Feasibility of DC readout with optimal homodyne angle

LCGT f2f meeting
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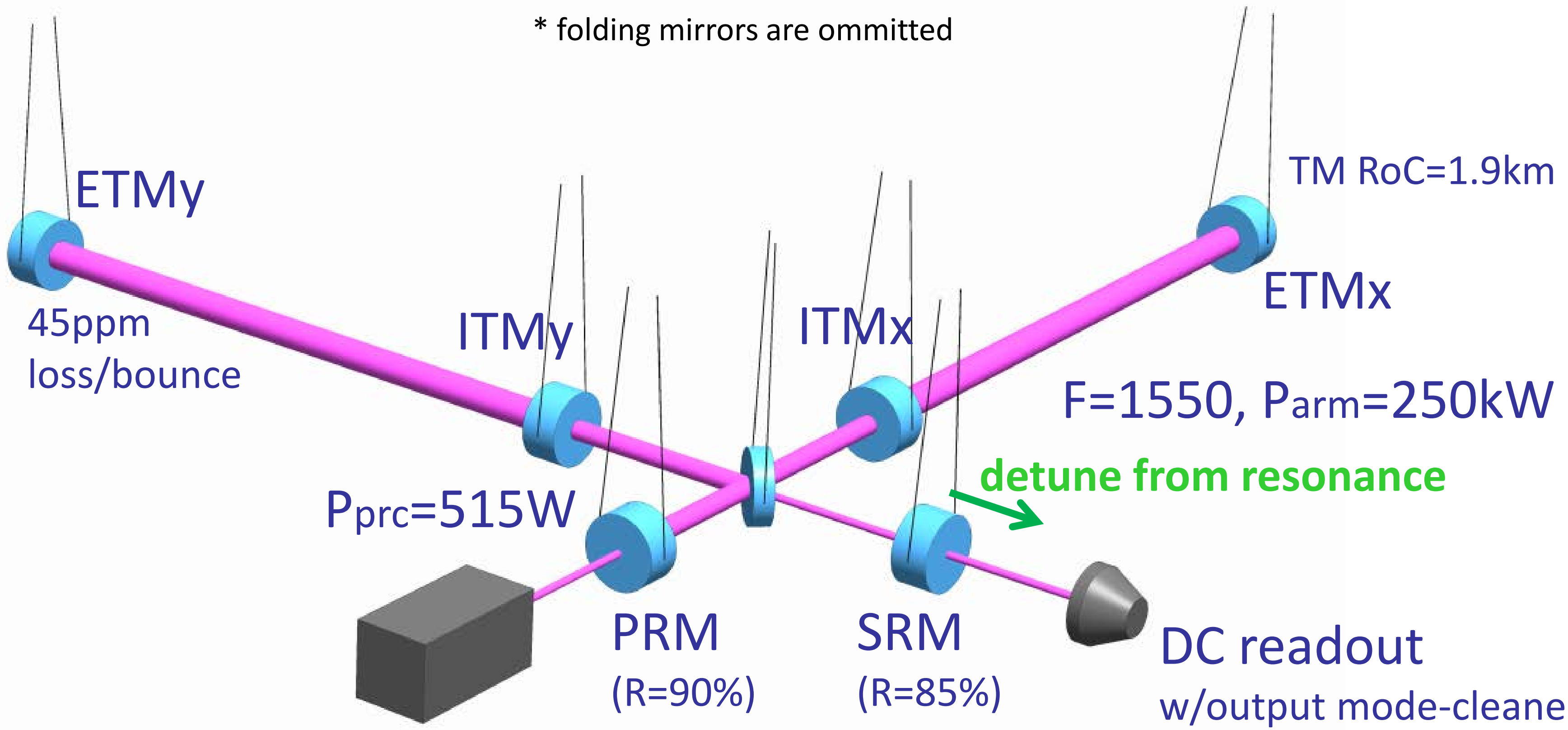
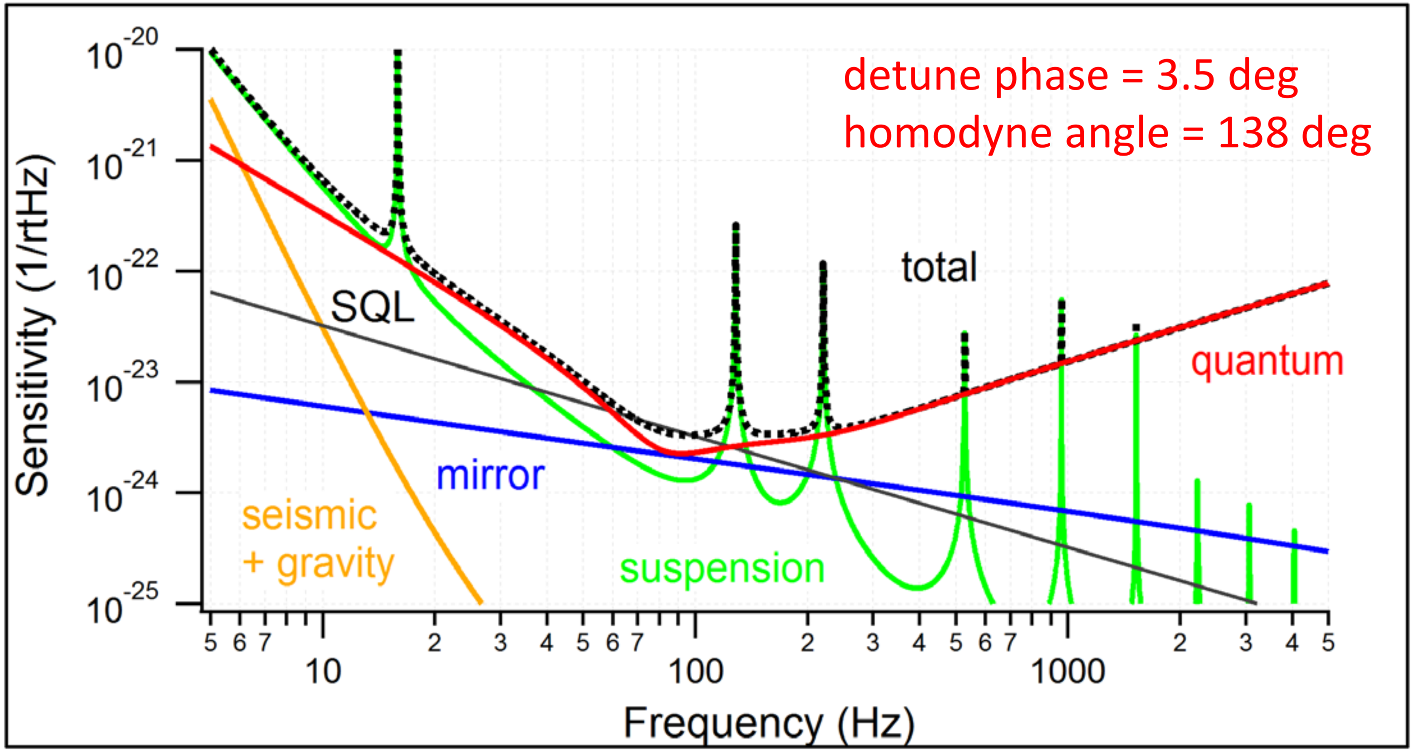
KAGRA main interferometer

* folding mirrors are ommitted



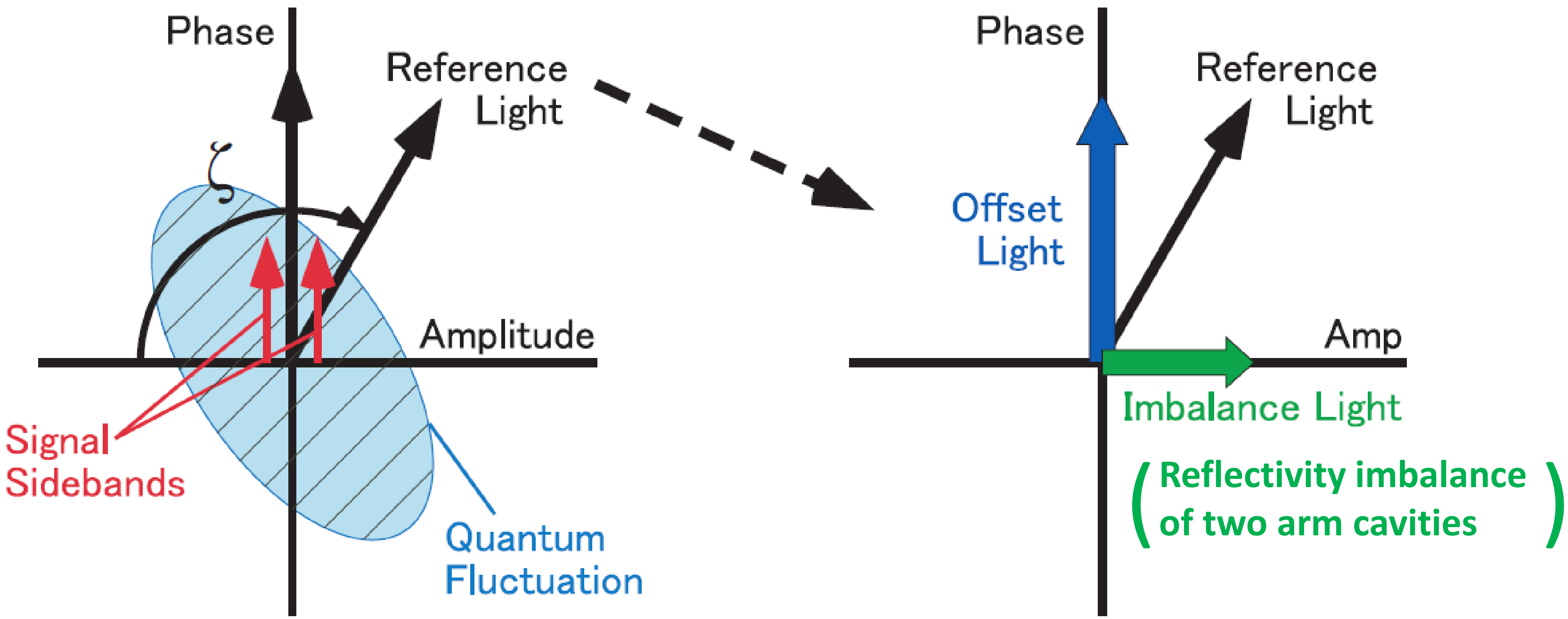
Optical parameters are selected to increase the observation range for NS-NS inspirals with a broad bandwidth.

KAGRA sensitivity



- KAGRA's sensitivity is mostly limited by quantum noise
- Optimization of homodyne angle ζ is essential to realize the goal sensitivity

Homodyne angle ζ



- Imbalance light amount is fixed due to existing mirrors
- The homodyne angle ζ can be tuned by DARM offset <u>*unless the imbalance happens to be too small*</u>

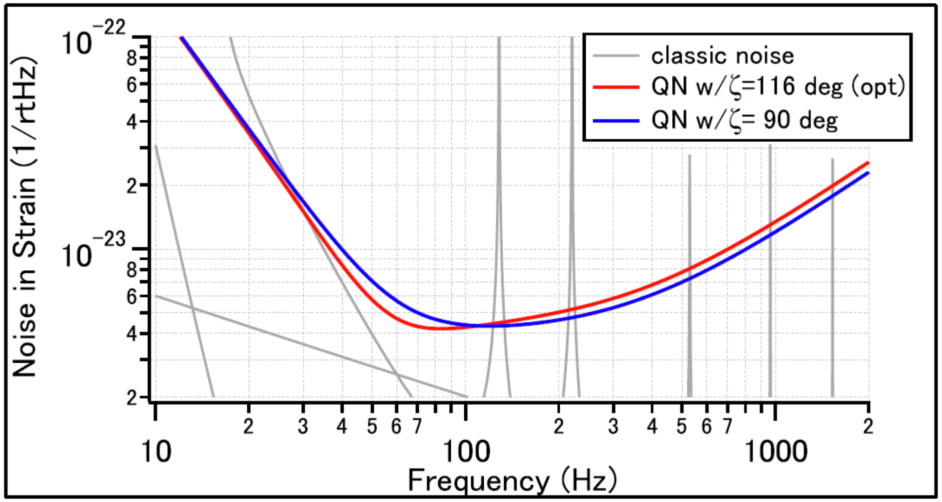
Overview of the talk

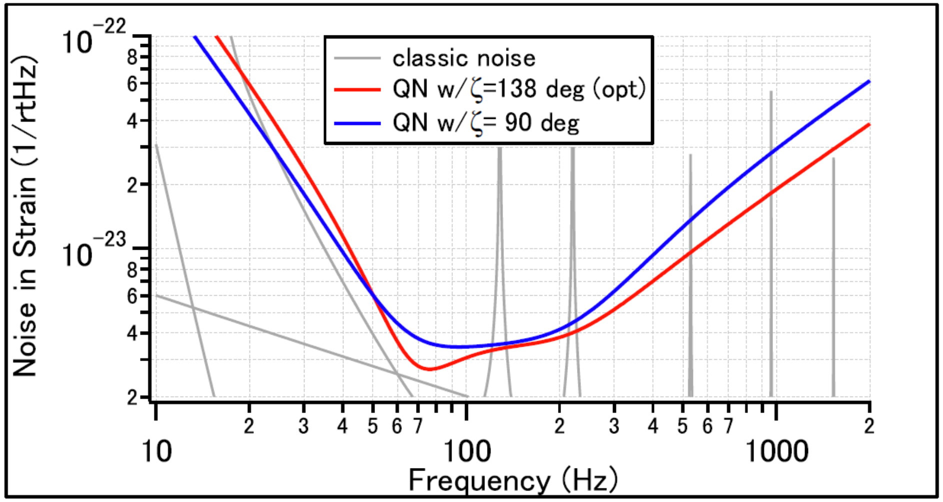
- How much imbalance is needed to realize the sensitivity?
  -> determined by OMC finesse and RF SB power at AS

- How often can the imbalance be smaller than the limit?
  -> modal-model simulation with mirror maps

- What if the imbalance is smaller than the limit?
  -> homodyne angle should be fixed to 90 deg

What if ζ is fixed to 90 deg



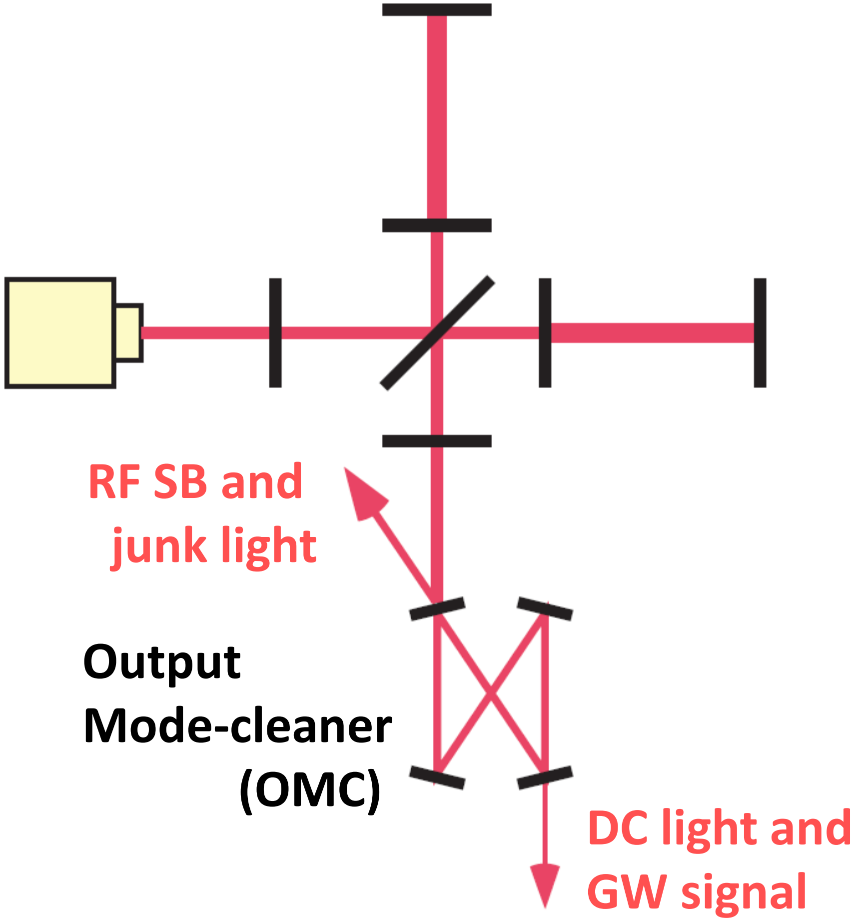


* Detune phase = 86.5 deg.
* Actually ζ = 89.86 deg with zero imbalance.

Inspiral Range	optimal	90 deg
BRSE	128 Mpc	116 Mpc
DRSE	147 Mpc	136 Mpc

In the case of DRSE, not only the IR decreases but also the sensitivity at high frequencies makes worse by 50%.

How much light is necessary?



OMC filters out RF SB.

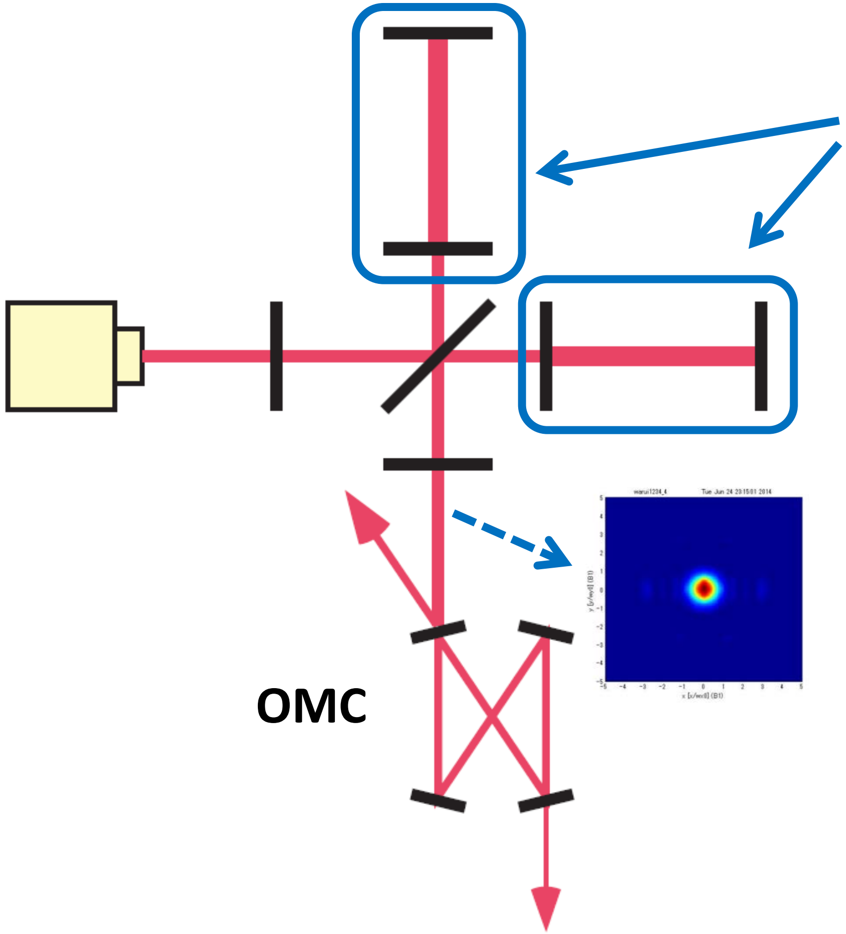
- High OMC finesse
  (DC light > RF SB)
  ⇒ - less RF SB at PD
  - more signal loss

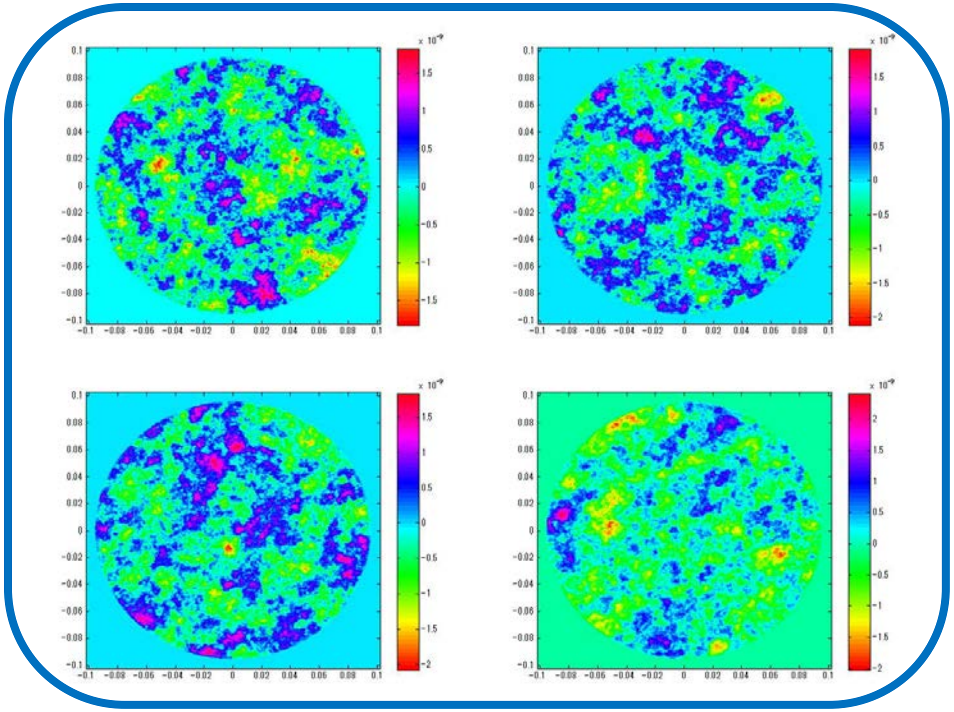
- Low OMC finesse
  (DC light < RF SB)
  ⇒ - shot noise by RF SB
  - less signal loss

- RF SB before OMC is ~400mW
- OMC opt loss is ~160ppm/RT

⇒ ~1mW DC light is necessary at AS

How much light would be coming out?



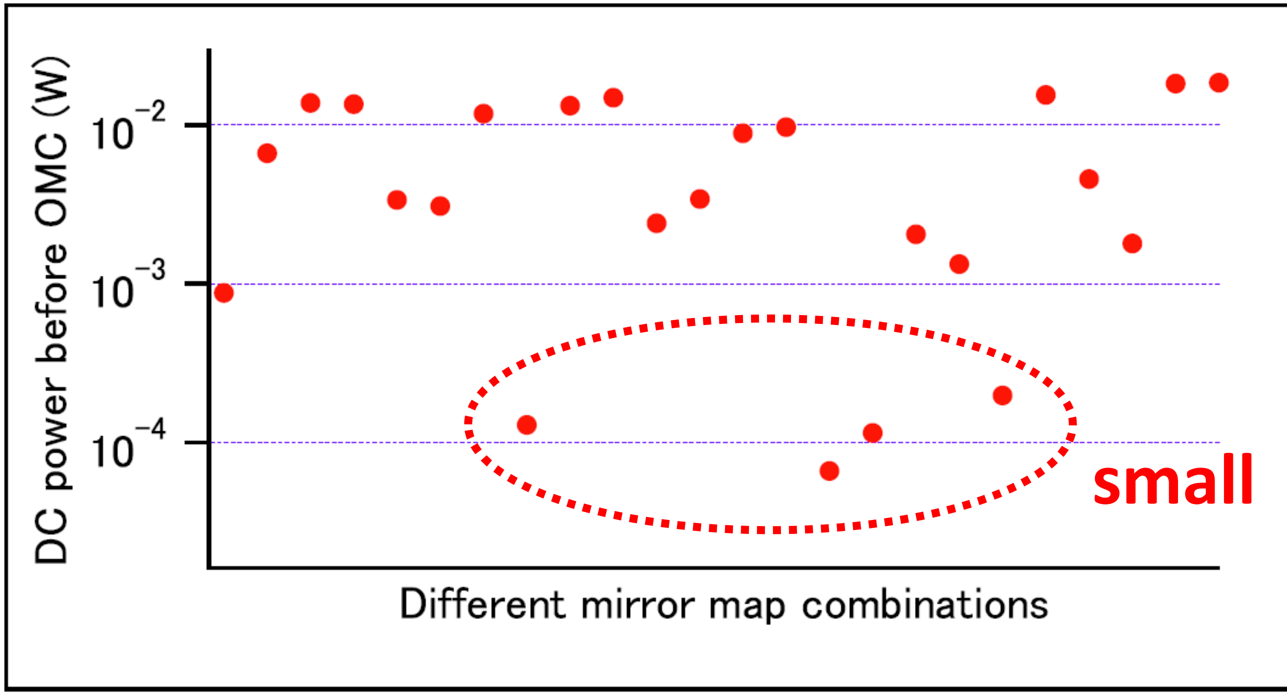


Simulated mirror maps for test masses (provided by H.Yamamoto)

- 45 ± 4ppm loss on TMs
- ±1% error in TM RoCs
- 0.5nm RMS on surface

⇨ Simulated by *FINESSE* (modal model simulation)

How much light would be coming out?



- Requirement: ~1mW
  -> RF SB shot-noise contribution will be 2.5% and the signal loss will be 2% with the OMC finesse of 800
- Simulation result: we tried 24 mirror map combinations
  -> 19 is good, 1 is ok, 4 is far below 1mW

OMC design

- If we could increase the OMC length: 80cm->2.5m, the RF SB would be 10 times lower in power and the requirement would be satisfied in all the 24 cases

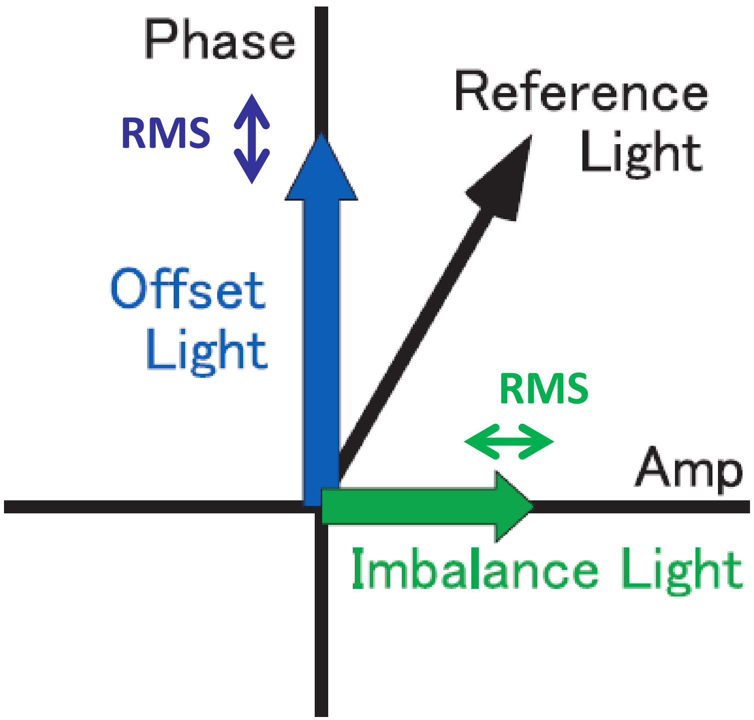
- However it is too long to be installed in a chamber, and it is harder to find a proper OMC design without letting major HOMs come close to the resonances

- We suggest to keep the OMC length to ~80cm and hope for the 20/24 probability

* Detail about the OMC design -> Kumeta-san's talk (next)

Calibration issue

preliminary



Reference light fluctuation may cause a calibration error.

DARM RMS fluctuation
-> offset change
ASC RMS fluctuation
-> reflectivity imbalance
(to be calculated...)

If offset is 4e-13m (P_{AS}~1mW) and DARM RMS is 2e-14,
BRSE/DRSE sensitivity at 100Hz changes for ±0.3/0.3%,
BRSE/DRSE sensitivity at 1kHz changes for ±1.0/0.4%.

Summary

- Realization of the KAGRA sensitivity requires some imbalance in arms and it depends on mirror profiles
- We need at least about 1mW DC light before the OMC otherwise remaining RF SB increases shot noise
- 24 combinations of 4 mirror maps in TMs being tested, 20 of them are ok while 4 makes DC light too small
- Calibration error has been partially investigated

supplementary slides

Mirror surface PSD