Alignment sensing in the SRC using a new 118.3 MHz SB scheme

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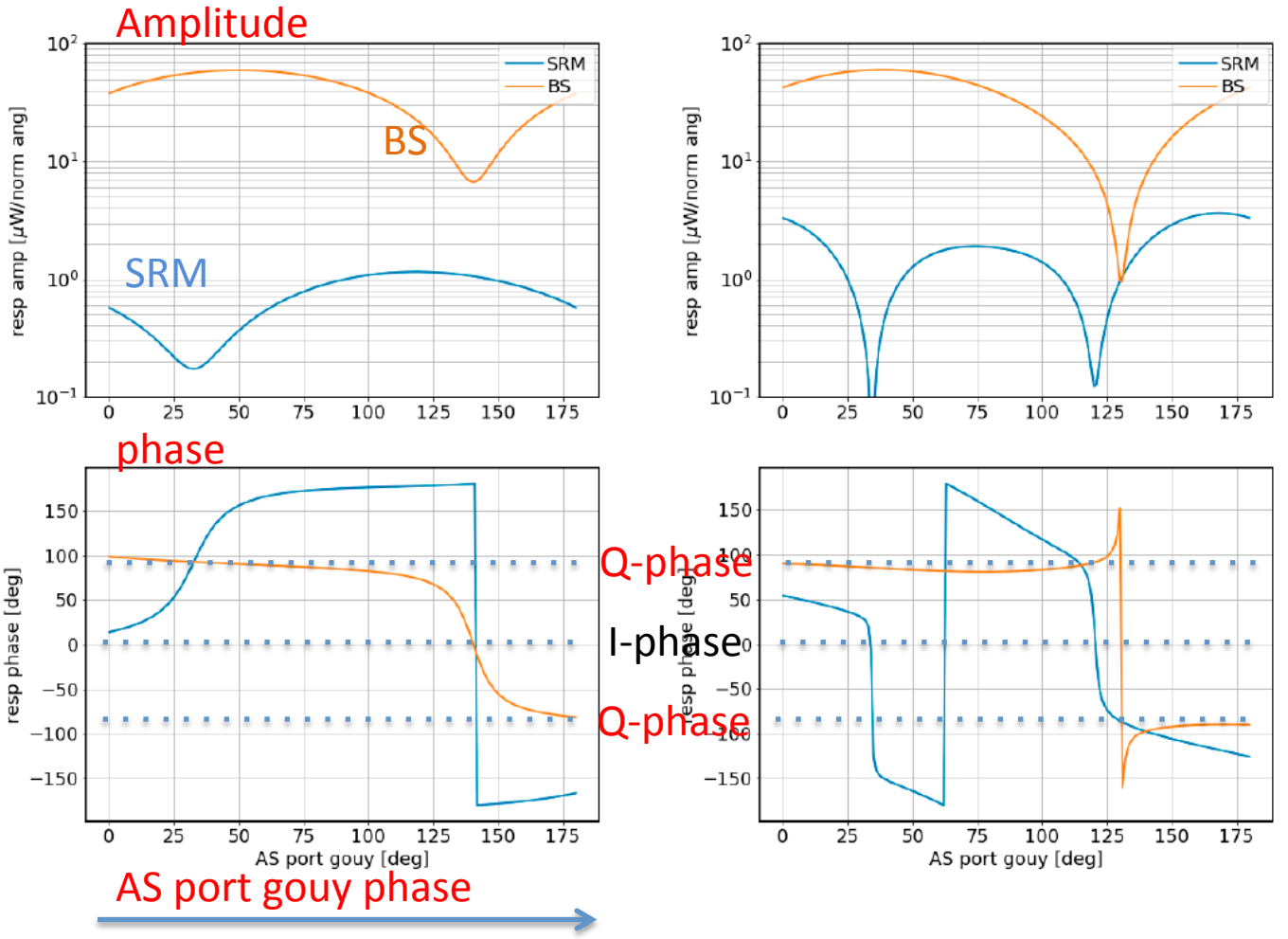
for the commissioning and modeling team

Current SRM scheme w/ AS36



(a) Nominal

(b) Extra 100km ITMX thermal lens

- Beat note 9.1MHz and 45.5MHz
- SRM/BS resp vs AS port gouy phase
- SRM sensitive to diff thermal lens
- Phased SUM signal to I (0/180 deg)
- Cannot distinguish SRM from spot centering signal.
- G1700603 for more

We thus want

- A new SRM ASC scheme that
  - Is robust against 02 modes
  - Can be decoupled from DC centering loops

- New scheme:
  - Adding a new SB at 118.3 (13x9.1) MHz
  - Look at ASC signal at 72.8MHz
    (beat note between 45.5MHz and 118.3MHz)

More robust against 02/20 modes

- Amp of 00: DRMI transmissivity

  ~ MICH transmissivity ~ $\sin\left(2\pi\frac{l_{\mathrm{asym}}}{c}f\right)$

  ~ f

- Amp of 02: ~ prop to the pumping field's amp

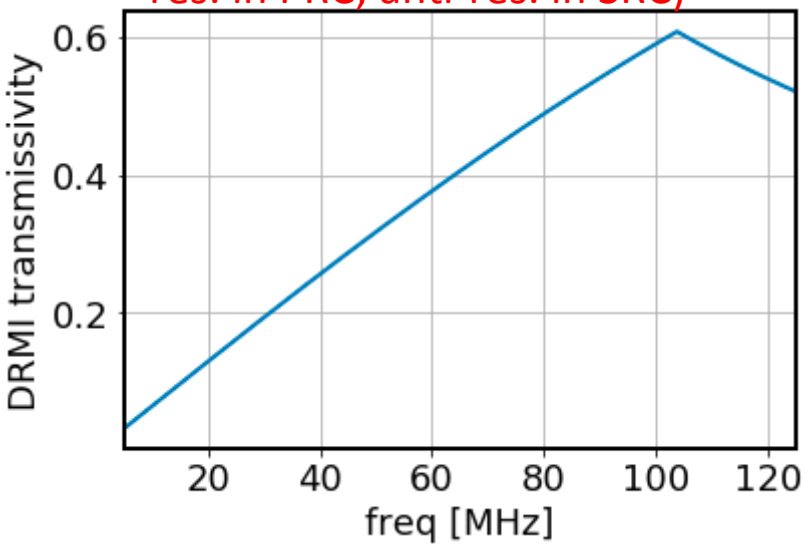
  ~ PRMI cav gain

  ~ slow varying w.r.t. f

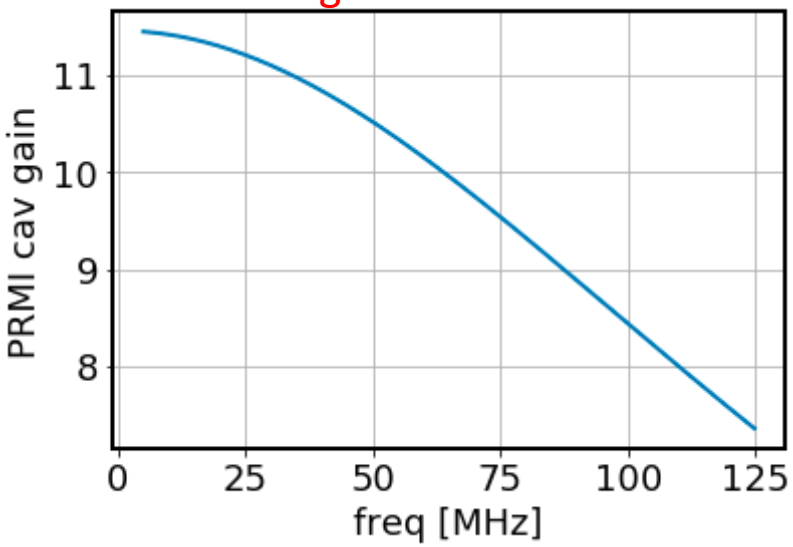
- Expect $\left[\frac{E_{00}}{E_{02}}(118.3\mathrm{MHz})\right] \Big/ \left[\frac{E_{00}}{E_{02}}(9.1\mathrm{MHz})\right]$

  $\sim 10-20$

DRMI transmissivity:
(assuming
res. in PRC; anti-res. in SRC)



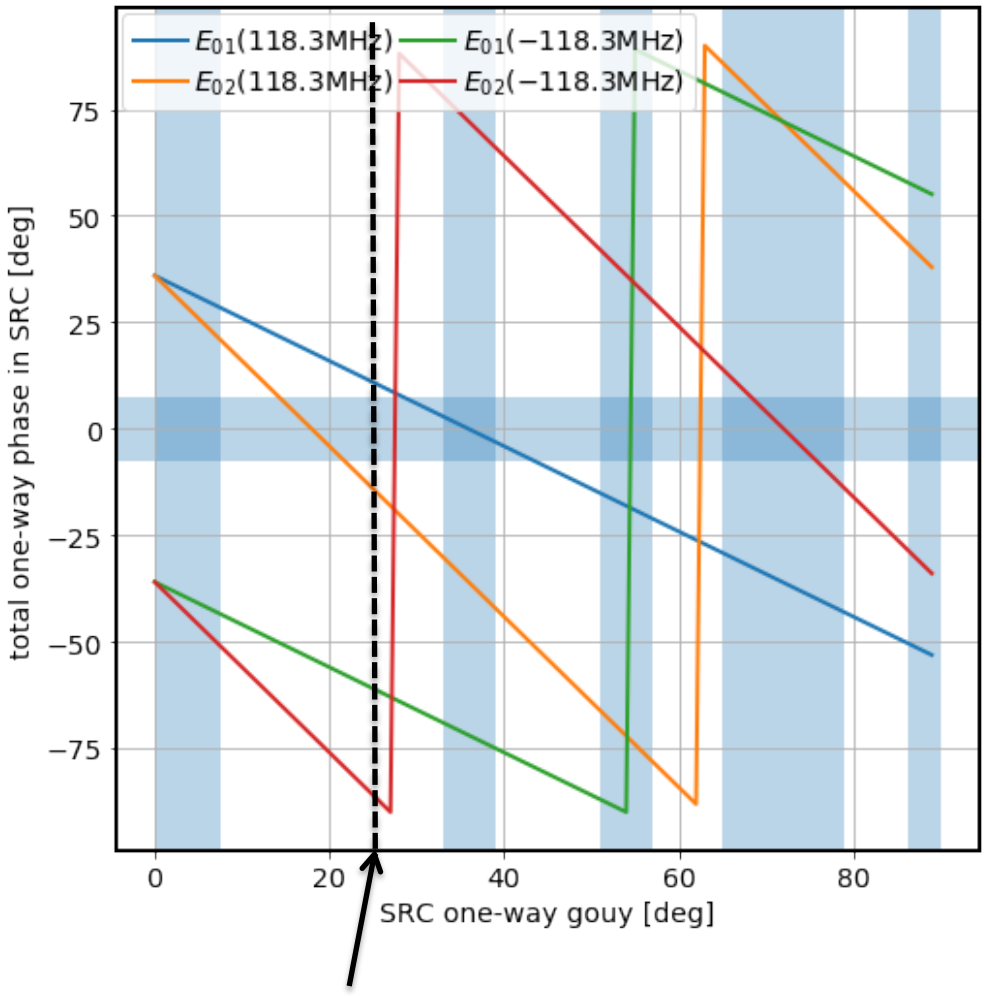
Proportional to
PRMI cav gain



$$\left[\frac{E_{00}}{E_{02}}(118.3\mathrm{MHz})\right] \Big/ \left[\frac{E_{00}}{E_{02}}(9.1\mathrm{MHz})\right]$$

$$\sim 10 - 20$$

Also allow the SRC gouy phase to vary



SRC one-way gouy =25deg

- Horizontal Band: SRC resonance
  02 needs to be off-resonance
  no requirements on 01
- Vertical bands:
  +- 9.1/45.5 MHz HOMs resonances;
  need to be avoided
- SRC one-way gouy 25 deg good candidate

Demod phase?

- *Case i)*.
  - If AS72 signal dominated by a pair of symmetric beat notes (the 01 mode is from the SB resonant in SRC):

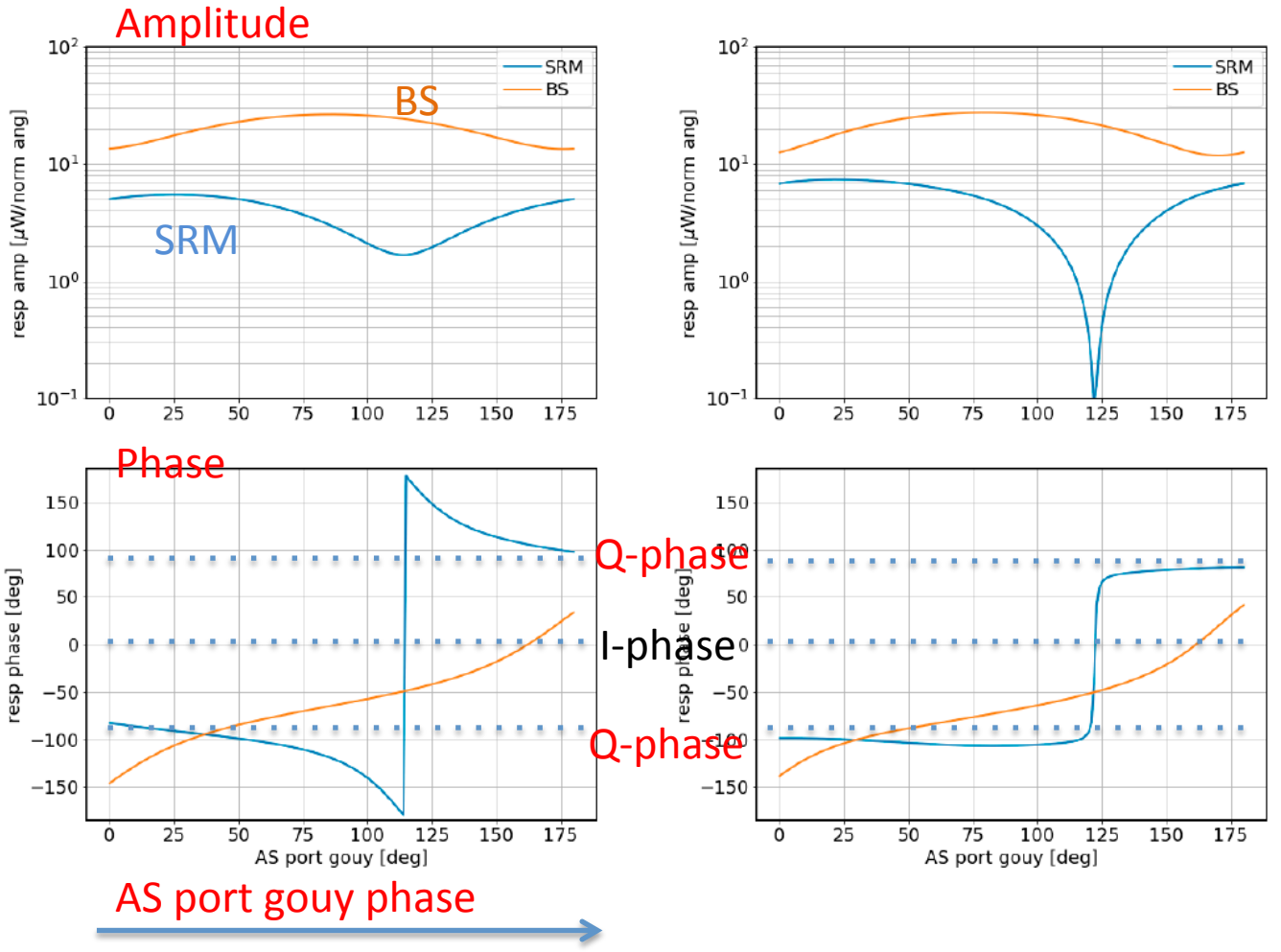
$$S(\phi_{\rm as}) = E^*_{01}(+45.5)E_{00}(+118.3) + E^*_{00}(-118.3)E_{01}(-45.5),$$
$$\propto e^{i(\phi_{\rm as}+\phi_0)} + e^{i(-\phi_{\rm as}+\phi_0)},$$
$$\propto \cos(\phi_{\rm as})e^{i\phi_0},$$

  - Demod phase fixed at ϕ_0
  - Changing gouy phase changes amp
- *Case ii)*.
  - If AS72 signal dominated by a single beat note (the 01 mode is from the off-resonance SB)

$$S(\phi_{\rm as}) = E^*_{00}(+45.5)E_{01}(+118.3) \propto e^{-i\phi_{\rm as}}.$$

  - Constant amp
  - Varying demod phase

AS72 in Finesse



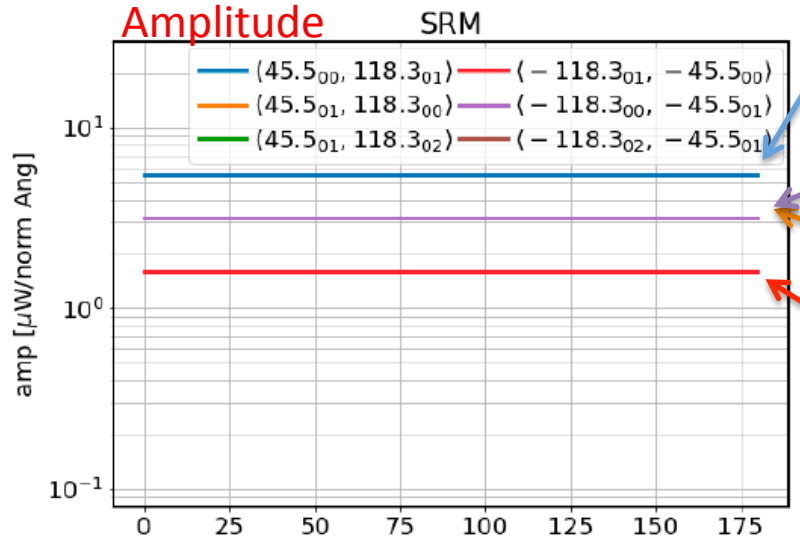
(a) Nominal

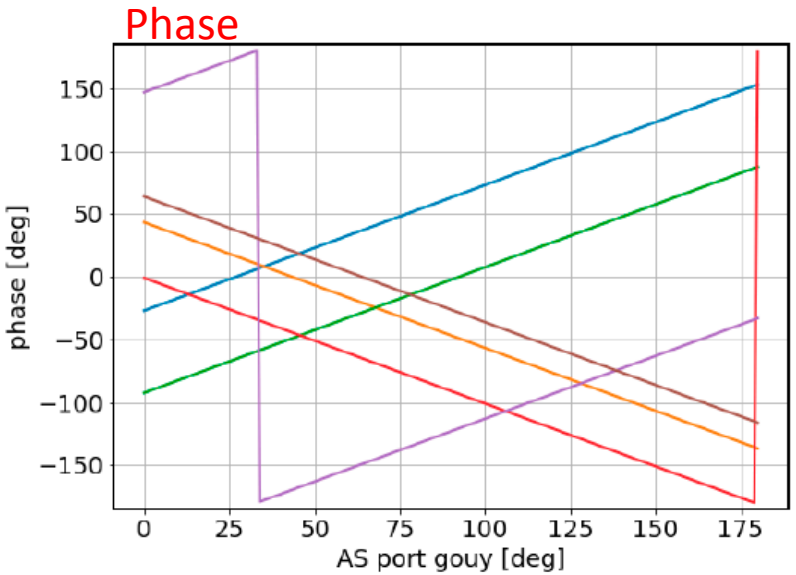
(b) Extra 100km ITMX thermal lens

- SRM/BS resp vs AS port gouy phase
- SRM robust against 02 modes!!!

- SRM shows up in Q phase (+-90 deg)
- BS always has Q component
- Can form sensing mtrx using the two Q's separated by 90 gouy phase
- WFS and DC centering loops decoupled!!!

SRM anatomy





$\langle E_{00}(+45.5), E_{01}(+118.3)\rangle$ → $\exp(+i\phi_{\rm as})$

$\langle E_{00}(-118.3), E_{01}(-45.5)\rangle$ → $\exp(+i\phi_{\rm as})$

$\langle E_{01}(+45.5), E_{00}(+118.3)\rangle$ → $\exp(-i\phi_{\rm as})$

$\langle E_{01}(-118.3), E_{00}(-45.5)\rangle$ → $\exp(-i\phi_{\rm as})$

- Blue largest, but not enough to dominate the signal
- Blue ~ 2x purple = 2x orange
- Blue and purple are 180 deg apart; cancel each other
- Collecting terms (vect sum): (**blue** + **purple**) ~ (**orange** + **red**)
- Effectively in ***case (i)***. w/ $\phi_0 \sim 90^\circ$

Sensing Matrix

Table 1: Sensing matrix for the two SRC gouy phase design.

		no lens		ex 100km lens at IX		ex 100km lens at IY	
		SRM	BS	SRM	BS	SRM	BS
$\phi_{\rm src}^{(g)} = 25°$	AS72A-Q	-5.386	-19.653	-7.087	-21.244	-7.097	-18.271
$T_{\rm srm} = 0.37$	AS72B-Q	1.029	-15.019	0.373	-15.940	-0.455	-17.805
$\phi_{\rm src}^{(g)} = 25°$	AS72A-Q	-3.871	-16.566	-5.467	-18.111	-5.057	-15.677
$T_{\rm srm} = 0.20$	AS72B-Q	-0.054	-6.979	-0.738	-7.901	-1.634	-10.398
$\phi_{\rm src}^{(g)} = 50°$	AS72A-Q	3.442	7.473	3.462	7.925	2.802	3.730
$T_{\rm srm} = 0.37$	AS72B-Q	3.197	5.105	3.739	3.534	3.757	1.249

- To connect with the plots shown previously: A is at gouy 35 and B at 125

CONCLUSION:

- ✓ Robust against 02/20 modes
- ✓ Q-phase only; decouples from DC centering loops
- ✓ Also works for T_srm = 0.20 case

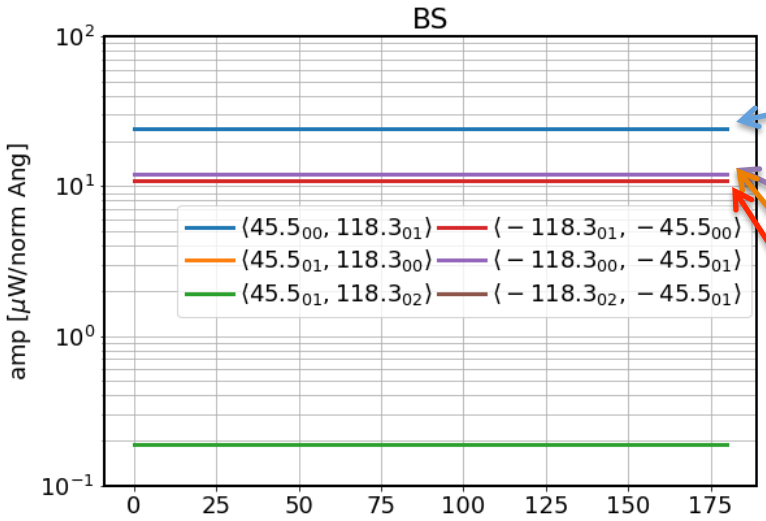
References

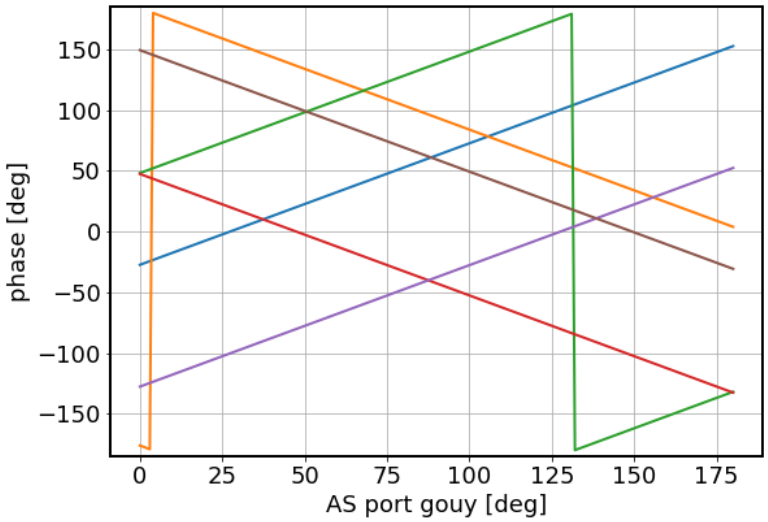
- Finesse:
  - http://www.gwoptics.org/finesse/
  - Input files: T1300904
- Current AS36 scheme:
  - T0900511
  - G1700603
- Point absorber at LHO ITMX:
  - LHO alog 34853
  - G1700588

SUPPLEMENTAL MATERIALS:

BS anatomy

(25 deg SRC gouy, no extra thermal lens)





$\langle E_{00}(+45.5), E_{01}(+118.3)\rangle$

$\langle E_{00}(-118.3), E_{01}(-45.5)\rangle$

$\exp(+i\phi_{\rm as})$

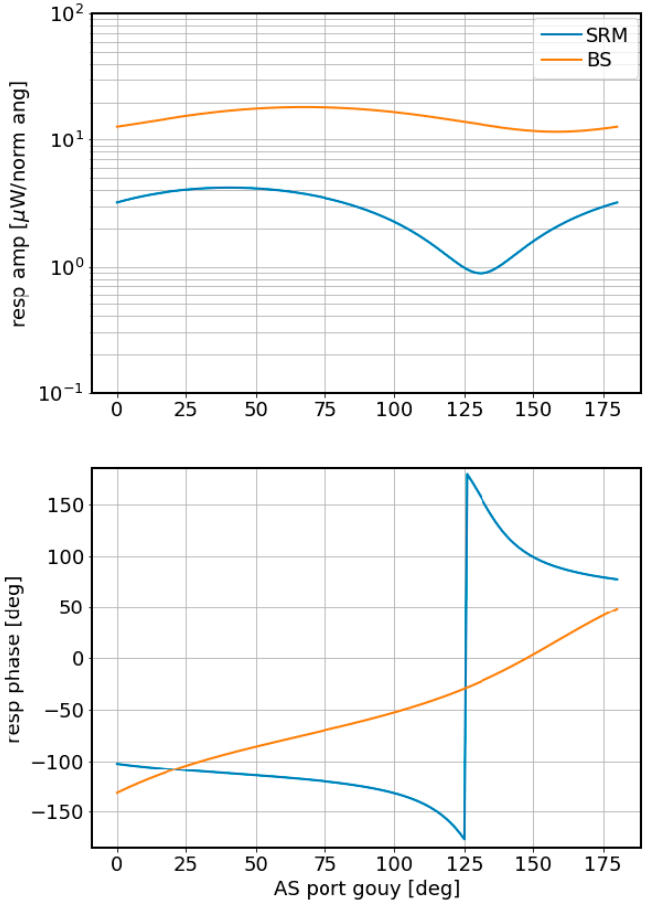
$\langle E_{01}(+45.5), E_{00}(+118.3)\rangle$

$\langle E_{01}(-118.3), E_{00}(-45.5)\rangle$

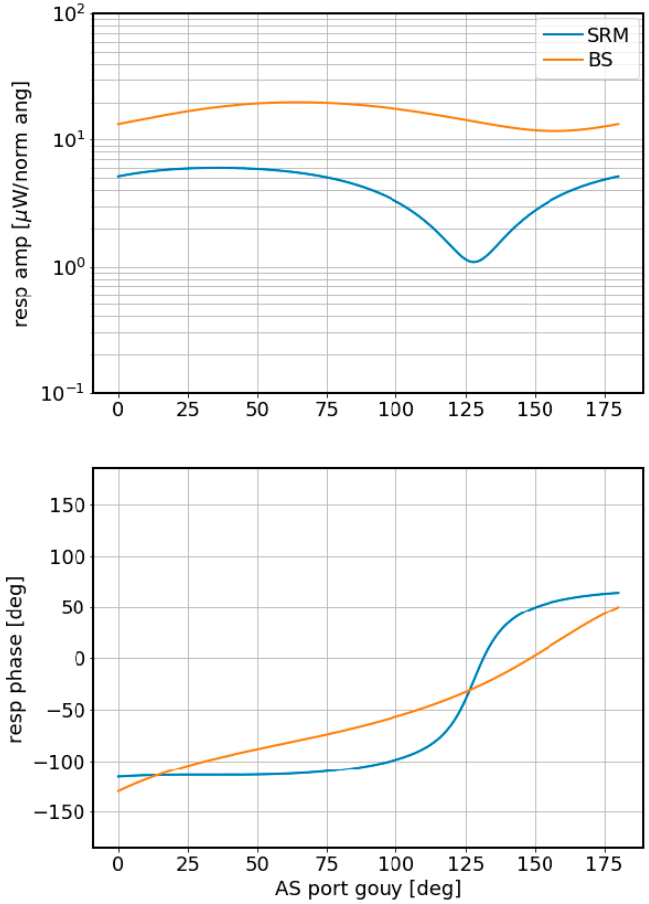
$\exp(-i\phi_{\rm as})$

- Blue largest, and not canceled by purple
- Orange and red are ~135 deg apart, cancels each other; even smaller
- Effectively in ***case (ii)***.

AS72 with T_srm = 0.20



(a) Nominal



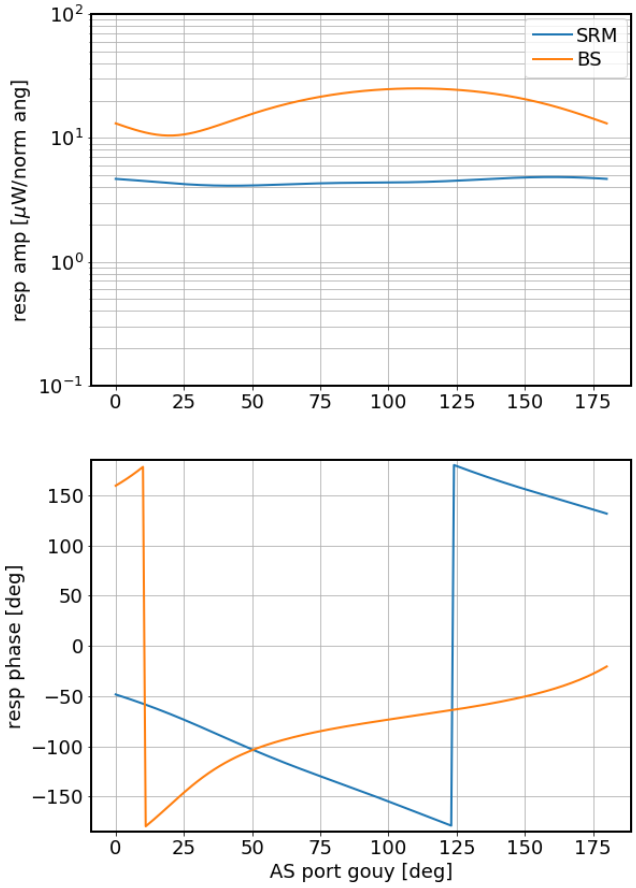
(b) Extra 100km ITMX thermal lens

- SRM/BS resp vs AS port gouy phase
- SRM not significantly modified by 02 modes

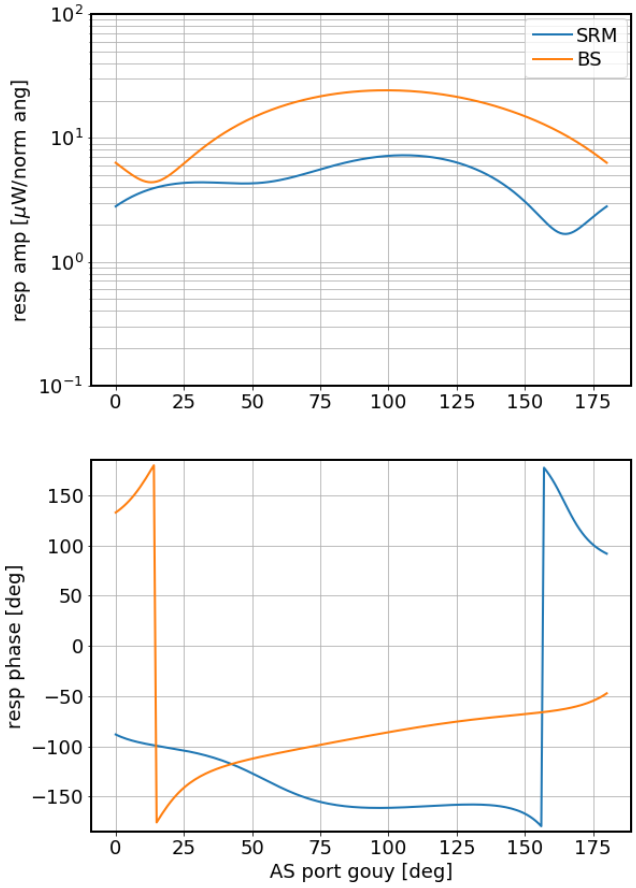
Still have:

- SRM shows up in Q phase (+-90 deg)
- BS always has Q component

AS72 w/ SRC one-way gouy 18 deg (current SRC)



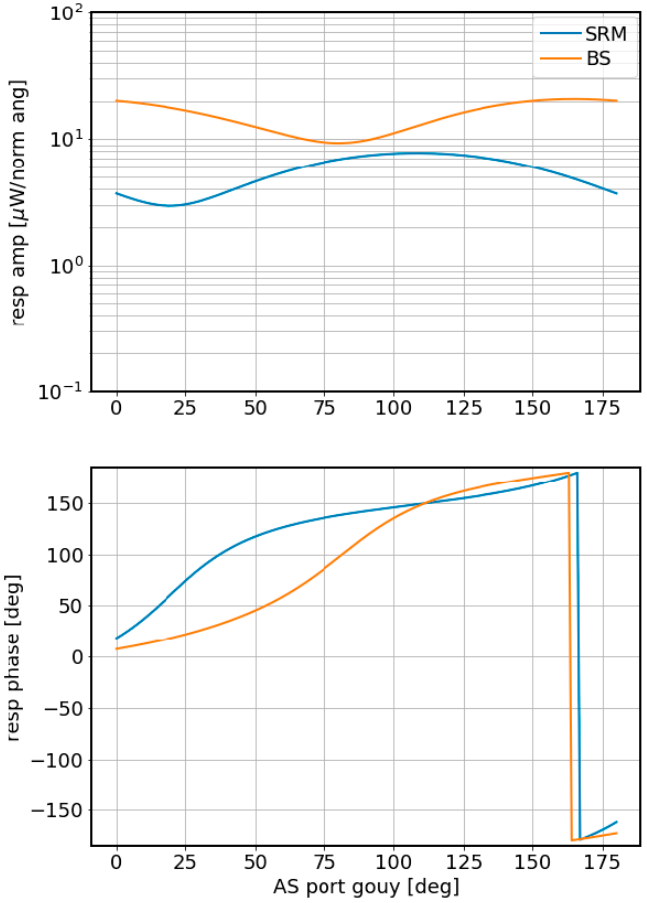
(a) Nominal



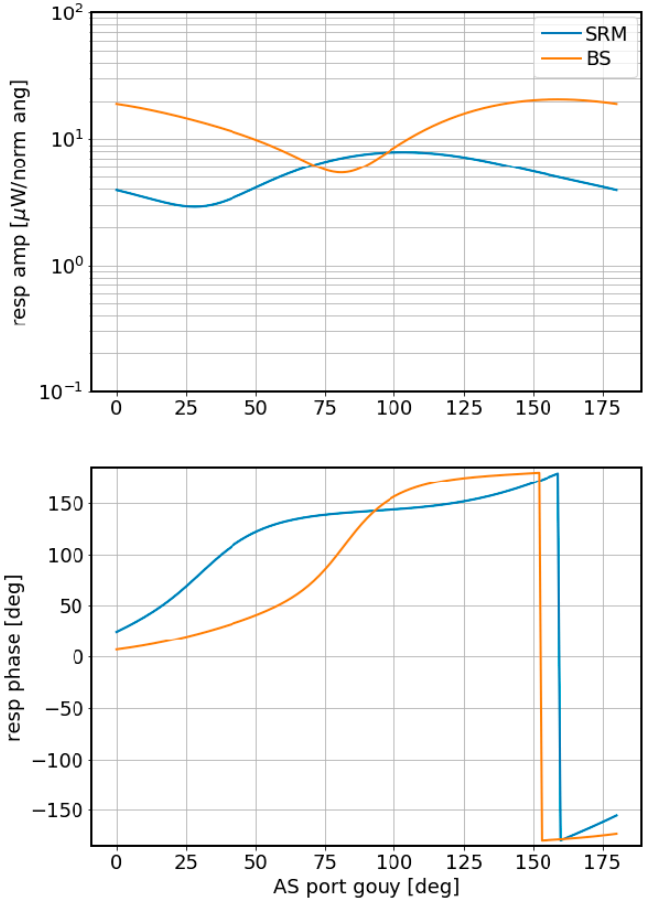
(b) Extra 100km ITMX thermal lens

- SRM/BS resp vs AS port gouy phase
- Both SRM and BS are in ***case (ii)*** w/o extra thermal lens.
- +118.3 MHz 02 mode resonant in SRC, changes SRM signal quite a bit
- But might actually work?

AS72 w/ SRC one-way gouy 50 deg



(a) Nominal



(b) Extra 100km ITMX thermal lens

- SRM/BS resp vs AS port gouy phase
- Both BS and SRM have a significant I-phase component
- Not as ideal as the 25 deg case
- Might still work if we mix in DC/ 90MHz signal to decouple spot motion from 72-I?