ET Recycling Cavities

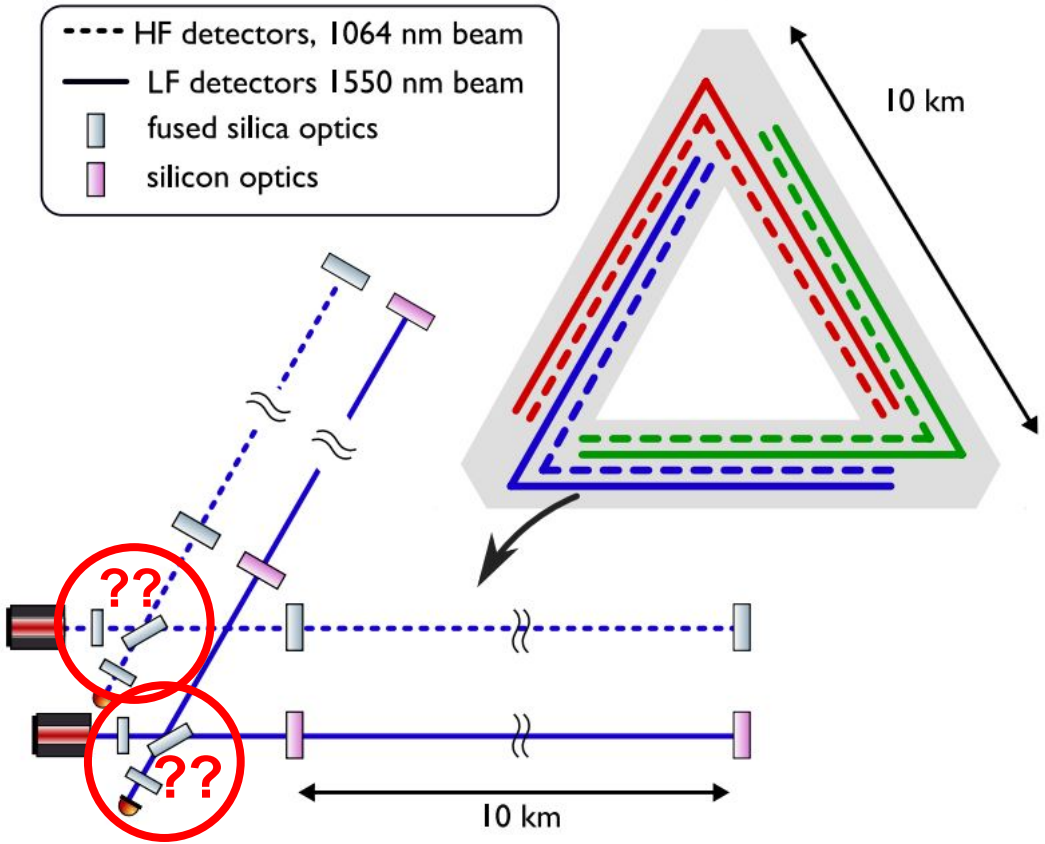
Workshop
ET-0247A-22

Recycling cavities: LF and HF

We need to converge on a recycling cavity design for both the LF and HF detectors.

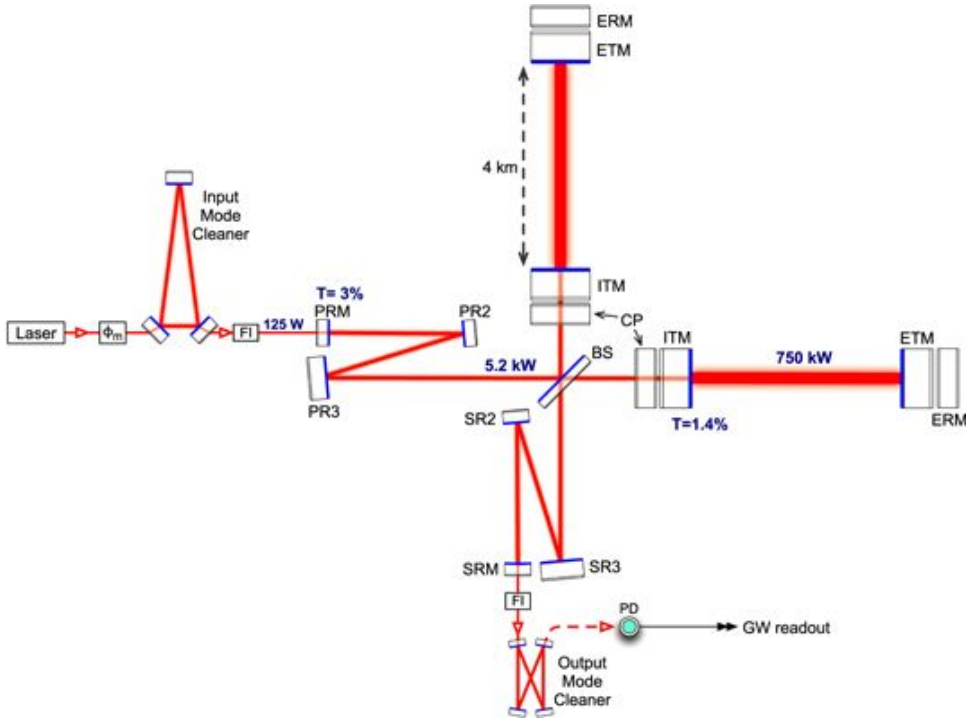
The most detailed design we have so far is from Rowlinson, et.al

https://doi.org/10.1103/PhysRevD.103.023004

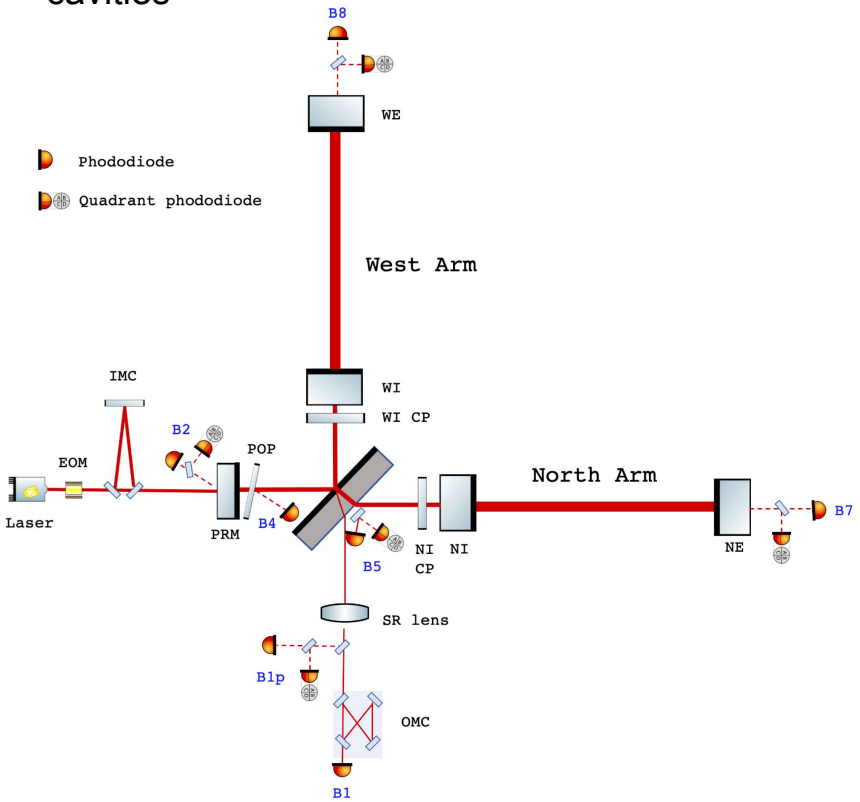


LIGO and Virgo

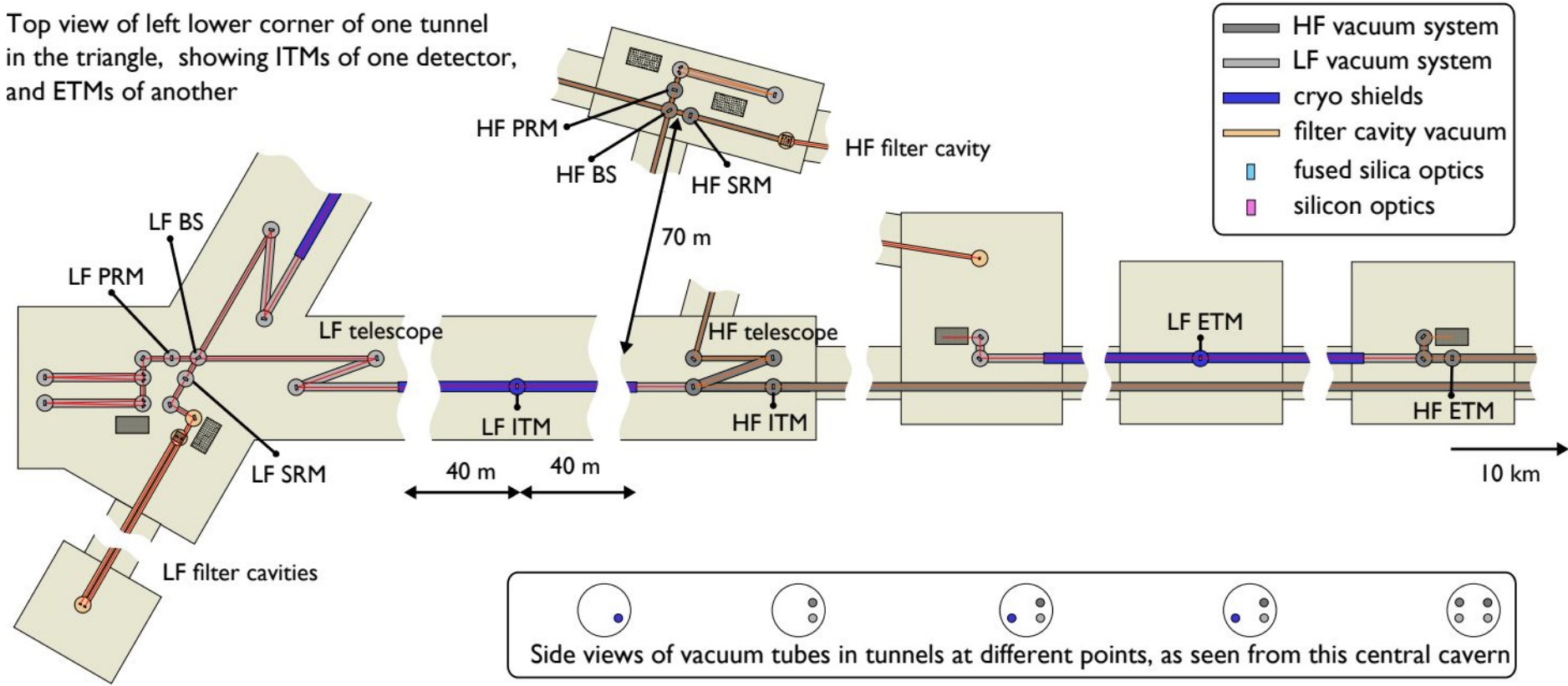
aLIGO has stable recycling cavities



Virgo has near unstable recycling cavities



Recycling cavities: LF and HF



https://doi.org/10.1103/PhysRevD.103.023004

Current telescope design

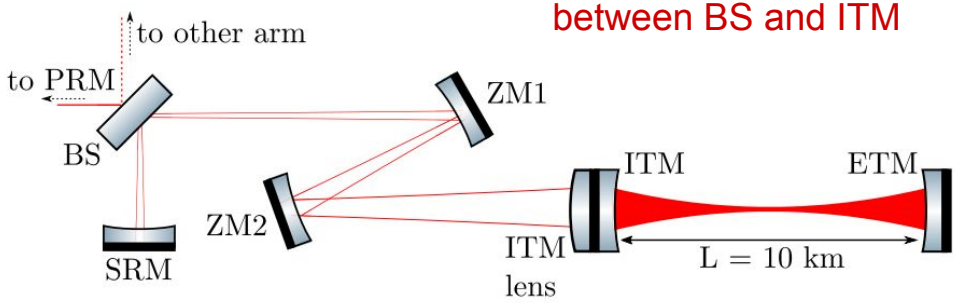
Readonly overleaf:

https://www.overleaf.com/read/yvxmxnsmnbfy

Overleaf document above which contains many thoughts and questions that need answering about the telescope design - please read and comment!

Waist at the BS

Steering mirrors between BS and ITM



Compensation plate shaped like a lens

Optic		SRM	BS	ZM1	ZM2		
ROC [m]	LF	−9410	inf	−50	−82.5		
	HF	−630			−63.2		
Beam radius [mm]	LF	6.1	6.2	8.9	30		
	HF	6.3	6.4	8.3	38		
Space		SRM-BS	BS-ZM1	ZM1-ZM2	ZM2-1TM		
Length [m]	LF	10	70	50	52.5		
	HF			80			
Gouy phase [deg]	LF	7.5	39	5.3	0.6	Total accumulated	52
	HF	4.8	26	4.9	0.2	Gouy phase [deg]	36

Recycling cavities: open questions

LF

The Rowlinson telescope design here is probably ok. Still need to check:

- Astigmatism/free-form optics
- Can we optimise the gouy phase any more to minimise HOM squeeze losses?

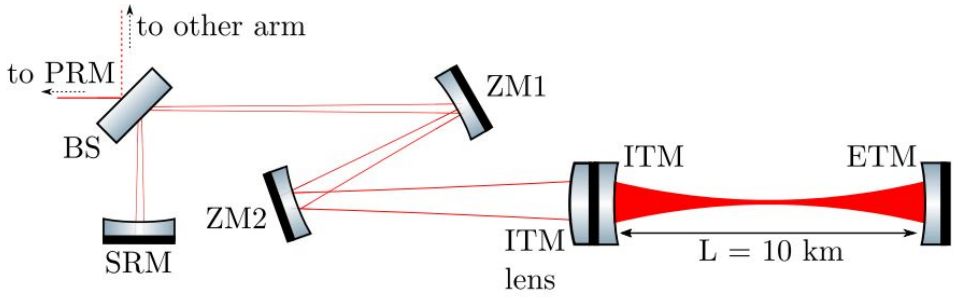
HF

The Rowlinson telescope design here is suggested to **not** be ideal

- Spot size at BS is too small, 6mm currently, >26mm needed
  - A. Rocchi and V. Fafone https://apps.et-gw.eu/tds/ql/?c=16427
  - BS thermal lensing will be an issue to correct at higher powers
- ***Do we need an alternative design??***

Propose we focus on HF telescope this week

HF telescope challenges



- *We want a big spot, why not put the BS close to the ITM like LIGO, Virgo?*

The beam size is very large at the ITM (~120mm), the BS is also at an angle which means the BS must be 1/cos(alpha) larger in diameter. This means suspending something even larger and heavier.

Alpha for ET would be 60 degrees…

Further away from the ITM means more room for separating ghost beams, reduce scattered light issues, etc.

Placing extra optics between the BS and the arms is also useful for individual arm control, mode-matching, and pick-offs for monitoring and alignment references

HF telescope challenges

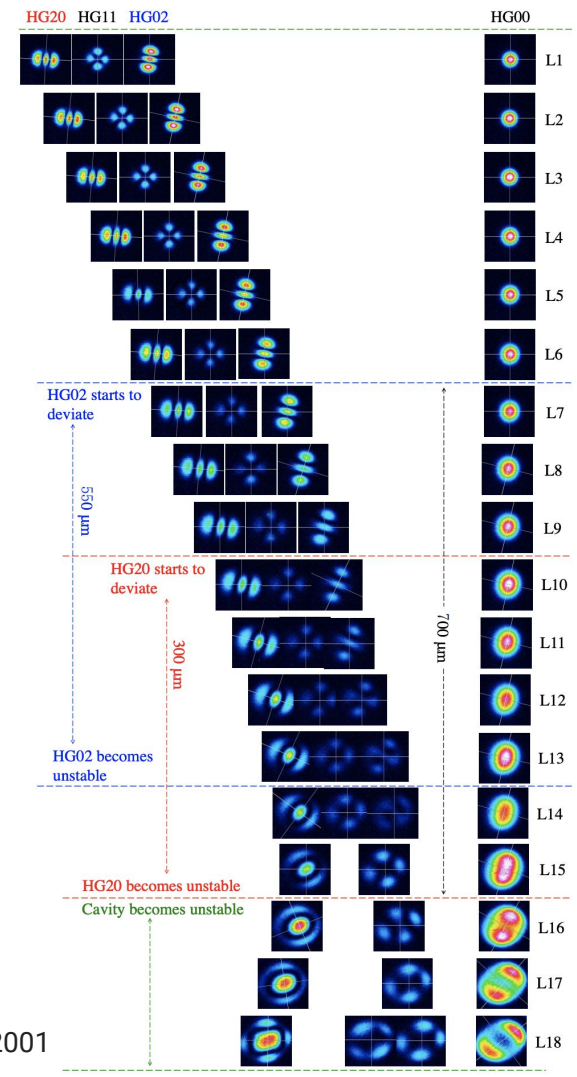
- *Should recycling telescopes be geometrically stable?*

Yes… better for sensing and control purposes

So we can't keep the beam big for 200m. We must focus the ~120mm cavity beam down to something smaller to accumulate enough Gouy phase to make the SRC cavity geometrically stable.

- *But, can we also have more telescopes outside the cavity to make the beam the right size for input/output optics?*

Yes, that could also be used, but we should use the least number of optics possible



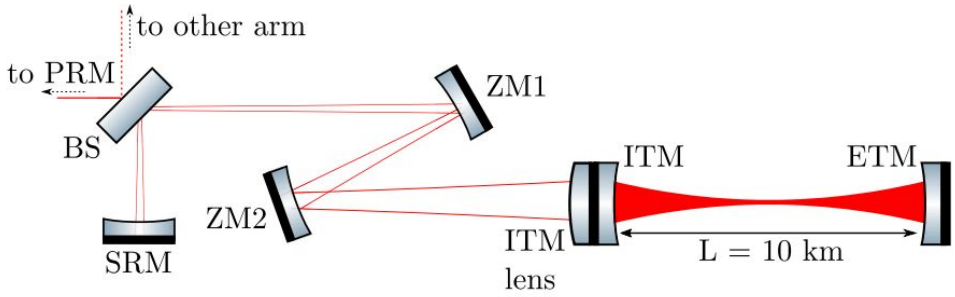
https://doi.org/10.1103/PhysRevD.97.022001

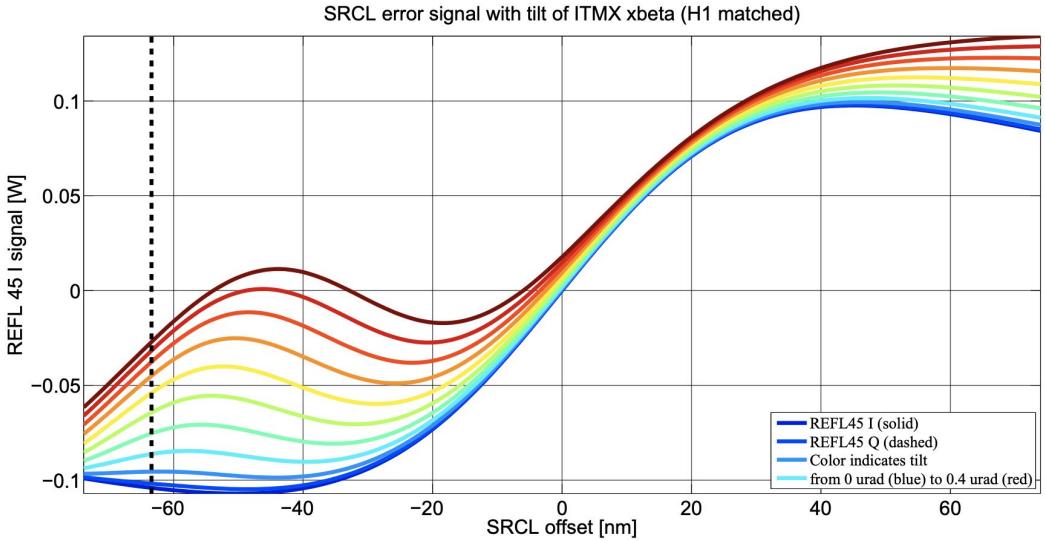
HF telescope challenges

How much SRC gouy phase?

- Higher order mode scattering generates frequency dependent squeezing losses

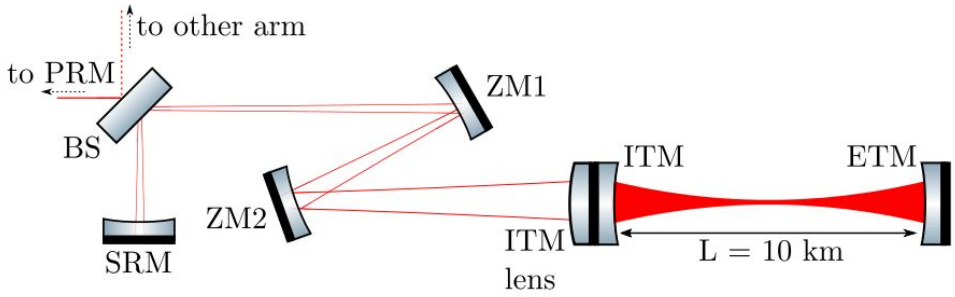
- Length and alignment sensing and control
  - Mode hopping: https://dcc.ligo.org/LIGO-T1500230
  - Need to model how tolerant we are, will put limits on RMS motions

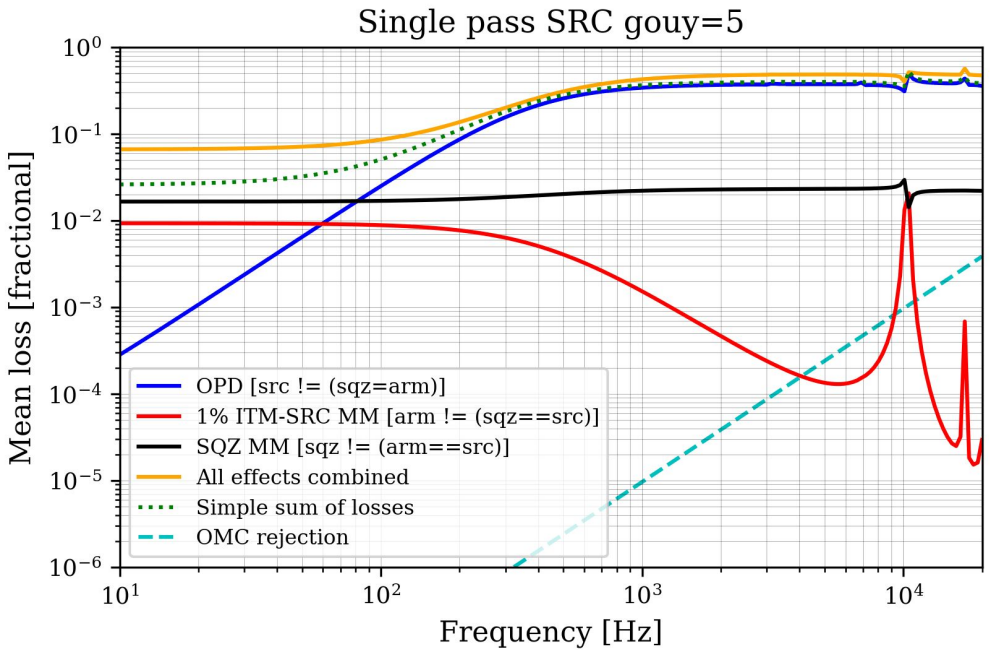


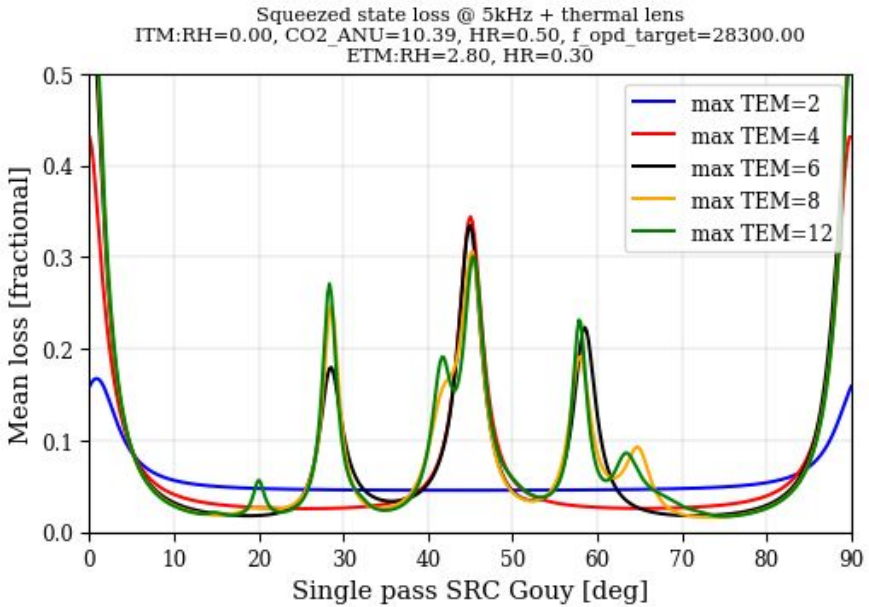


HF telescope challenges

How much SRC gouy phase?







Very preliminary results from LIGO modelling, D.Brown & H.T.Cao

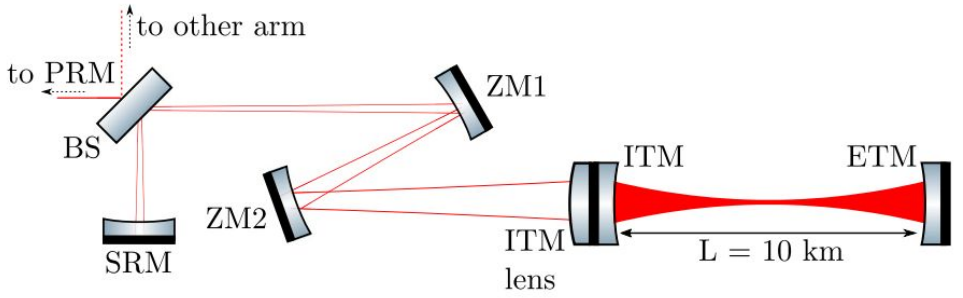
HF telescope challenges

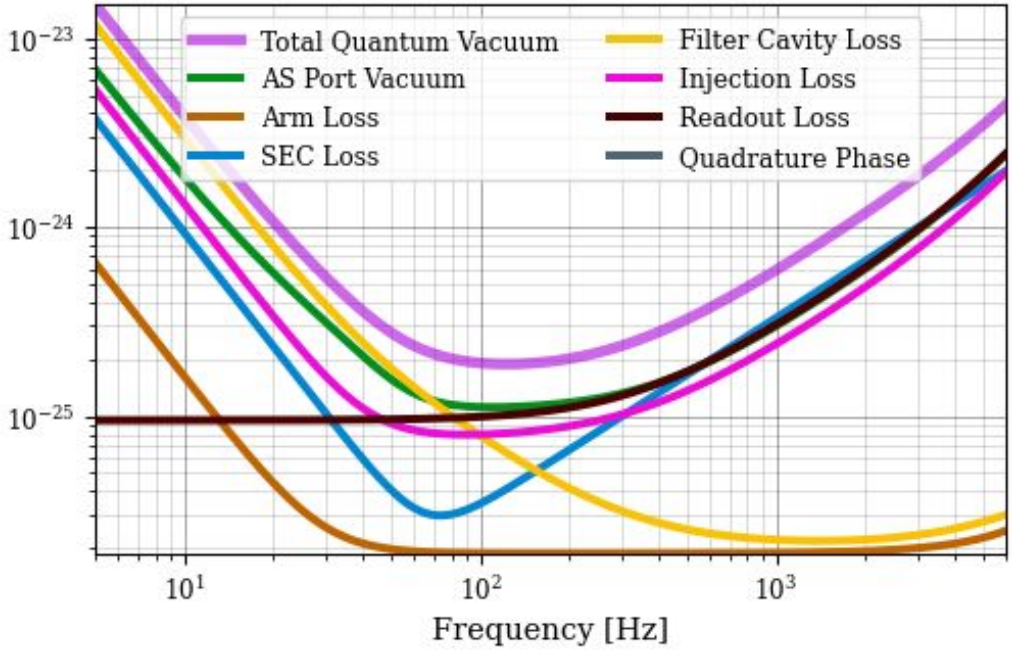
Signal recycling losses

SRC losses can dominate the quantum noise budget at higher frequencies. HF budgets for **1000ppm** of roundtrip SRC loss.

What do LIGO and Virgo have at the moment? Who knows…

5,000–10,000 ppm maybe, difficult to measure

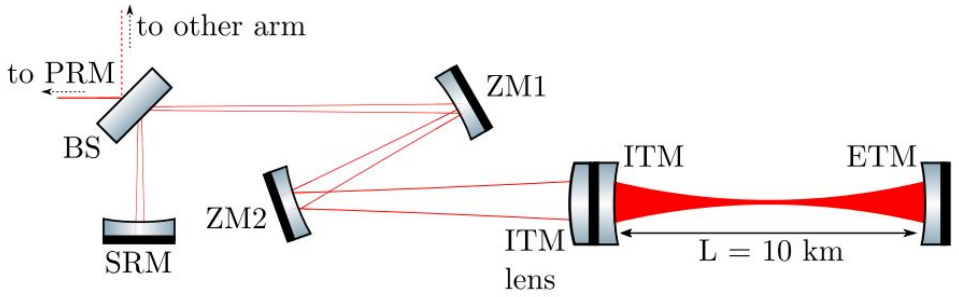


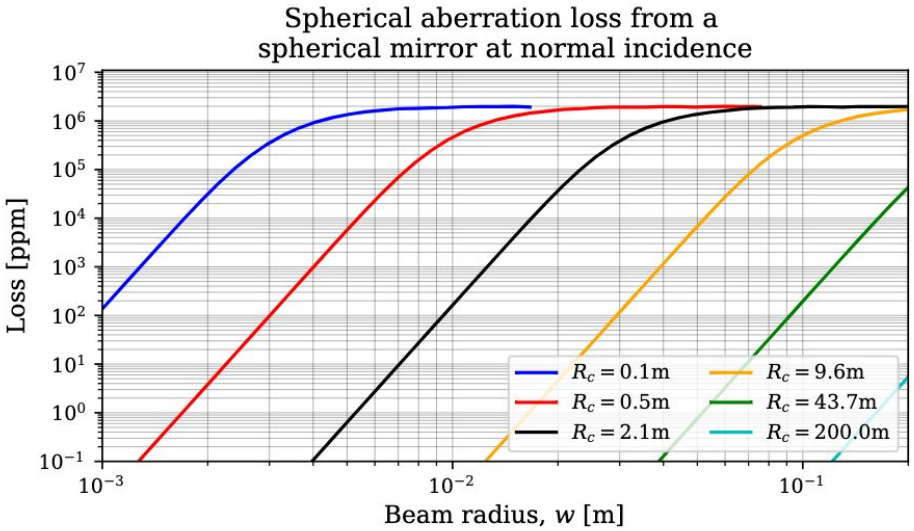


https://journals.aps.org/prx/abstract/10.1103/PhysRevX.9.011053

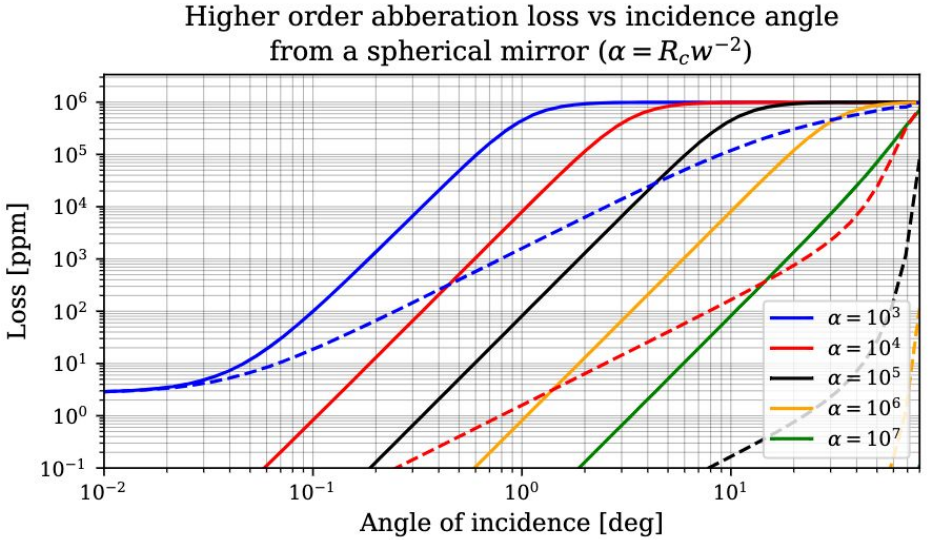
HF telescope challenges

Signal recycling losses



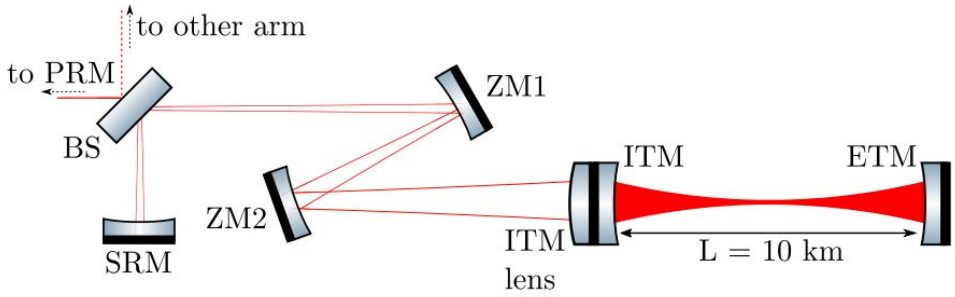


Can free-form optics help??



Dashed-lines are loss from coma aberrations, solid-lines astigmatism and spherical

HF telescope challenges

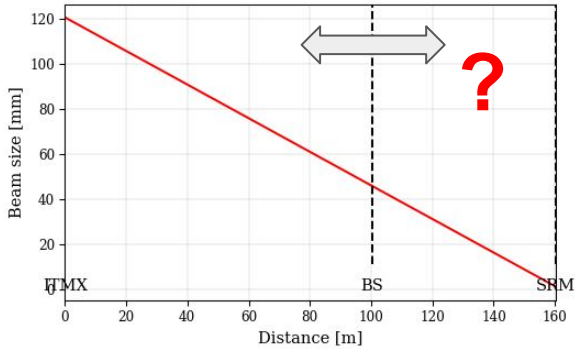


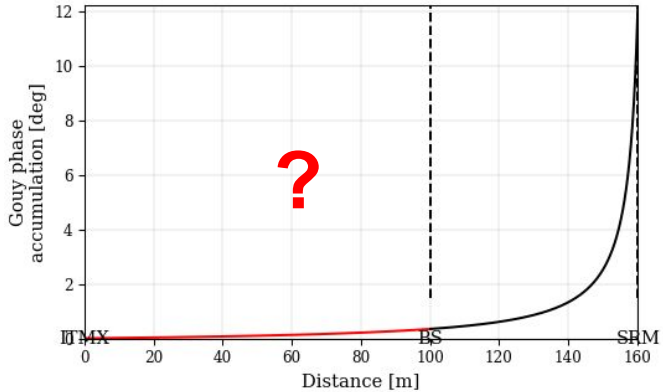
What shall we tackle this week?

If we need a new HF telescope design we should come up with one!

One simple idea:

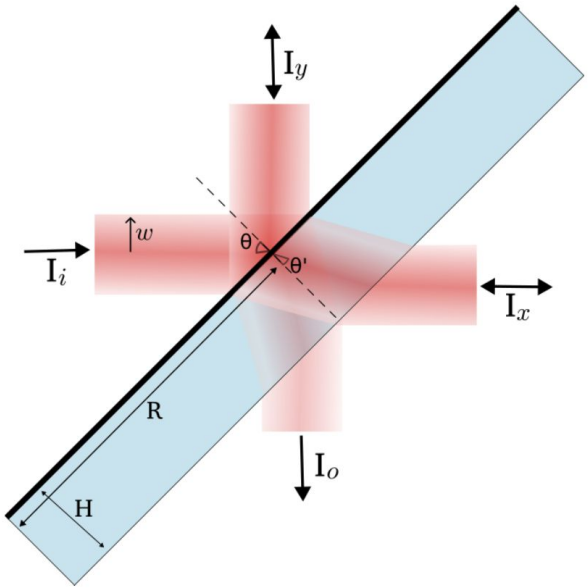
- Compensation plate has a focal length, focus down a waist after the SRM, ZM1/2 flat mirrors
- **where would we put ZM1/ZM2 go for good alignment control, BHD pick-offs?**
- Put BS somewhere that satisfies >26mm spot size. Beam would converging through it, **how much of a problem if beam is not collimated at the BS?**
- **Can we fit this around with the current ET LF telescope design?**
- **Can we make the SRC cavity longer? How much before it impacts science case?**
- **Any better ideas??**



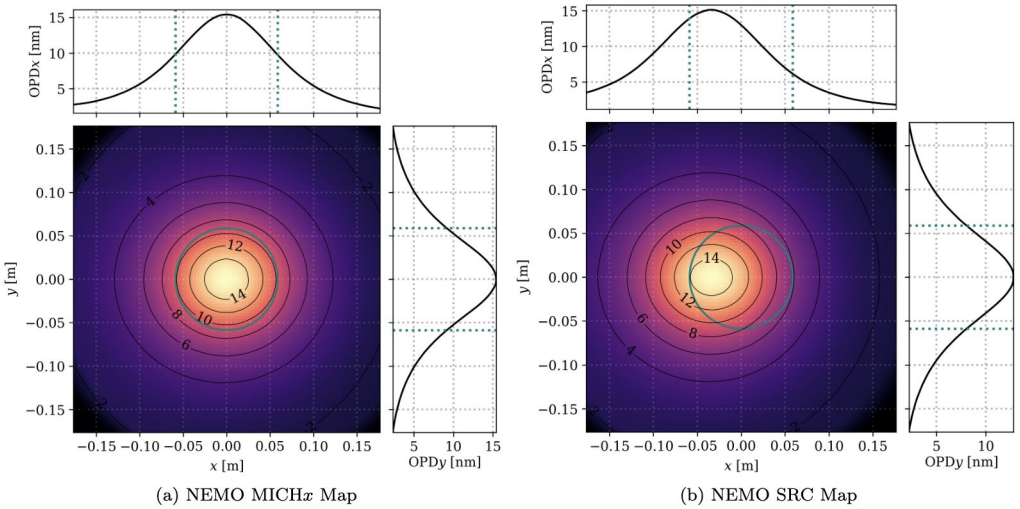


Questions?

Thermal issues

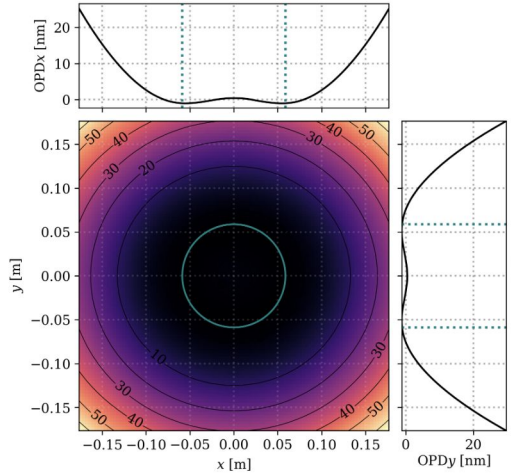


Plots from Muskan Pathak

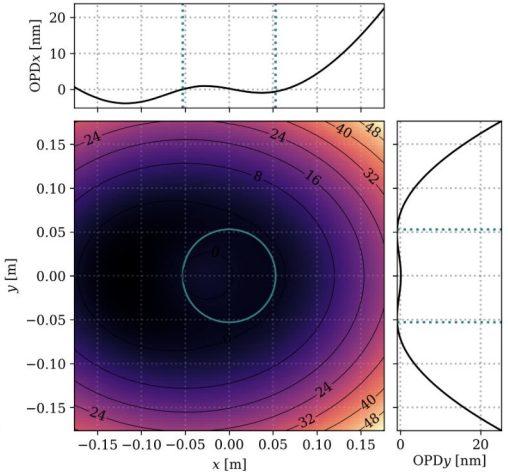


(a) NEMO MICHx Map

(b) NEMO SRC Map



(c) NEMO MICHx Map with curvature and tilt removed



(d) NEMO SRC Map with curvature and tilt removed