.02	0.07	0.00	0.00	-0.00	0.00	0.00	-0.00	0.00	0.00	0.00
POP_A1Q	0.00	0.00	-0.02	0.02	-0.02	0.00	0.00	-0.00	0.00	0.00	0.00
POP_B1I	0.06	-0.00	0.00	-0.00	0.02	-0.03	-0.00	-0.01	-0.07	-0.01	-0.01
POP_B1Q	0.00	0.00	-0.02	0.02	-0.02	0.00	0.00	-0.00	0.00	0.00	0.00
POP_A2I	-5.25	3.21	0.01	-0.01	3.95	11.31	1.47	1.30	-0.00	-0.00	-0.00
POP_A2Q	0.04	-0.04	-0.00	0.00	-0.03	-0.09	-0.01	-0.01	-0.00	-0.00	-0.00
POP_B2I	-3.65	1.95	0.01	-0.01	2.68	7.67	1.00	0.88	-0.00	-0.00	-0.00
POP_B2Q	0.14	-0.09	-0.00	0.00	-0.11	-0.30	-0.04	-0.03	-0.00	-0.00	-0.00
REFL_ADC	-11.66	-27.45	-0.06	0.07	-12.55	-37.22	-4.78	-6.81	-1.32	-0.17	-0.16
REFL_BDC	-24.98	-112.77	-0.11	0.13	-41.36	-118.21	-15.12	-12.36	-0.03	-0.00	-0.00
REFL_A1I	-47.80	-125.23	-0.00	-0.01	0.13	0.85	0.45	3.96	-0.04	-0.00	-0.00
REFL_A1Q	-0.02	-0.06	-0.04	0.05	-0.04	0.00	0.00	0.00	0.00	0.00	0.00
REFL_B1I	-1.76	-0.15	0.00	-0.00	-0.94	-2.84	-0.37	12.12	-0.29	-0.04	-0.03
REFL_B1Q	0.00	0.00	-0.02	0.03	-0.02	-0.00	-0.00	0.01	0.00	0.00	0.00
REFL_A2I	-56.99	-111.06	0.02	-0.04	9.00	26.25	3.73	6.67	-0.00	-0.00	-0.00
REFL_A2Q	0.11	-0.35	-0.01	0.01	-0.16	-0.43	-0.06	-0.04	-0.00	-0.00	-0.00
REFL_B2I	-3.35	-2.10	-0.01	0.01	-2.59	-7.24	-0.94	10.91	-0.00	-0.00	-0.00
REFL_B2Q	-0.40	-0.23	-0.00	0.00	-0.29	-0.84	-0.11	-0.08	0.00	0.00	0.00
AS_ADC	0.00	-0.00	0.00	-0.00	0.00	-0.00	-0.00	0.00	-0.00	-0.00	0.00
AS_BDC	-0.00	0.00	-0.00	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00
AS_A1I	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00
AS_A1Q	0.00	0.00	0.46	1.19	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
AS_B1I	-0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
AS_B1Q	0.00	0.00	-0.01	-0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.00
TRX_ADC	-11.01	-0.03	-11.01	-0.03	0.00	-0.01	-0.00	-0.00	0.00	0.00	0.00
TRX_BDC	-5.53	26.23	5.53	26.23	0.00	-0.03	-0.00	-0.00	0.00	0.00	0.00
TRY_ADC	-11.01	-0.03	11.01	0.03	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
TRY_BDC	-5.53	26.23	-5.53	-26.23	-0.02	-0.03	-0.00	-0.00	-0.00	-0.00	-0.00

SR2はWFSでは  
制御しない

# 選択後のSensing Matrix

WFS Sensing Matrix [W/mrad/sqrt(2/pi)]

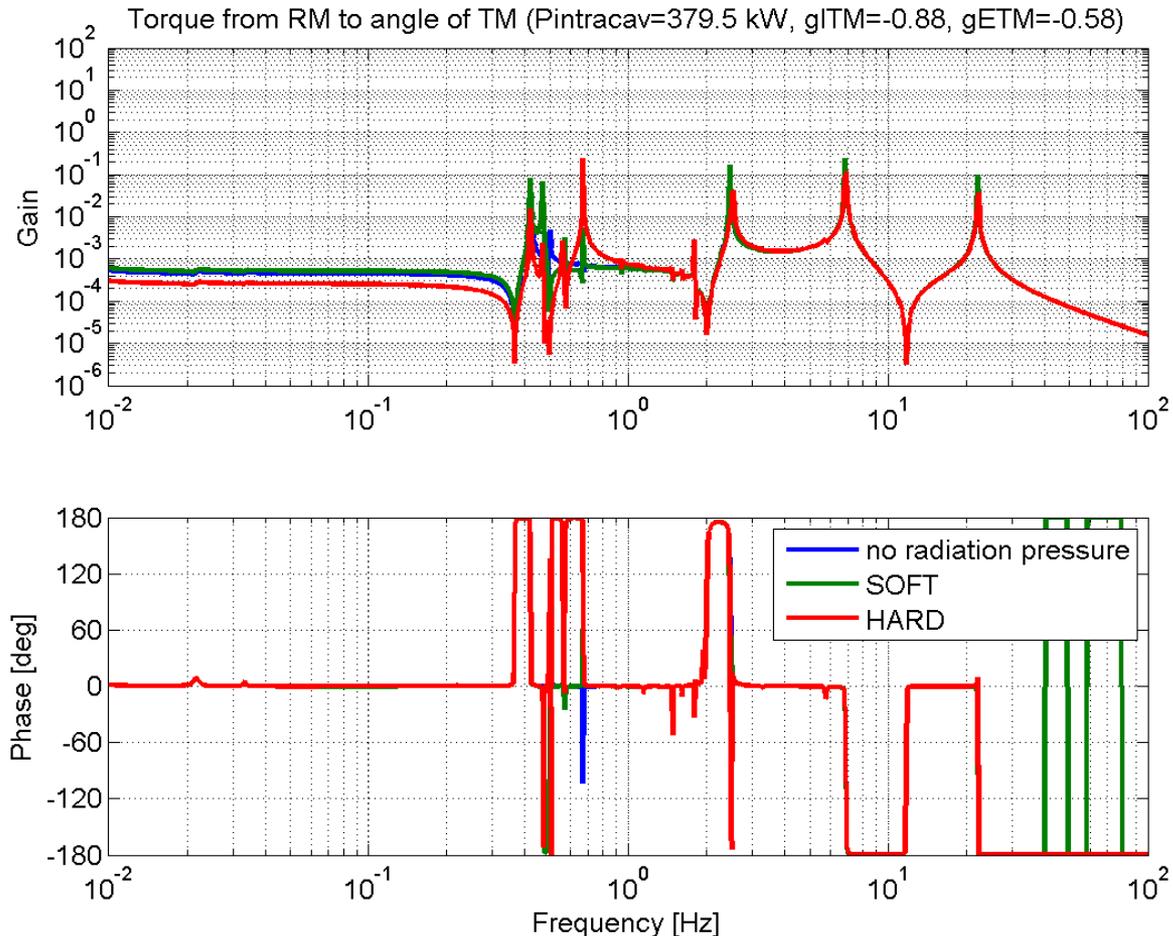
(Gouy phases at POP A:80.8, POP B:42.2 REFL A:80.6, REFL B:-0.9, AS A:89.0, AS B:-1.0, TR A:-67.8 deg)

	CS	CH	DS	DH	BS	PR3	PR2	PRM	SR3	SR2	SRM
TRX_ADC	-11.01	-0.03	-11.01	-0.03	0.00	-0.01	-0.00	-0.00	0.00	0.00	0.00
REFL_A1I	-47.80	-125.23	-0.00	-0.01	0.13	0.85	0.45	3.96	-0.04	-0.00	-0.00
TRY_ADC	-11.01	-0.03	11.01	0.03	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
AS_A1Q	0.00	0.00	0.46	1.19	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
AS_B1Q	0.00	0.00	-0.01	-0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.00
POP_A2I	-5.25	3.21	0.01	-0.01	3.95	11.31	1.47	1.30	-0.00	-0.00	-0.00
POP_ADC	-0.06	0.08	-0.00	0.00	0.07	0.16	-2.72	-2.35	0.00	0.00	0.00
REFL_B1I	-1.76	-0.15	0.00	-0.00	-0.94	-2.84	-0.37	12.12	-0.29	-0.04	-0.03
POP_B1I	0.06	-0.00	0.00	-0.00	0.02	-0.03	-0.00	-0.01	-0.07	-0.01	-0.01
AS_ADC	0.00	-0.00	0.00	-0.00	0.00	-0.00	-0.00	0.00	-0.00	-0.00	0.00

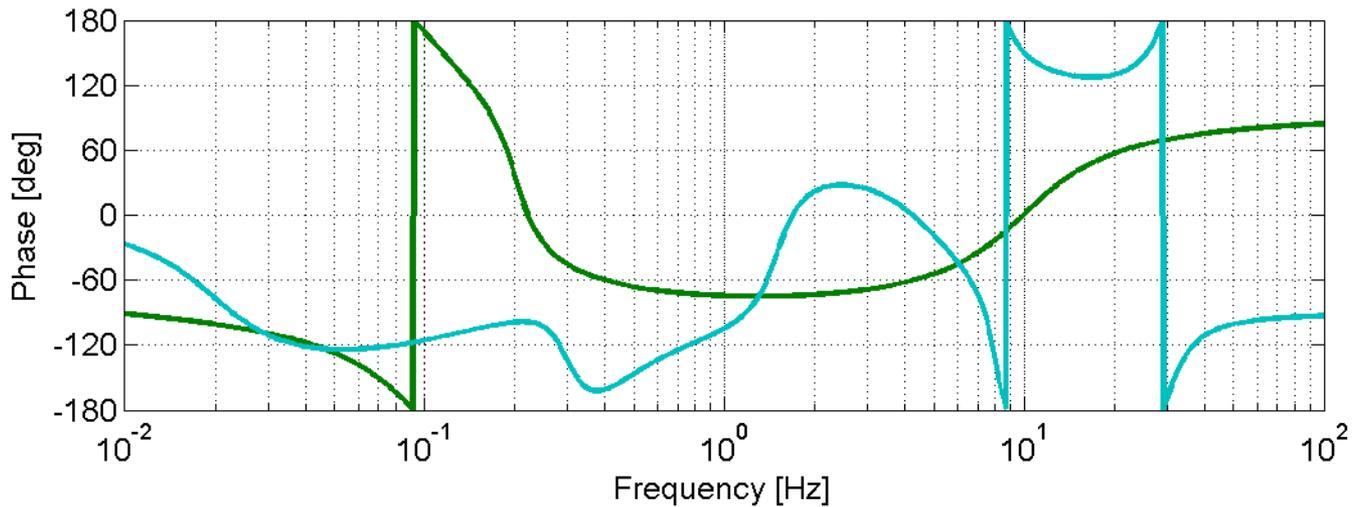
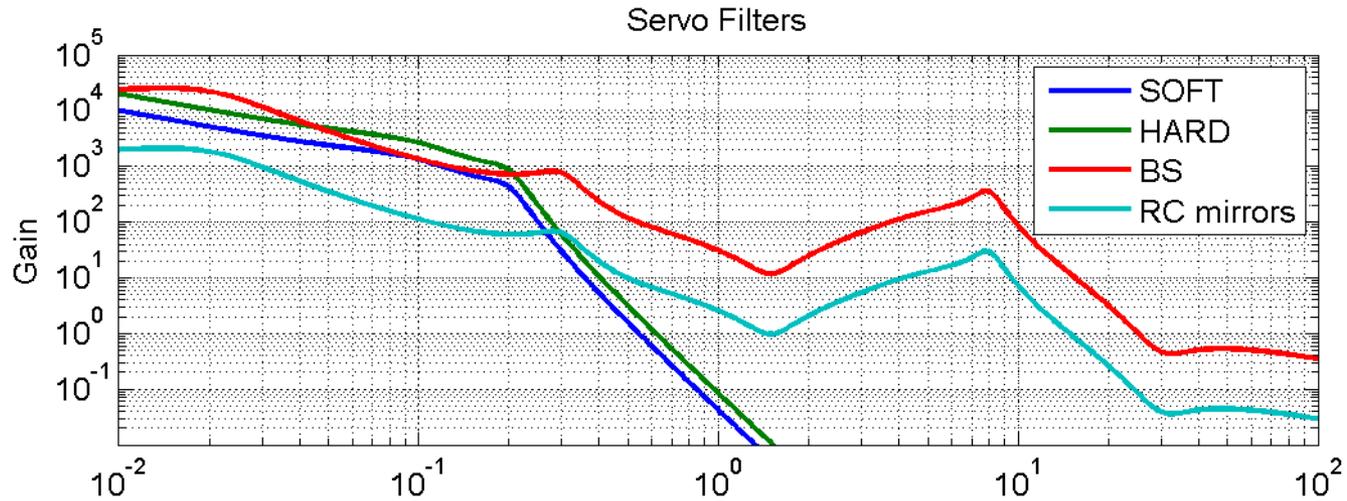
SR2はWFSでは  
制御しない

# Opto-mechanical TF

- リコイルマスに加えたトルクから鏡の角度へのTF (pitch)  
青が輻射圧( $P_{\text{incav}}=379\text{kW}$ ) 下で緑と赤に

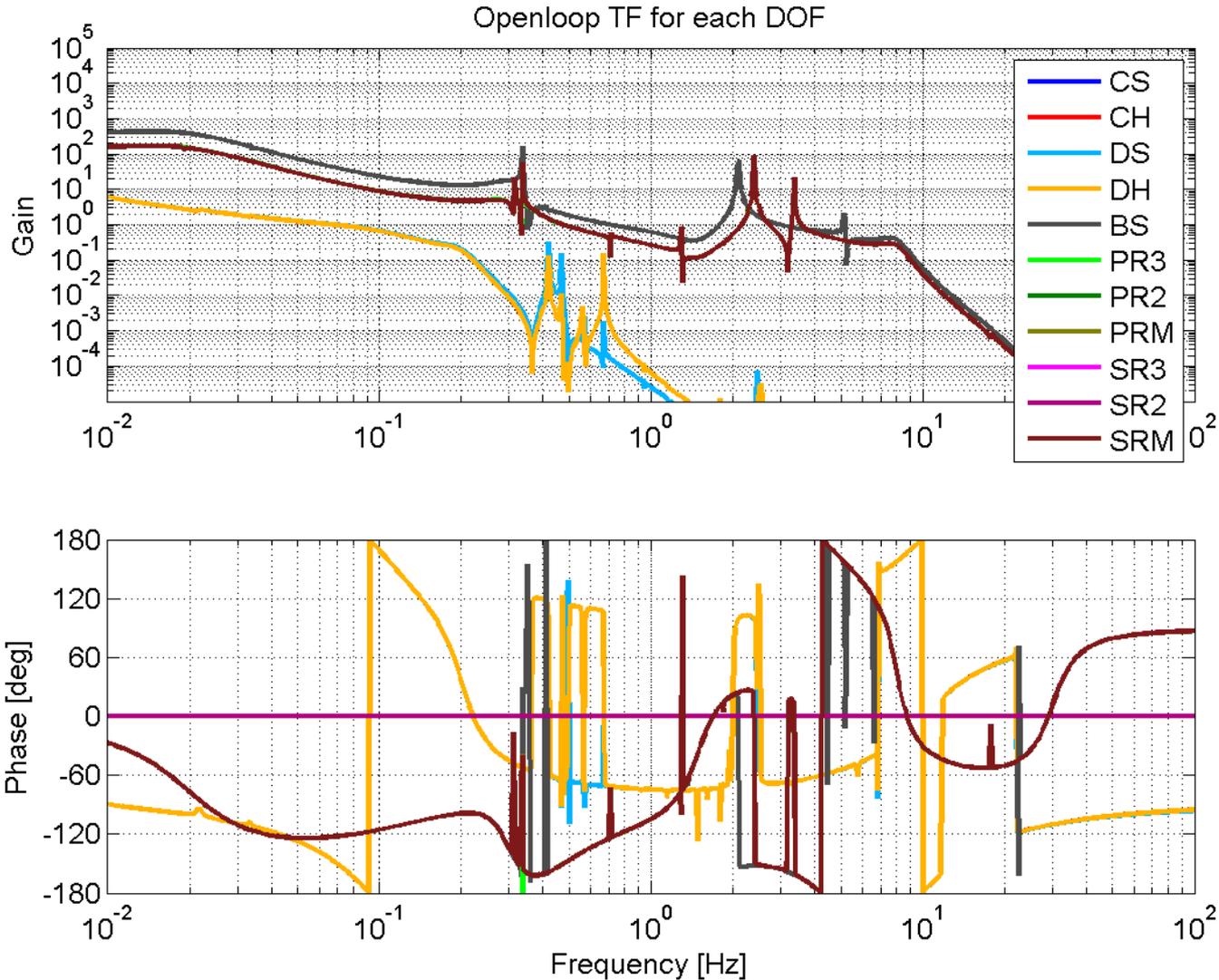


# 制御フィルタ



TMの制御は低周波 (<0.06Hz)だけにする

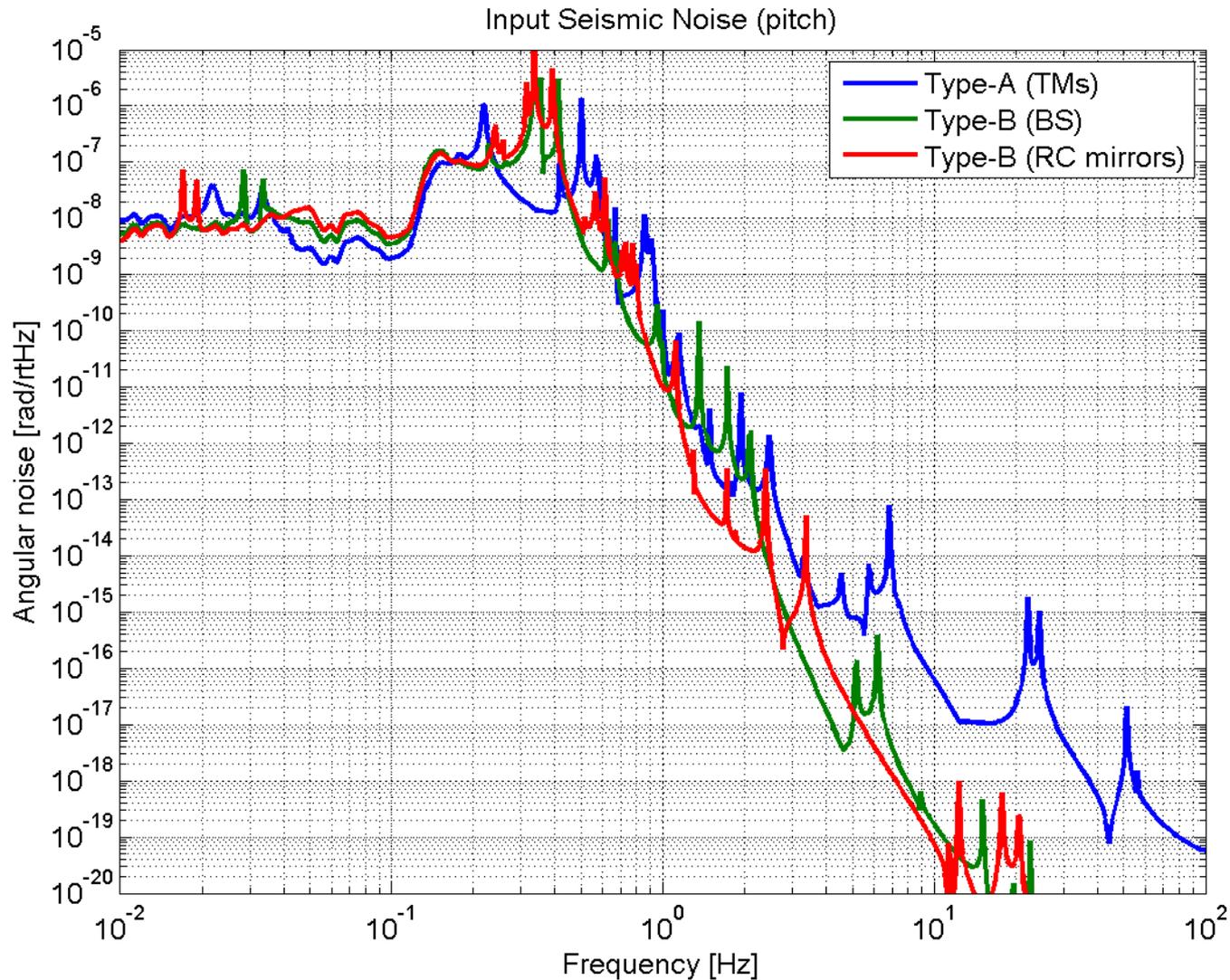
# オープンループ伝達関数



細かいunity gain crossingはやってられないので無視してください

TMの制御帯域はだいたい0.06Hz以下、BSとRC鏡がだいたい4Hz以下

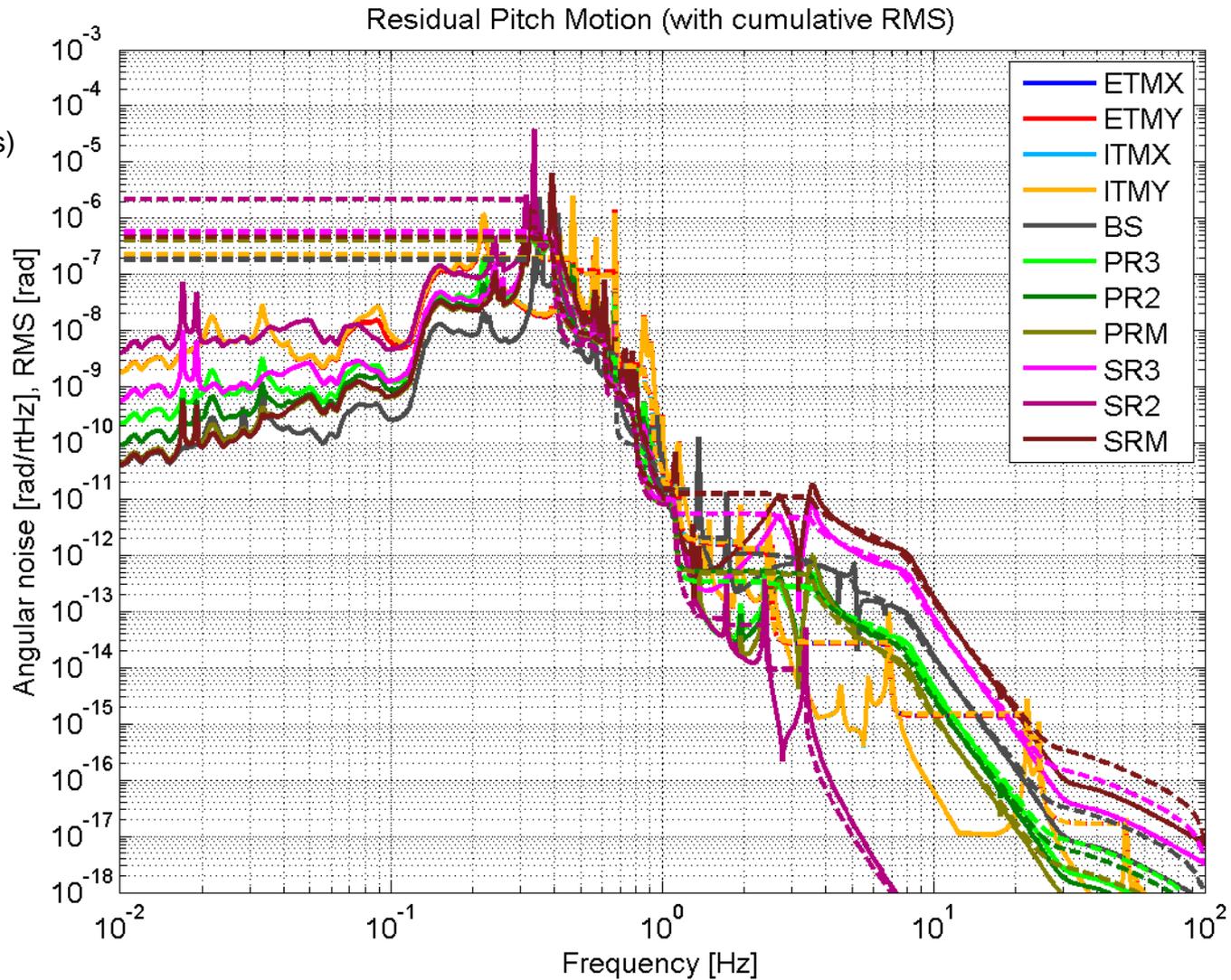
# 地面振動による角度揺れ



関口くん提供  
(2011/5/23版)  
“Noisy day”

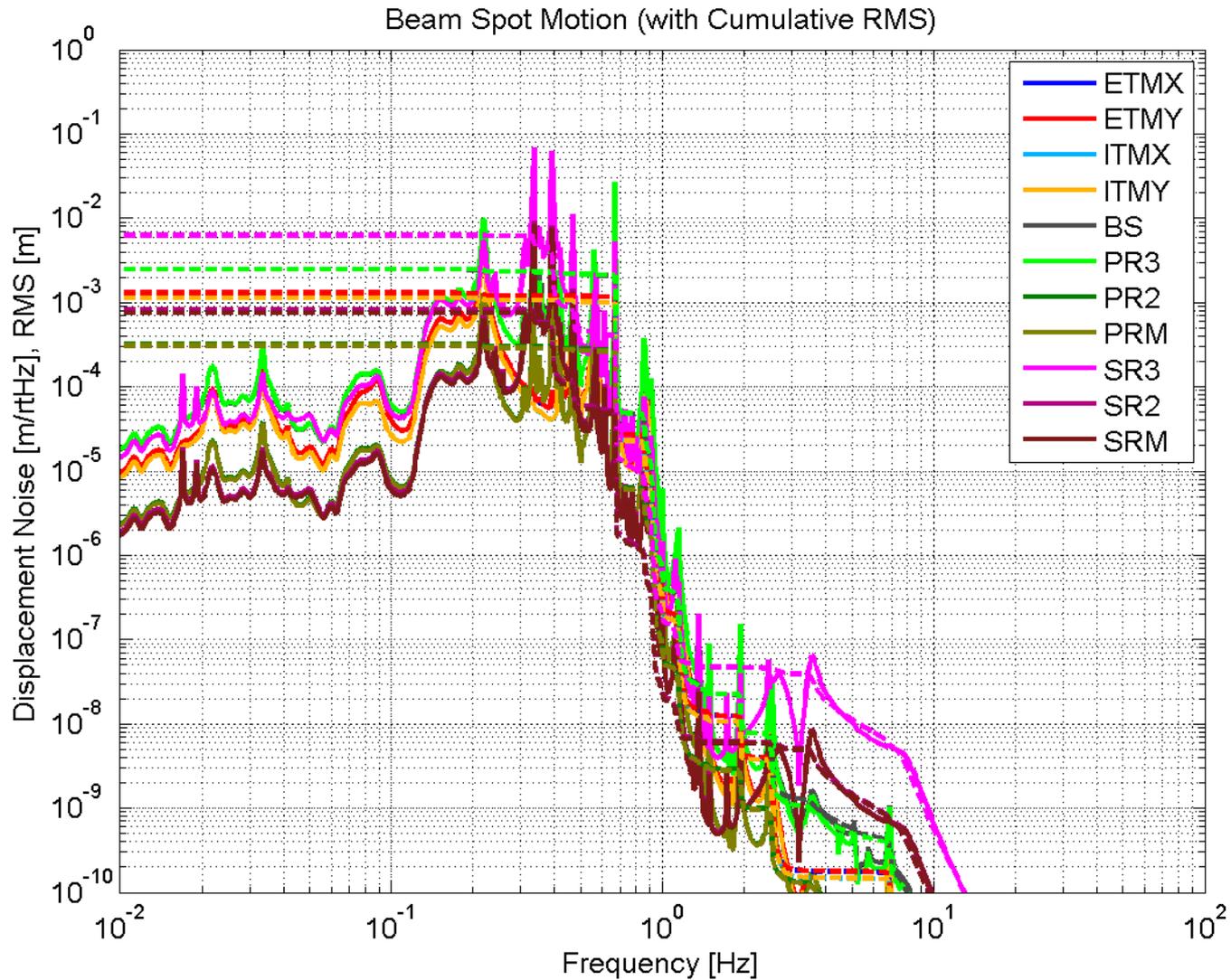
# 残留角度揺れ

累積RMS  
~2e-7 rad(TMs)



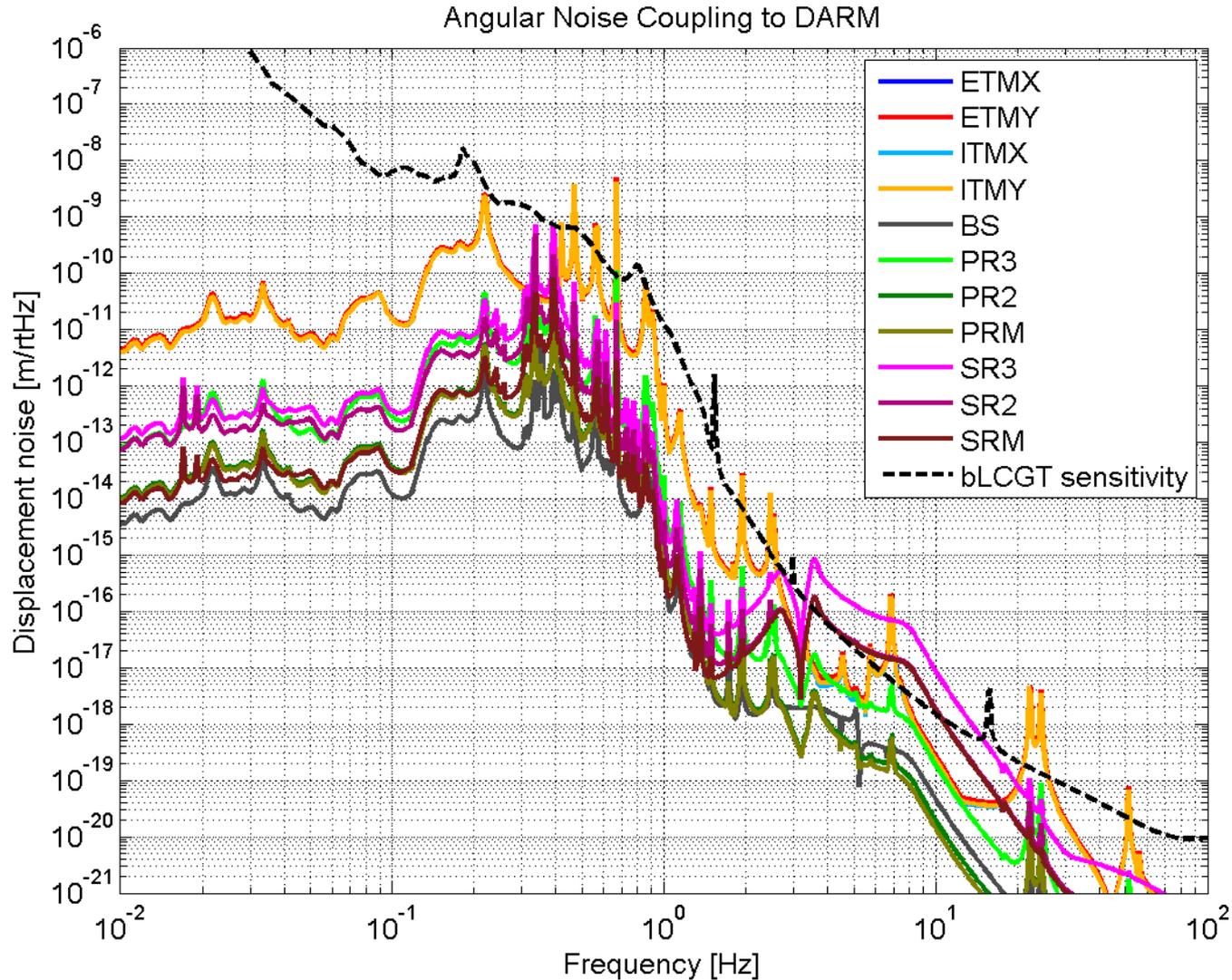
# ビームスポットの動き

累積RMS  
~1e-3 m (TM)



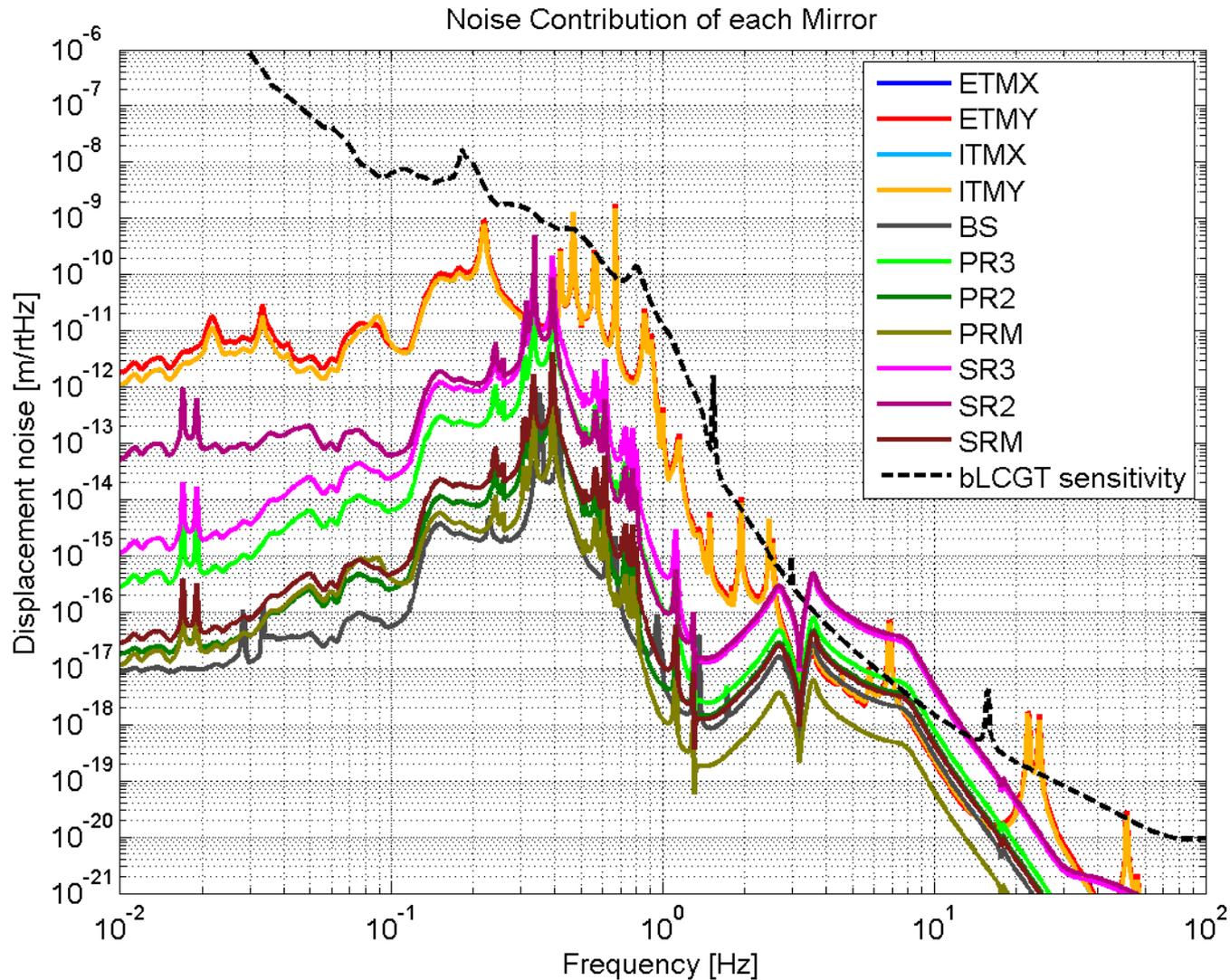
# DARMへのカップリング

$$\Delta L(f) = c \cdot d_{\text{spot}}(f) * \theta_{\text{Mirror}}(f)$$





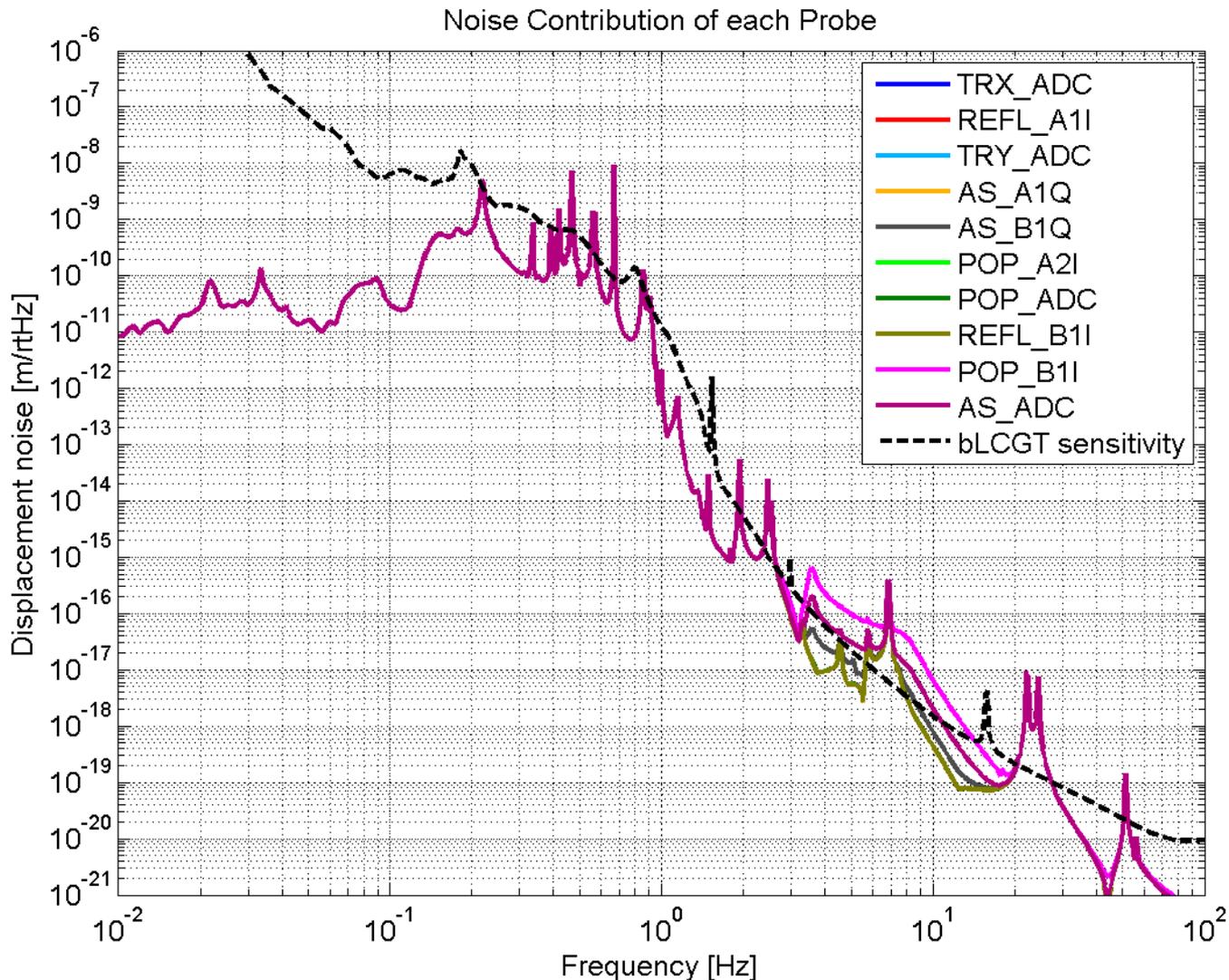
# 各鏡の揺れの寄与



1つの鏡だけを地面振動で揺らすとDARMに合計どれだけノイズが出るか。

どの鏡の揺れが実際に悪さをしているか、もっと揺れを抑えなければいけないかがわかる。

# 各QPDのショットノイズの寄与



1つのQPDのショットノイズでDARMIに合計どれだけノイズが出るか。

その1つ以外のショットノイズを0にして計算をし、各鏡の寄与を全て足したものをそのQPDのショットノイズの寄与とする。

飛び抜けて大きいものがあつたら、ポート選択をやり直す。

POP\_B1Iが少し大きいですが、これは信号の混合が大きいための仕方ないと思われる。

# わかったこと

- SOFTのstable, unstableは時に微妙
- SOFTがstableでもぎりぎりstableだと、SOFTモードのピークが問題になる  
(positive g-factorの場合がこれ)
- 安全策は確実にstableにする or 若干unstableにすること? (unstableだとピークが出ない)
- positive/negative によって特にWFS信号が出やすさが変わるということはなさそう  
negativeにするとSOFTが出にくく、HARDが出やすくなる程度(まあ、当たり前)

# TO DO

- yaw制御の計算
- DC readout等に対応
- aLIGOパラメータを使っての計算  
pickleの結果と一致するか？
- sensing port選択の自動化
- filter設計の自動化
  
- いずれにせよ、サスペンションのデザイン、ローカルダンピングを考えないとこれよりいい結果は出ません。