# OMC optical design

Koji Arai / Jan. 25, 2013


The previous version of the slides were presented in the ISC meeting on Oct. 18, 2012
The parameters and plots in this slides have been updated to accommodate the update after the presentation and keep the consistency with the design document T1000276-v5

## Mission of the OMC:

- Transmit TEM00 mode
- Filter higher order modes
- Filter RF sidebands

## Previous design progress (by Sam W)

- two choices (bowtie & no BS)
- RoC of the curved mirror ~2.5m
- Roundtrip length of the cavity 1.1~1.3m

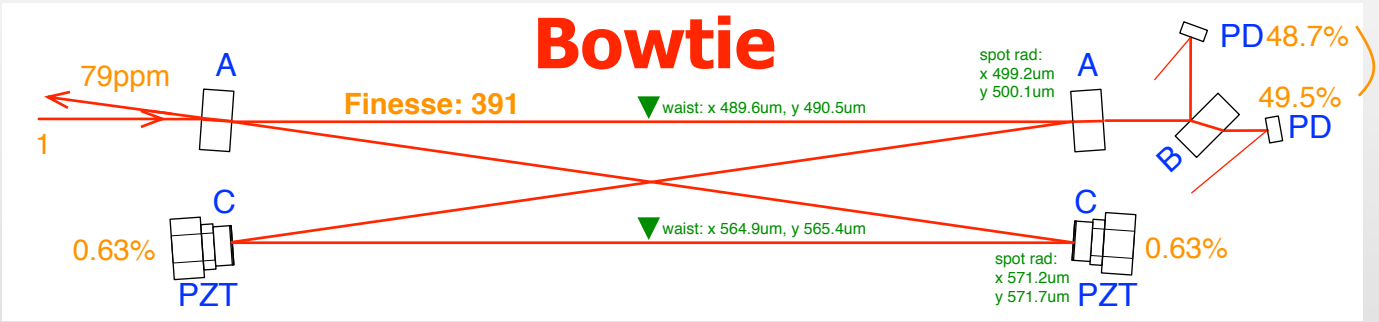
==> The mirrors have been ordered and delivered

## Precise design based on the delivered optics

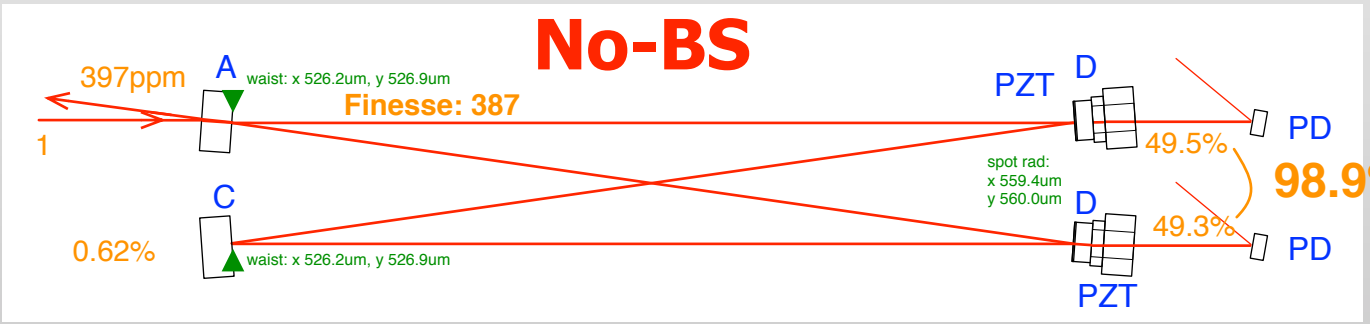
- Using actual Rs&Ts, RoC

# OMC optical design

## Bowtie or No-BS?: TEM00 Transmission




526.1992 μm ω0y = 526.8864 μm




- "NoBS" has less leakage loss

| | AOI | Request | Data sheet |
|---|---|---|---|
| A) IO coupler | 4deg(P) | T~8300ppm | T=7931ppm |
| B) Beam splitter | 45deg(P) | T~50% | T=50.385% |
| C) High Reflector | 4deg(P) | T~50ppm | T=51.48 or 46.40 ppm |
| D) Output mirror | 4deg(P) | T~4150ppm | T=4089ppm |
| E) Leaky HR | 45deg(P) | T~7500ppm | T=7400ppm |

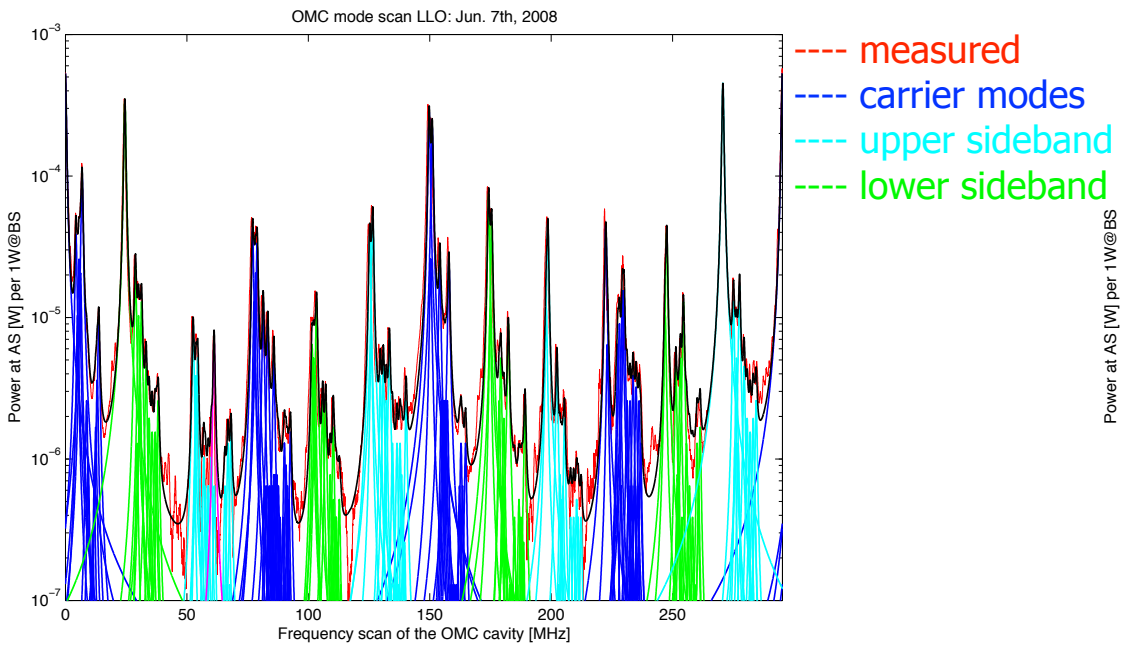
L(roundtrip):
1.132[m] for bowtie
1.175[m] for no-bs
RoC=2.575[m]
AR loss ignored
Loss(roundtrip)=40ppm

# Bowtie or No-BS?: Filtering Performance

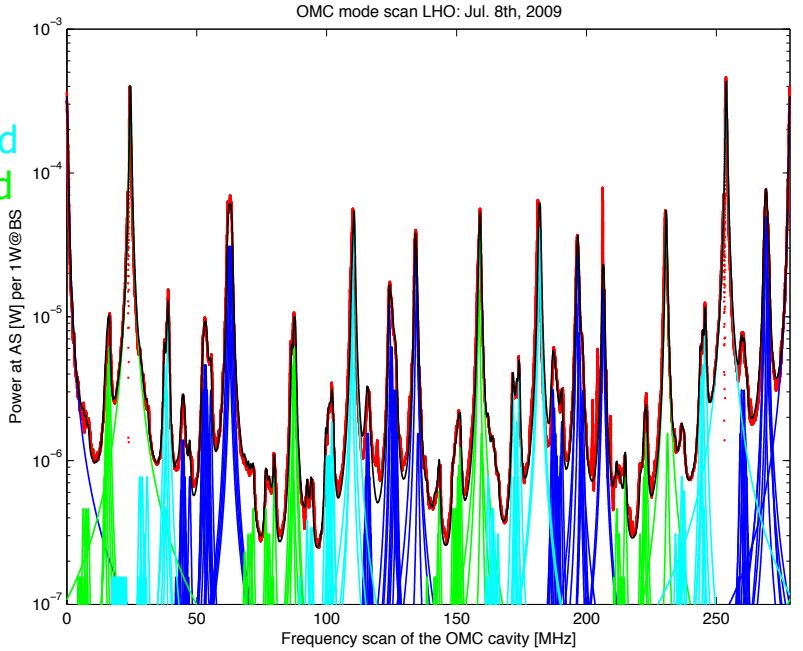
How to guess the amount of HOMs? ==> eLIGO OMC scan data

Note:
aLIGO may have better beam quality at the dark port owing to the better optics.
But it is unknown for now.
=> The same analysis should be redone once the results of the aLIGO simulation or actual measurement are taken place.

## LLO

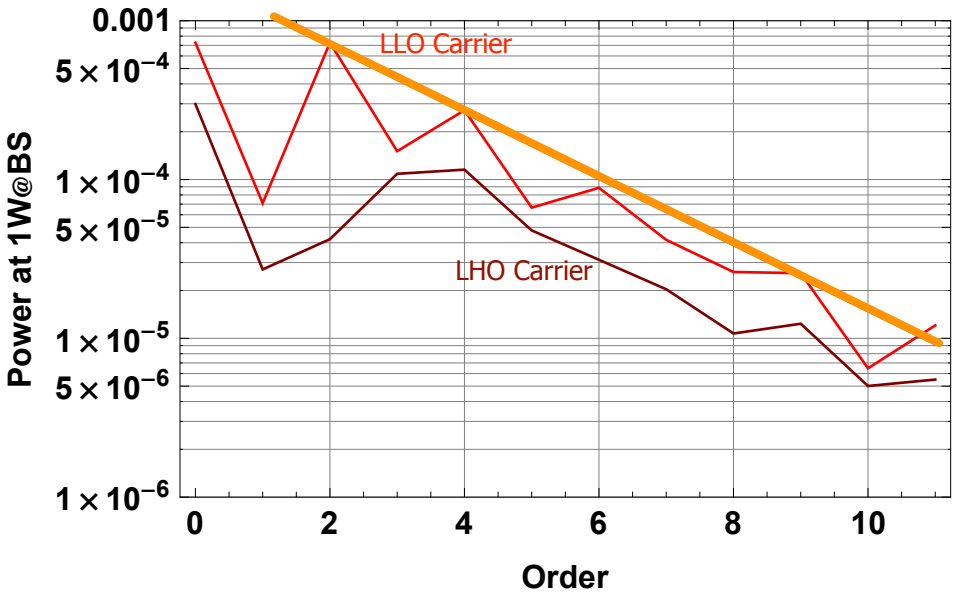


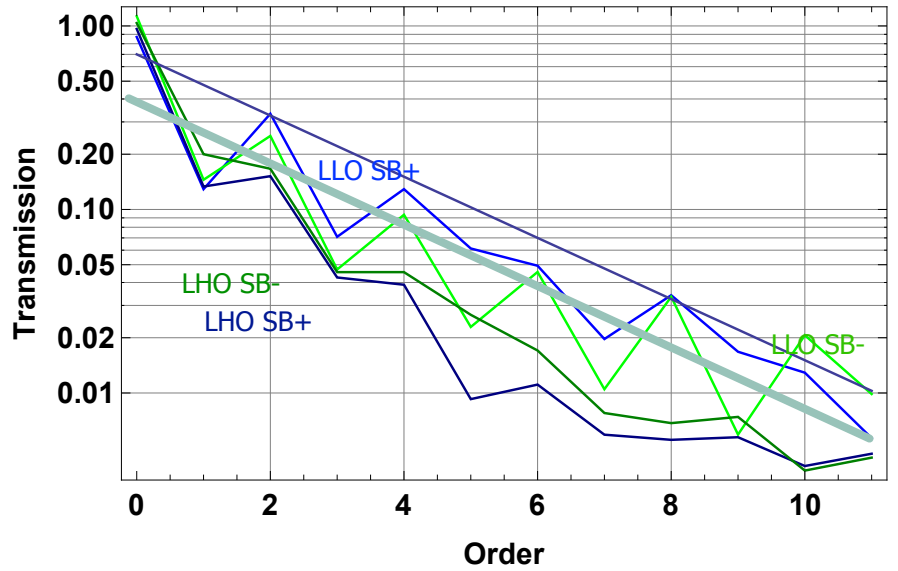

## LHO



# OMC optical design

## Power-law modeling of the mode scan data




### HOM Model

**OMC output:** Calibrated with the sideband power

**Carrier:**

How much carrier higher-order modes leak out from the IFO when the carrier of 1W is hitting on the BS

- 0 for TEM00
- 7e-5 [W/W] for the 1st order
- 1.8e-3 x 10^(-n/4.8) for the order n>2 (total of modes in an order)
- No correction for SR (No mode healing)

PRG of aLIGO: ~45

**Sidebands:**

Thru-put from incident to the dark port

For 45MHz sidebands

- 1 for TEM00
- 0.17 for the 1st order
- 7.0e-1 x 10^(-n/6) for the order n>2

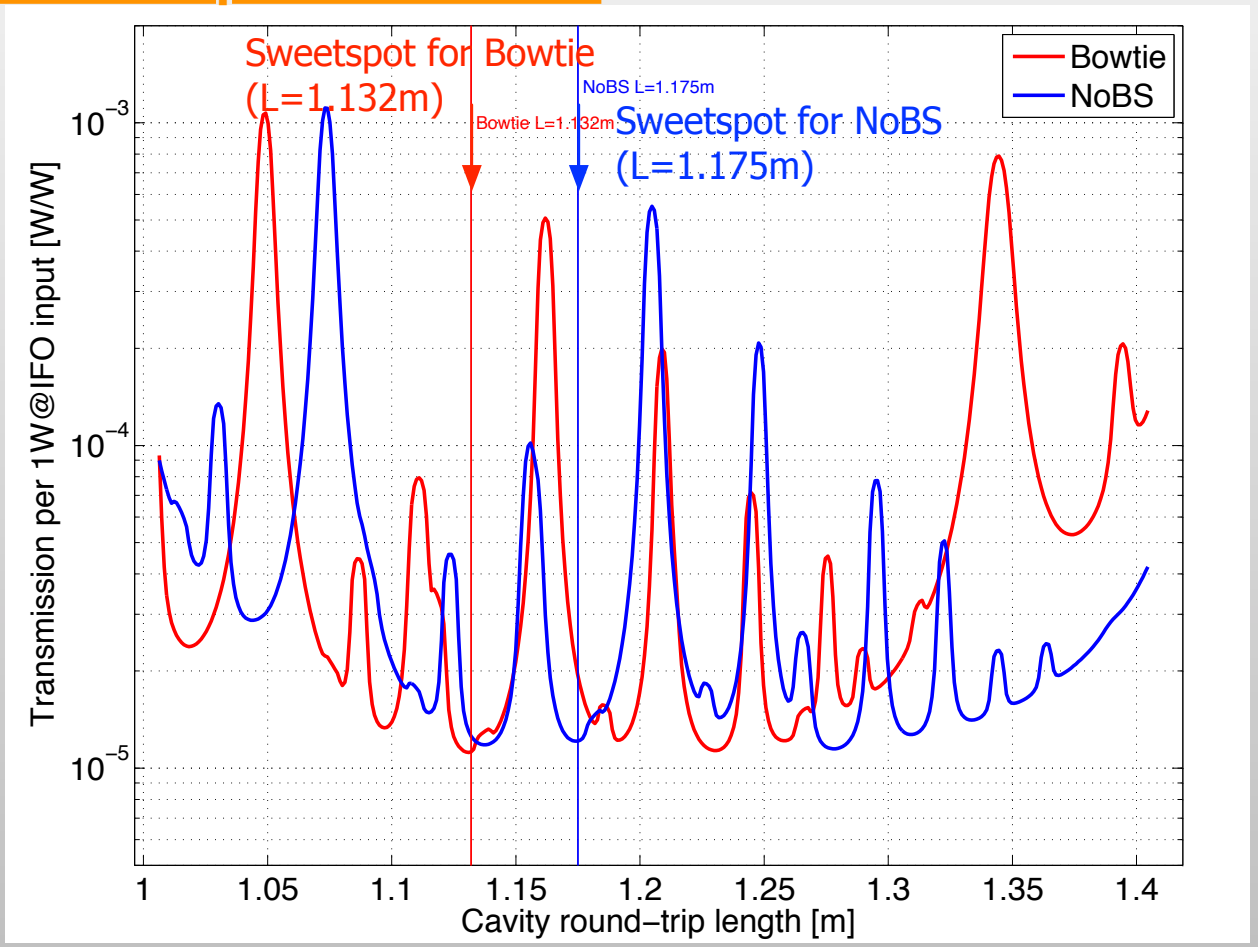
For 9MHz sidebands

- 1/1000 of 45MHz sidebands (T070247-01 P.9, Fig.4)

# Bowtie or No-BS?: Filtering Performance

RoC = 2.575m

**Excess transmitted power to the DCPD**
**in relative to the incident laser power to the IFO**



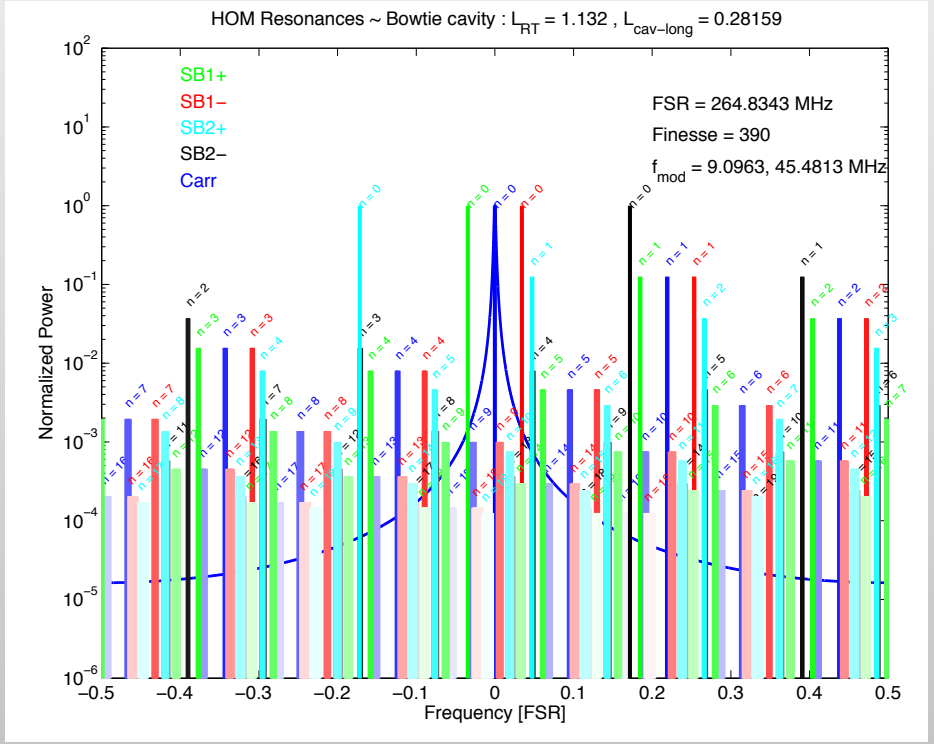

**These two cases have very similar mode structure**
**except that No-BS tends to have a slightly longer cavity length for a same spot**

# OMC optical design

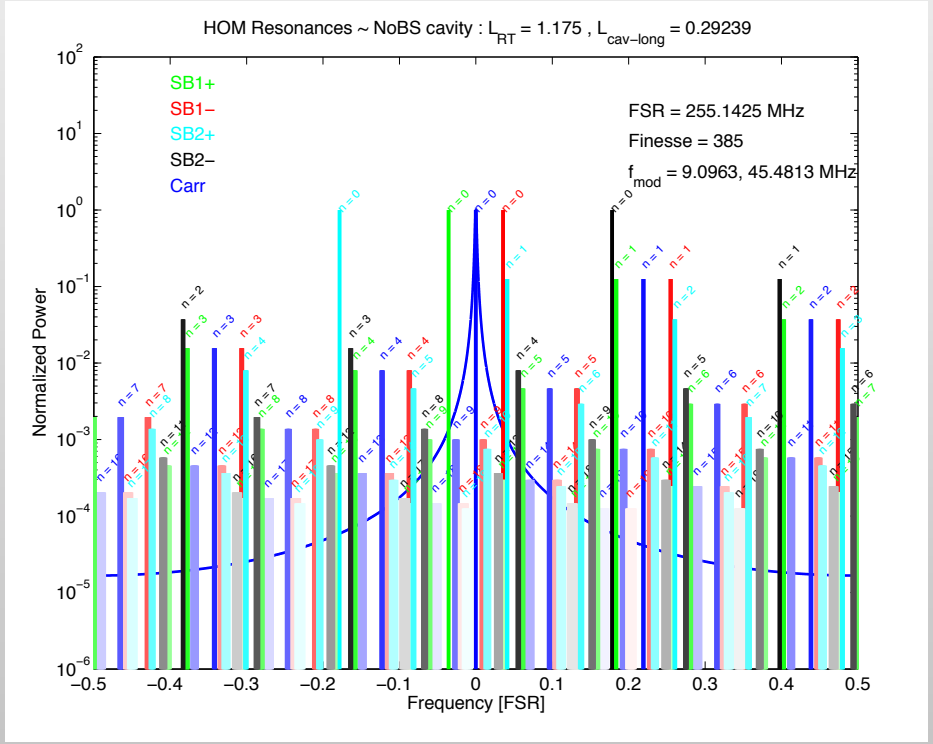
## Bowtie or No-BS?: HOM structure

RoC = 2.575m

The mode structure is very similar for both cases.




Bowtie (L=1.147)




NoBS (L=1.280)

Calculated by "ArbCav" by Zach Korth

# OMC optical design



**Bowtie or No-BS:**

- No-BS has slightly higher TEM00 transmission
  (98.2% vs 98.7%, for loss of 10ppm per bounce)

- They have equivalent filtering performances
  once the cavity parameters are optimized

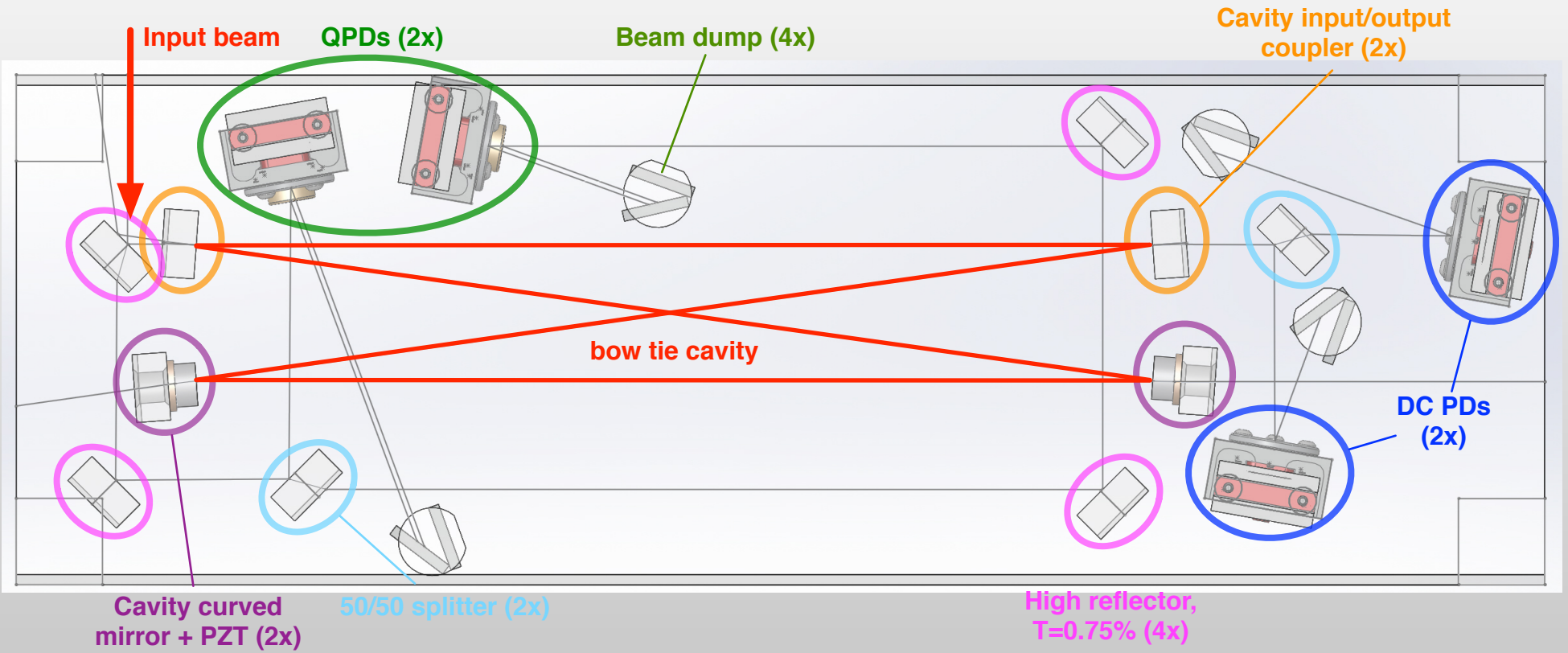
- "No-BS" tends to have slightly (~4%) longer optimum length

- Intuition:
  "The beams for the PDs should be common as far as possible"

**For the first OMC for LLO, I decided to adopt "Bowtie" design**

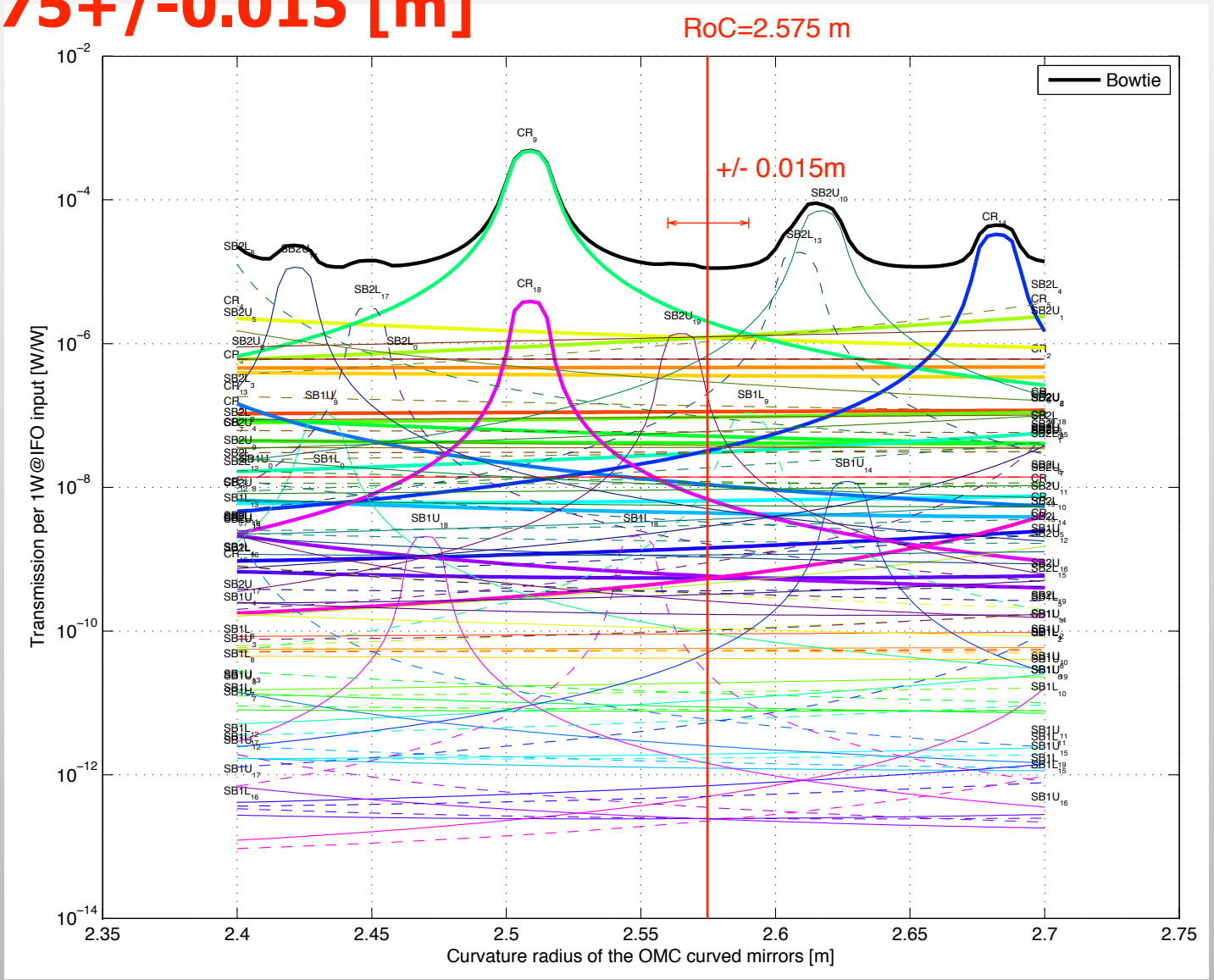
# OMC optical design





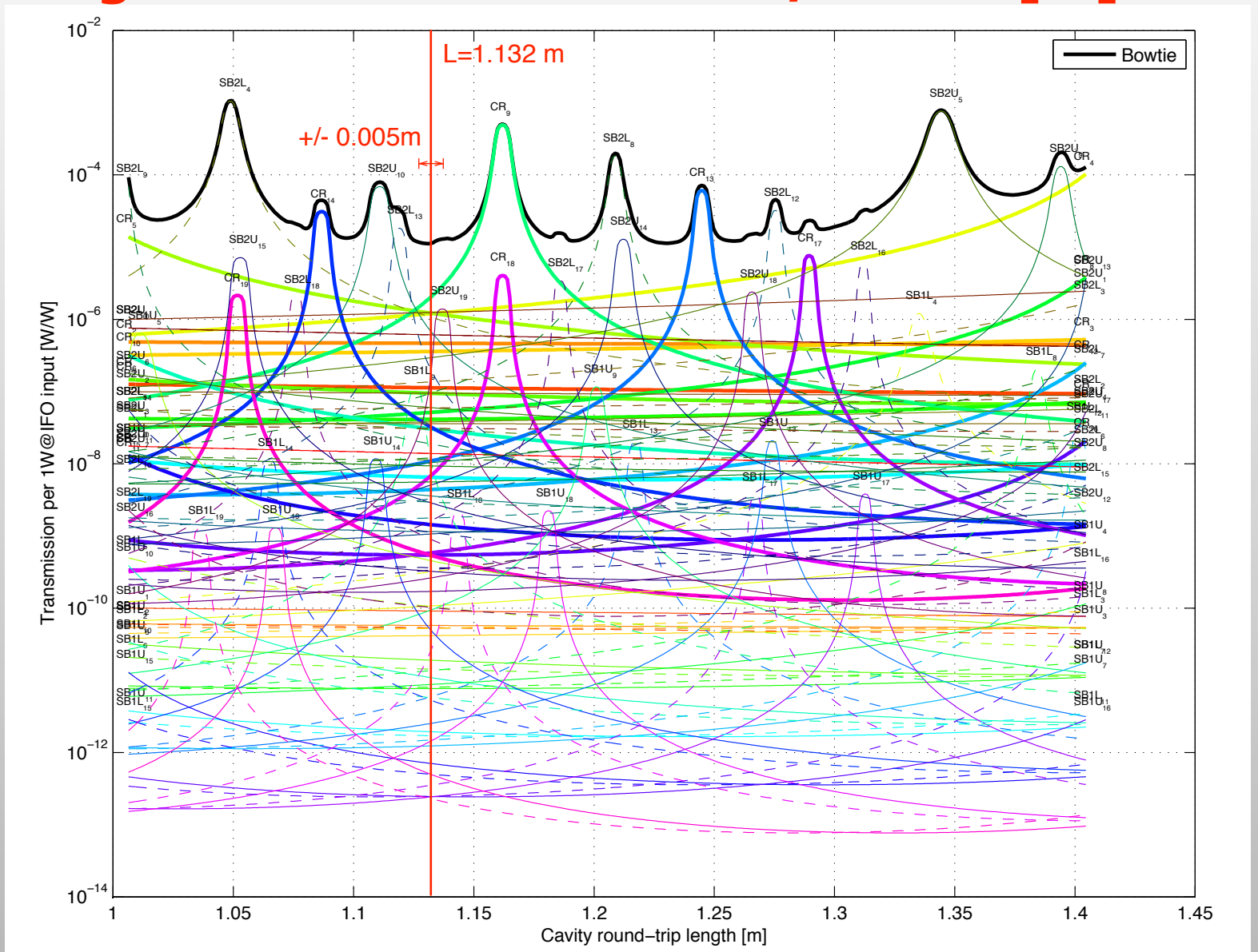
# OMC optical design

## Curvature radius tolerance of the curved mirrors L=2.575+/-0.015 [m]



# OMC optical design

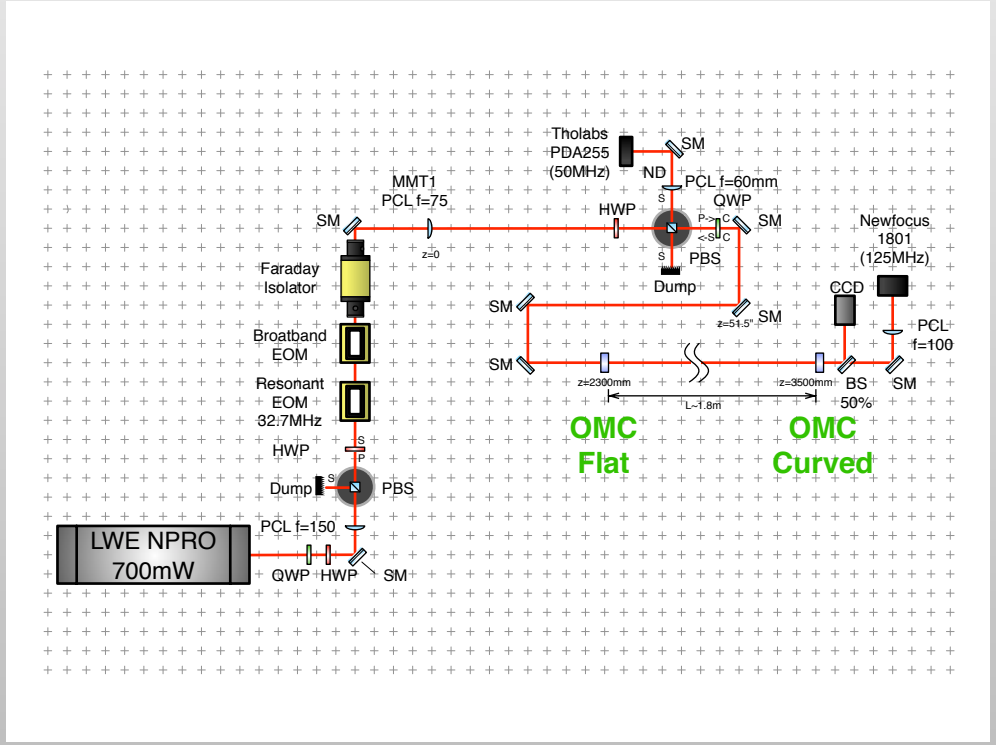
## Cavity length tolerance: L=1.132+/-0.005 [m]

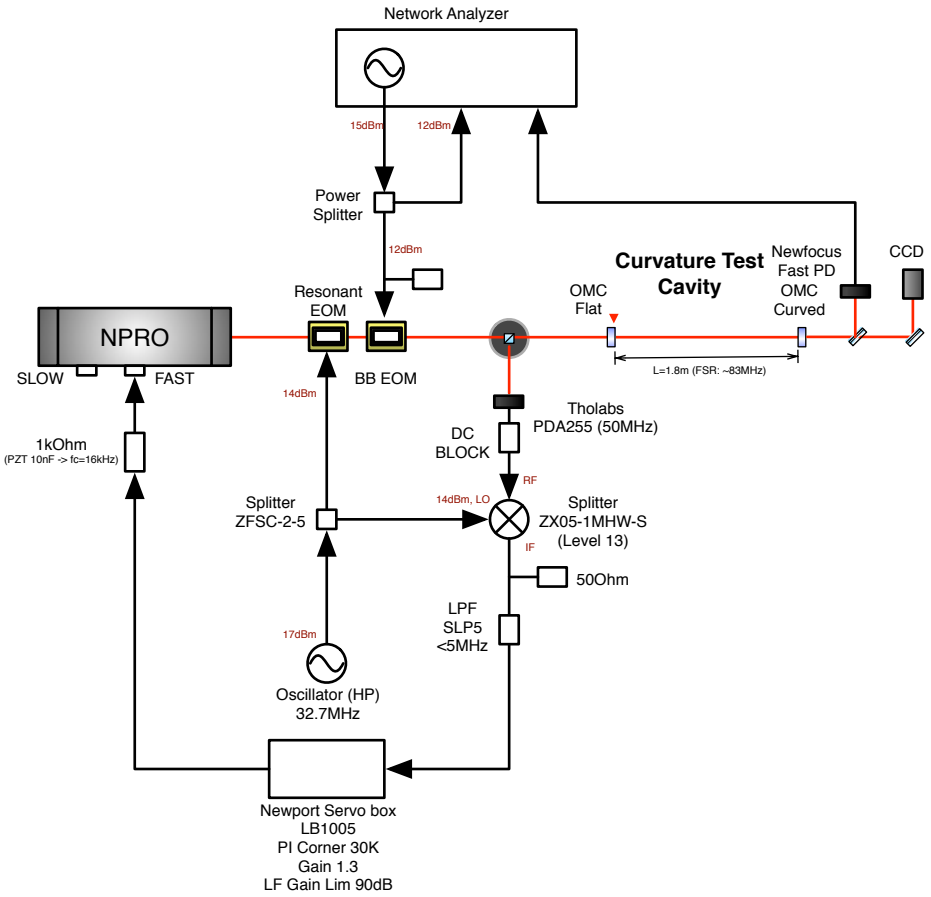


# OMC optical design

## Mirror curvature meaurement

- The optimum length of the OMC: really depends on the mirror RoC.
- The vender did not provide an absolute RoC spec
  (only the phase map results relative to a reference sphere)

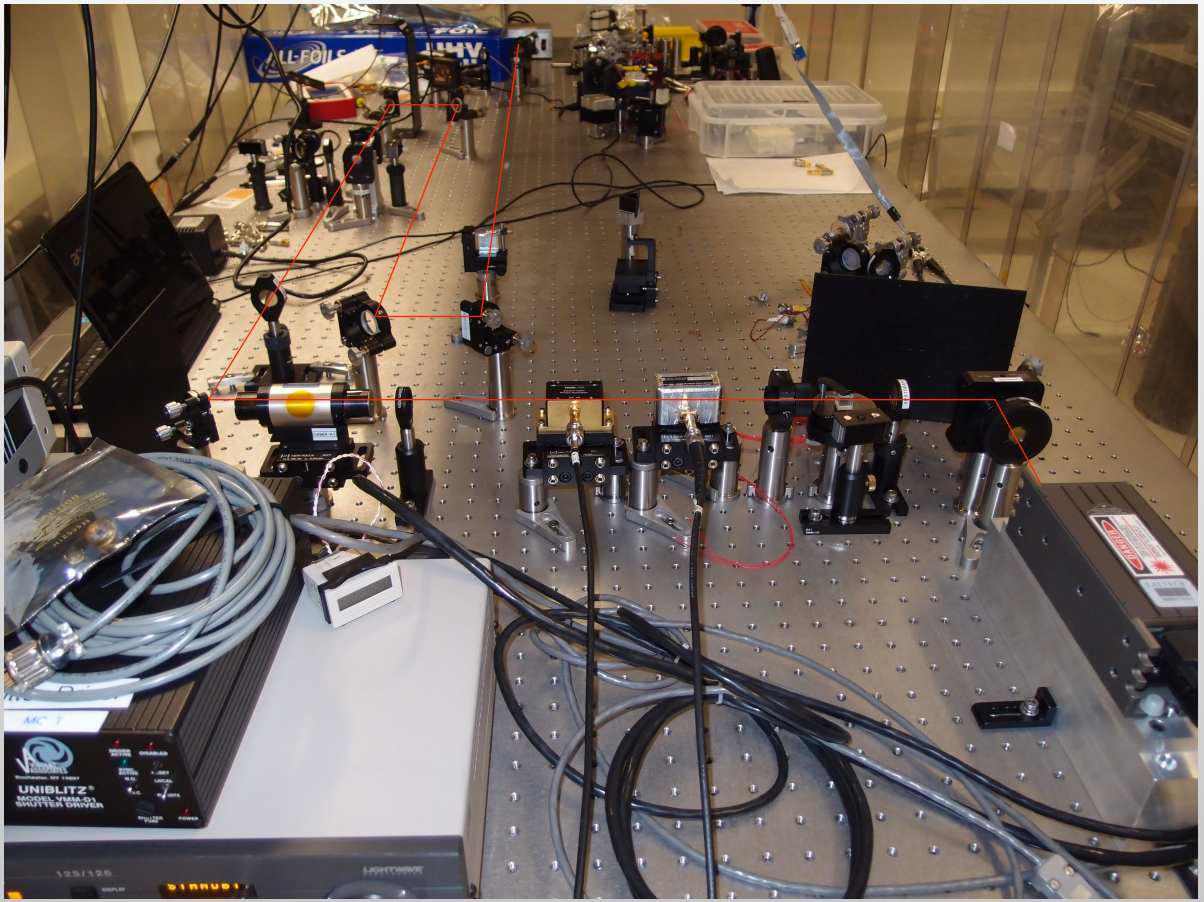


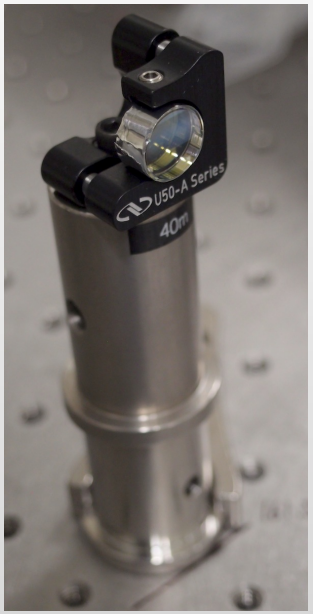
# OMC optical design



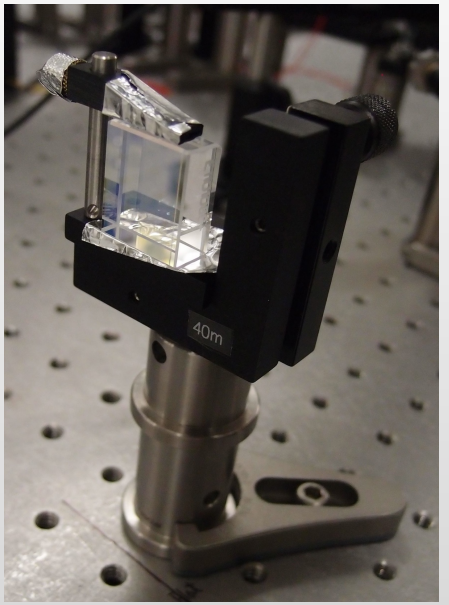
## Gallery



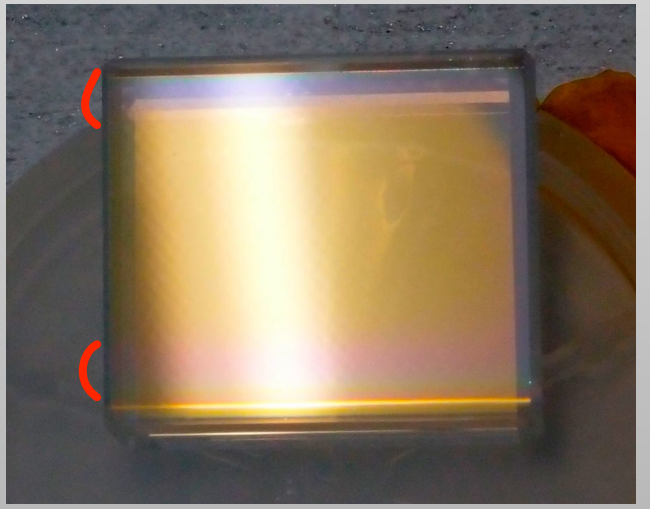

Setup




1/2" curved mirror



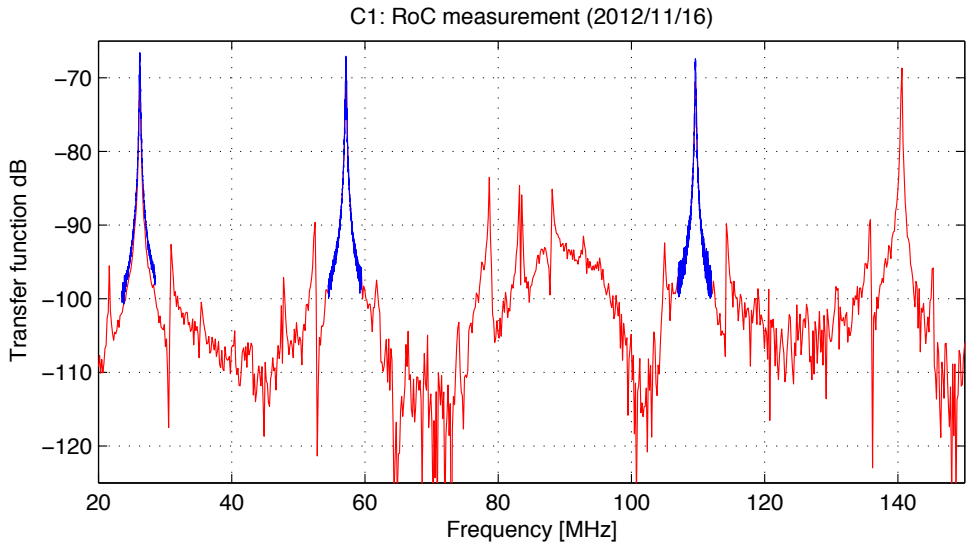

flat mirror "tombstone"

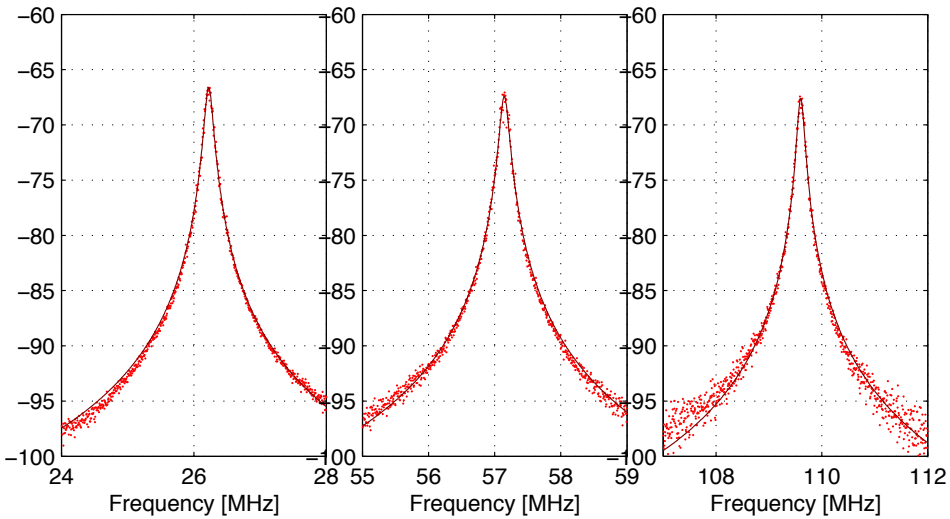


bands seen on the edge of the coating!?

# OMC optical design

## Measurement example




Fit Result

**== Yaw Misalign 26MHz ==**
Peak1: 26.2249 +/– 0.00035971 MHz
FWHM: 63.8807 +/– 0.36584kHz

**== Yaw Misalign 57MHz ==**
Peak1: 57.1457 +/– 0.00054872 MHz
FWHM: 69.0865 +/– 0.55881kHz

**== Yaw Misalign 109.5MHz ==**
Peak1: 109.602 +/– 0.00041511 MHz
FWHM: 66.3678 +/– 0.42243kHz

**== Yaw Misalign Summary ==**
FSR: 83.3771 +/– 0.00054928 MHz
Cavity length: 1.7978 +/– 1.1844e–05 m
Lock offset: 3.2642 +/– 0.49773 kHz
RoC: 2.578450 +/– 0.000042 [m]

# OMC optical design

## RoC measurement of the 9 OMC curved mirrors

#1: RoC: 2.57845 +/− 4x10$^{-5}$ m

#2: RoC: 2.54363 +/− 5x10$^{-5}$ m

#3: RoC: 2.57130 +/− 6x10$^{-5}$ m

#4: RoC: 2.58176 +/− 7x10$^{-5}$ m

#5: RoC: 2.57369 +/− 9x10$^{-5}$ m

#6: RoC: 2.57321 +/− 4x10$^{-5}$ m

#7: RoC: 2.56244 +/− 4x10$^{-5}$ m

#8: RoC: 2.56291 +/− 5x10$^{-5}$ m

#9: RoC: 2.57051 +/− 7x10$^{-5}$ m

==> 2.575 +/- 0.005 [m] (#2, #7, #8 excluded)