Output mode-cleaner

LCGT f2f meeting
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Tokyo Inst of Technology
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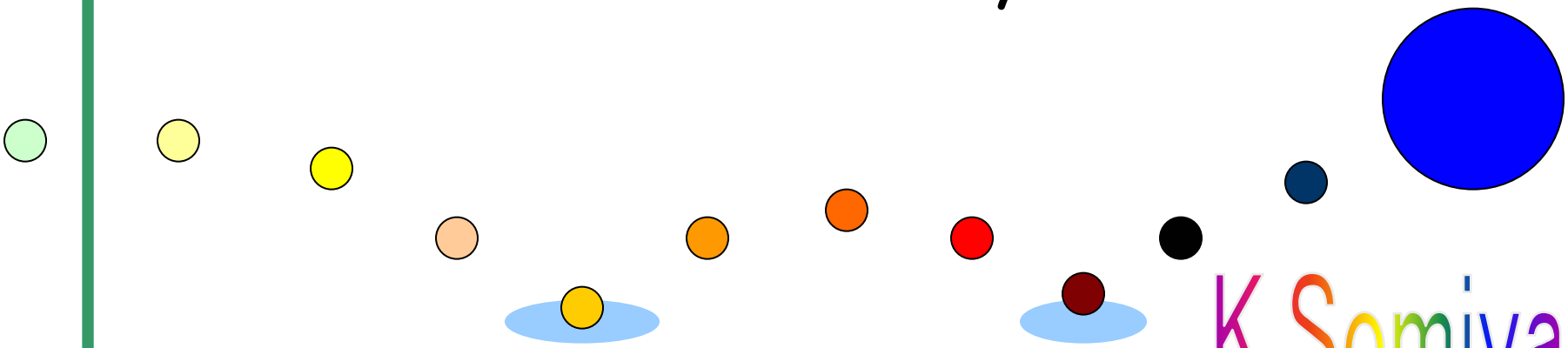
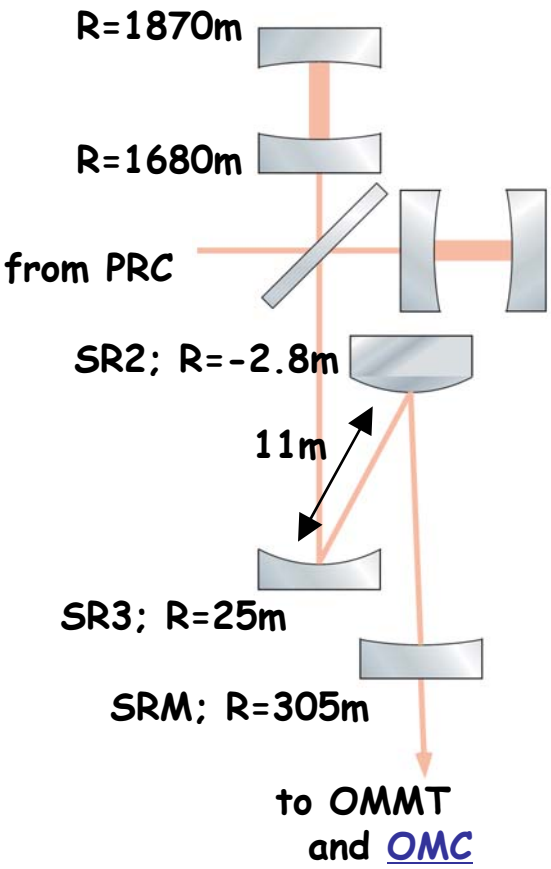
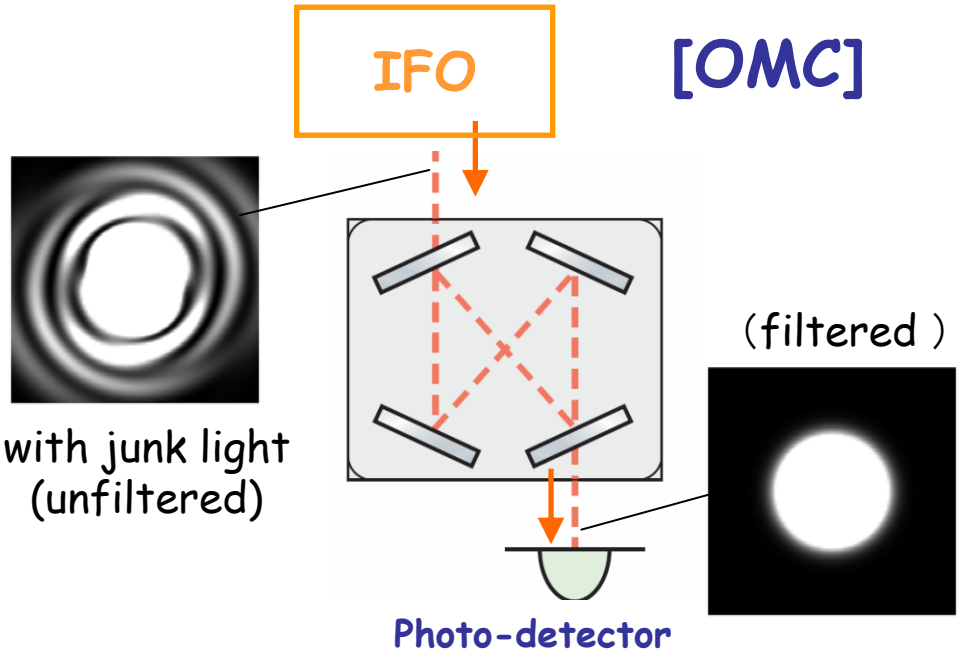


Purpose of OMC



[Output Optics]

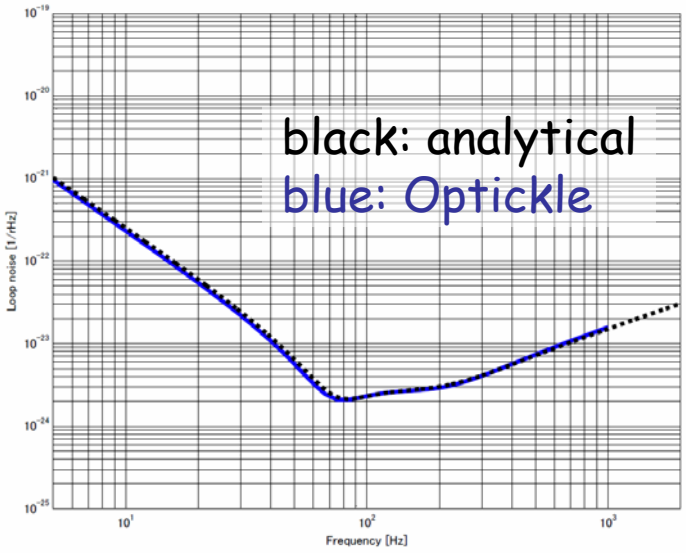
(wSRM=4.0mm, wSR2=4.0mcm,
wSR3=36mm, wITM=35mm, ηSRC=20deg)

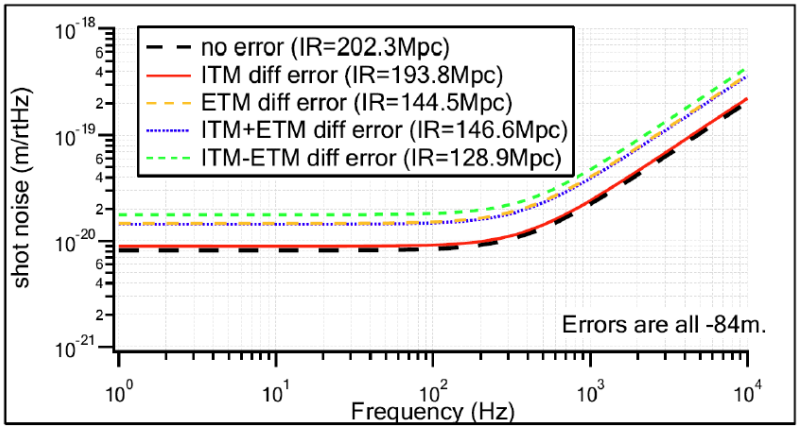


(i) Clean-up of the carrier light
[local oscillator for DC readout]

(ii) Removal of 16.875MHz SB

Junk-light simulations





[shot noise calculated by **FINESSE**]

- Optickle includes radiation pressure
- FINESSE includes higher order modes

Check parameters with Optickle

(DARM offset)

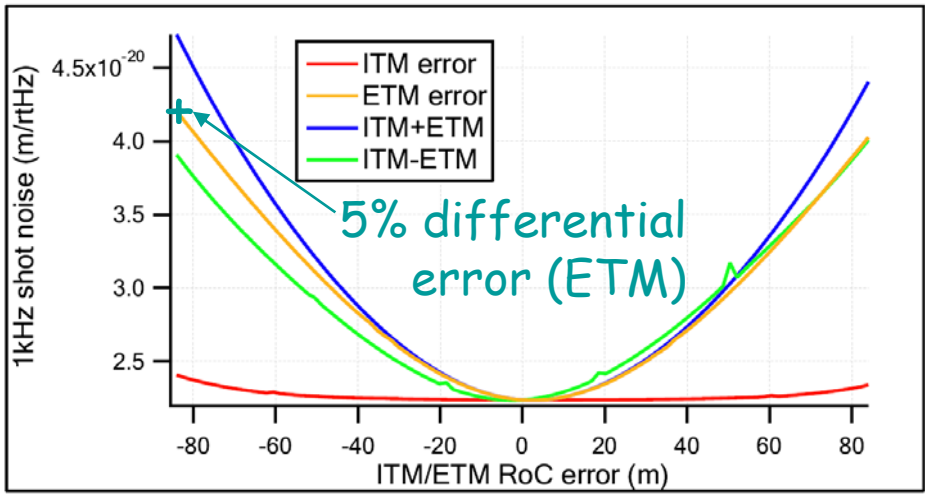
HOM simulation by FINESSE

(Tuned RSE shot noise)

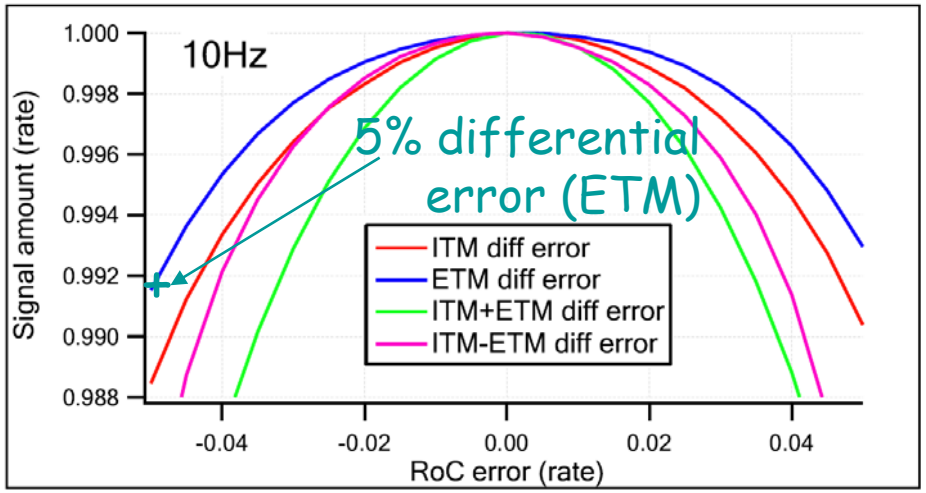
Calculate junk light at dark port

- A dummy SR-arm for reference
- A dummy OMC for reference
- Modal expansion

Mirror RoC errors



[Shot noise increase due to junk light]



[Signal reduction for mode-mismatch]

Shot noise increases in 3 ways

(i) Mode-mismatch due to common-mode RoC errors;

- This can be solved by tuning the SRC telescope (~13cm).

  [cf. JGW-G1100553 (Agatsuma, Chen)]

(ii) Junk light increase;

- This can be somewhat reduced with the use of OMC.

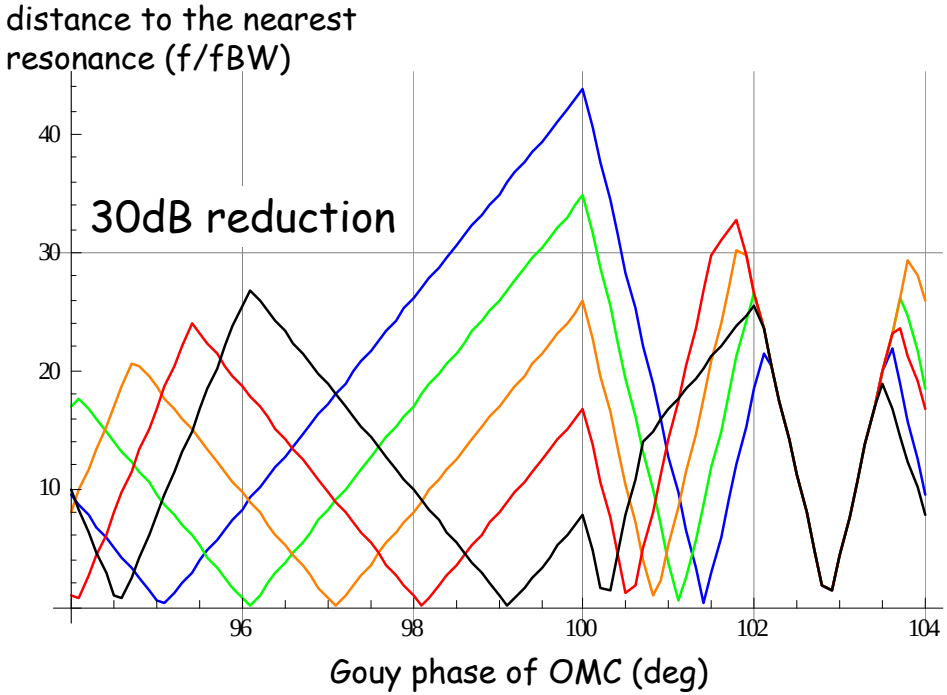
(iii) Signal reduction;

- Influence is smaller than others.

OMC design

* TM loss: 41ppm/49ppm
* Finesse difference 0.5%
* RoC error 1% (differential)

RF						DC					
TEM00	TEM20	TEM02	TEM40	TEM04	TEM22	TEM00	TEM20	TEM02	TEM40	TEM04	TEM22
85mW	0.1mW	0.1mW	4uW	4uW	3uW	1.0mW	8.9mW	8.9mW	30uW	30uW	20uW



(L=0.5m,0.6m,0.7m,0.8m,0.9m)

[Astigmatism -> ~1deg Gouy phase diff in X/Y]

Requirements

(i) Signal loss in the OMC < ~1%
-> finesse ~ 520 (30ppm/mirror)

(ii) RFSB reduction of 80dB+
-> Lomc > 85cm

(iii) 2nd HOM reduction of 60dB+
-> OMC Gouy phase ~ 45deg
and finesse ~ 1000+

(iv) Other HOMs far from reso.
-> Good Gouy phase ~ 19or99deg
(MMT length: 4m, 10m)

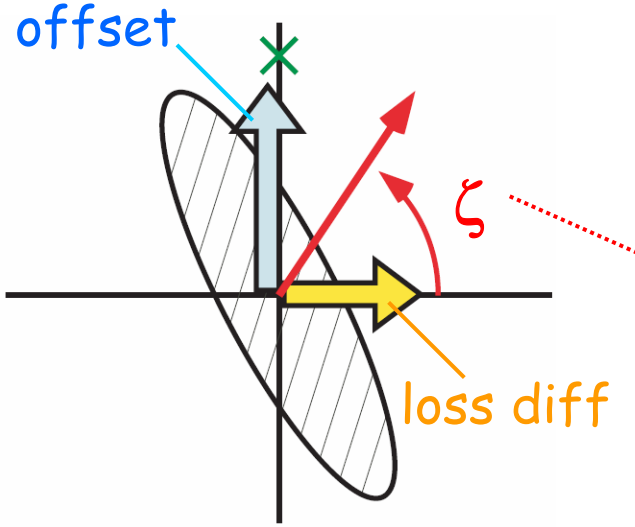
Comparison with aLIGO

~ 2 reasons why requirements are so hard for KAGRA ~

(1) SB freq is 16.875MHz (aLIGO's is 45MHz)

-> RFSB reduction rate is ~6 times smaller.

(2) Back-action evasion readout



KAGRA's sensitivity is limited by quantum noise, so BAE is important.

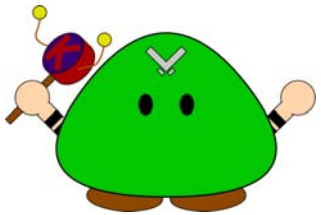
[238Mpc->218Mpc (DRSE), 206Mpc->196Mpc (BRSE)]

~90deg for aLIGO; ~64deg for KAGRA (BRSE)

aLIGO adds more offset and the DC light at dark port is ~40mW, while KAGRA's is 1~4mW to realize BAE.

Summary and misc.

- OMC design is ongoing
- BAE is a bit challenging but is critical to lose it
  ~We'll certainly give it up if the loss imbalance is < 4ppm.
- Some alternative ideas:
  ~double OMC, reflective OMC, balanced homodyne, etc.
- MMT-OMC experiment will start at TITech
  ~Daniel Friedrich will come and help us.

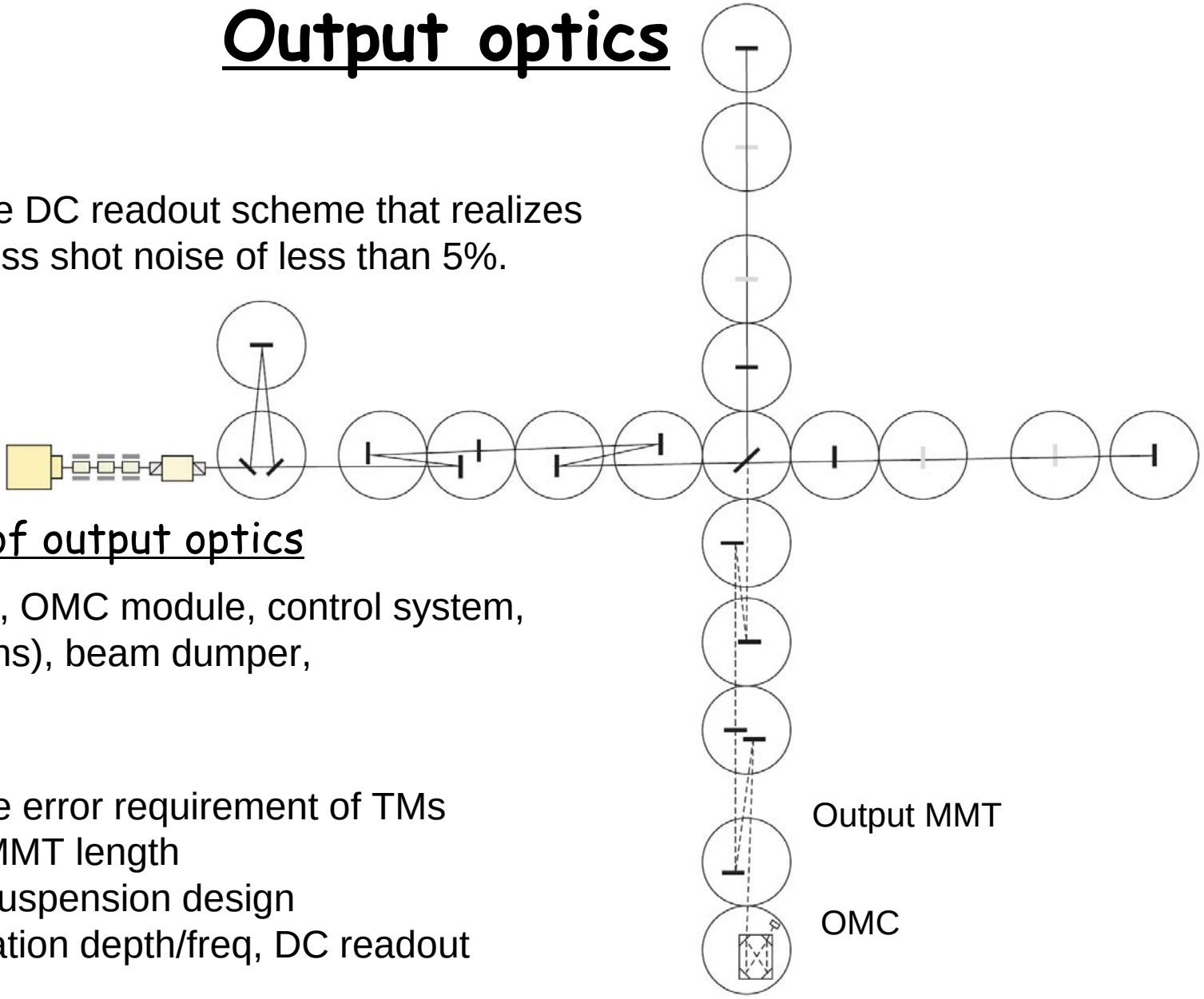


Supplementary slides

Output optics

Scope

Establish the DC readout scheme that realizes BAE w/excess shot noise of less than 5%.



Components of output optics

output MMT, OMC module, control system,
PD (refl, trans), beam dumper,

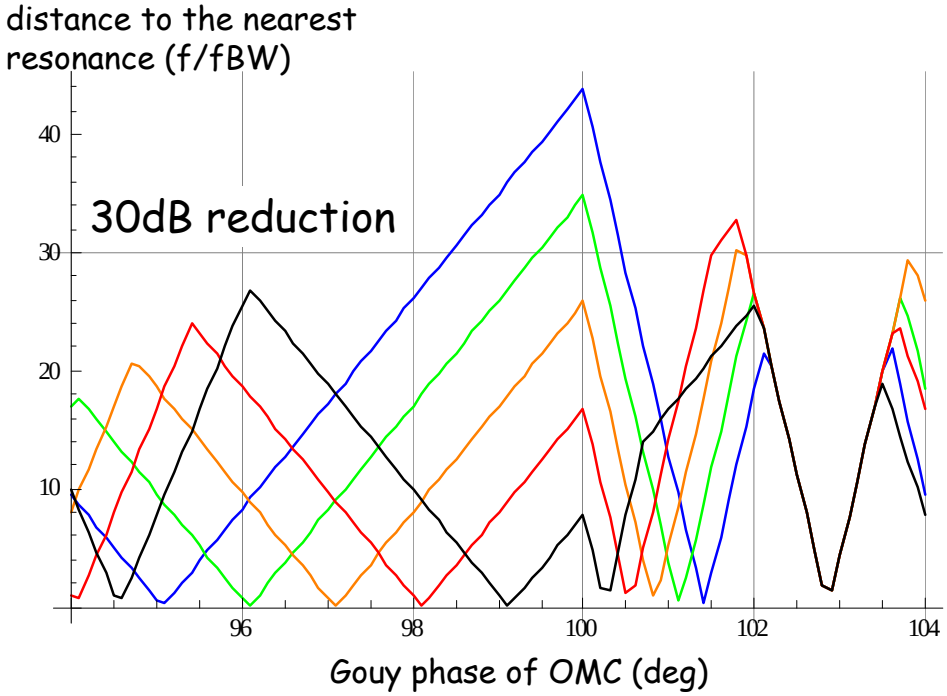
Interface

MIR: surface error requirement of TMs
VAC/FCL: MMT length
VIS: OMC suspension design
MIF: modulation depth/freq, DC readout

With 2% RoC errors

* TM loss: 41ppm/49ppm
* Finesse difference 0.5%

RF						DC					
TEM00	TEM20	TEM02	TEM40	TEM04	TEM22	TEM00	TEM20	TEM02	TEM40	TEM04	TEM22
85mW	0.1mW	0.1mW	4uW	4uW	3uW	1.3mW	42mW	42mW	43uW	43uW	28uW



(L=0.5m,0.6m,0.7m,0.8m,0.9m)

[Astigmatism -> ~1deg Gouy phase diff in X/Y]

Requirements

(i) Signal loss in the OMC < ~1%
-> finesse ~ 520 (30ppm/mirror)

(ii) RFSB reduction of 75dB+
-> Lomc > 85cm

(iii) 2nd HOM reduction of 70dB+
-> OMC Gouy phase ~ 45deg
and finesse ~ 3000+

(iv) Other HOMs far from reso.
-> Good Gouy phase ~ 19or99deg

Confirmation of the accuracy

highest mode	TEM00
1	0.0001954
3	0.0016304
5	0.0042656
7	0.0056478
9	0.0058341
11	0.0058838
13	0.0058732
15	0.0058757
17	0.0058744
19	0.0058739

We should better calculate up to at least the 7^{th} mode.
It was 5 for the calculations shown in the slides, though.