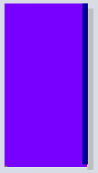
Thermal lensing compensation for AIGO High Power Test Facility

Jerome Degallaix

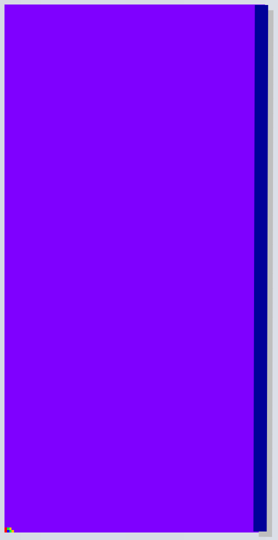
- Thermal lensing
- Influence on the performance of the interferometer
- How to compensate its effects

Thermal lensing (TL)



Optical absorption
in the material

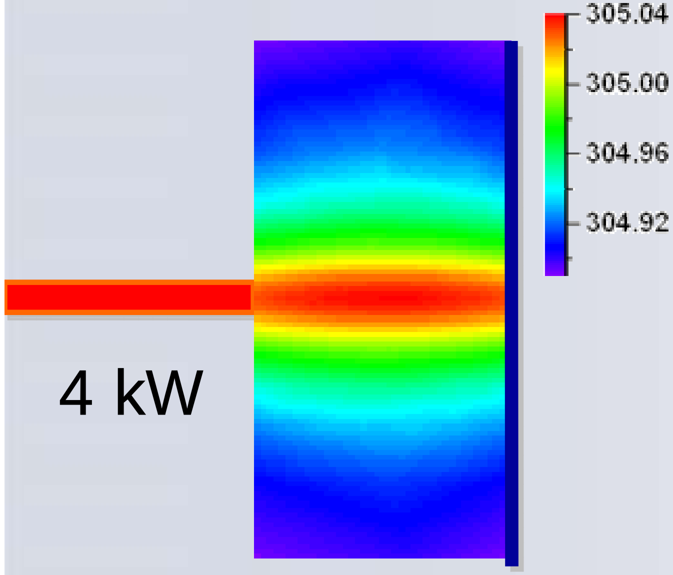
ITM temp. distrib.



$T_{ITM} = 300\ K$

Thermal lensing (TL)

ITM temp. distrib.



ITM power absorbed
Substrate = 1W

Optical absorption in the material

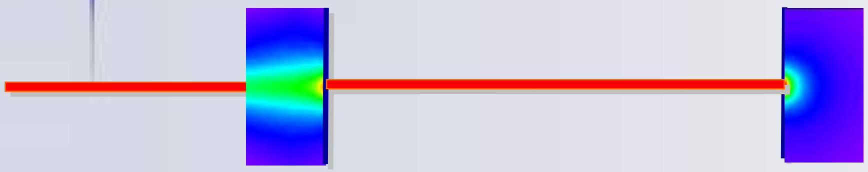
+

High power laser beam

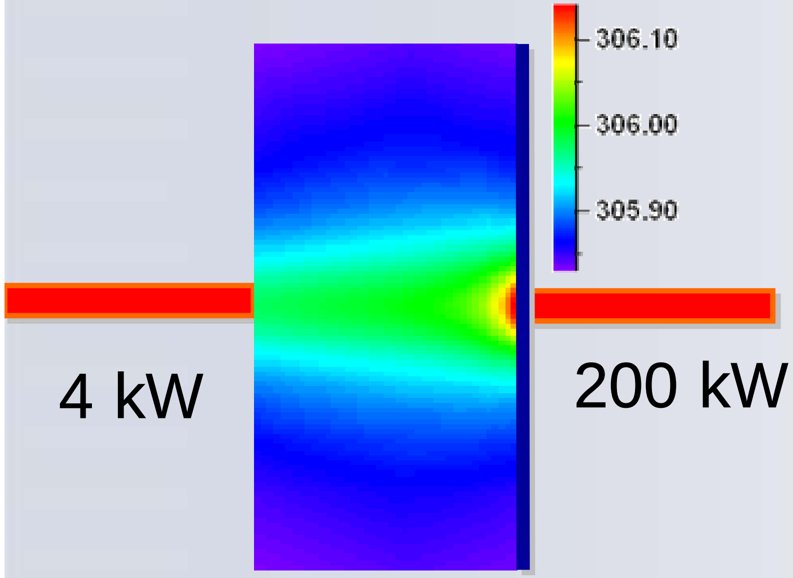
⇓

Non-uniform heating of the optics

Thermal lensing (TL)



ITM temp. distrib.



ITM power absorbed
Substrate = 1W
Coating = 0.2W

Optical absorption in the material

+

High power laser beam

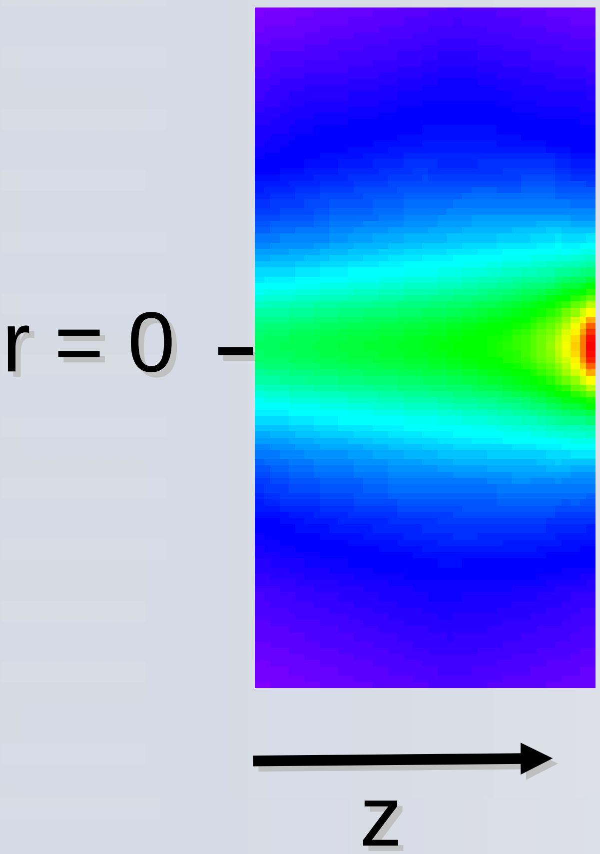
⇓

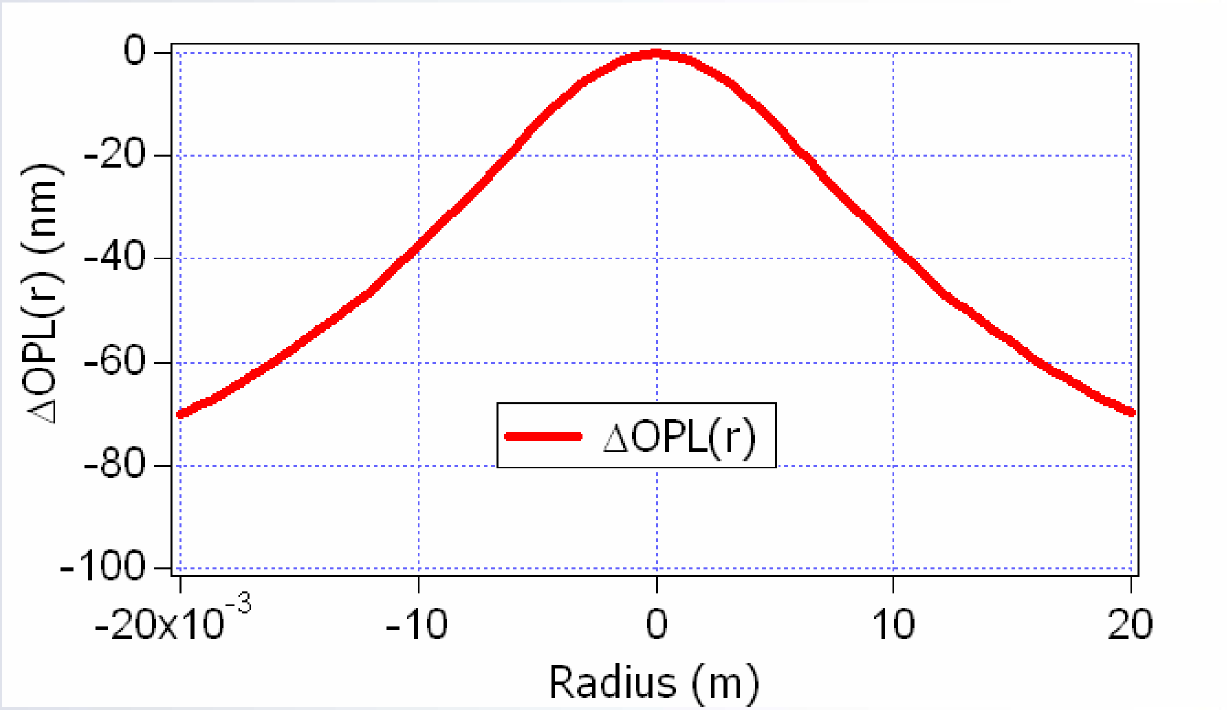
Non-uniform heating of the optics

TL characteristics

$$\text{if T} \nearrow, \text{n} \nearrow \quad (\beta > 0)$$

$$\Delta OPL(r) = \beta \int_0^L (T(r,z) - T(0,z))dz$$

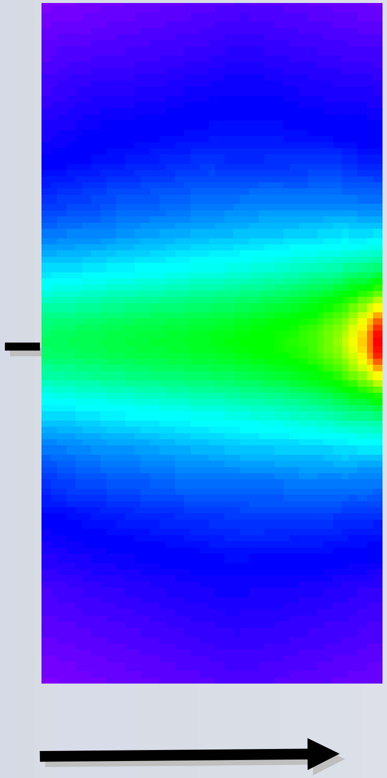




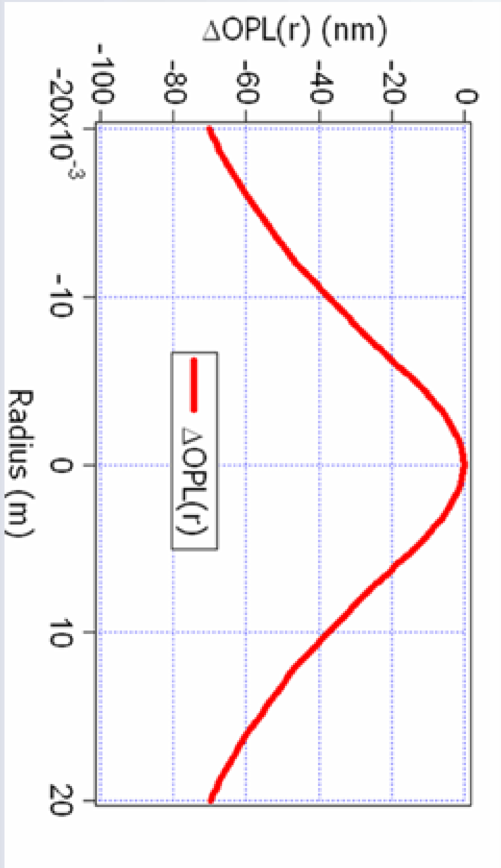
TL characteristics

$$\Delta OPL(r) = \beta \int_0^L (T(r,z) - T(0,z))dz$$

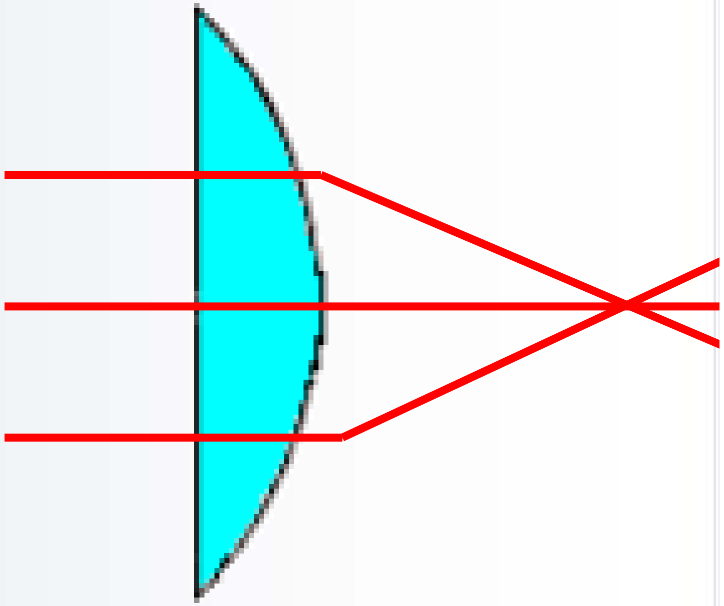
r = 0



z

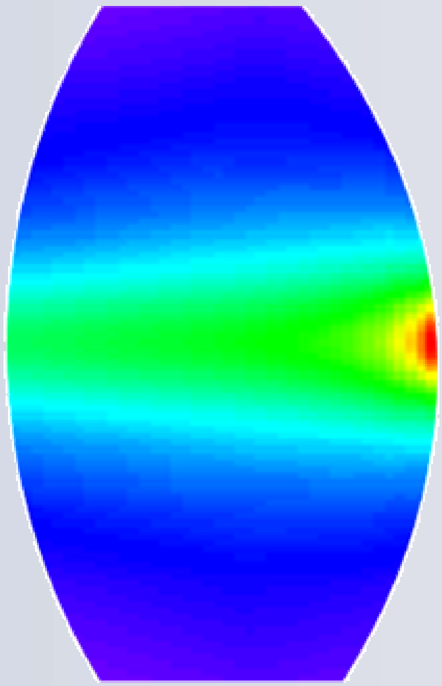


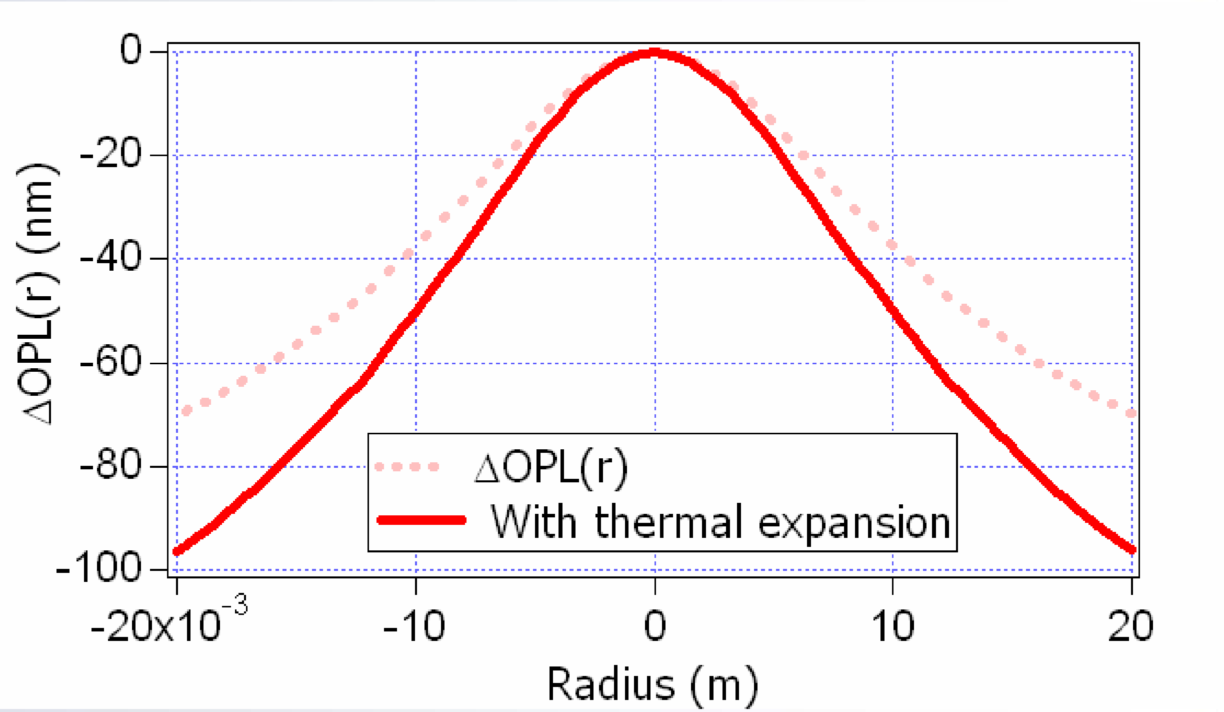
Equivalent to:



TL characteristics

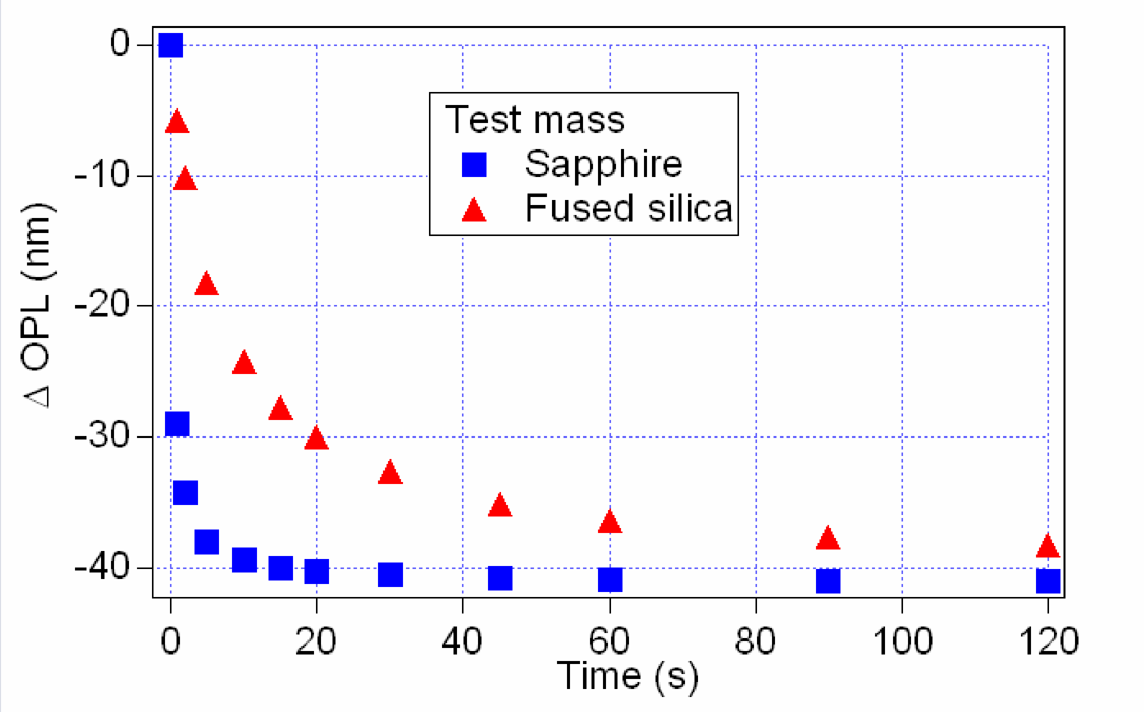
$$\Delta OPL(r) = \beta \int_0^{L+\Delta L(r)} (T(r,z) - T(0,z))dz$$





TL characteristics

$$\Delta OPL = \beta \int_0^L (T(w,z) - T(0,z))dz$$



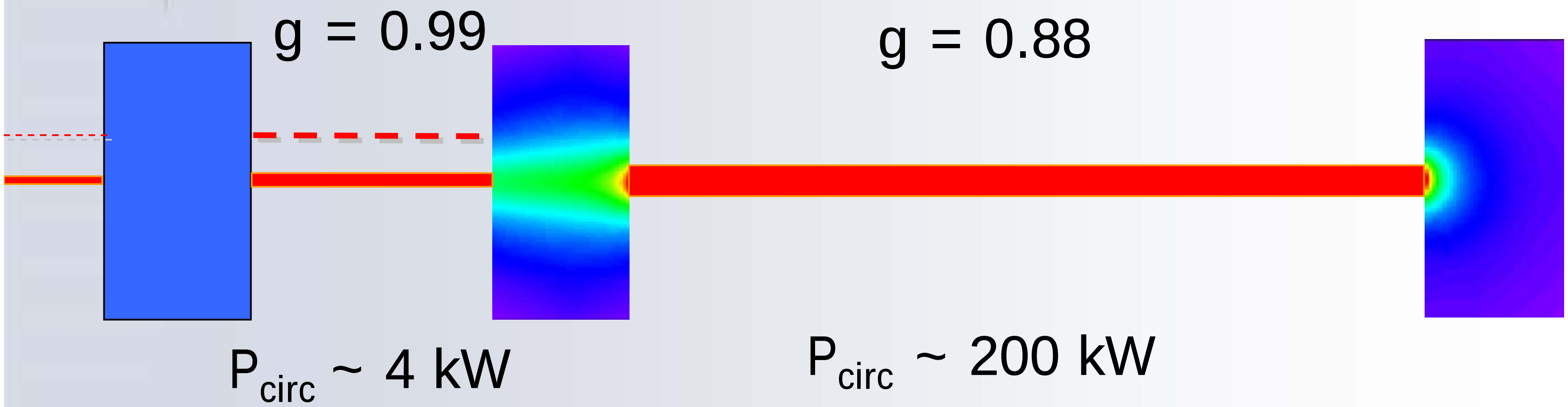
- Same TL magnitude for fused silica and sapphire
- Short TL time constant (< 1 minute)

Test mass TL effects

- Test mass acts like a convergent lens (focal length ~ km)
- Non spherical lens $\Rightarrow$ higher mode conversion (< 0.5 %)
- Change the mirror radius of curvature (change in sagitta ~ nm)

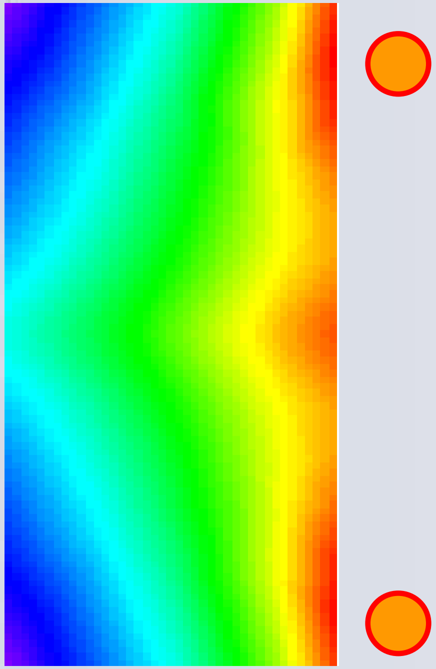
Cavity TL effects

Gingin Test 3



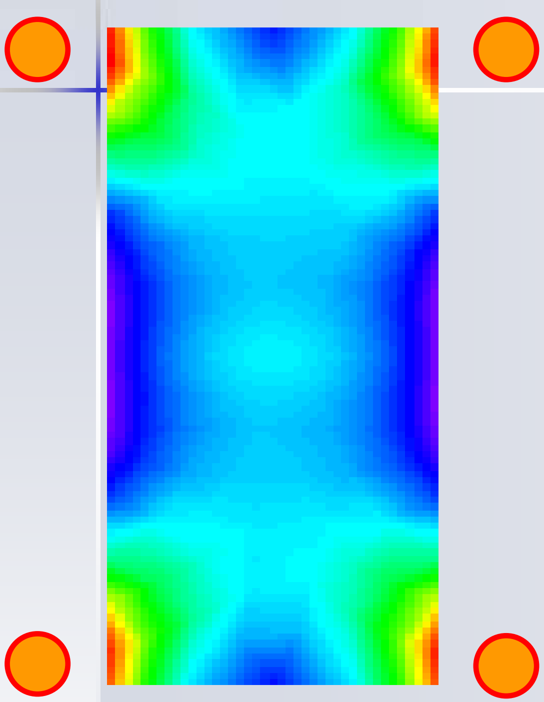
- Change the cavity modes
- Decrease in the circulating power
  - 3% for the carrier in the arm
  - 17% for the sidebands

Heating ring



- Due to the sapphire high thermal conductivity, the compensation is more difficult than for silica
- More difficult for small beam radius

Heating ring



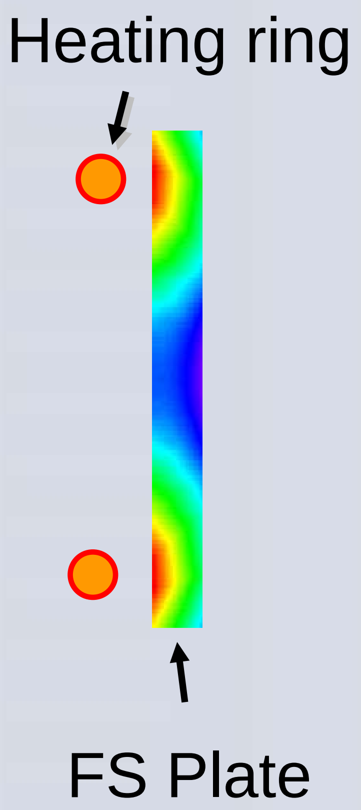
ITM temp. distrib.
$T_{ITM} = 400\ K$
$P_{ring} = 60\ W$

- Due to the sapphire high thermal conductivity, the compensation is more difficult than for silica
- More difficult for small beam radius
- Use of 2 heating rings ?

Not practical for Gingin on sapphire TM!

Compensation plate

Compensate the TL on an external silica plate



- Diameter same as the TM
- Thickness optimized (~ 10 mm)

Advantage:

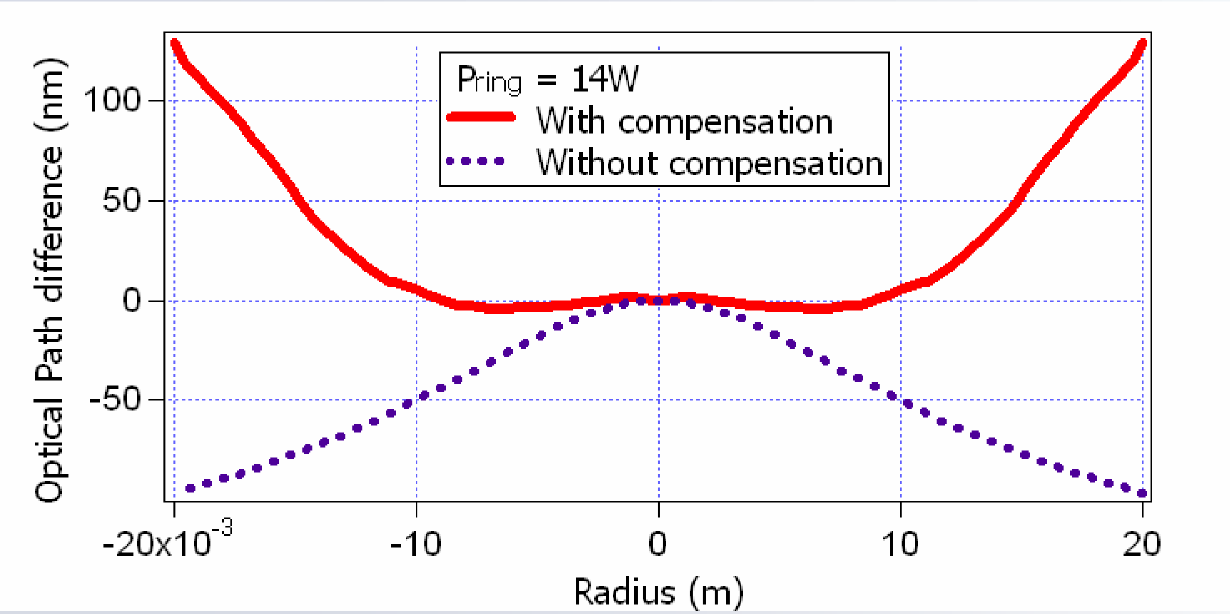
TM remains intact

Drawback:

Object inside the cavity

For Gingin...

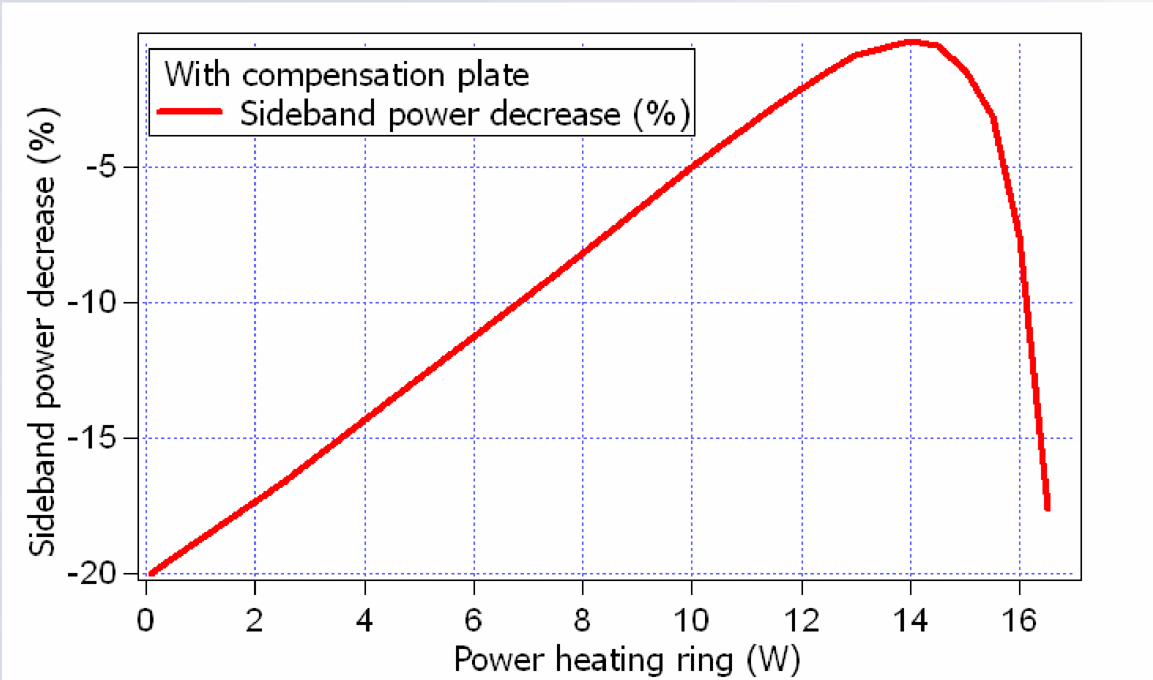
Gingin Test 3



P_{ring} = 14 W

T_{plate} = 340 K

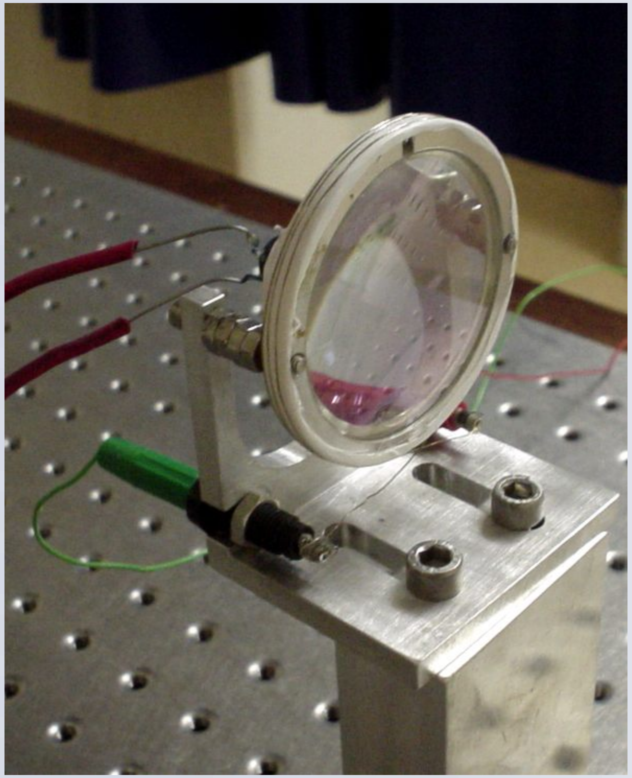
For Gingin...



- No change in arm circulating power
- Restoration of the sideband gain

Experiments

Experiments required to validate the simulations



- 50 mm diameter plate
- Heating by conduction
- Using a Mach-Zender interferometer

First result:
thermo-optic coefficient

Further work

The main issues remain:
Quantification of the noise added by the plate

- Suspension requirement ?
- Influence of the AR coating ?
- Control accuracy ?

- Strong thermal lensing in AIGO
- Compensation plate essential
- Need more research

Regarding the thermal lensing:

Be alert not alarmed !

Special thanks to ACIGA and LIGO people