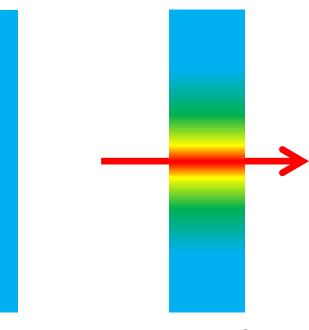
# BS Thermal Lensing in KAGRA

Yuta Michimura

Tsubono Group University of Tokyo

## What's Thermal Lensing?

- high power beam + absorption in a mirror
- heats a mirror and
  - the mirror deformation by thermal expansion
    - → mirror curvature changes
  - non-uniform refractive index change
    - → mirror act like a lens
- cause wavefront distortion
  - → reduce sensitivity



# Why BS?

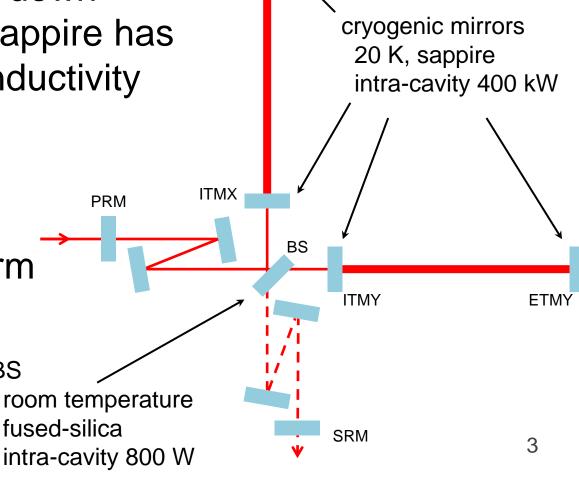
ETMX

 mirrors that transmits light matters ITMs and BS

BS

 ITMs are cooled down in KAGRA and sappire has high thermal conductivity

 BS introduces asymmetry between X / Y arm



#### How to Estimate the Effect?

- Simulate temperature distribution and thermal expansion using COMSOL Multiphysics (finite element analysis)
- 2. Calculate wavefront distortion of the BS reflected/transmitted light
- Calculate the sensitivity decrease using FINESSE (IFO simulation software)

#### **Estimation Procedure**

Simulate temperature distribution and thermal expansion
 using COMSOL Multiphysics
 (finite element analysis)

- 2. Calculate wavefront distortion of the BS reflected/transmitted light
- Calculate the sensitivity decrease using FINESSE (IFO simulation software)

#### Parameters Used

incident beam power
P\_in = 800 W
beam radius
w = 36 mm
incident angle
theta\_in = 44.9684

BS reflectivity R BS = 0.5

substrate absorption

a\_sub = 1 ppm/cm

HR absorption

a\_HR = 10 ppm

AR absorption

a\_AR = 10 ppm

arm reflectivity R\_arm = 1

BS thickness d = 8 cm BS diameter phi = 37 cm

refractive index n = 1.45 beta = dn/dt = 8e-6 /K

thermal expansion alpha = 0.51e-6 /K

arm reflectivity R\_arm = 1

power goes to SRM P\_t = 3.5 W (mainly f1 sideband)

### Temperature Distribution

COMSOL result

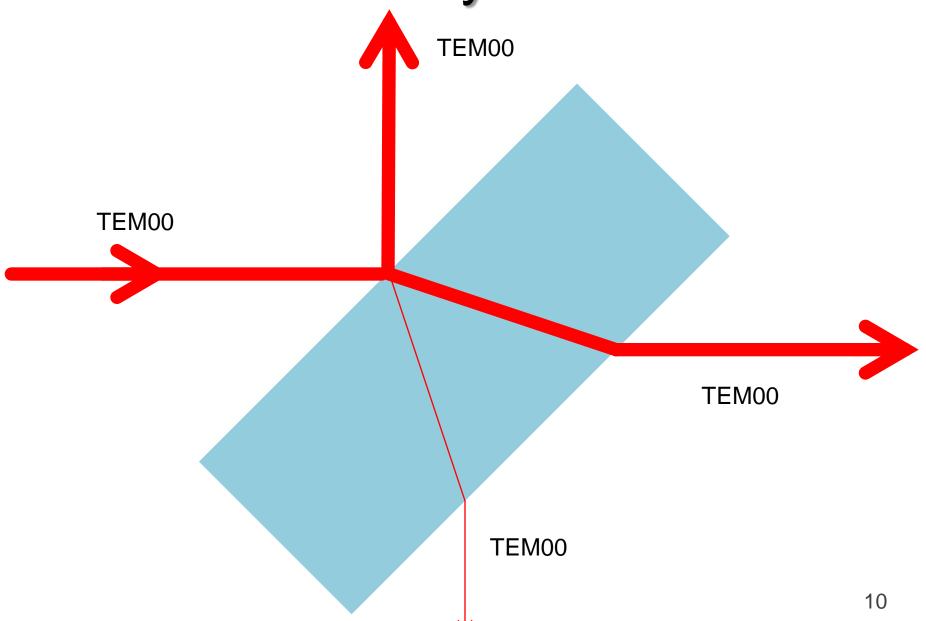
# Thermal Expansion

COMSOL result

#### **Estimation Procedure**

- Simulate temperature distribution and thermal expansion using COMSOL Multiphysics (finite element analysis)
- 2. Calculate wavefront distortion of the BS reflected/transmitted light
- Calculate the sensitivity decrease using FINESSE (IFO simulation software)

# Without Any Distortion



#### With Distortion

wavefront distorted from - HR surface reflection

TEM00

#### wavefront distorted from

- HR surface transmission
- substrate refractive index
- AR surface transmission

#### wavefront distorted from

- HR surface transmission
- substrate refractive index
- AR surface transmission

# **Treating Distortion**

TEM00' + HOMs

- TEM00 different from the incident
- HOM can be treated as HR reflection loss

TEM00

TEM00' + HOMs

- TEM00 different from the incident
- HOM can be treated as transmission loss

TEM00' + HOMs

- TEM00 different from the incident
- HOM can be treated as transmission loss

### Breaking Down to Some Numbers

- fit HR surface by simple curvature
- fit AR surface by simple curvature integrated optical path length from HR surface considering refractive index distribution
- calculate TEM00' simply by using ABCD matrix
- loss = 1 (distorted beam) x (TEM00')
   = 1 (TEM00' + HOMs) x (TEM00')
   = (HOMs) x (TEM00')

#### **Estimation Procedure**

- Simulate temperature distribution and thermal expansion using COMSOL Multiphysics (finite element analysis)
- 2. Calculate wavefront distortion of the BS reflected/transmitted light
- Calculate the sensitivity decrease using FINESSE (IFO simulation software)

# Calculating Sensitivity Decrease

- numbers we've got so far
  - HR surface curvature
  - AR surface curvature
  - HR reflection loss
  - transmission loss
- put them all into the FINESSE model
  - → IFO sensitivity