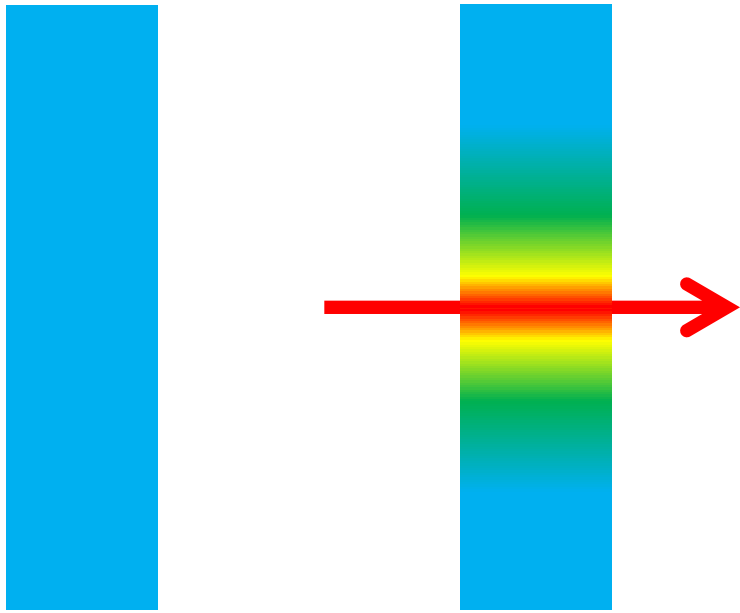
BS Thermal Lensing in KAGRA

Yuta Michimura

Tsubono Group
University of Tokyo

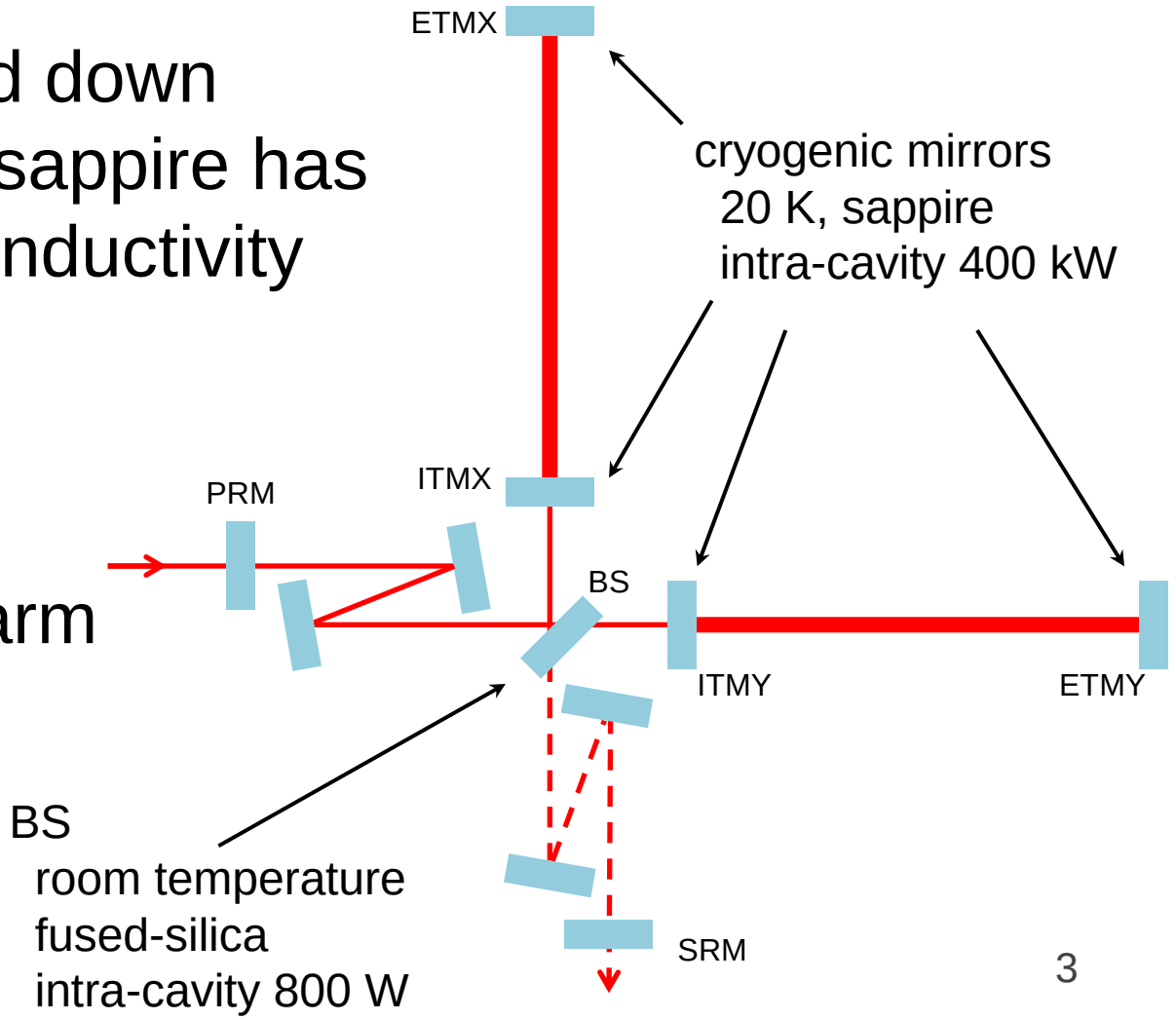
What's Thermal Lensing?

- 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?

- mirrors that transmits light matters
  ITMs and 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?

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

2. Calculate wavefront distortion of the BS reflected/transmitted light

3. Calculate the sensitivity decrease
   using FINESSE
   (IFO simulation software)

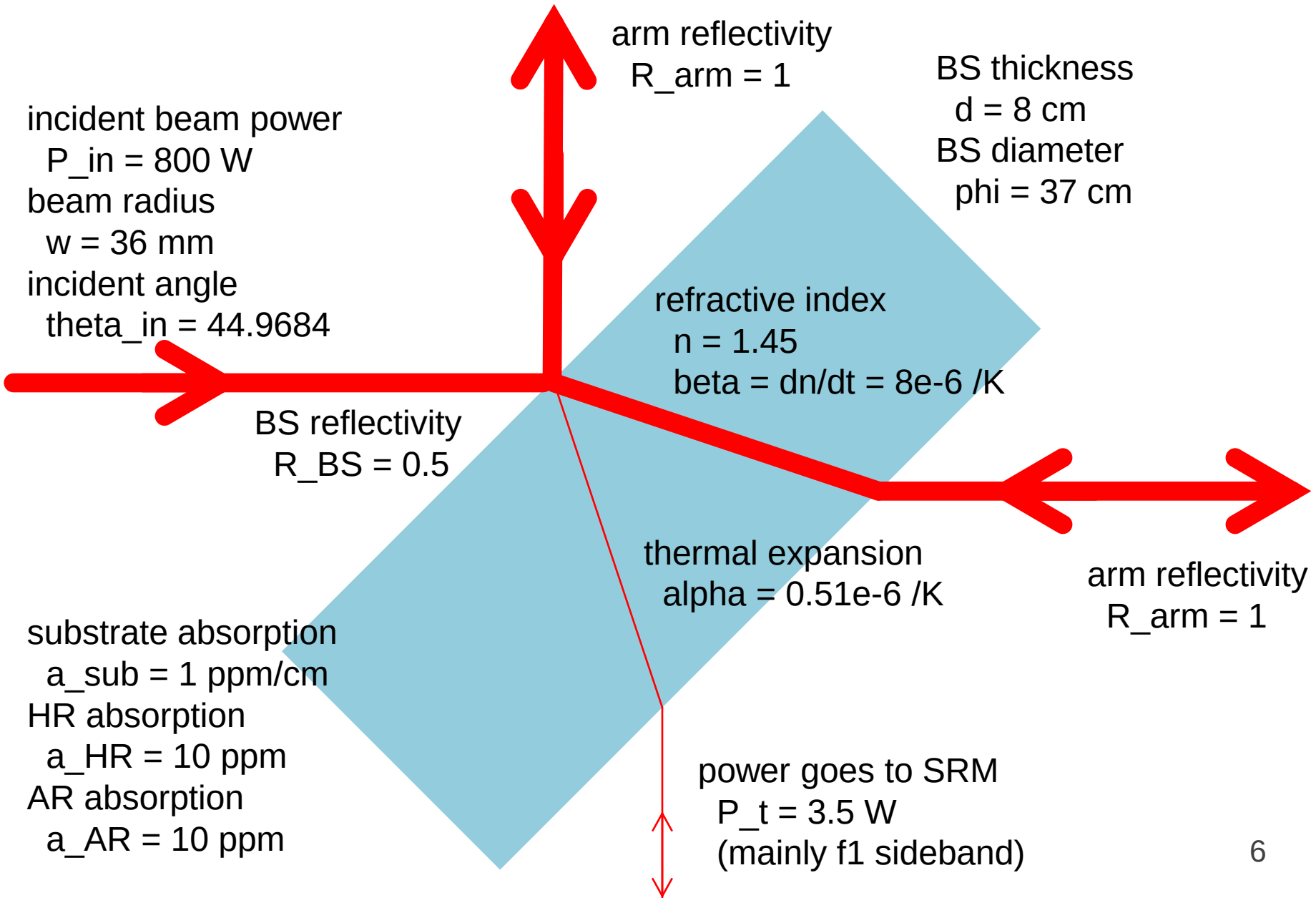
Estimation Procedure

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

2. Calculate wavefront distortion of the BS reflected/transmitted light

3. Calculate the sensitivity decrease
   using FINESSE
   (IFO simulation software)

Parameters Used



Temperature Distribution

- COMSOL result

Thermal Expansion

- COMSOL result

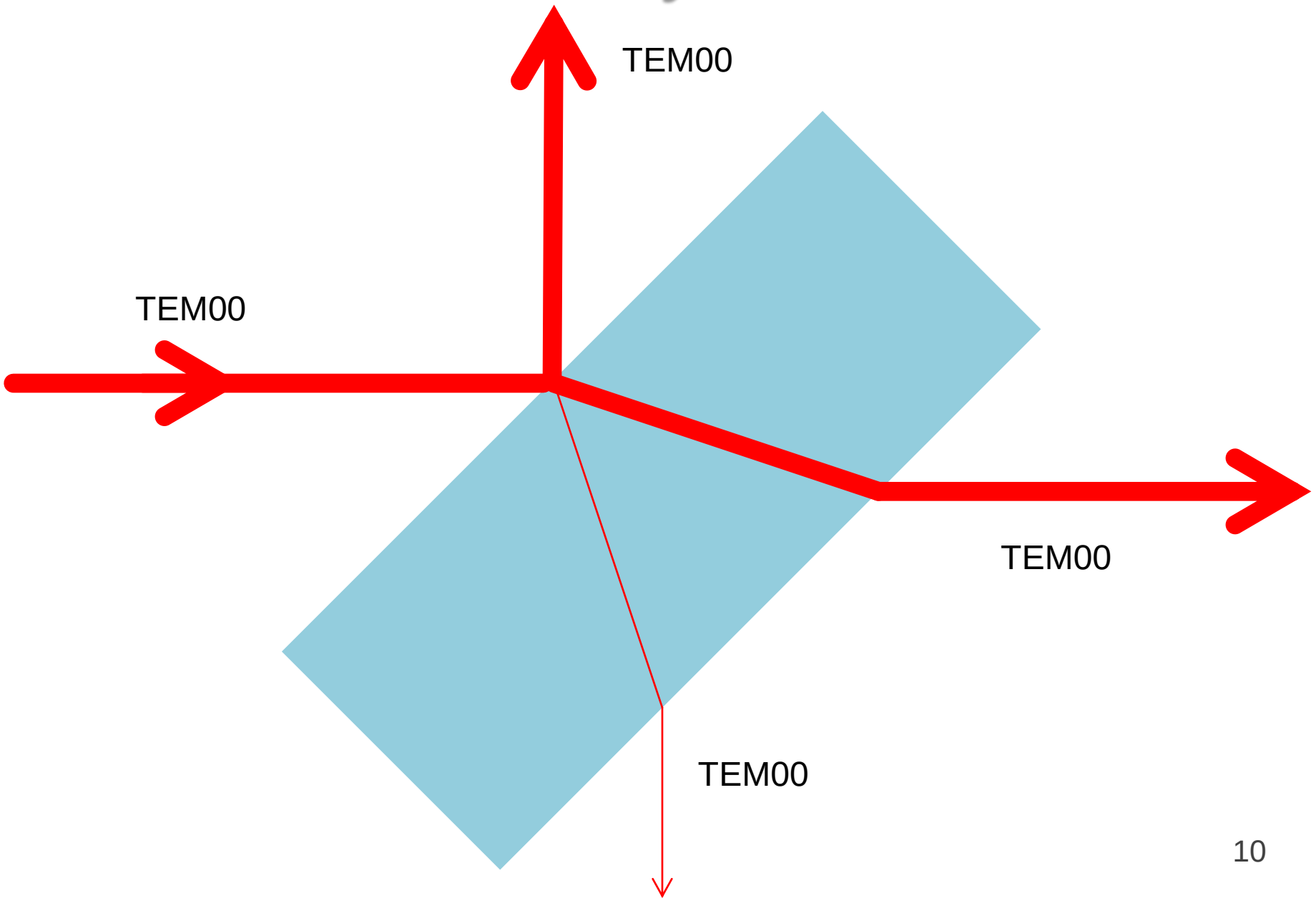
Estimation Procedure

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

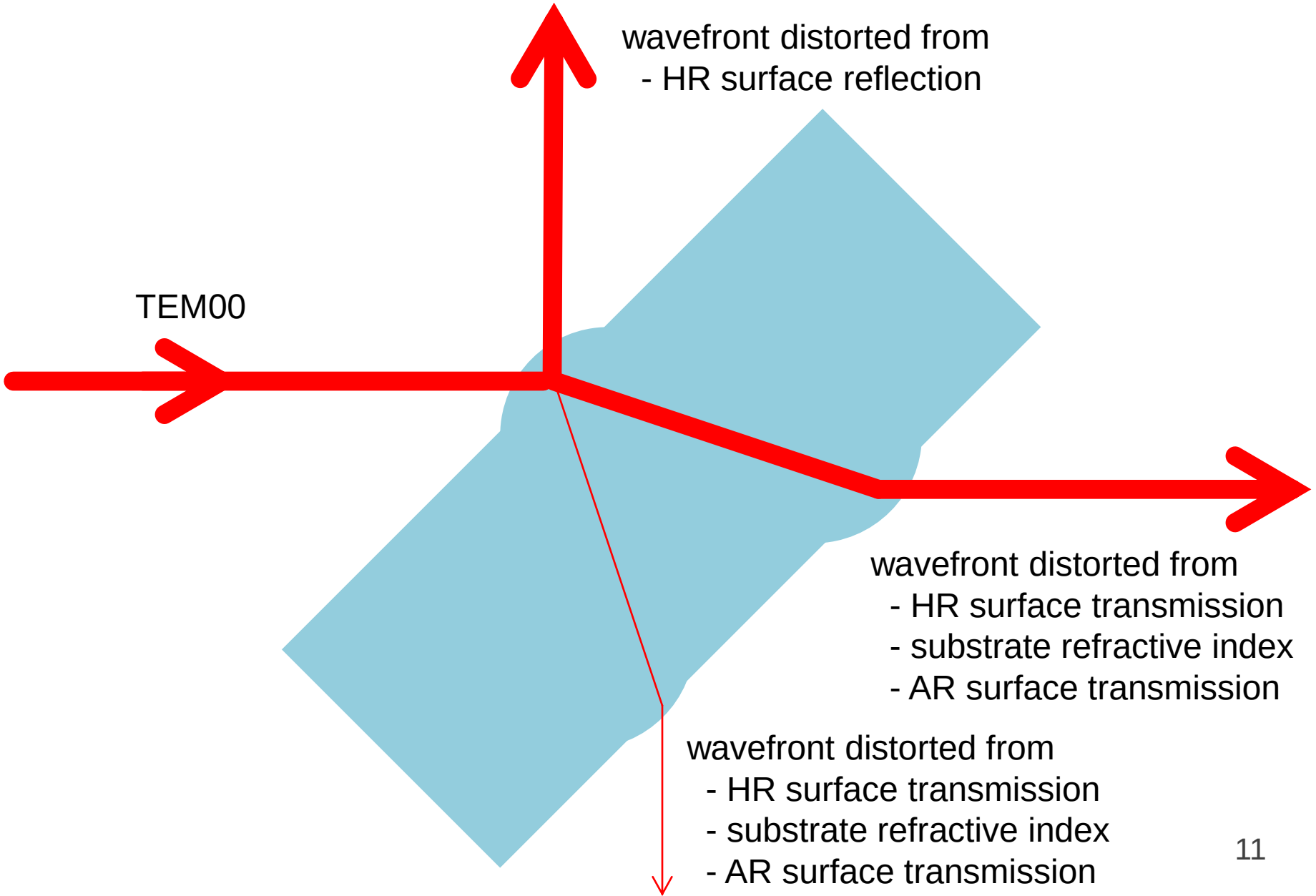
2. Calculate wavefront distortion of the BS reflected/transmitted light

3. Calculate the sensitivity decrease
   using FINESSE
   (IFO simulation software)

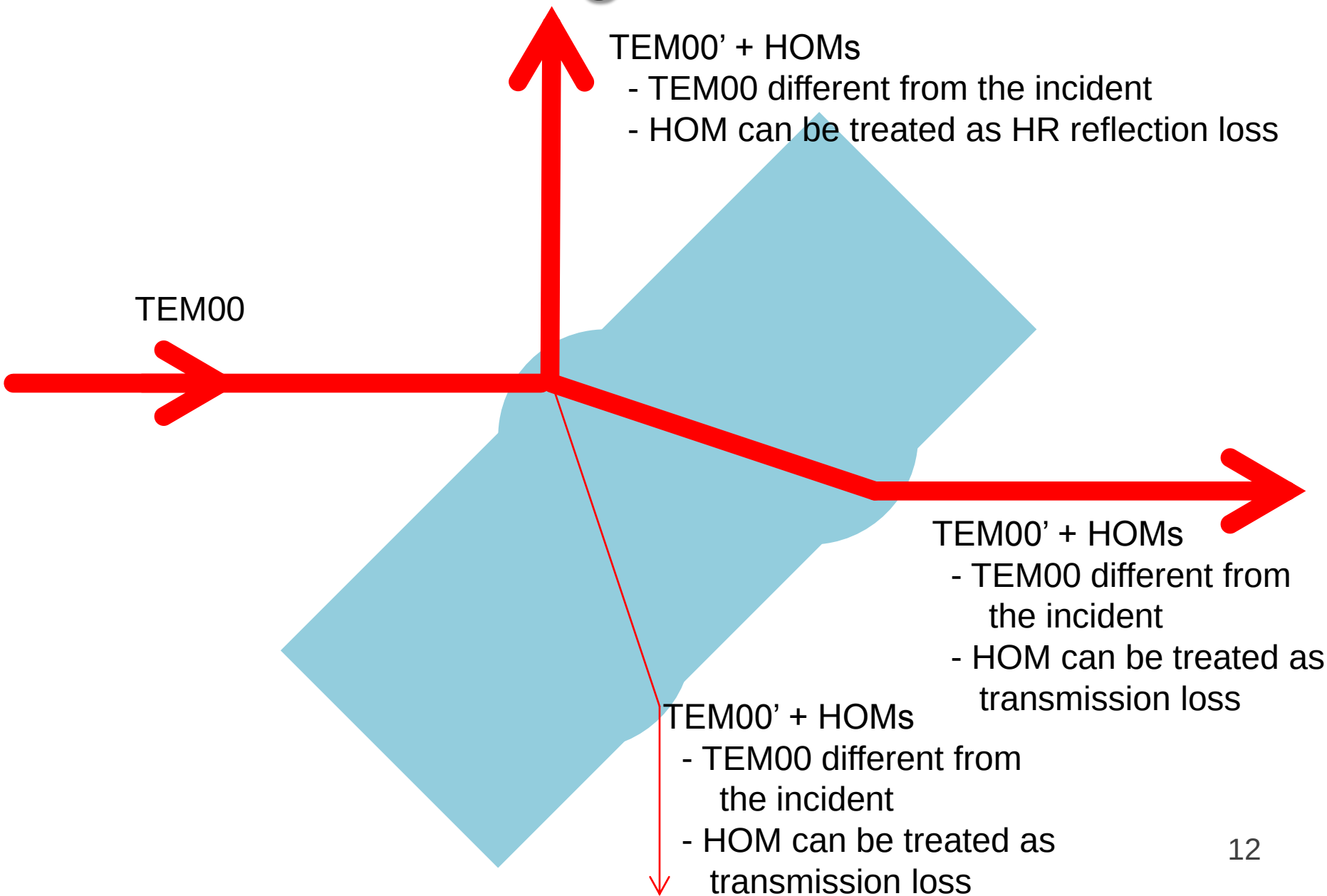
Without Any Distortion



With Distortion



Treating Distortion



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

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

2. Calculate wavefront distortion of the BS reflected/transmitted light

3. 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