
Estimation of each loop shot noise limit for AdLIGO

LSC meeting at LHO

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AdLIGO shot noise sensitivity for all loop

- Tools
 - » Finesse0.93, Matlab, BENCH33

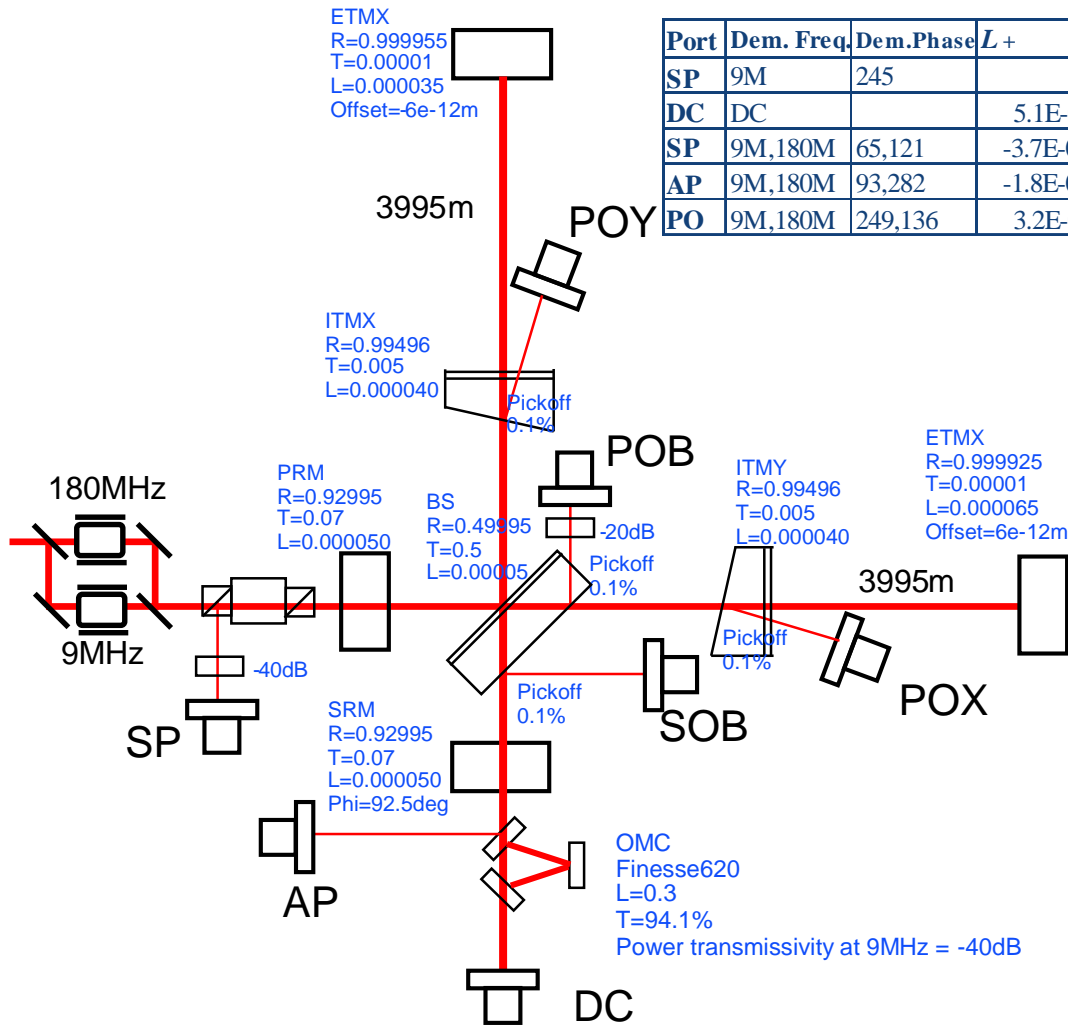
- As close as AdLIGO setting
 - » 2 RF modulations, no sideband of sideband
 - » Single demodulation, DDM
 - » Index of refraction $n=1.44963$ in the substrate
 - » 1000ppm pickoff at AR coating on BS, ITMX, ITMY
 - » PD at SP, AP, POB, POX, POY, SOB
 - » DC readout, L- offset
 - » OMC

- Implemented functions
 - » Procedure to find demodulation phase
 - » Power budget at each port
 - » Shot noise at each port
 - » Shot noise limited sensitivity for each loop at each port
 - » Coupling to L- shot noise
 - » PD dynamic range limit
 - » L- optical spring using BENCH

- Important but not implemented
 - » Optical spring on L+, I-, I+, Is loop
 - » Non stationary shot noise
 - » Frequency noise for L+ loop



AdLIGO default, 9MHz, 180MHz



Port	Dem. Freq.	Dem. Phase	L +	L -	l +	l -	l _s	Norm.	Power[W]
SP	9M	245	1	2.6E-03	-1.6E-03	3.5E-06	1.6E-06	1.8E+20	0.013
DC	DC		5.1E-04	1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079
SP	9M,180M	65,121	-3.7E-03	5.2E-03	1	-6.4E-02	3.8E-01	-3.3E+16	0.013
AP	9M,180M	93,282	-1.8E-03	5.8E-03	1.2E-02	1	1.6E-02	1.7E+16	0.319
PO	9M,180M	249,136	3.2E-03	9.3E-03	3.0E-01	-1.6E-01	1	9.1E+14	0.079

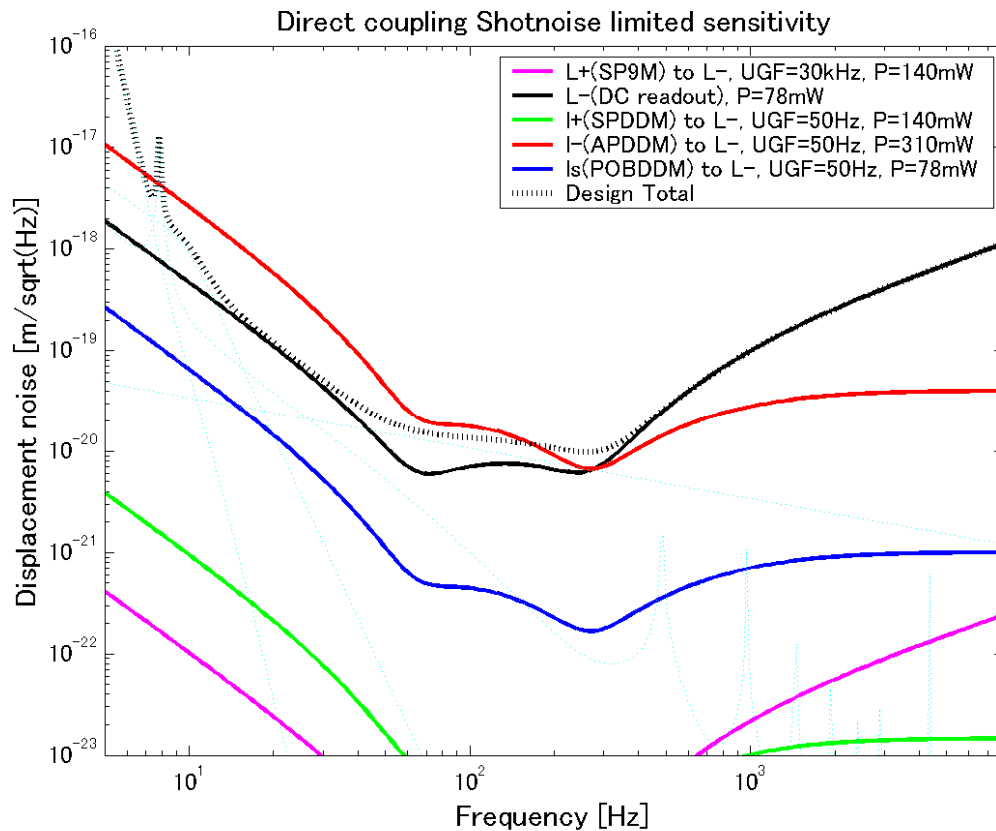
Parameters

- Modulation frequencies
- Lengths between mirror and mirror
- Ports
- Demodulation frequencies
- Demodulation phases



AdLIGO design, direct coupling

Port	Dem. Freq.	Dem.Phase	$L+$	$L-$	$l+$	$l-$	l_s	Norm.	Power[W]	
SP	9M	245		1	2.6E-03	-1.6E-03	3.5E-06	1.6E-06	1.8E+20	0.013
DC	DC		5.1E-04		1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079
SP	9M,180M	65,121	-3.7E-03	5.2E-03		1	-6.4E-02	3.8E-01	-3.3E+16	0.013
AP	9M,180M	93,282	-1.8E-03	5.8E-03	1.2E-02		1	1.6E-02	1.7E+16	0.319
PO	9M,180M	249,136	3.2E-03	9.3E-03	3.0E-01	-1.6E-01		1	9.1E+14	0.079

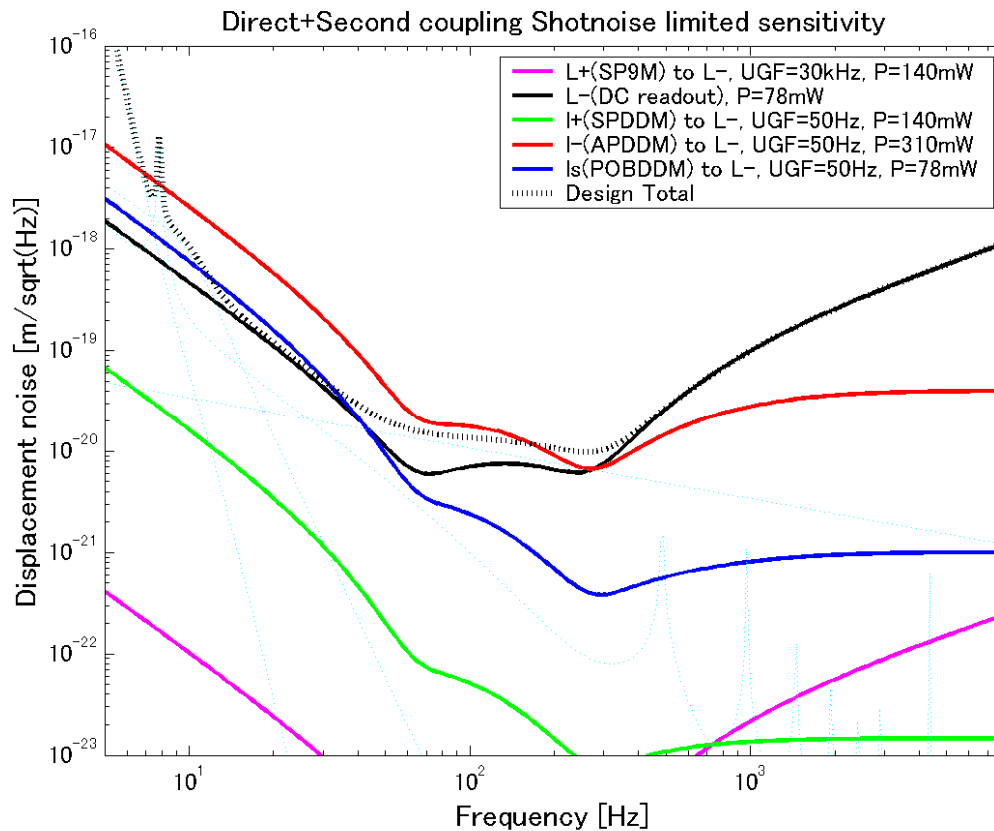


Feedforward will reduce I- contribution by factor of 30.



AdLIGO design, direct+second coupling

Port	Dem. Freq.	Dem.Phase	$L+$	$L-$	$l+$	$l-$	l_s	Norm.	Power[W]
SP	9M	245	1	2.6E-03	-1.6E-03	3.5E-06	1.6E-06	1.8E+20	0.013
DC	DC		5.1E-04	1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079
SP	9M,180M	65,121	-3.7E-03	5.2E-03	1	-6.4E-02	3.8E-01	-3.3E+16	0.013
AP	9M,180M	93,282	-1.8E-03	5.8E-03	1.2E-02	1	1.6E-02	1.7E+16	0.319
PO	9M,180M	249,136	3.2E-03	9.3E-03	3.0E-01	-1.6E-01	1	9.1E+14	0.079

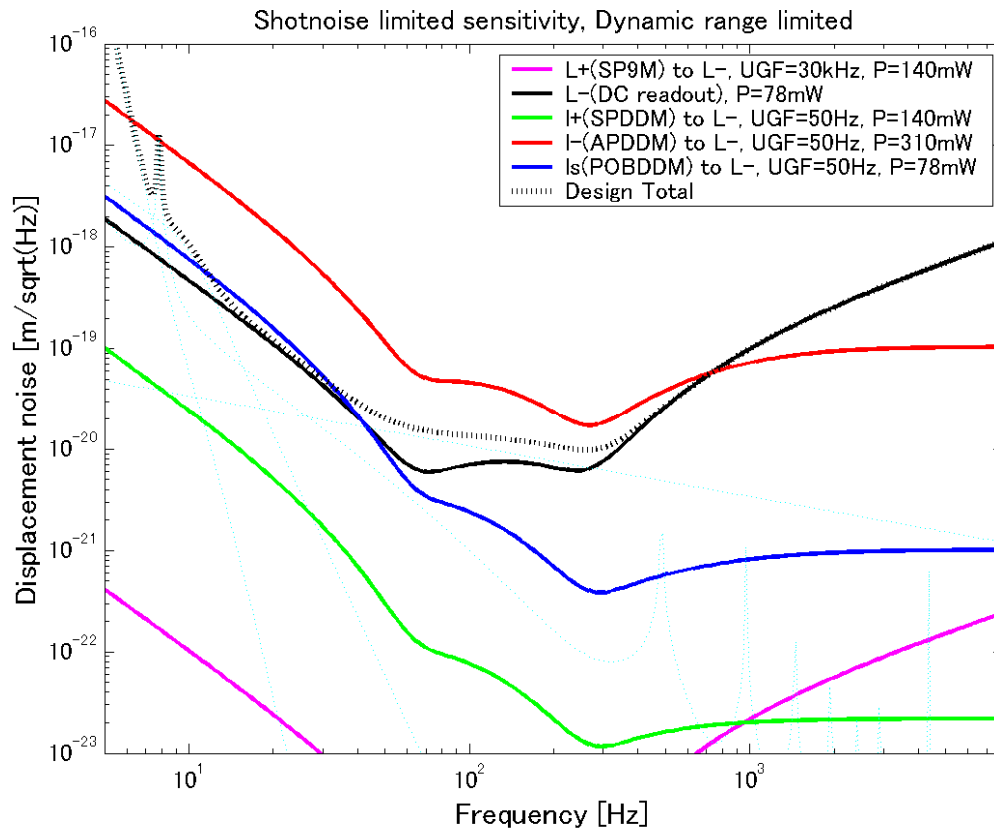


Feedforward for l_s is also necessary.



AdLIGO design, Dynamic range limit

Port	Dem. Freq.	Dem. Phase	$L+$	$L-$	$l+$	$l-$	l_s	Norm.	Power[W]	D. range factor
SP	9M	245	1	2.6E-03	-1.6E-03	3.5E-06	1.6E-06	1.8E+20	0.013	
DC	DC		5.1E-04	1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079	
SP	9M,180M	65,121	-3.7E-03	5.2E-03	1	-6.4E-02	3.8E-01	-3.3E+16	0.013	1.490
AP	9M,180M	93,282	-1.8E-03	5.8E-03	1.2E-02	1	1.6E-02	1.7E+16	0.319	2.594
PO	9M,180M	249,136	3.2E-03	9.3E-03	3.0E-01	-1.6E-01	1	9.1E+14	0.079	1.005



Demodulated signal has a dynamic range limit due to

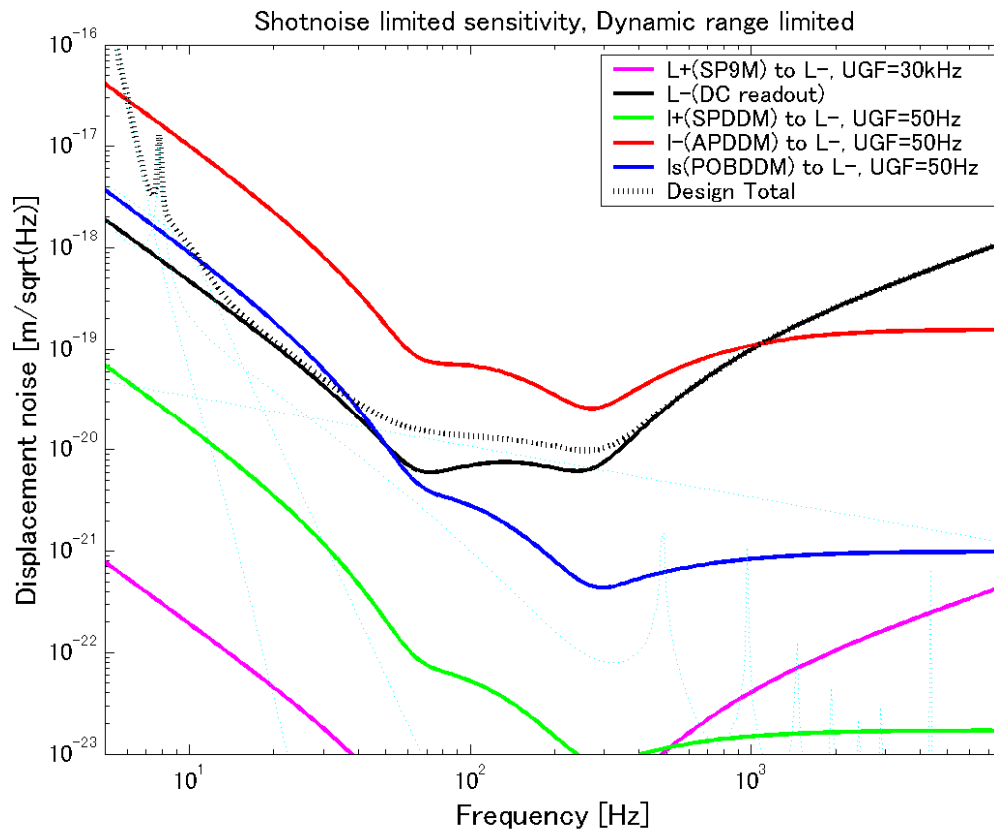
- 300mV offset at DDM
- 5nV/sqrt(Hz) shotnoise

l- is 2.5 times worse.



d/-<75cm,9MHz-90MHz

Port	Dem. Freq.	Dem.Phase		L +	L -	l +	l -	l s	Norm.	Power[W]	D. range factor
SP	9M	96		1	2.5E-03	-1.2E-03	1.8E-05	-7.2E-05	9.5E+19	0.013	
DC	DC			5.1E-04	1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079	
SP	9M,90M	66	4	6.1E-03	1.5E-02	1	-3.1E-02	3.7E-01	3.2E+16	0.013	1.155
AP	9M,90M	92	131	-2.4E-03	4.9E-03	-1.1E-02	1	-1.9E-02	1.6E+16	0.328	3.670
PO	9M,90M	73	33	3.0E-02	3.6E-02	2.9E-01	-7.1E-02	1	9.3E+14	0.079	1.002

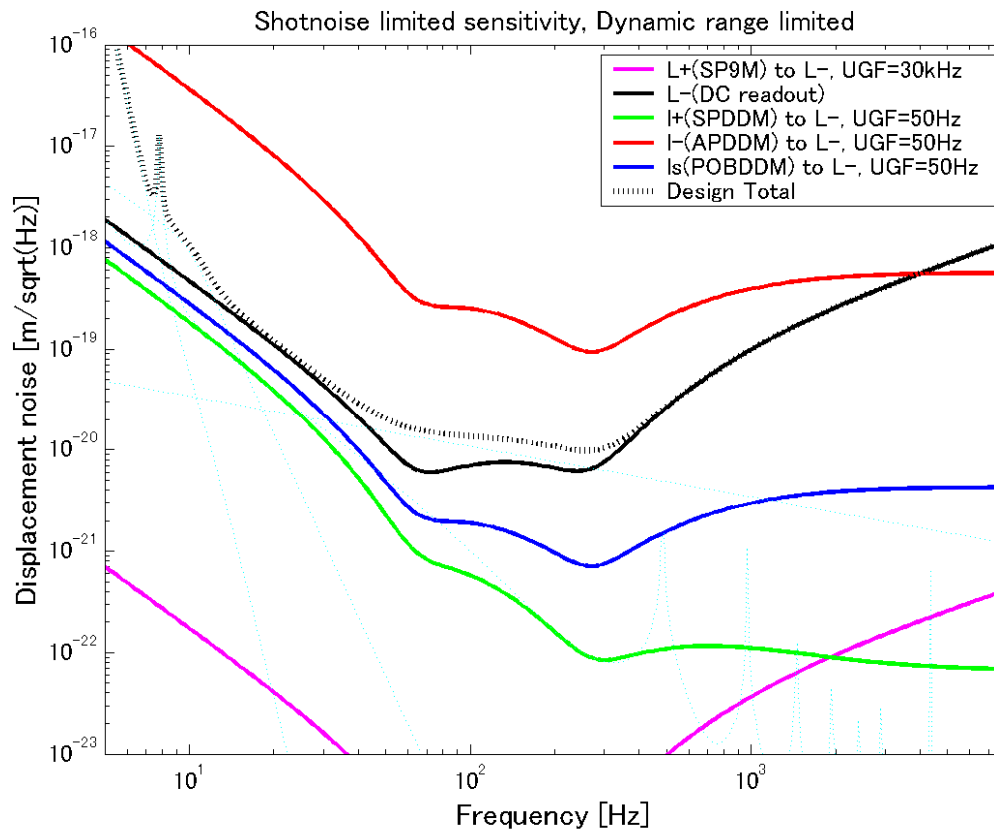


90MHz is the minimum f2.



d/-<75cm,9MHz-45MHz

Port	Dem. Freq.	Dem. Phas	$L +$	$L -$	$l +$	$l -$	l_s	Norm.	Power[W]	D. range factor		
SP	9M	192		1	2.6E-03	-1.6E-03	6.3E-06	3.4E-06	1.1E+20	0.014		
DC	DC		5.1E-04		1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079		
SP	9M,45M	65	102	-3.3E-02	-2.7E-02		1	-1.4E-01	-4.3E-02	1.1E+16	0.014	1.590
AP	9M,45M	92	23	-2.7E-03	5.0E-03	3.0E-02		1	-2.7E-04	7.2E+15	0.244	5.973
PO	9M,45M	253	110	5.4E-01	5.5E-01	-3.3E+00	8.8E-01		1	2.2E+14	0.080	1.020

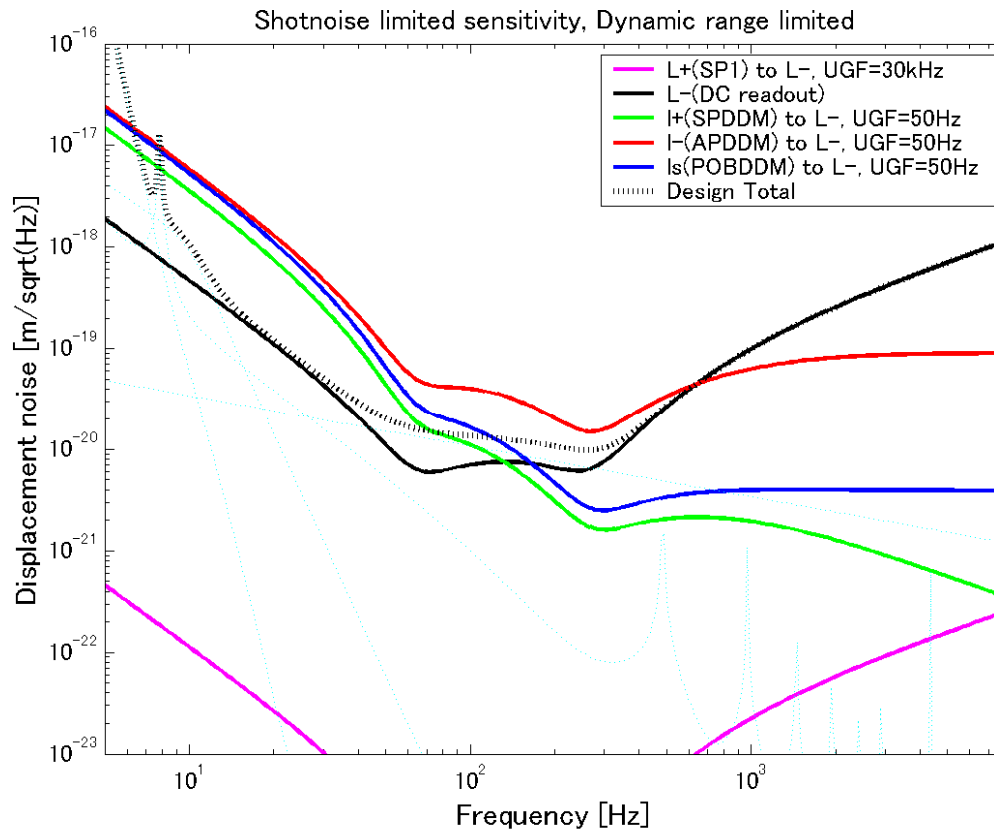


Transmissivity of 45MHz is less than 1 at Michelson.



LF-LF, 27MHz-45MHz

Port	Dem. Freq.	Dem. Phas	$L+$	$L-$	$l+$	$l-$	l_s	Norm.	Power[W]	D. range factor		
SP	27M	50		1	2.6E-03	-1.6E-03	-4.6E-05	3.3E-06	1.7E+20	0.014		
DC	DC		5.1E-04		1	8.8E-07	1.3E-03	1.7E-06	7.7E+19	0.079		
SP	27M,45M	230	275	5.6E-02	5.8E-02		1	5.4E-01	1.4E-01	-2.0E+16	0.014	1.858
AP	27M,45M	185	250	1.6E-01	1.6E-01	-9.1E-01		1	2.9E-02	2.4E+16	0.205	3.141
PO	27M,45M	210	85	5.9E-01	6.0E-01	6.8E-01	4.2E+00		1	2.4E+14	0.080	1.004





Summary

- Tool is ready, but still too many parameters.
- Third coupling
- No DDM
- DDM with smaller offset

P: plant, IFO
F: feedback filter
S: suspension
C: coupling constant from *l*- to *L*-
l_{sn}: shotnoise limited sensitivity of *l*-
G: open loop gain

Calibrated noise

$$\frac{G_l l_{sn}}{1+G_l} \frac{C}{P_{L-}} \times \frac{-G_{L-}}{1+G_{L-}} \times (1+G_{L-}) / G_{L-} = \frac{G_l}{1+G_l} l_{sn} \frac{C}{P_{L-}}$$

