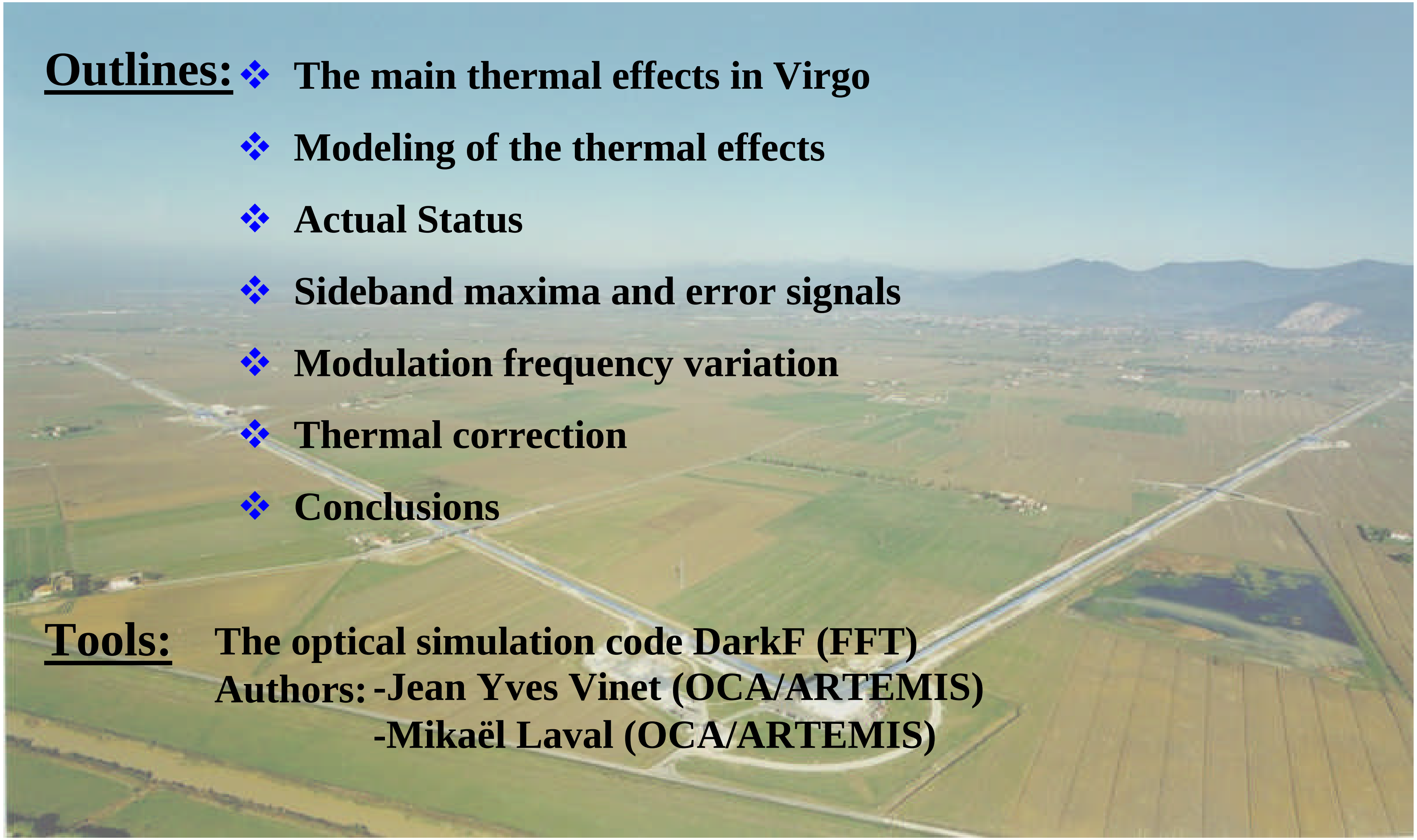
Thermal effects and correction

Mikael Laval (ARTEMIS/OCA)   LIGO-G070305-00-Z



Outlines:

- The main thermal effects in Virgo
- Modeling of the thermal effects
- Actual Status
- Sideband maxima and error signals
- Modulation frequency variation
- Thermal correction
- Conclusions

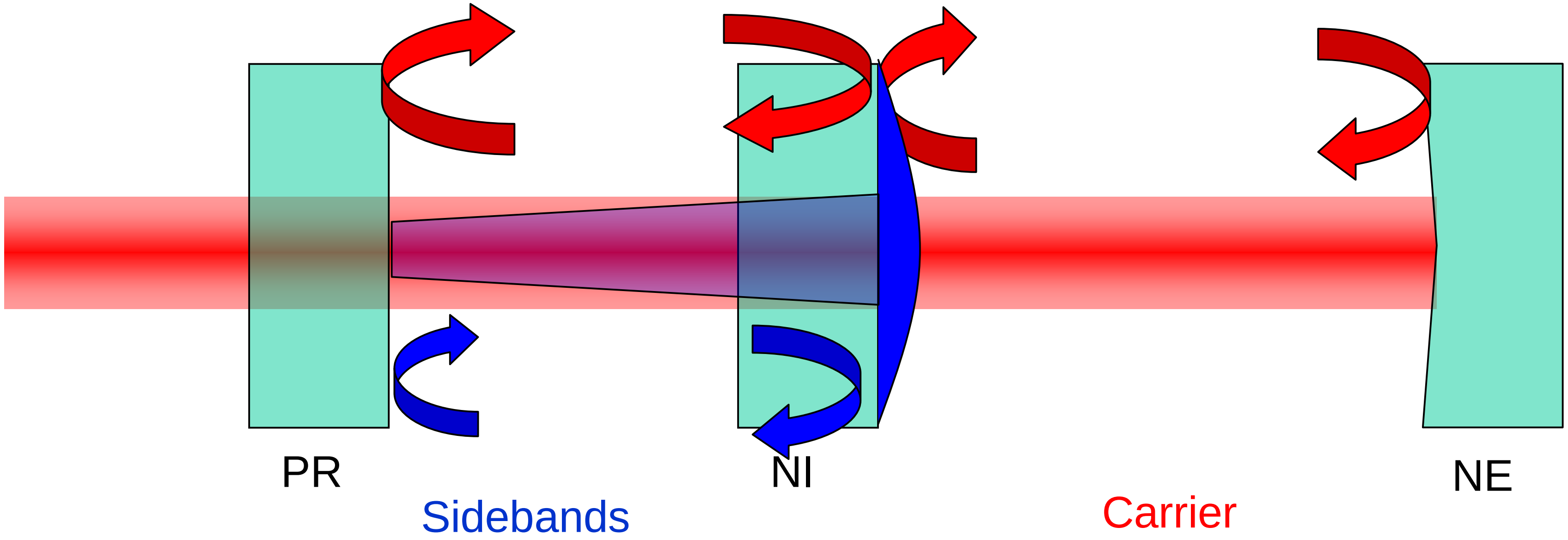
Tools: The optical simulation code DarkF (FFT)

Authors: -Jean Yves Vinet (OCA/ARTEMIS)
-Mikaël Laval (OCA/ARTEMIS)

The main thermal effects in Virgo

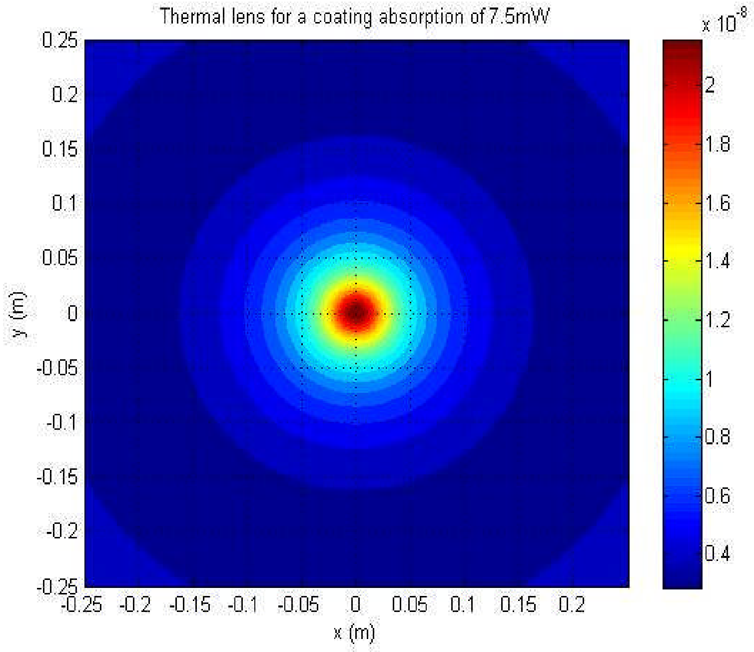
The main thermal effect is produced by the carrier in the long arm of Virgo. The coating absorbs a fraction of the high power in the arms and its temperature increases.

Consequently, there are some deformations of the coating but also a variation of the refractive index in the substrate.



Modeling of the thermal effects (according to the SUPRASIL properties)

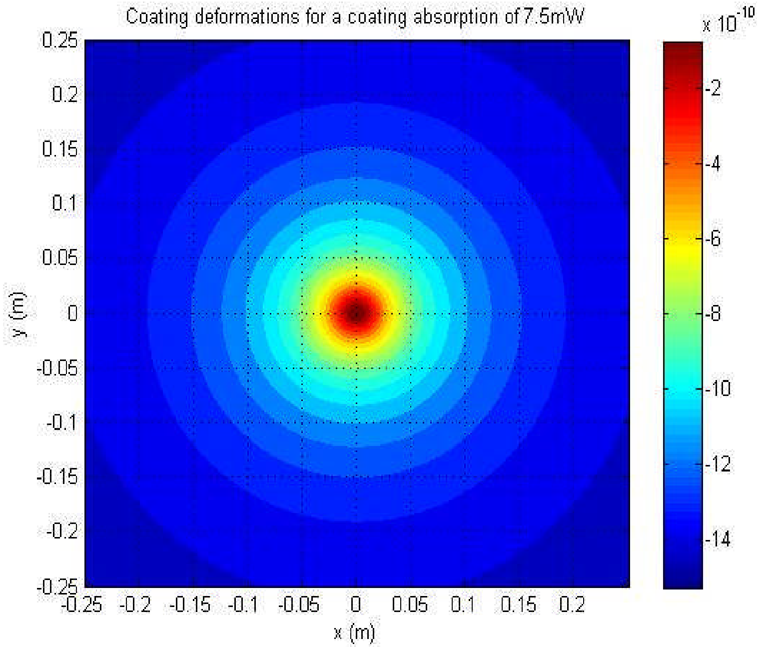
Thermal lens



Rc=a/P(absorbed)

a=-367m.W (Converging lens)

Coating deformation



Rc=a/P(absorbed)

a=-5818m.W

Convex seen from the long arms

The thermal lens produces an effect 16 times larger than the coating deformations.

Actual status

•Power stored in the long arms: **5 kW**

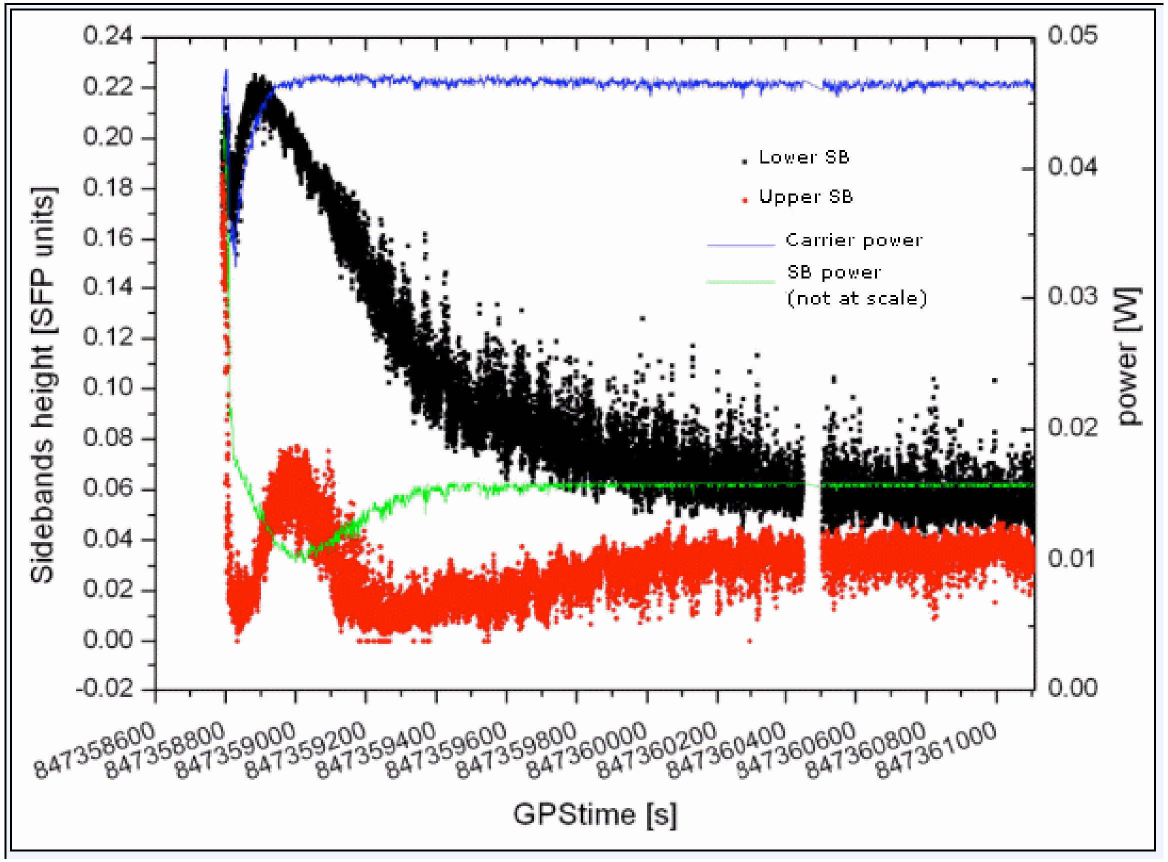
•Absorption of the north input mirror reflective coating: **5 ppm**
•Power absorbed: **25 mW**

•Absorption of the west input mirror reflective coating: **13.8 ppm**
•Power absorbed: **69 mW**

North input mirror	West input mirror
Rc(thermal lens) = -14,68 km	**Rc(thermal lens) = -5,32 km**
Rc(coating deformation) = -232,72 km	**Rc(coating deformation) = -84,32 km**

Sideband behavior during thermalization
Virgo results

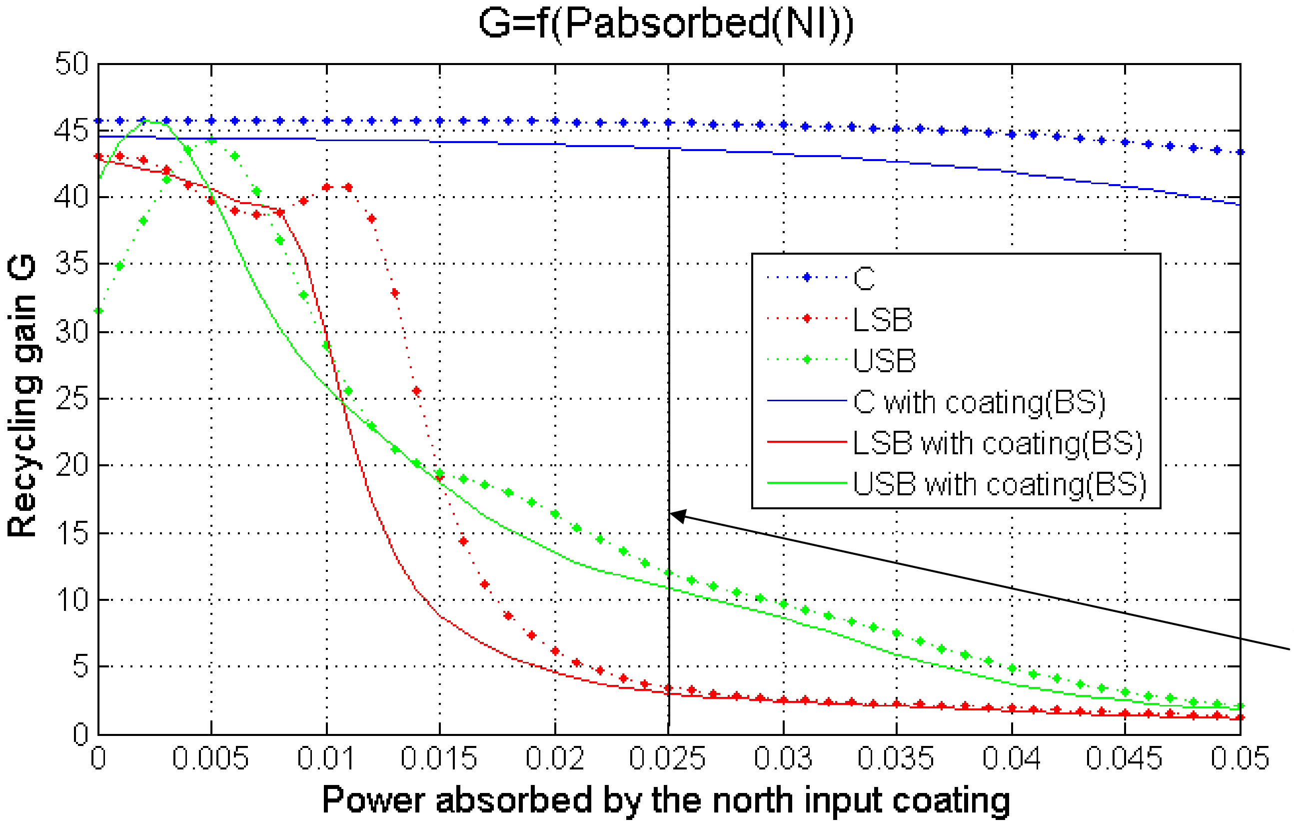
Sideband behavior in Virgo during the first minutes of a lock



The stored power of the sidebands decreases by a factor 3-4.

Sideband behavior during thermalization
Simulation results (DarkF)

Sideband recycling gain during the thermalization



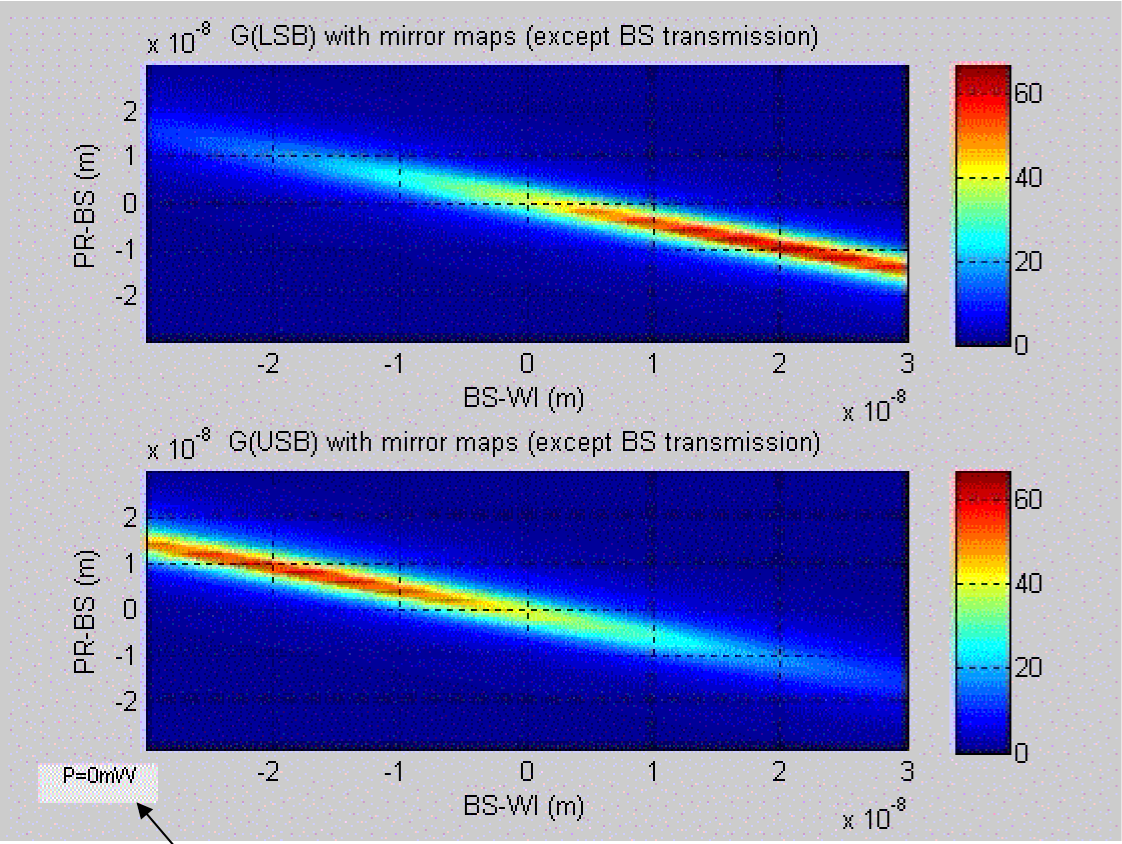
Simulation shows also a dissymmetry and a decrease of the sideband recycling gains but with different factors.

Virgo position

Missing parameters: no splitter transmission maps

Missing results: sideband recycling gain values without thermal effects.

Sideband maxima when we detune the Michelson



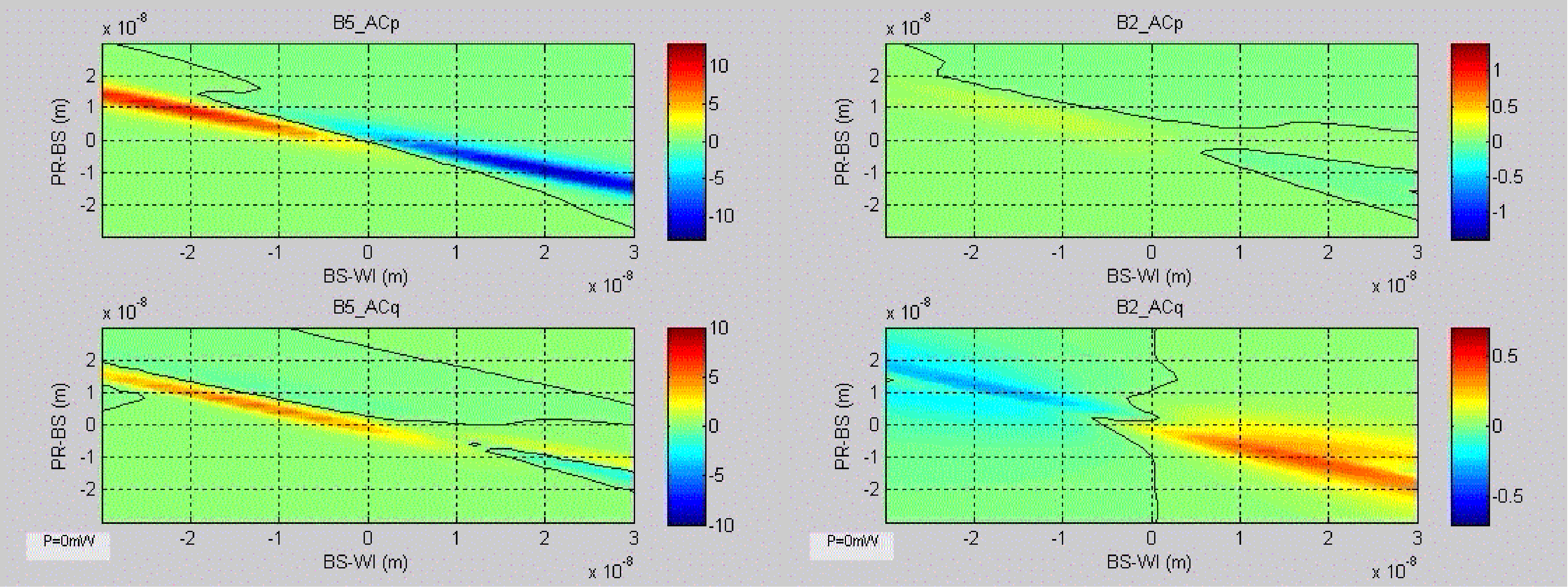
Power absorbed by the input mirror of the north arm.

Method to calculate the error signals: $V = dx^2 \times \sum \left(Carrier \times LSB^* - Carrier^* \times USB \right)$

$$Sp = \mathrm{Im}(V) \qquad Sq = \mathrm{Re}(V)$$

Corresponding error signals

(B5=beam splitter antireflective coating; B2=interferometer reflection)



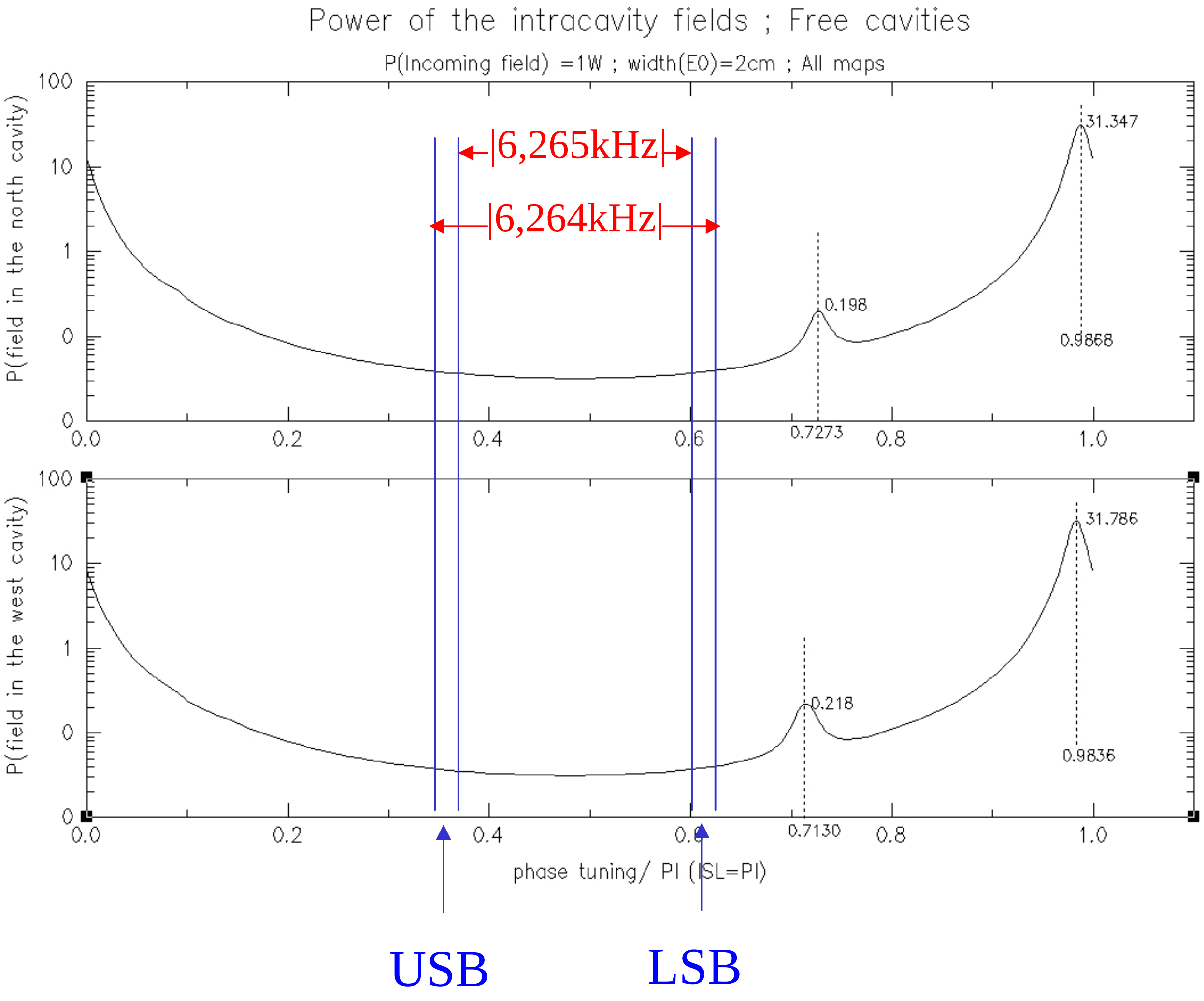
Black lines shows the zero of the error signal. (Signal on the dark fringe in annex)

•They are some offsets with respect to the DarkF locking position (0,0).

•They are several cases where two stable positions are possible.

Discussion with the locking group is necessary (Virgo locking position?)

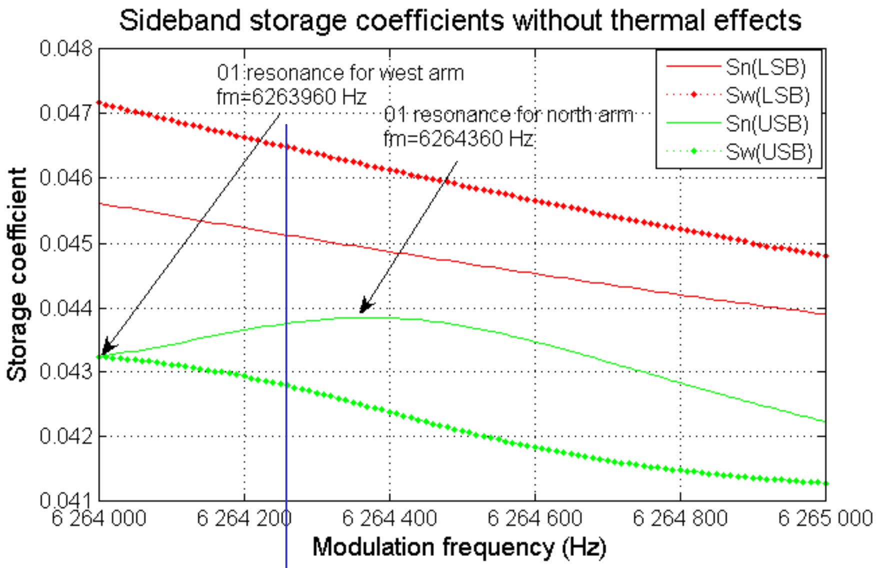
Modulation frequency variations
(Storage coefficient of the long arms (1/2))



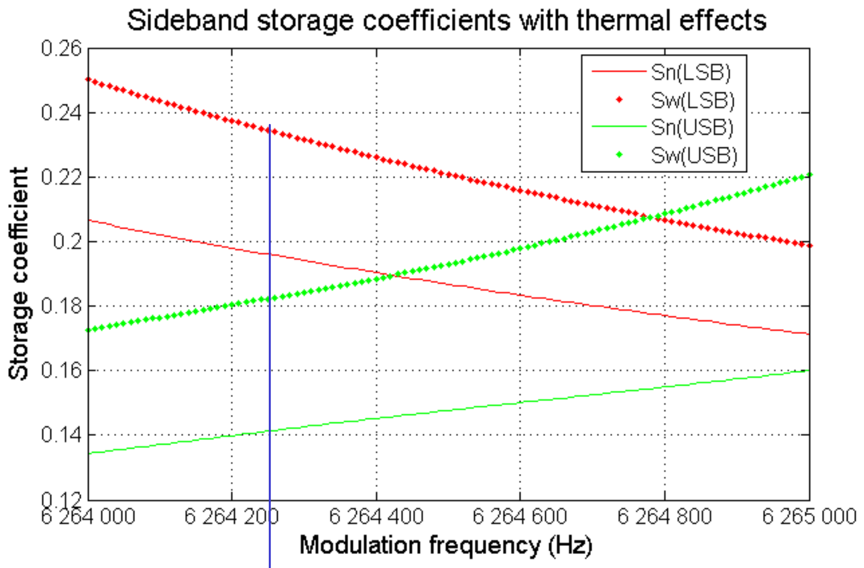
When the modulation frequency increases from 6,264 to 6,265MHz, the storage coefficient of the sidebands should decrease.

Modulation frequency variations
(Storage coefficient of the long arms (2/2))

“Cold” interferometer


Sideband storage coefficients without thermal effects

After thermalization

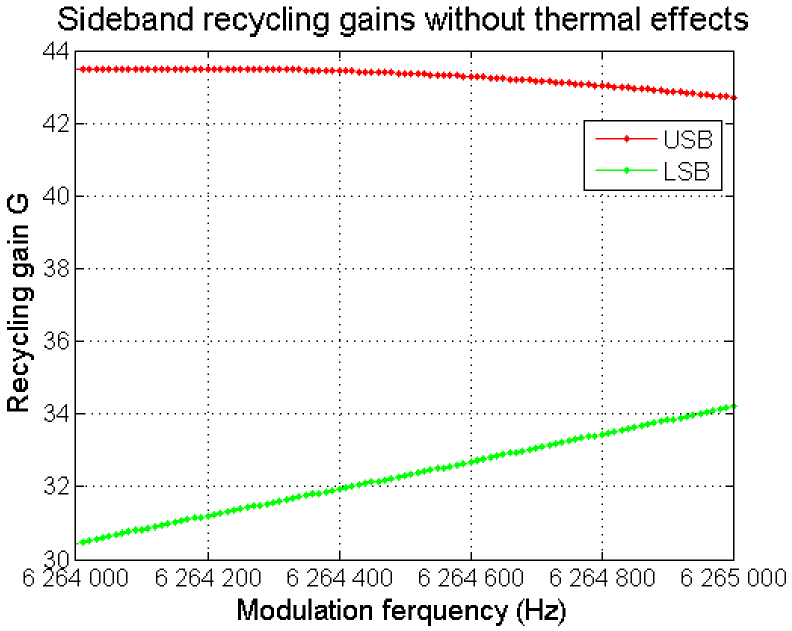

Sideband storage coefficients with thermal effects

Actual status : fm=6264280MHz

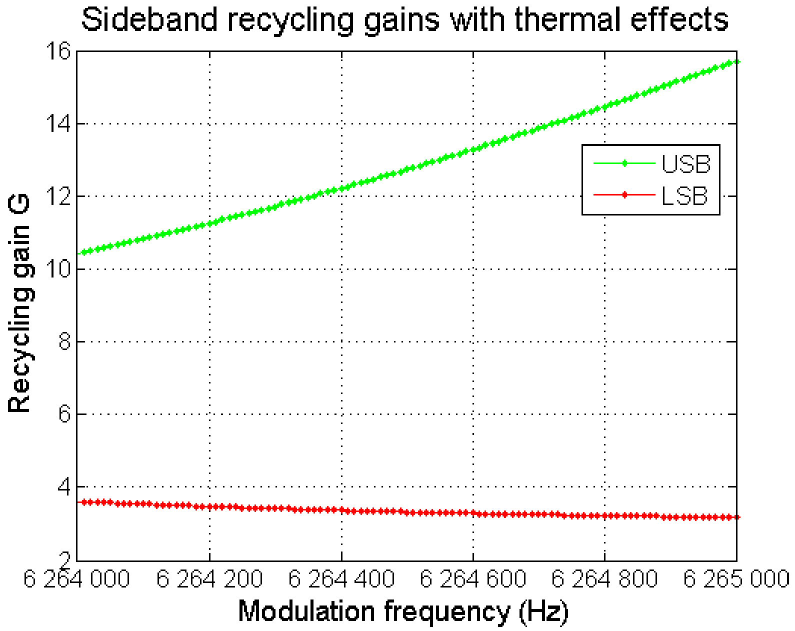
Why does the upper sideband storage coefficient increase with the modulation frequency after the thermalization?

Modulation frequency variations (Sideband recycling gains)

“Cold” interferometer



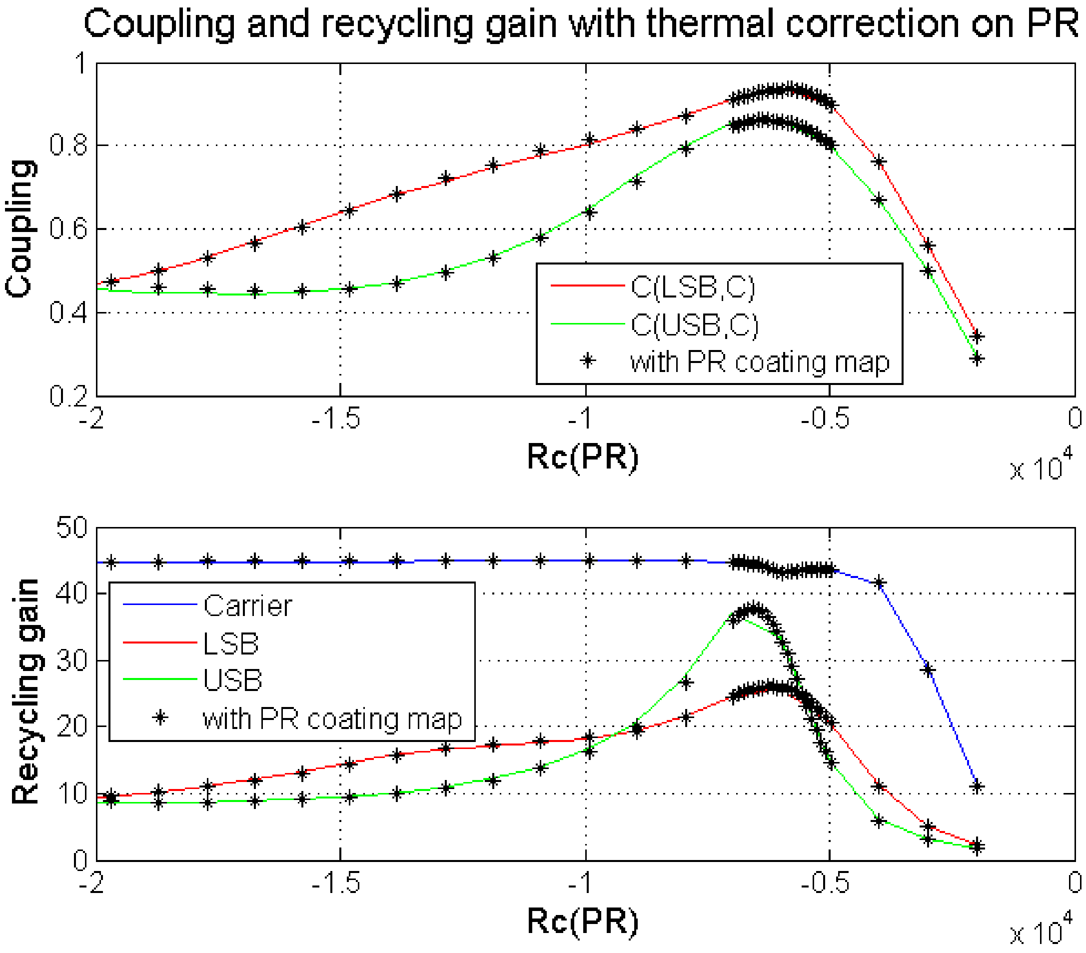
After thermalization



Conclusion : A weak modification of the modulation frequency cannot correct the shift between the recycling gains of the sidebands before and after the thermalization.

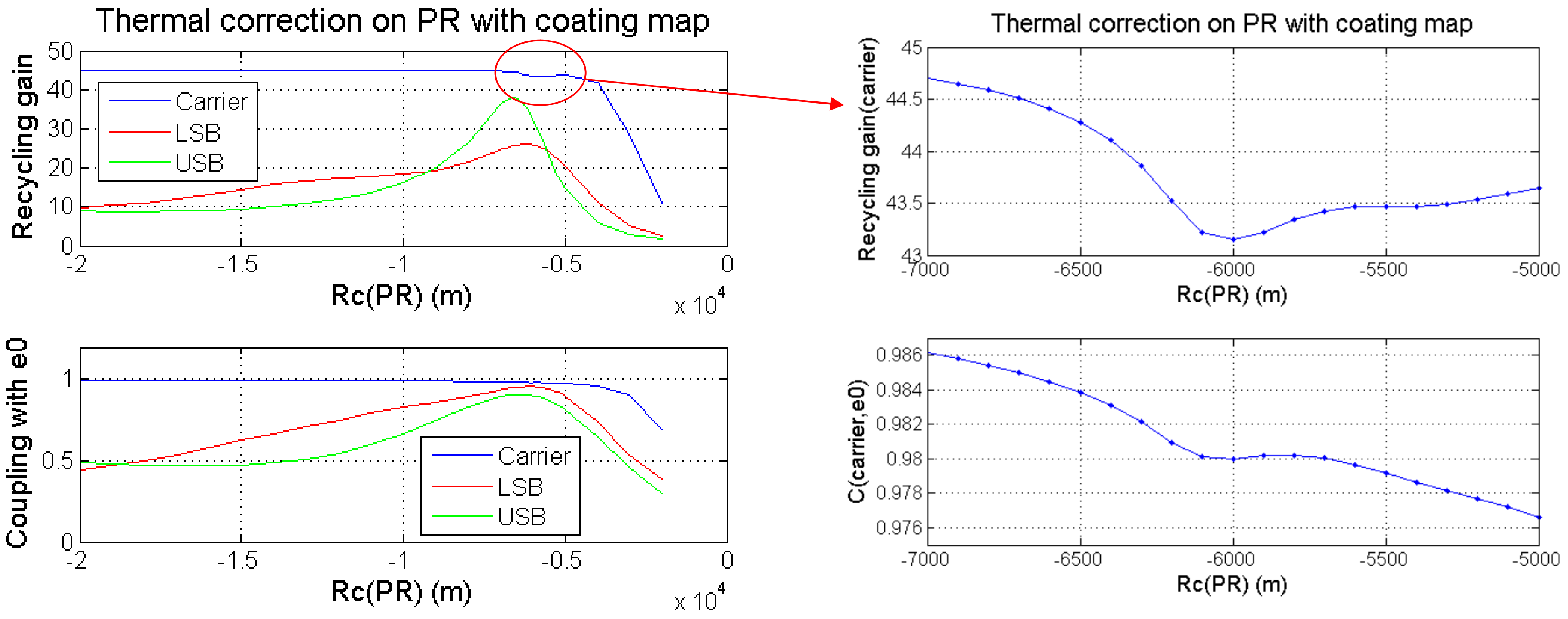
Thermal correction (1/2)

We modify the curvature of the recycling mirror to model a thermal correction.



By adjustment of the recycling mirror curvature, we can increase the coupling between the carrier and the sidebands and the sideband recycling gains.

Thermal correction (2/2)

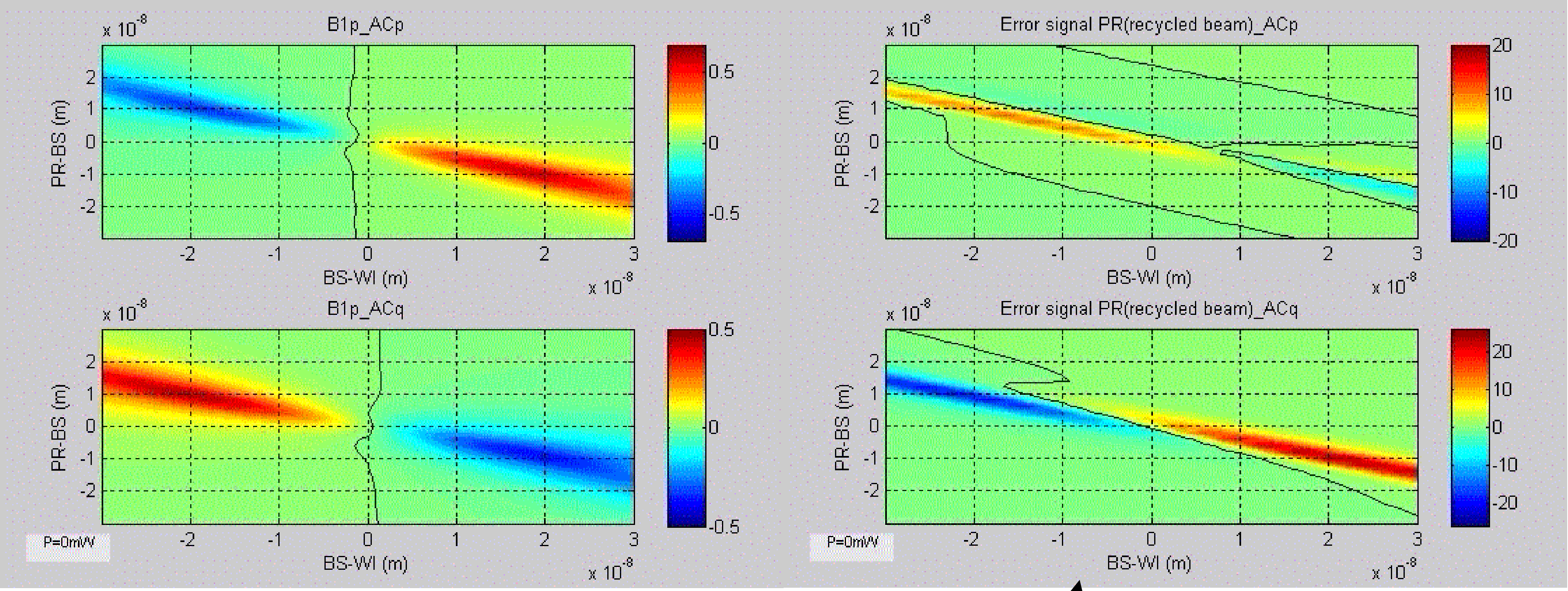


Why does the carrier coupling with a perfect TEM00 of waist 2cm decrease when the recycling mirror curvature radius is around -6km?

To be done & Conclusions

- **Virgo results and simulation results (DarkF) are different. We need some experiments for having converging results (dissymmetry of the sidebands without thermal effects?)**
- **DarkF error signals show some offsets between the zero and the DarkF locking position. Moreover, during the thermalization different stable positions appear. Is it possible to know exactly where is the Virgo locking position (discussion with the locking group is necessary)?**
- **A weak modification of the modulation frequency cannot correct the dissymmetry in the sideband recycling gains before and after the thermalization. We have to understand why the storage coefficient in the long arms of the upper sideband increases with the modulation frequency.**
- **A correction of the curvature radius of the recycling mirror could increase the sideband recycling gains but could imply a carrier modification (recycling gain, coupling with a TEM00).**

error signals on the dark fringe before the output mode cleaner (B1p) and on the recycled beams



Error signals calculated on the recycled beams.