BS Thermal Lensing in KAGRA

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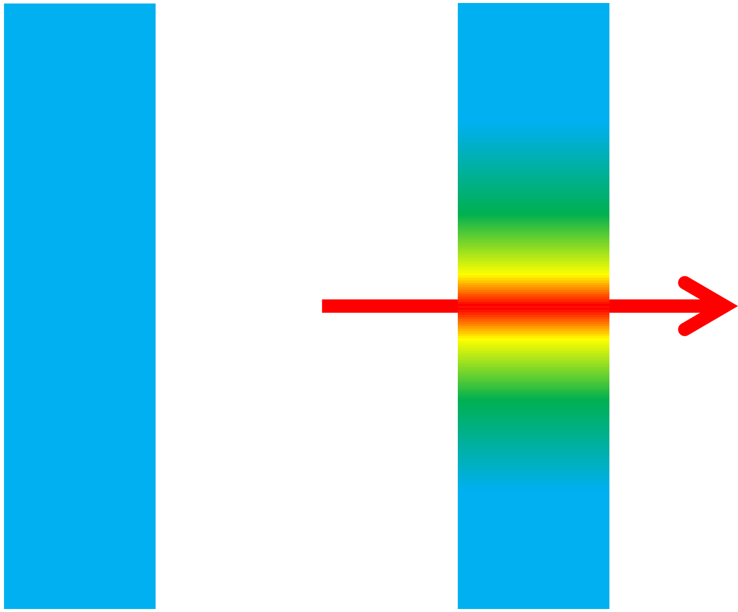
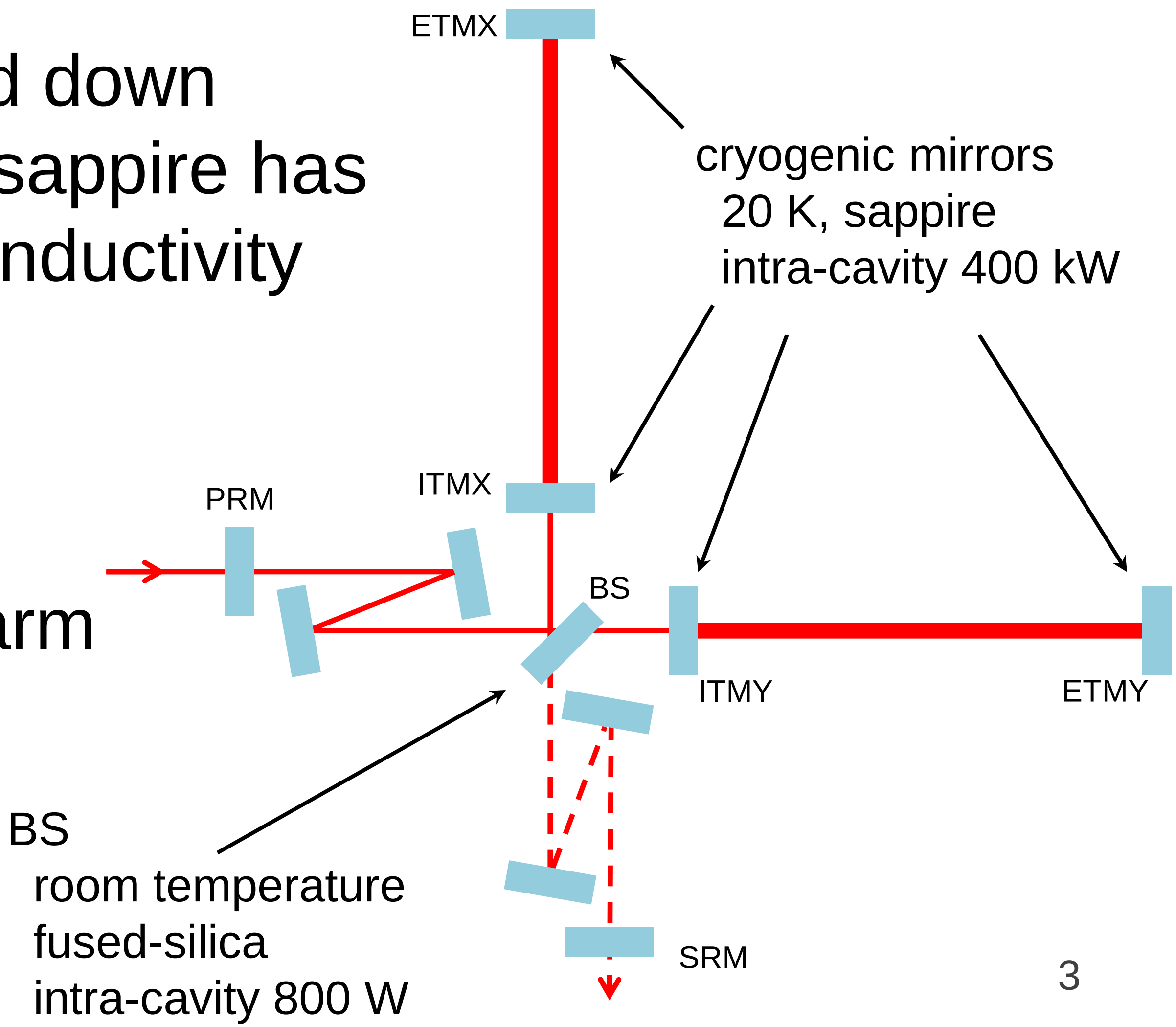
What's Thermal Lensing?

- 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

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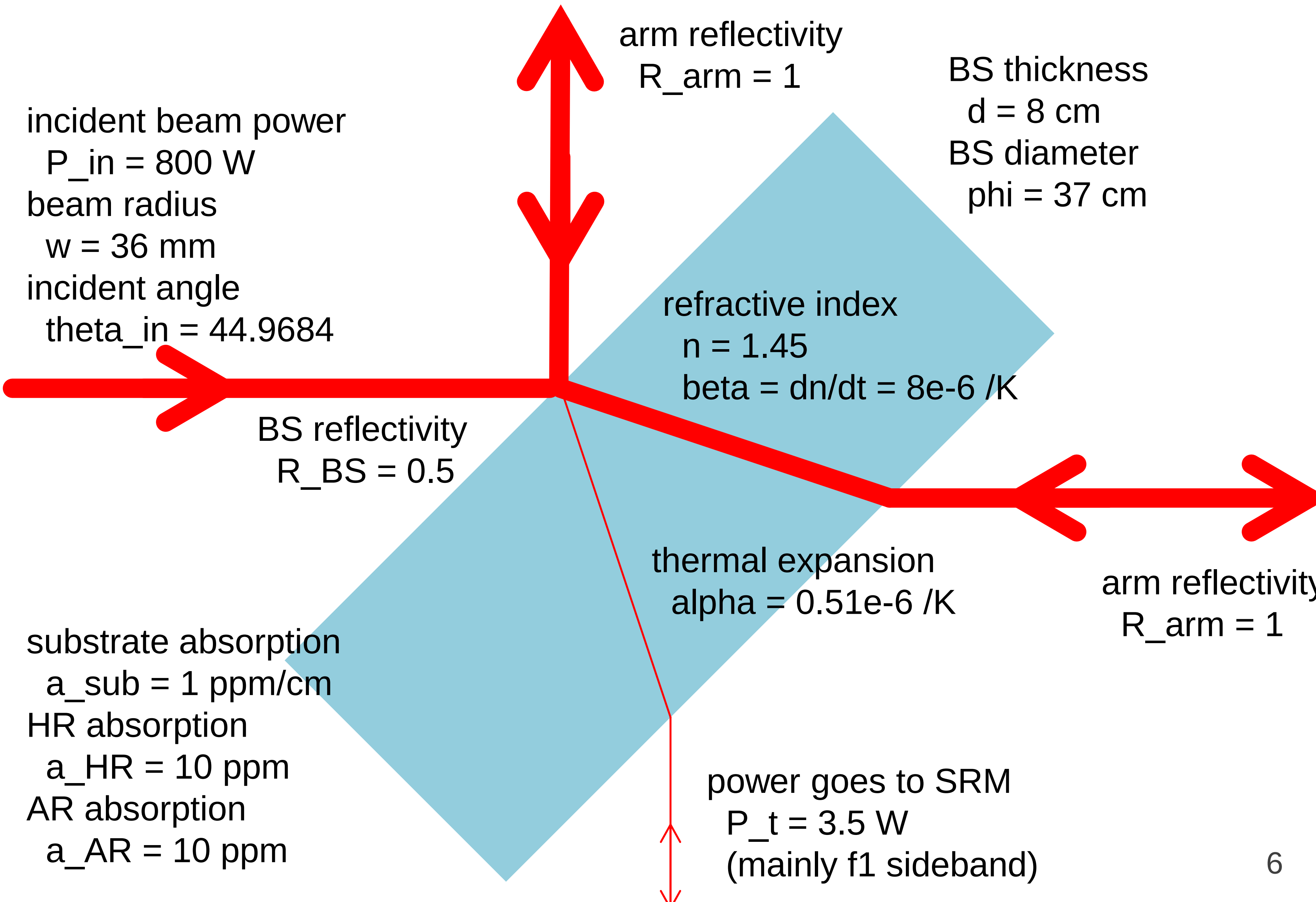
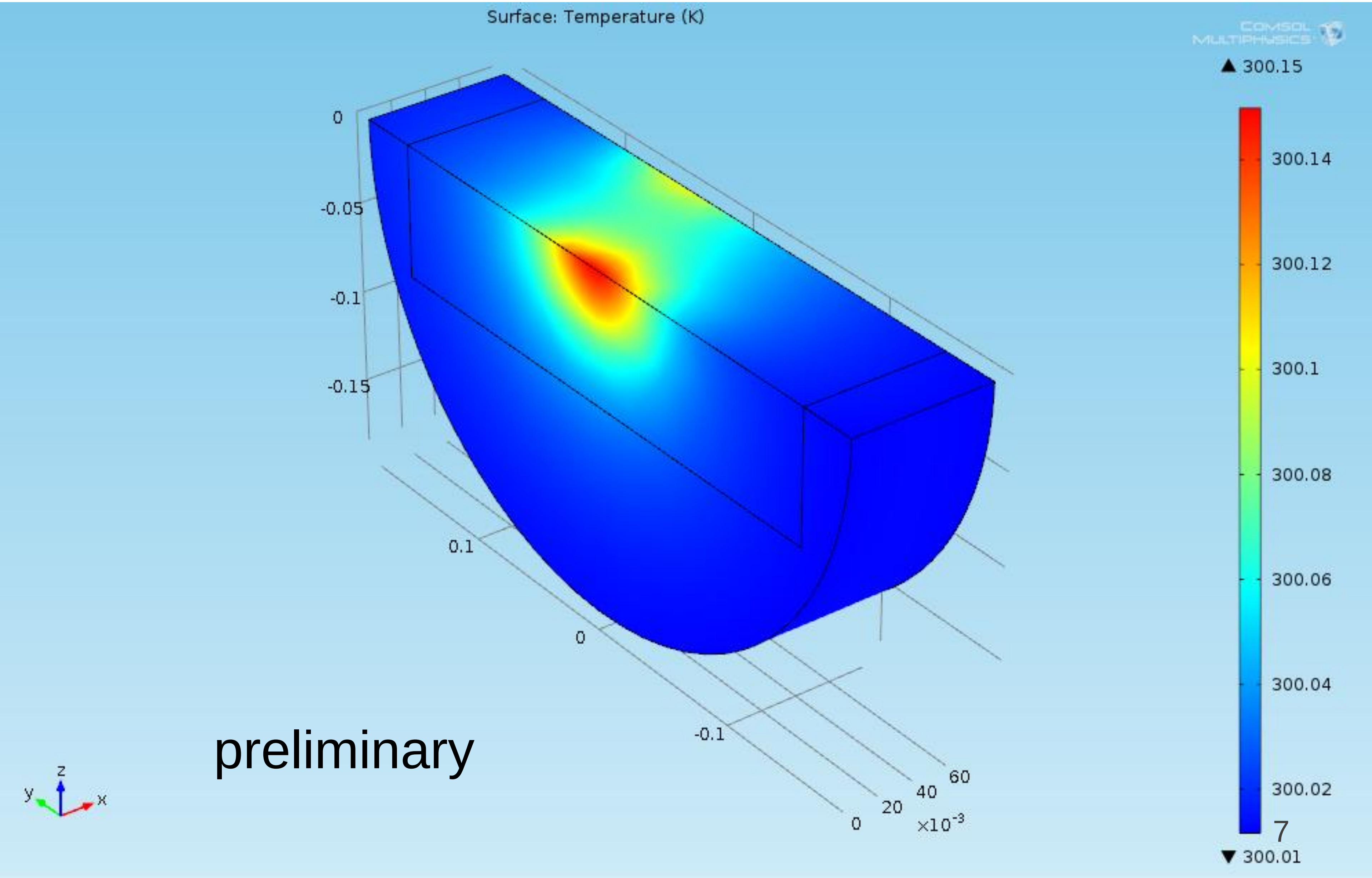
Parameters Used

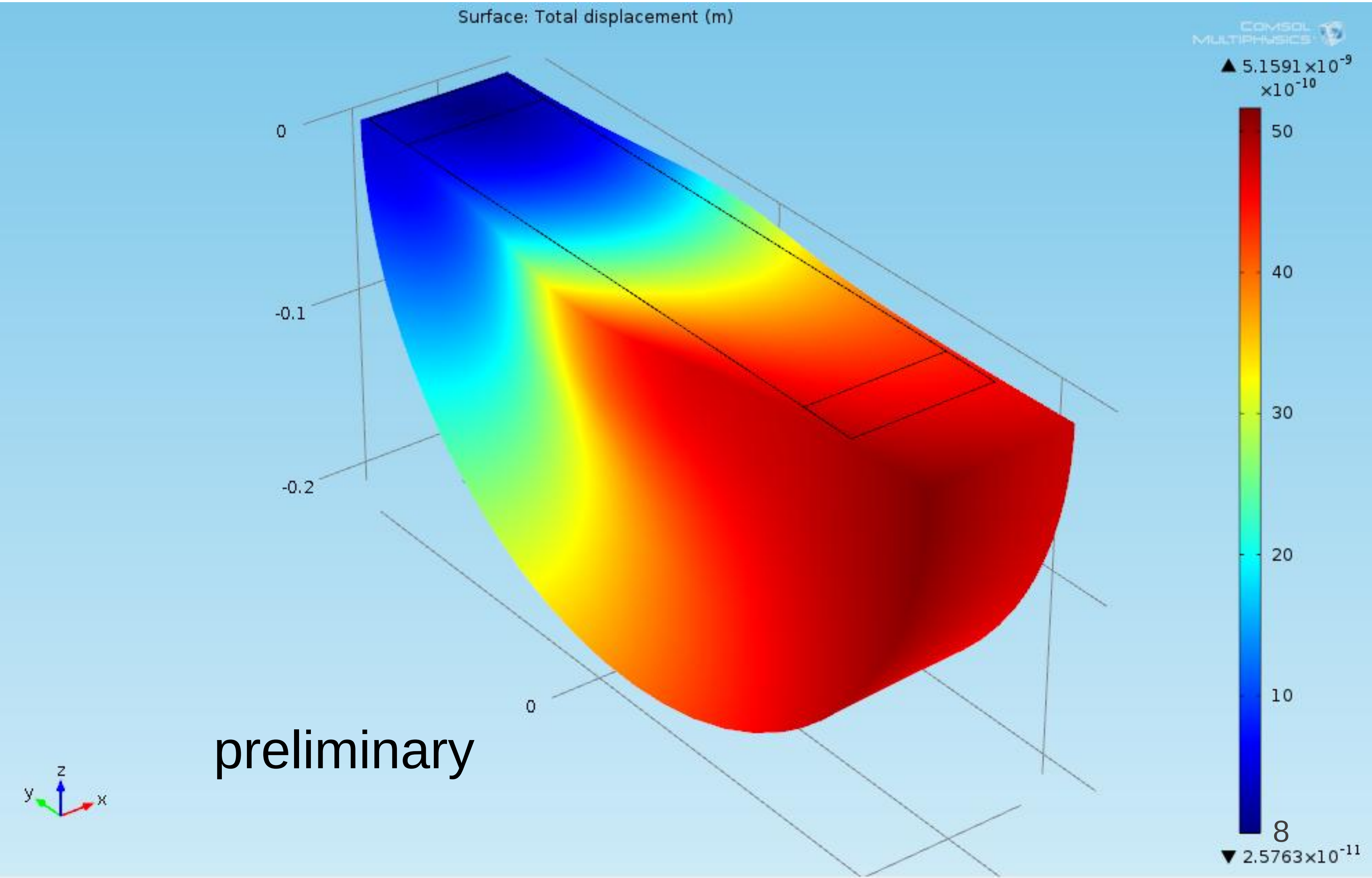


Temperature Distribution



preliminary

Thermal Expansion



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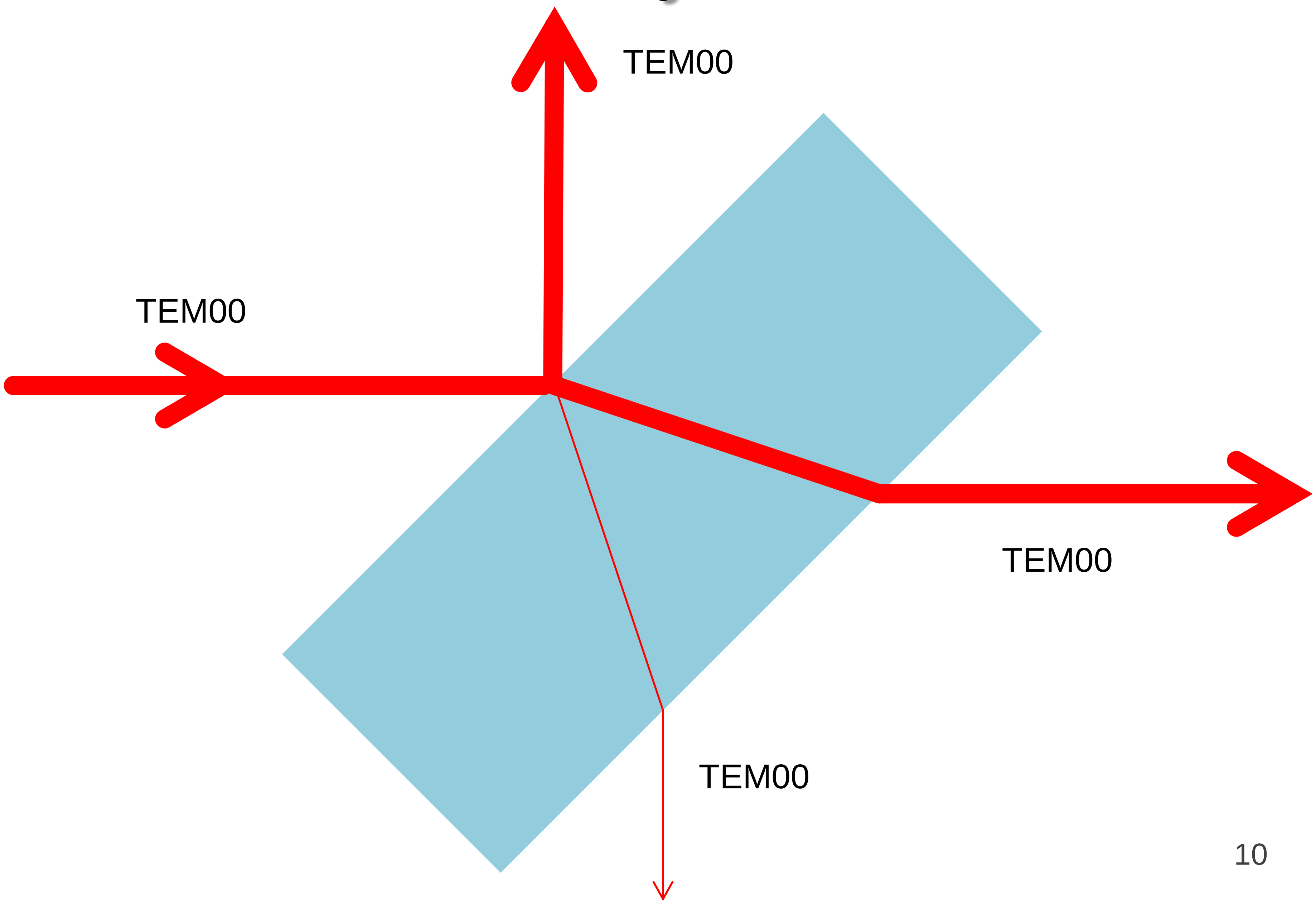
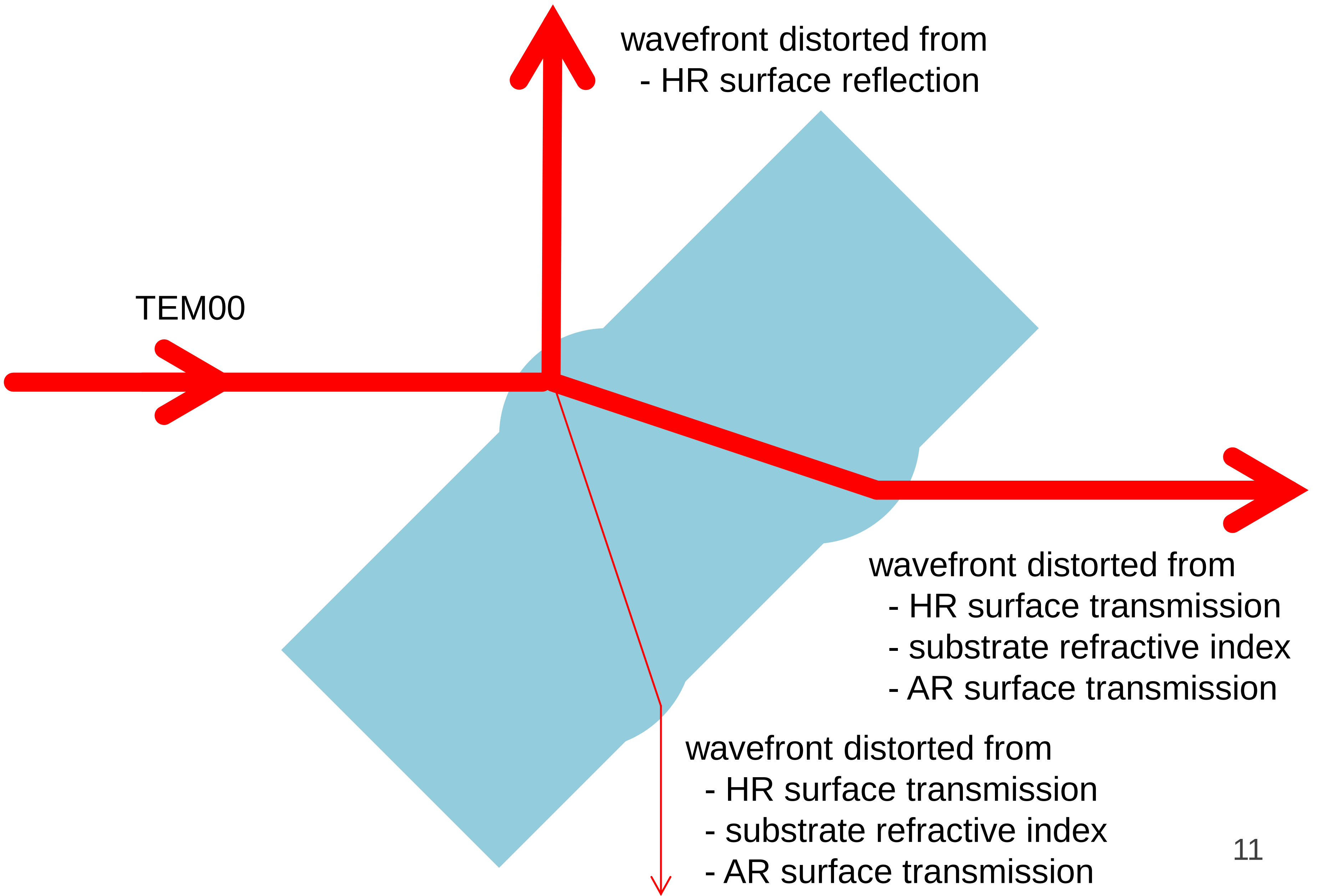
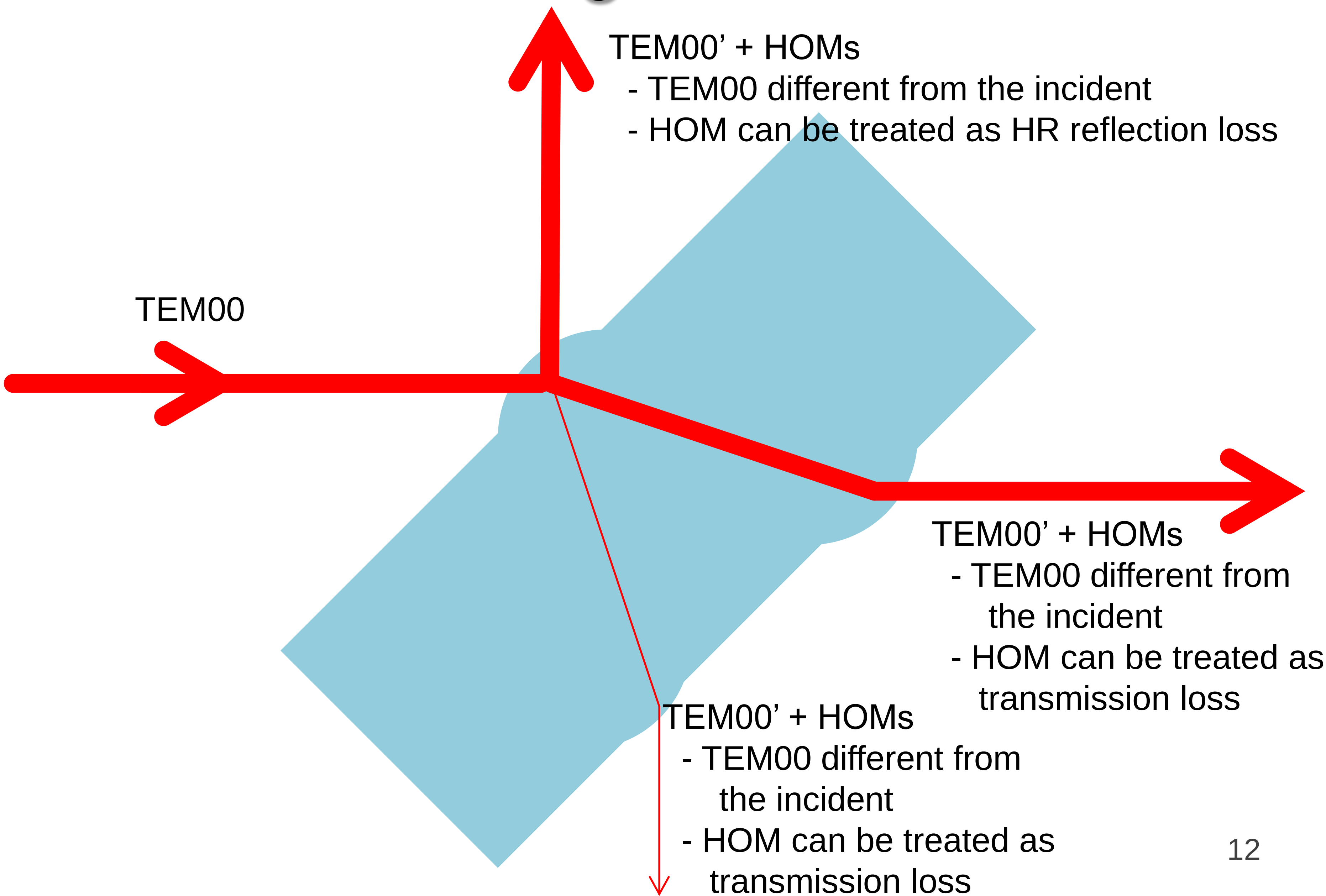
Without Any Distortion



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')

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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