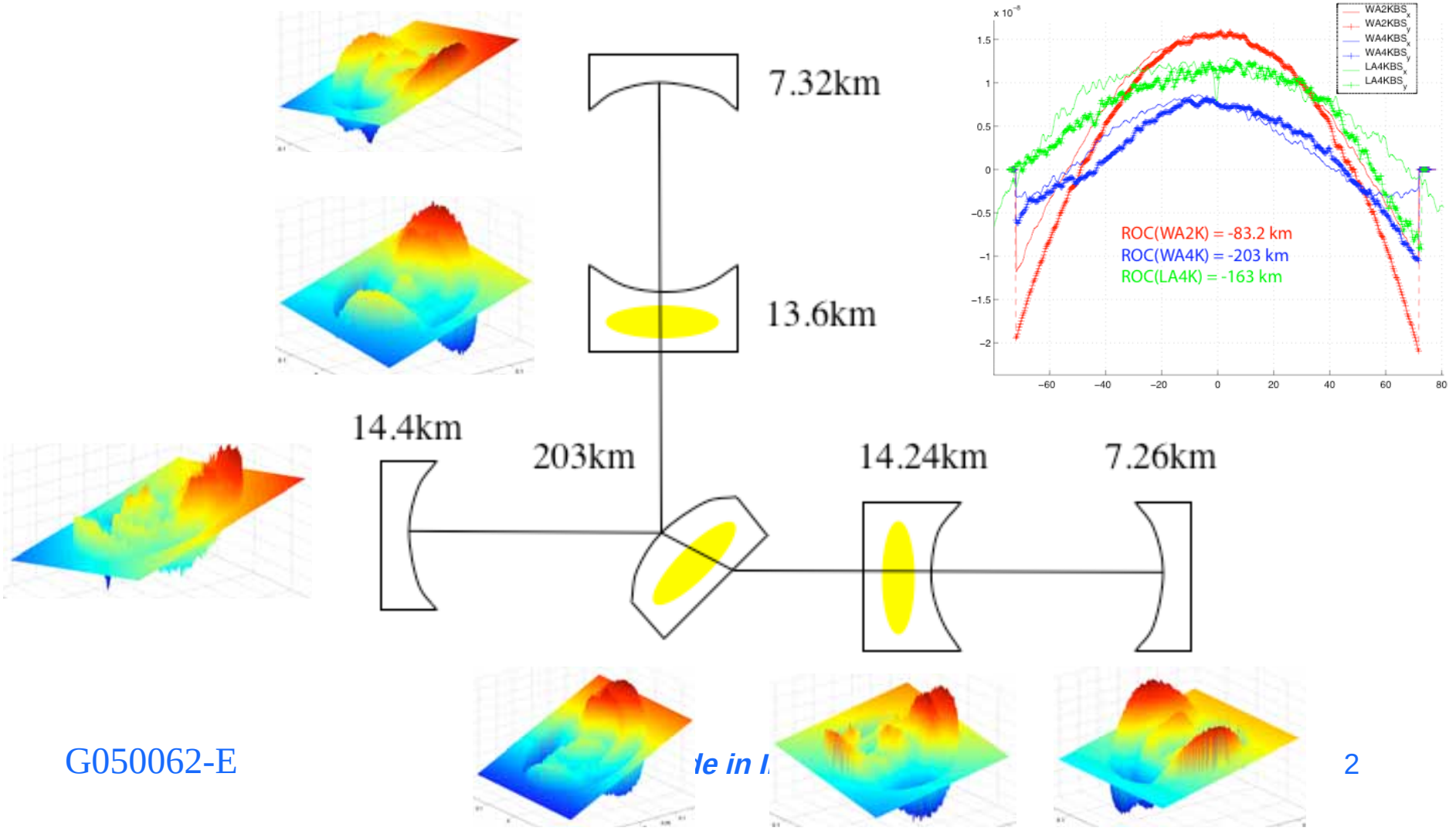
Results from FFT modeling

Hiro Yamamoto / Caltech

- Mirror surface phase map
- Thermal lensing effect
  - »ITM and BS
- Lock acquisition
- Revised FFT code

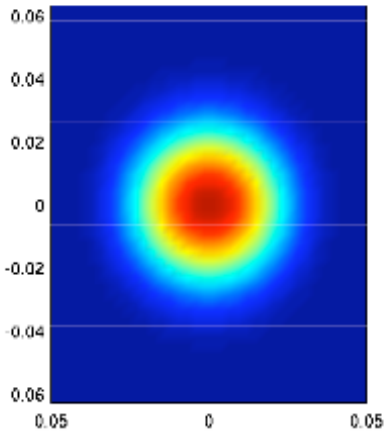
With a little bit of reality

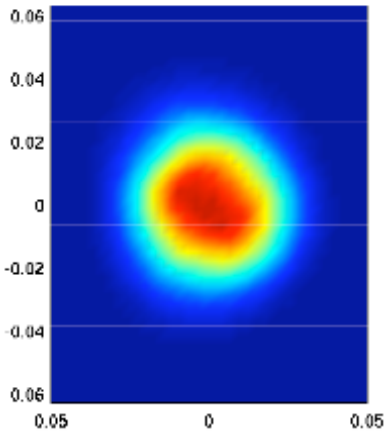


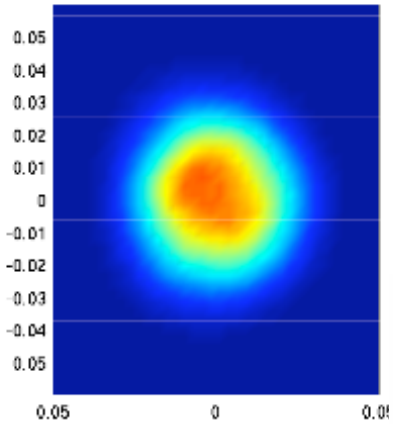
Dark Port beam profile by FFT

- ideal vs reality-prime -

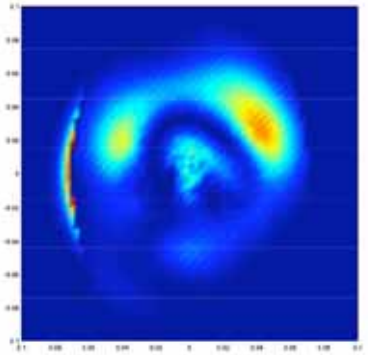
upper SB







and CR



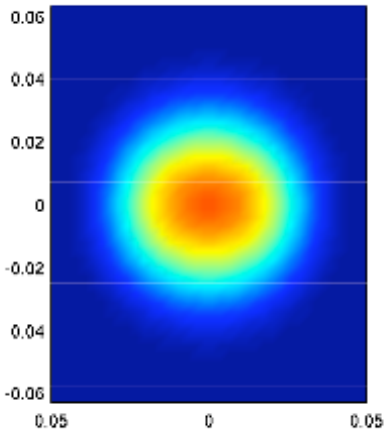
200k BS curvature

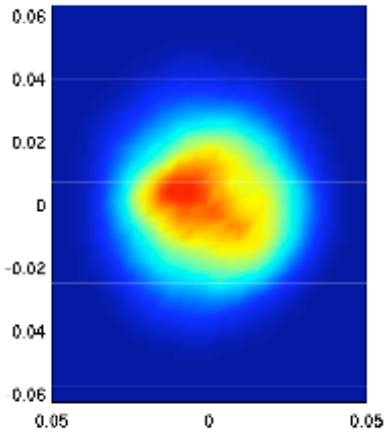
No phase map
Symmetric heating

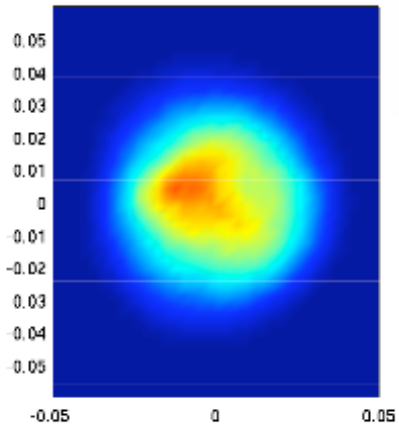
With phase map
Symmetric heating

With phase map
Differential heati

lower SB







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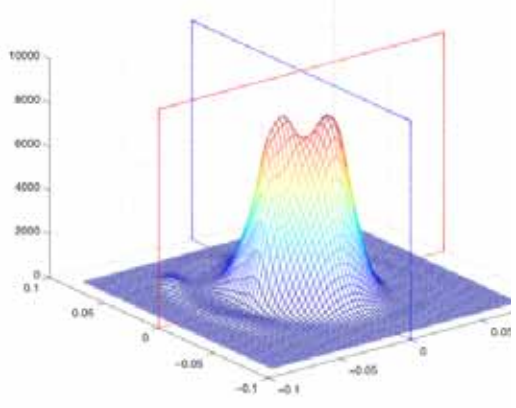
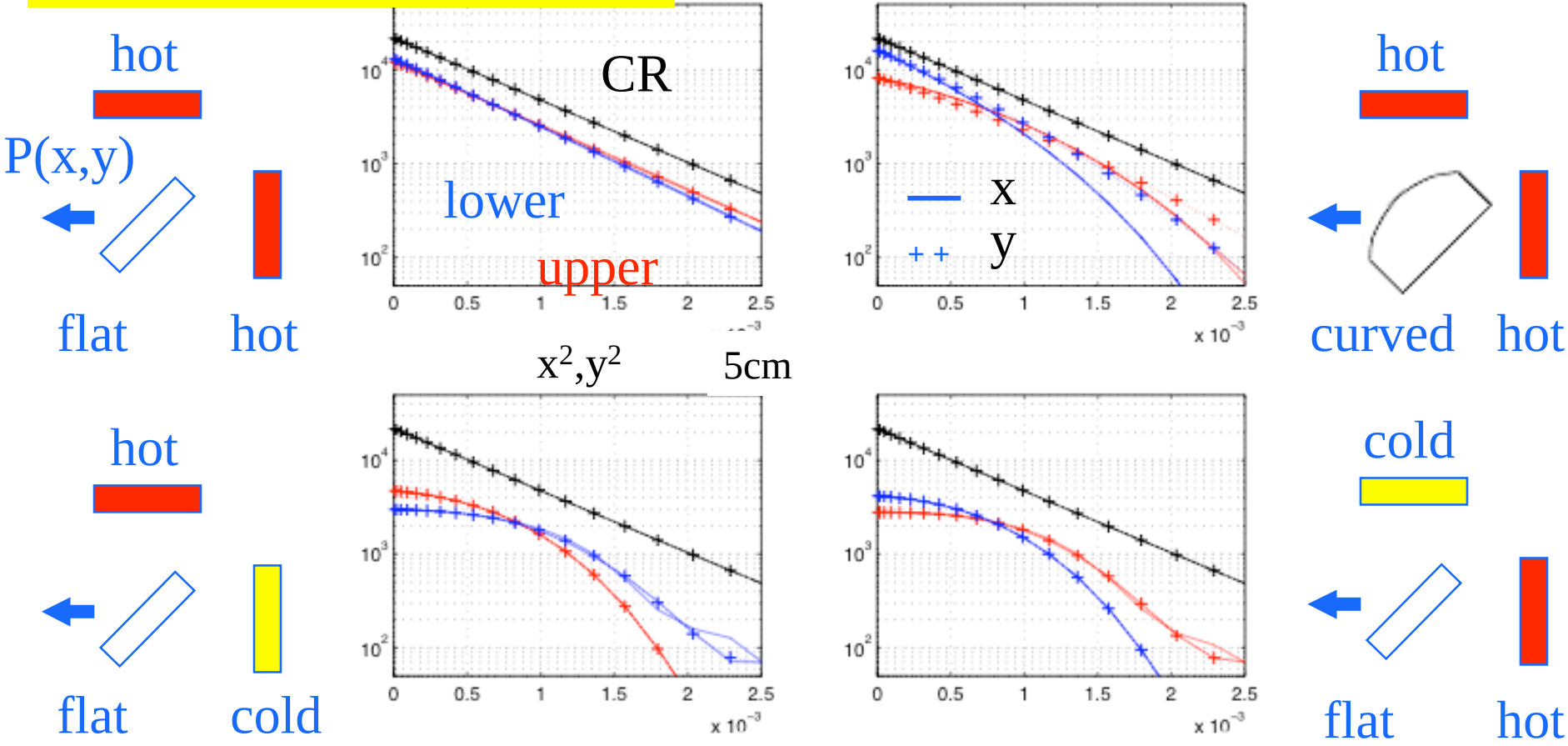
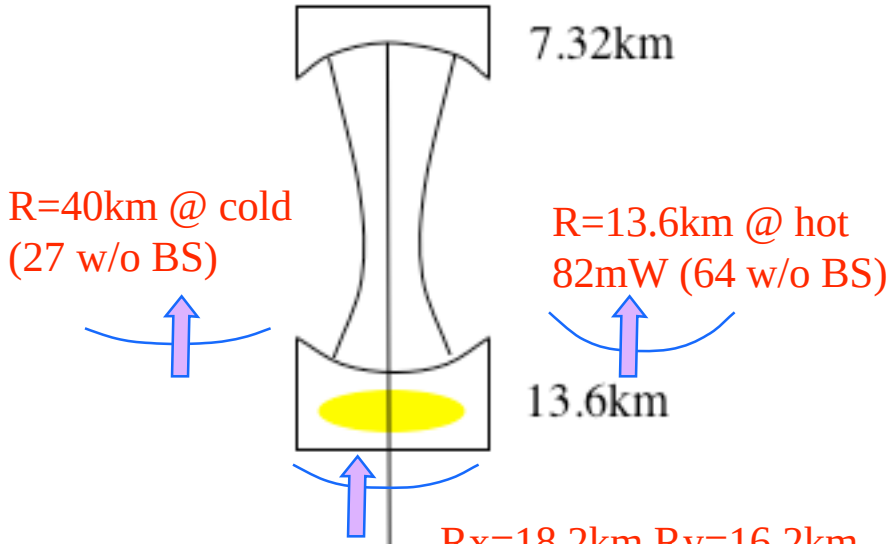
LIGO ITM differential heating and beam splitter effect



- Linear line : gaussian
- Blue vs red : sideband imbalance
- --- vs + + + : astigmatism



Mode matching with BS



Reflection by BS

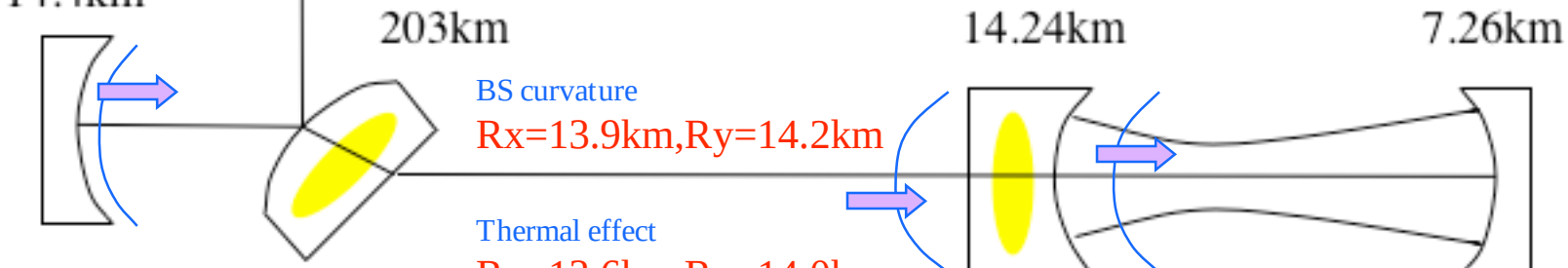
$$\frac{R_{in}}{R_{out}} = 1 - \frac{2}{R_{BS}} \frac{R_{in}}{C_{x/y}} \qquad C_x = 1/\sqrt{2},\ C_y = \sqrt{2}$$

Transmission through BS

$$\frac{R_{in}}{R_{out}} = 1 + \left(\frac{n_0 - 1}{R_{BS}} - \frac{1}{f_{thermal}^{BS}}\right) \frac{R_{in}}{C_{x/y}}$$

Transmission through ITM

$$\frac{R_{in}}{R_{out}} = 1 + \left(\frac{n_0 - 1}{R_{ITM}} - \frac{1}{f_{thermal}^{ITM}}\right) R_{in}$$



BS curvature
Rx=13.9km,Ry=14.2km

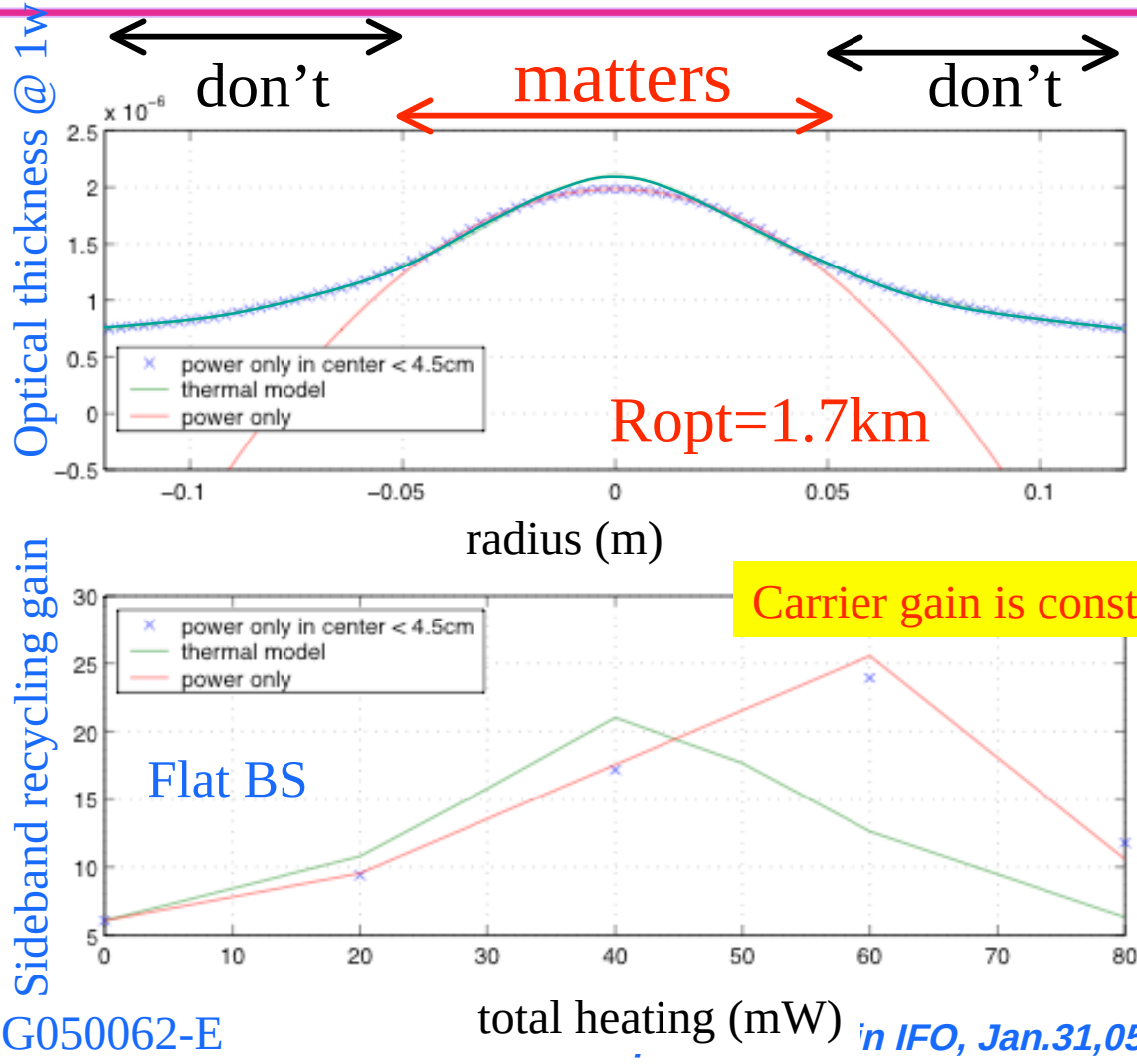
Thermal effect
Rx=13.6km,Ry=14.0km

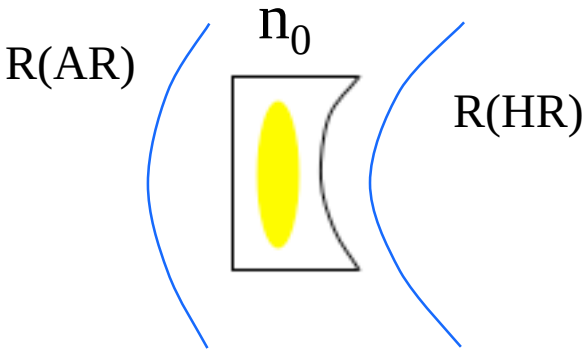
$$\frac{1}{f_{thermal}^{BS}} = \frac{1}{2}\frac{1}{2}\frac{4}{10}\frac{1}{f_{thermal}^{ITM}(hot)}$$

R=14.24km @ hot
52mW (54 w/o BS)
only BS effect

Thermal lensing and $n_{effective}$

- P. Willems calculated based on MIT model -





$$\frac{1}{f} = -\frac{n_0 - 1}{Rm} + \frac{Power}{Ropt}$$

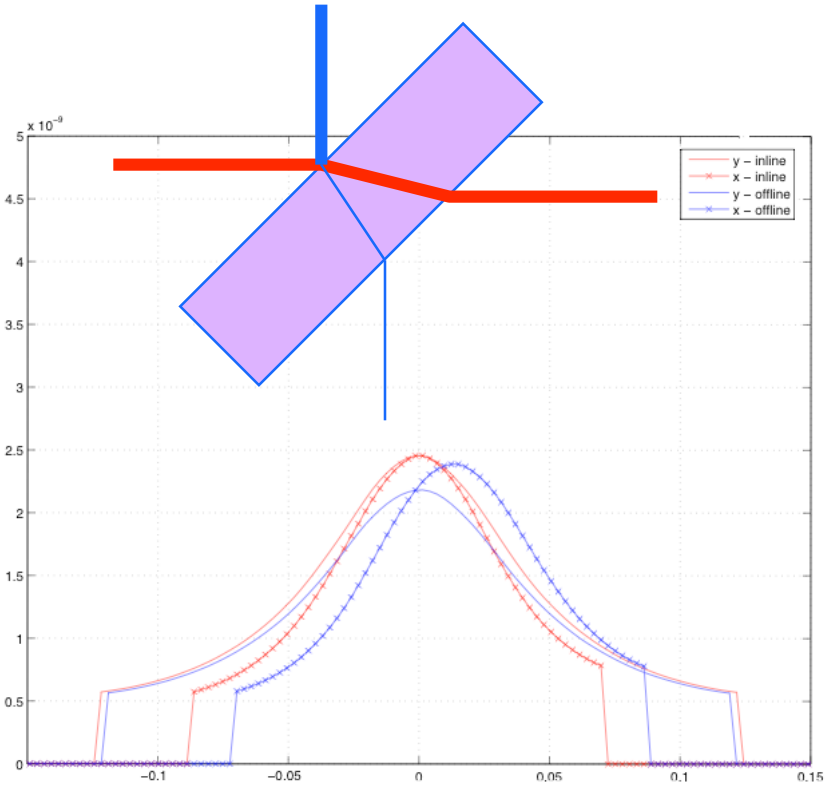
$$= -\frac{n_{effective} - 1}{Rm}$$

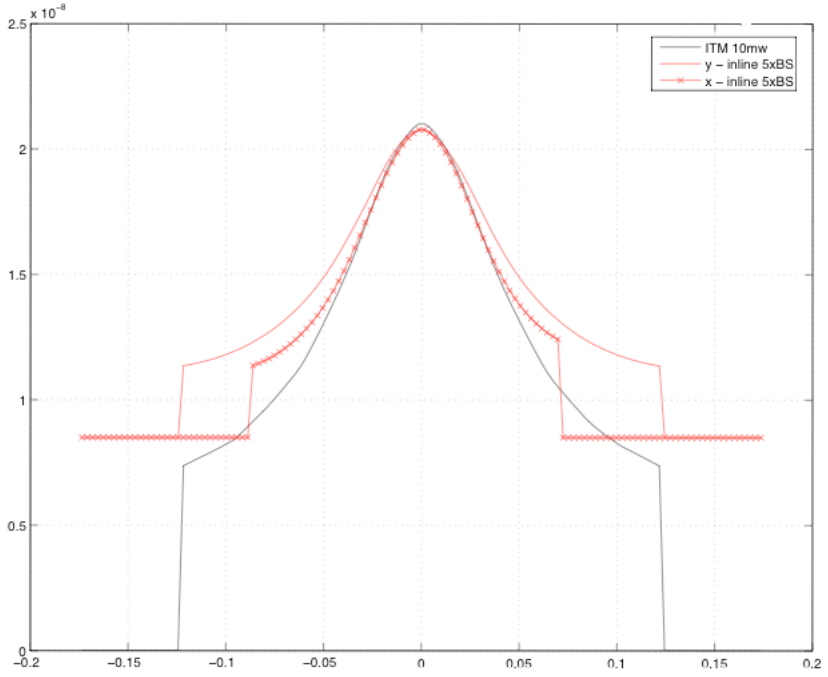
$$\frac{1}{R_f(HR)} = \frac{1}{R_f(AR)} - \frac{1}{f}$$

Power = 58mW

BS phase map

0.75mW in HR, 0.85mW in substrate : 5ppm x 4cm x 40W



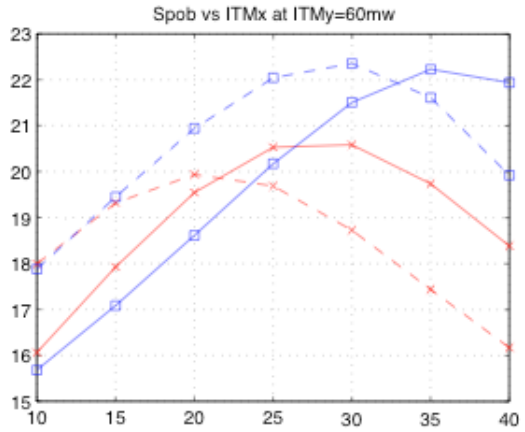


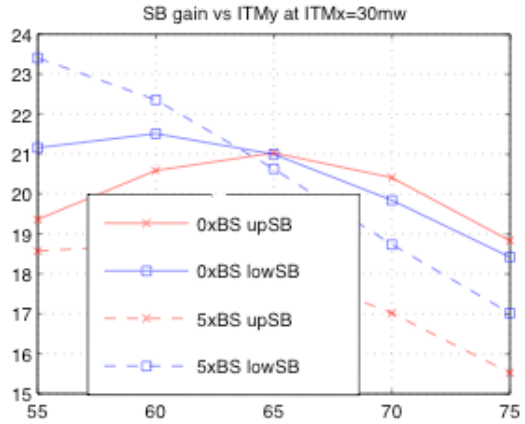
ITM heating vs BS heating

ITMy fixed at 60mW

ITMx fixed at 60mW

sideband recycling gain

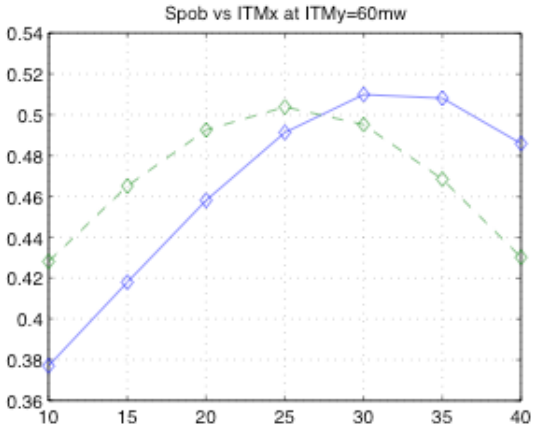


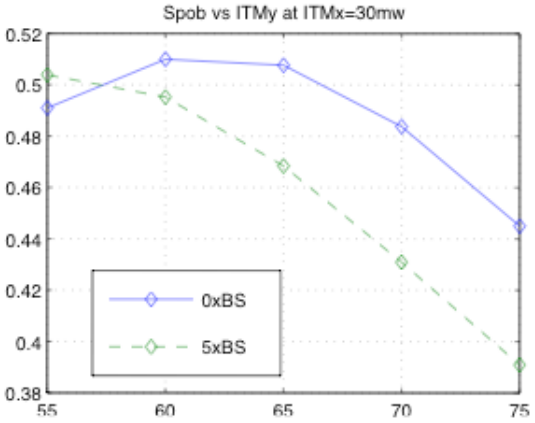


P(ITMx)

P(ITMy)

Spob





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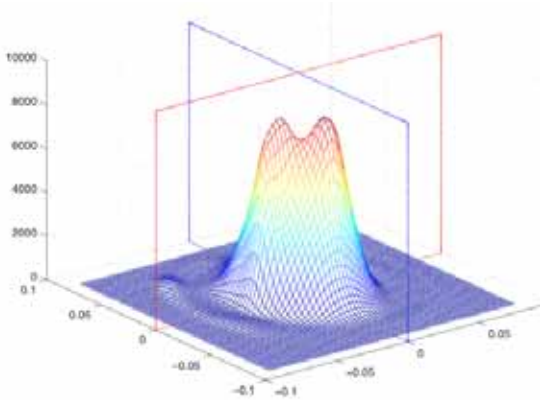
Comparison between ITMx vs BS effect

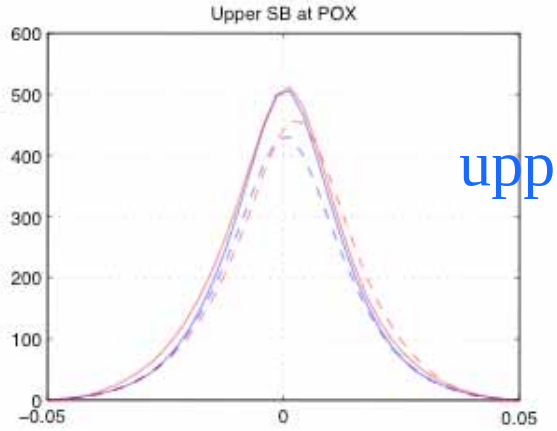


ITMy : 60mW

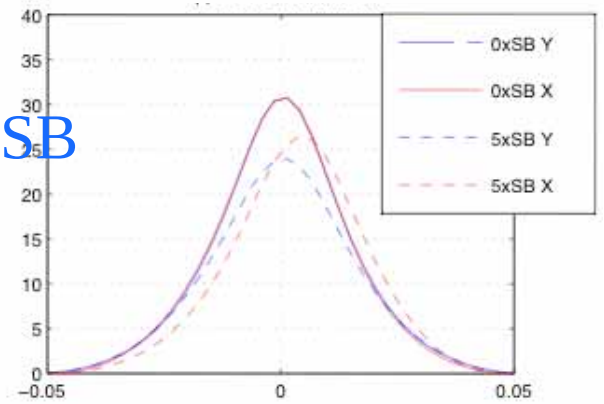
ITMx : 25mW
BS : no lensing

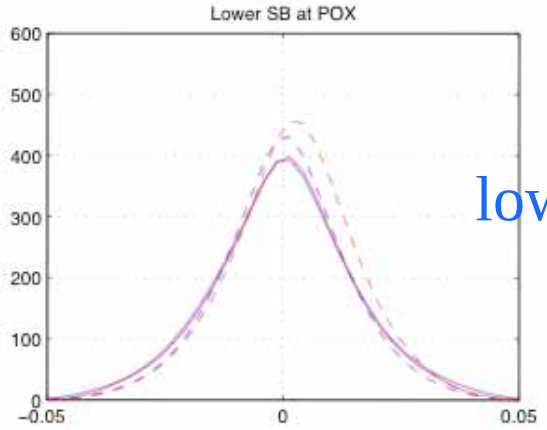
vs

ITMx : 15mW
BS : 5xBS

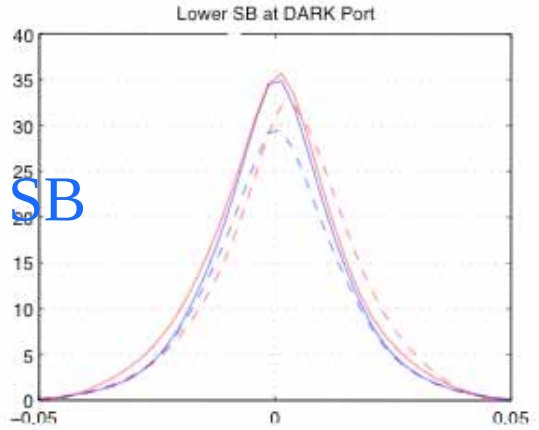


upper SB





lower SB



at POX

at dark port

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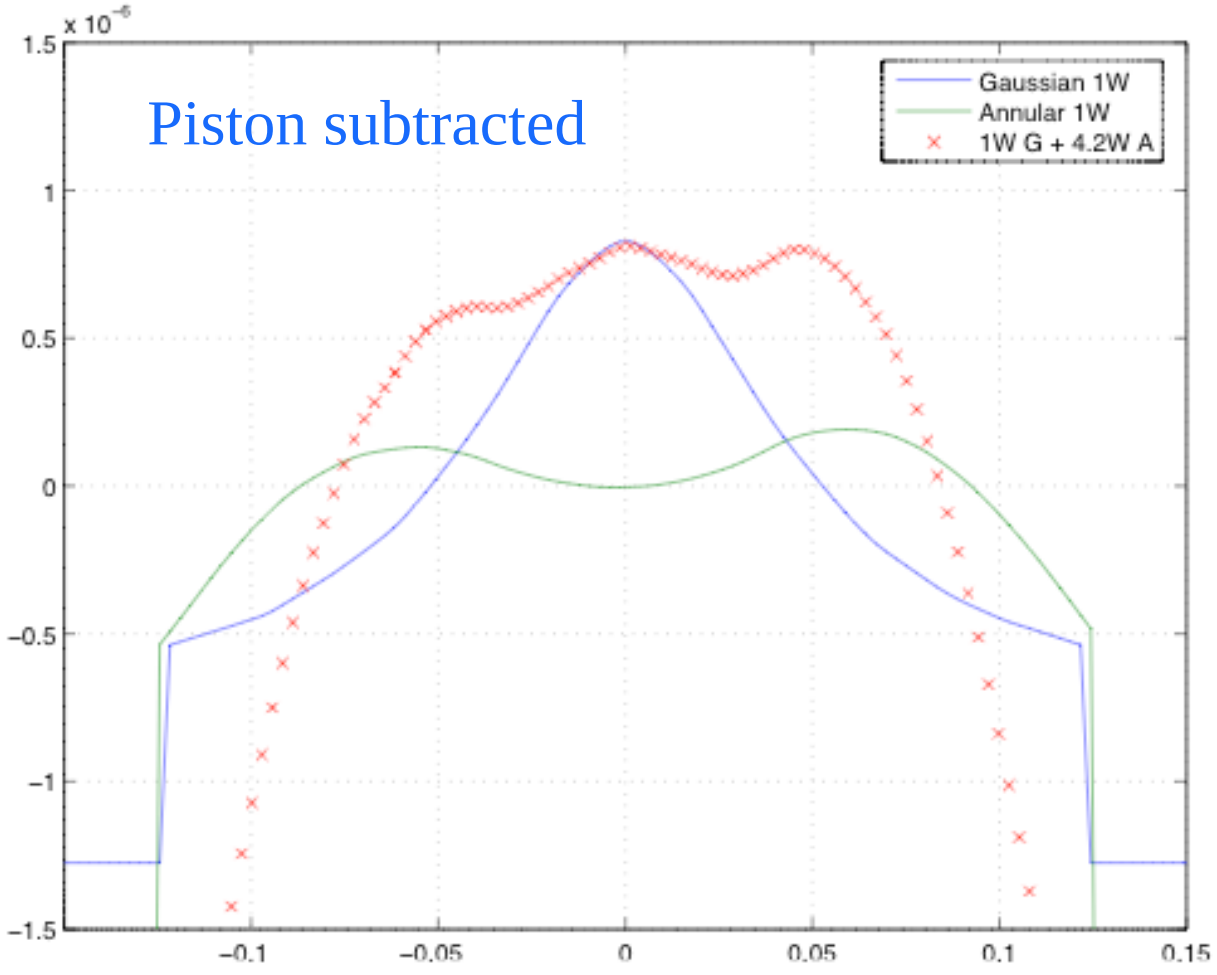
Gaussian and Annular



FFT vs LSC lock

n(ITMx)-n(ITMy)

0.96-0.96

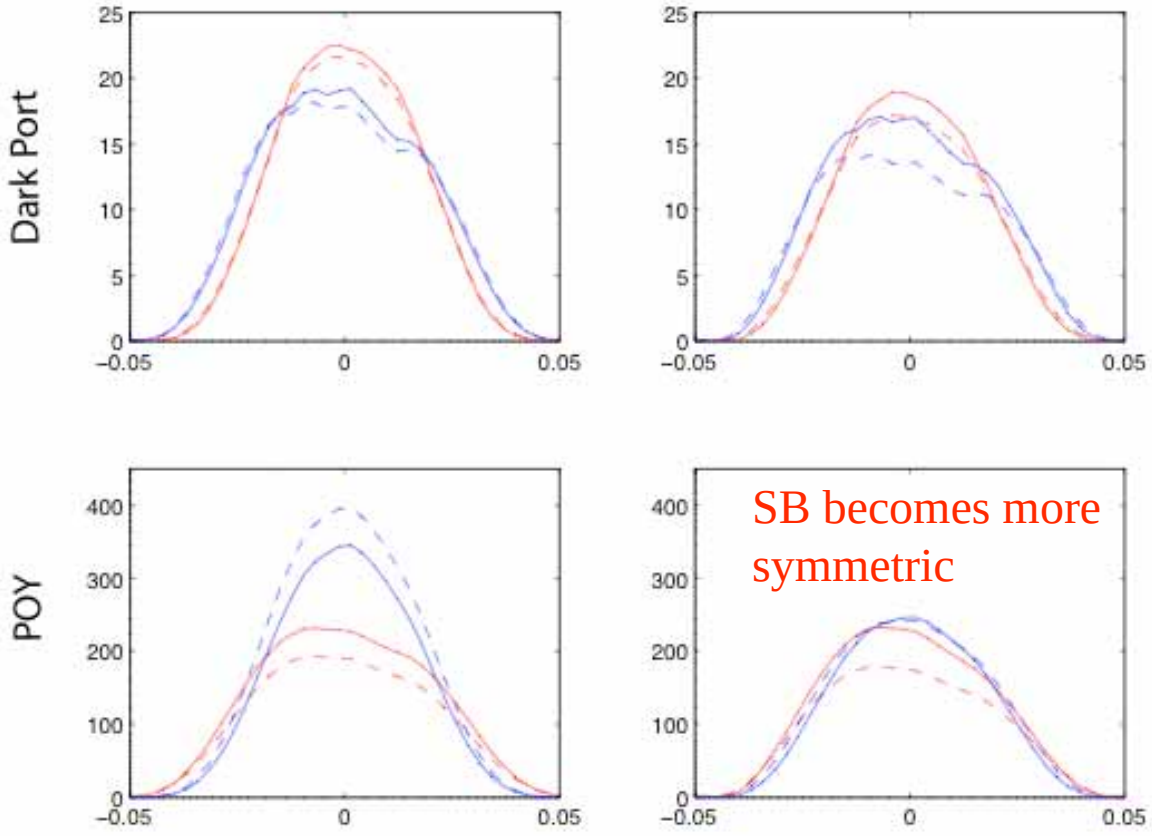
Symmetric Heating

1.10-0.96

Differential Heating
ITMx cooler than ITMy

lower SB upper SB

FFT lock LSC lock



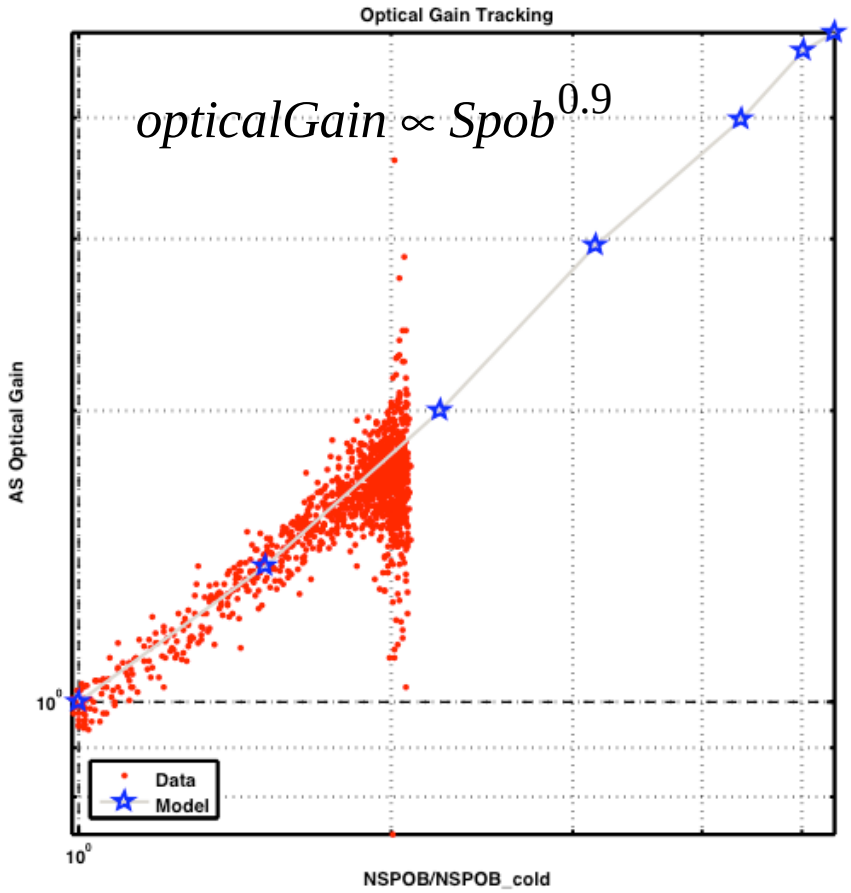
		FFT	LSC
symmetric	θCR	0.3	-1.9
	θSB+	-0.6	-2.3
	θSB-	7.2	5.1
	Spob	-0.57i	-0.57i
differential	θCR	0.2	-8
	θSB+	4.9	-1.2
	θSB-	11.8	5.1
	Spob	-0.48i	-0.50i

IFO performance

	Lock	CR gain	Upper SB gain	Lower SB gain	Contrast Defect x10^{-6}
symmetric arm, best TCS	FFT	46	23.7	23.7	58
As built arm, best TCS	FFT	46	21.7	25.3	220
As built arm, com.TCS	FFT	46	19.6	24.6	233
	LSC	46	22.3	22.3	244
As built arm, com.TCS w/ phase map	FFT	36	18.3	23.3	429
	LSC	36	21.5	20.2	439

SB imbalance comes from R_{ITM} and R_{BS}

optical gain vs Spob



Revised FFT code

- Input beam can be specified properly when ITMx is thermally distorted
- ITMx, ITMy and BS thermal effect can be scaled
- refractive index can be specified separately for each mirror (poor man's thermal model)
- Easy setup for LSC-lock
- All current LIGO detector ports (pox, etc)
- Easy input setup
- Faster