Optical characterization of Fabry-Perot arm cavities of Virgo and preparation of numerical methods

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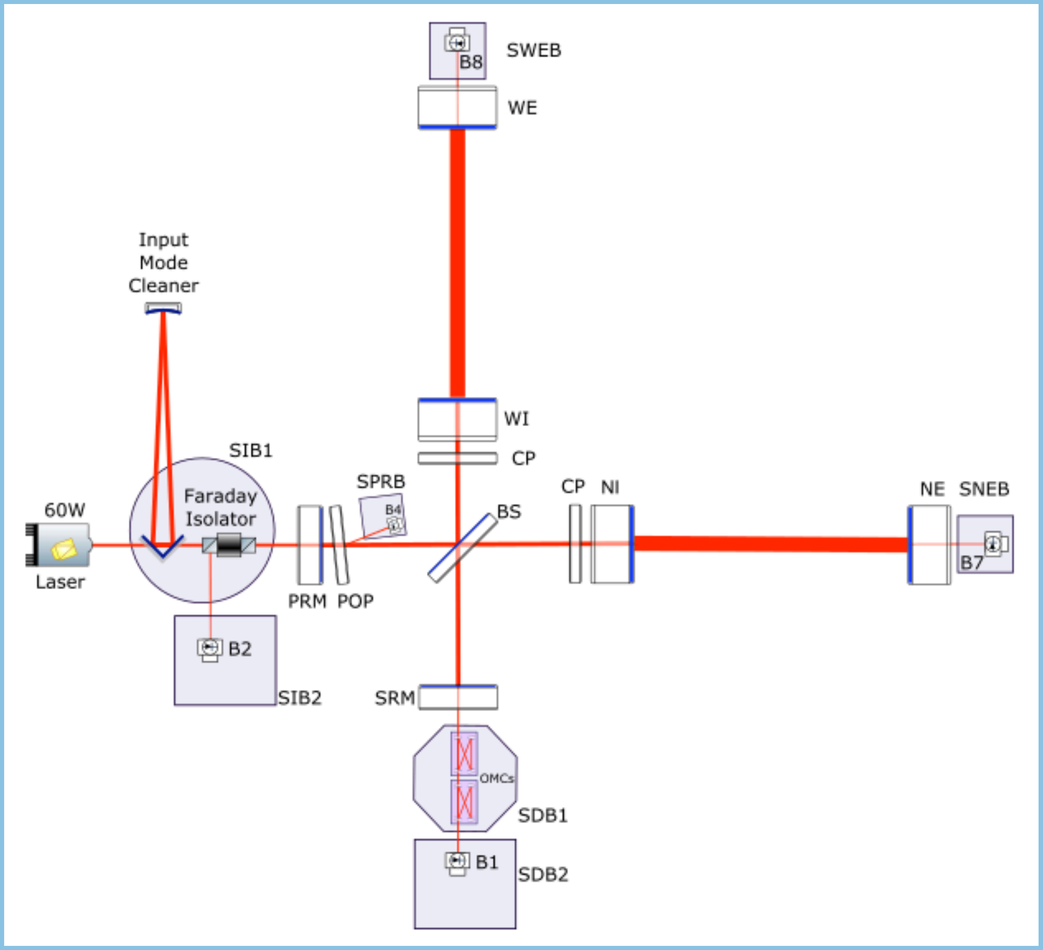
Summary



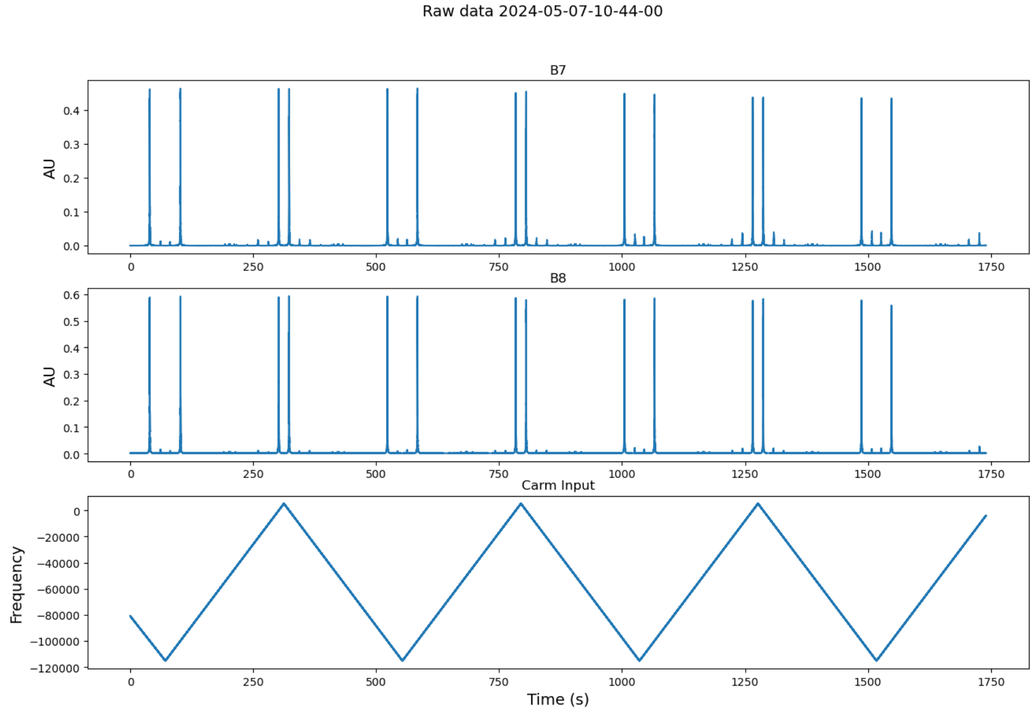
1. Importance of the simulations for commissioning and detector development.
2. Scan analysis and how commissioning and optical characterization are used to build simulations.
3. Consideration for the simulations of future optical layouts of gravitational wave detectors.

Concerning the needs of complex simulations

- Simulations are essential in order to understand the behavior of the interferometer during commissioning and for the study of futur configuration of optical layout. For this, precise and detail simulation are needed.
  - To build a simulation of Virgo, data from optical characterization and commissioning need to be take into account if we want to have a precise simulation of the interferometer.
  - Once the interferometer is well reproduced numerically, future changes can be added if we want to model the O5 and/or Virgo_nEXT version of Virgo. A particular effort has te be made on how we model optical components that are not produced yet as for example mirrors of stable cavities and larger mirror of the arms.

Arm scan principle

Principle



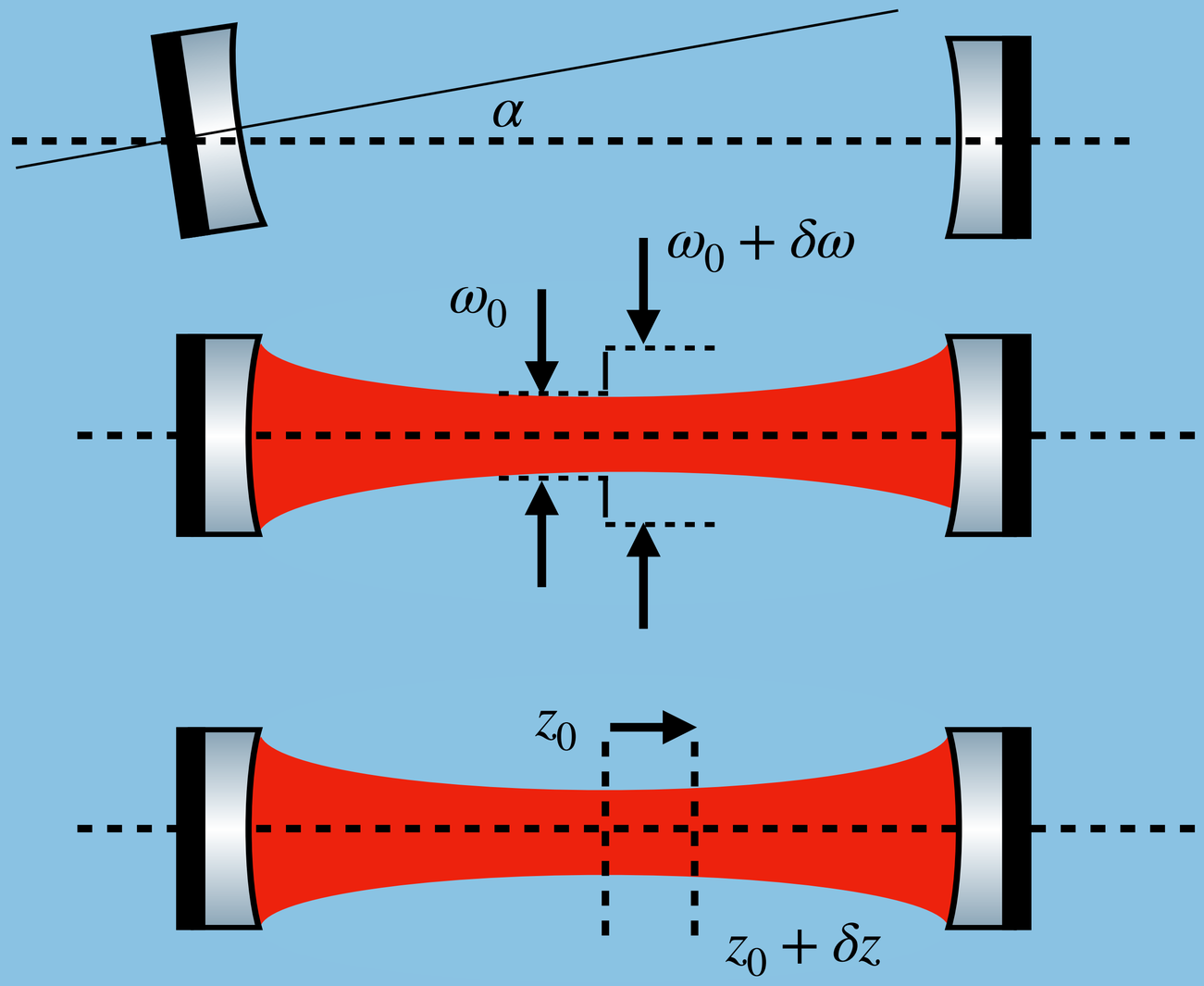
- During a scan :

  —> The cavities are locked with a green laser.
  —> Frequency ramps, over a little larger range than the free spectral range, are done in series.

- The transmitted beam through the end test mass, allow us to observe the resonance of :

  —> The fundamental mode.
  —> The higher order modes.
  —> The sidebands at 6MHz and 56MHz.

Higher order mode in Fairy Perot cavities

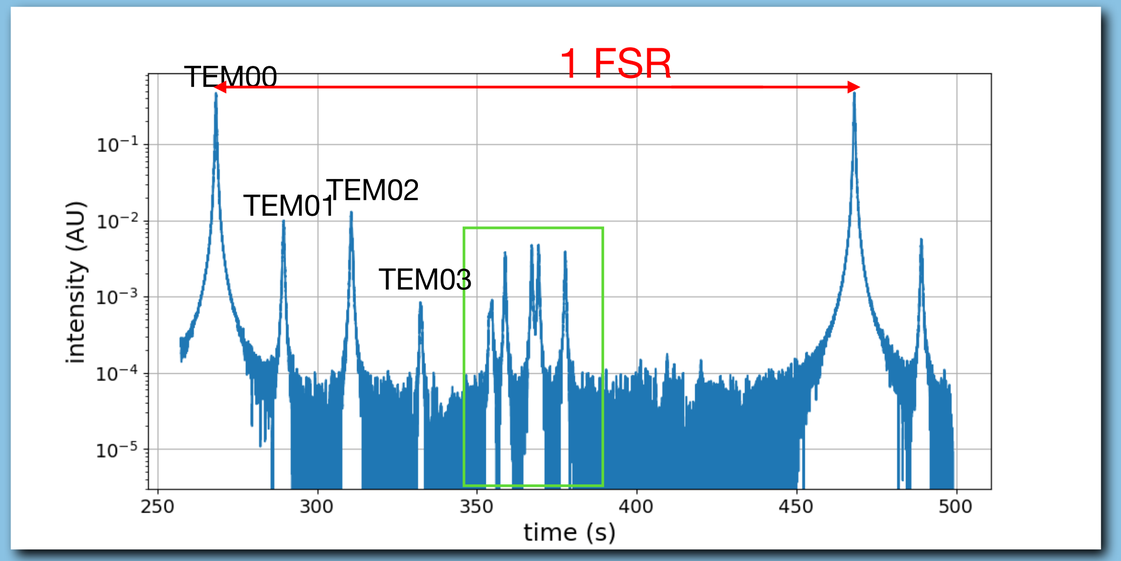


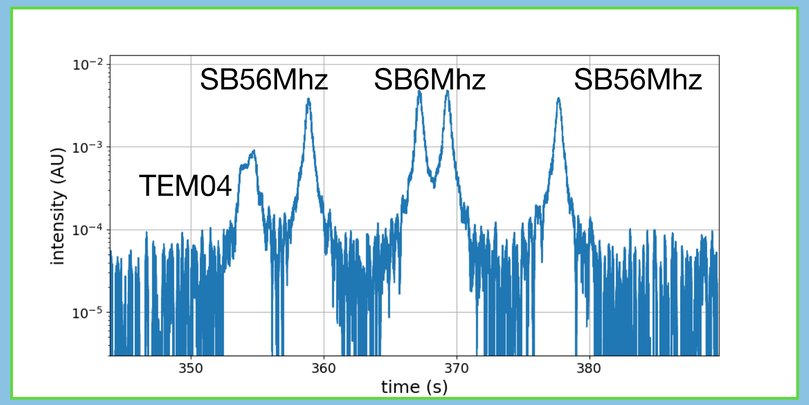
Cavity misalignment
TEM01 and TEM03

Waist diameter mismatch
TEM02 and TEM04

Waist postion mismatch
TEM02 and TEM04

Arm scan principle
Modal study





- Using a scan we can estimate :

  —> from the distance between the modes : the g factor of the cavity and the radius of curvature of the mirrors.
  —> from the height of the modes: The mismatch and the misalignment.

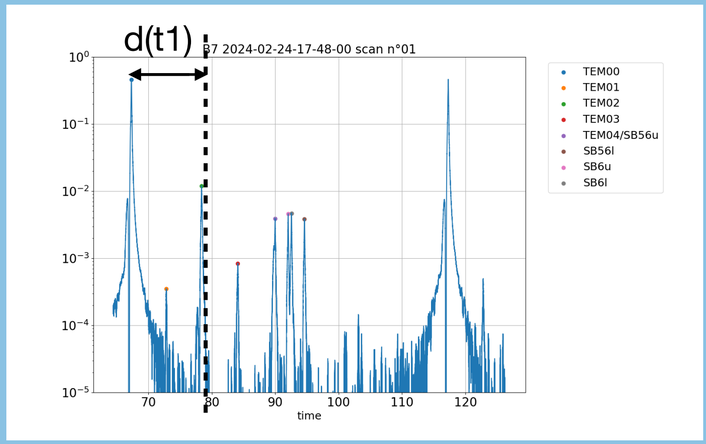
- There is two types of scan:

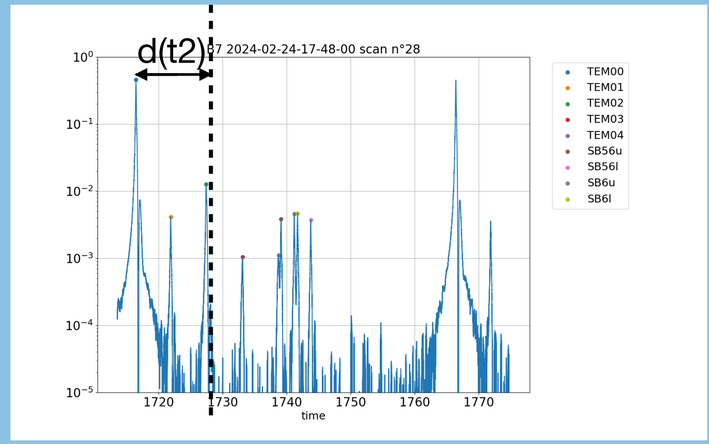
  —> Hot to cold scan are done just after an unlock. Then we can observe the cooling effect of the cavity
  —> « Cold scan » are done a long time after the unlock.

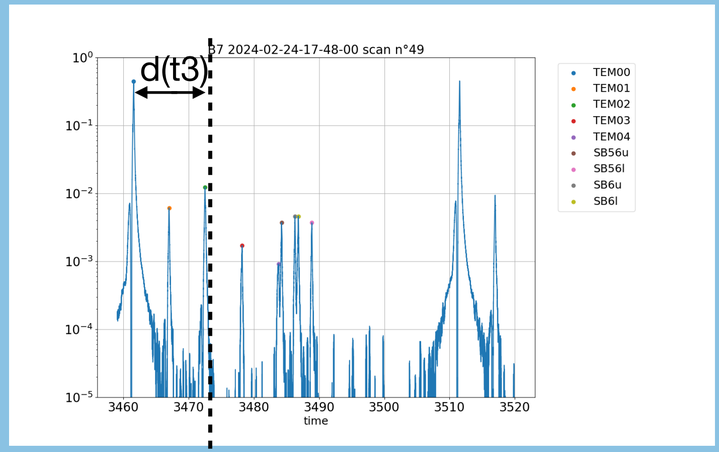
Hot to cold scans

Estimate the variation of the cavity parameters

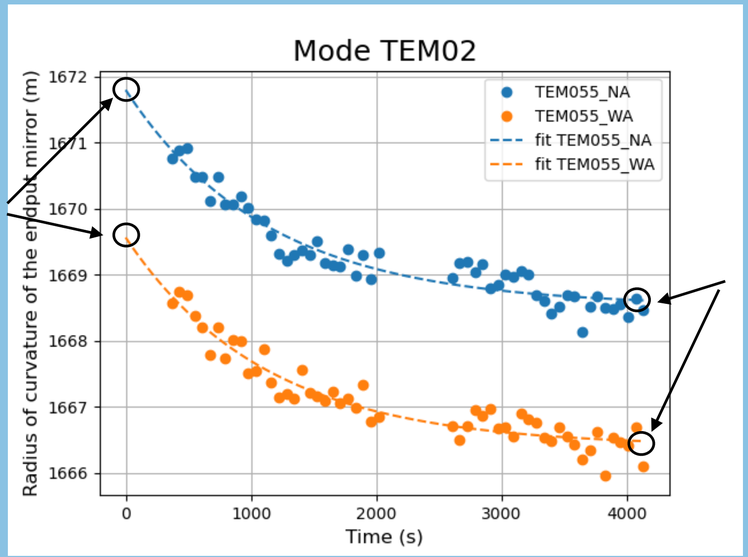
TIME







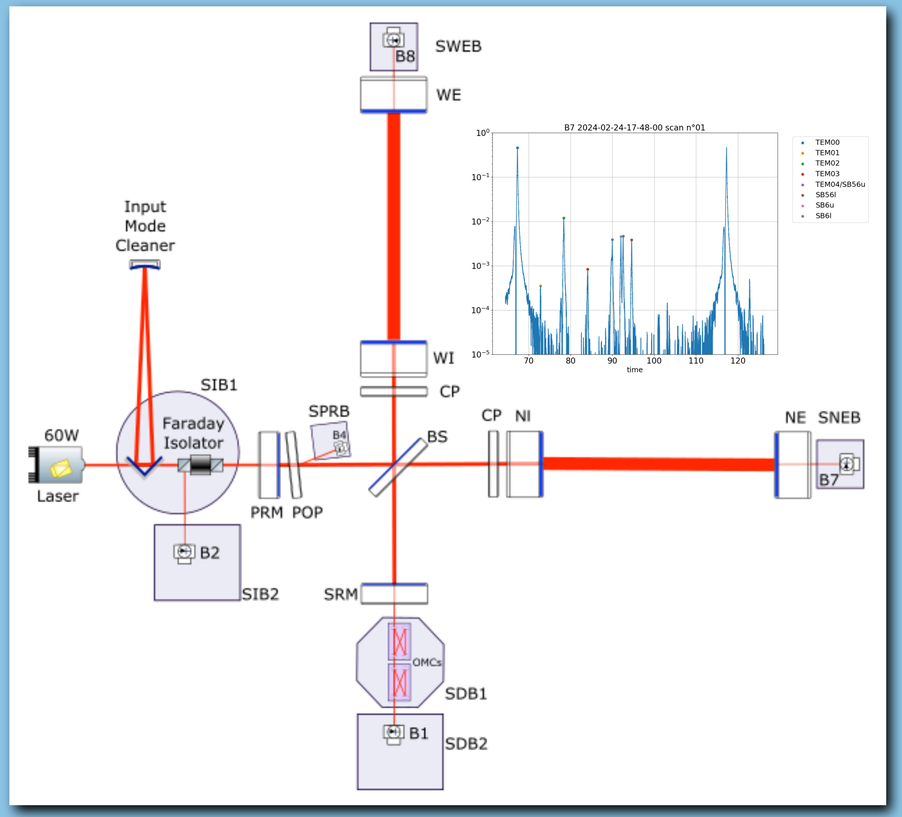
Radius of curvature when the high power laser was on.



Radius of curvature after the cooling of the cavity.

Build a precise and complex simulation of Virgo

Finesse 3.0



Use the data and measurement to understand and create simulation

Use the simulation in order to understand some results obtained during the measurement

Finesse 3

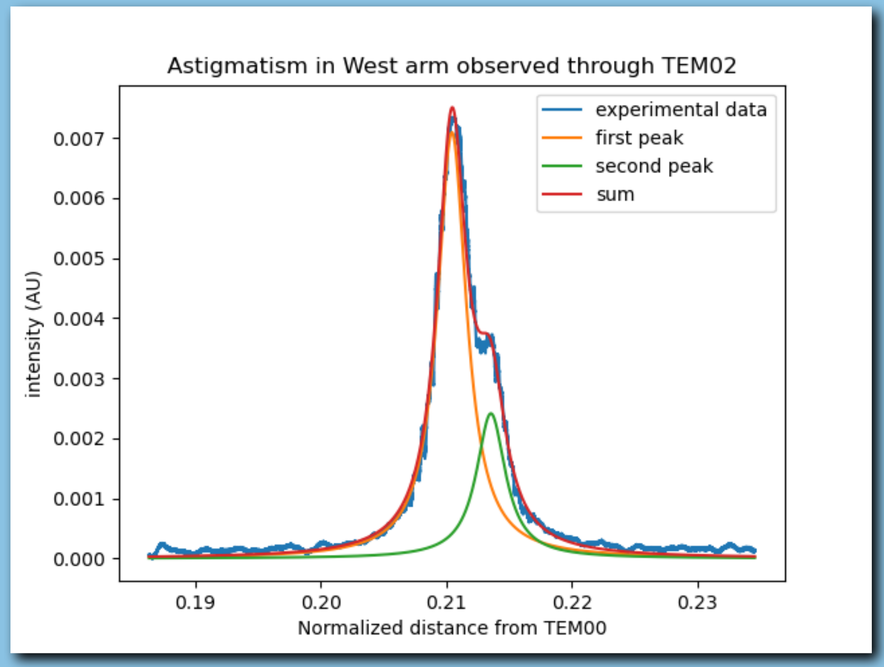
Step 1 : Use the data from optical characterization and commissioning to build a realistic simulation of Virgo.

Step 2 : implement the future change of the next version of Virgo Adv+ Phase II, Virgo_nEXT, with the constrain of simulate a futur interferometer without knowing exactly the Optical component that will be implemented.

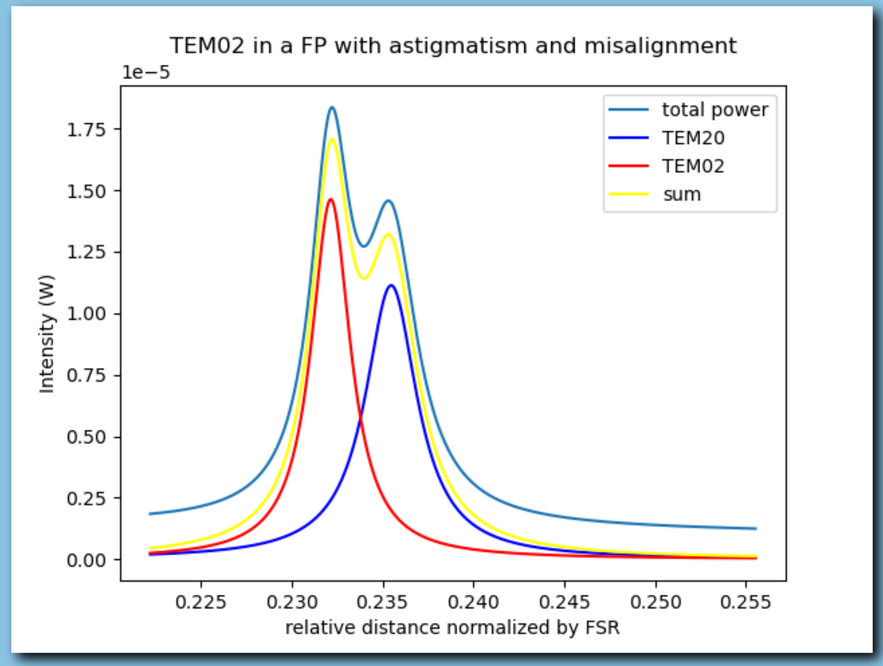
Step 3 : Simulate the limiting physical phenomenon such thermal effect

Utilisation of experimental data for simulation

Example : Astigmatism in the arm



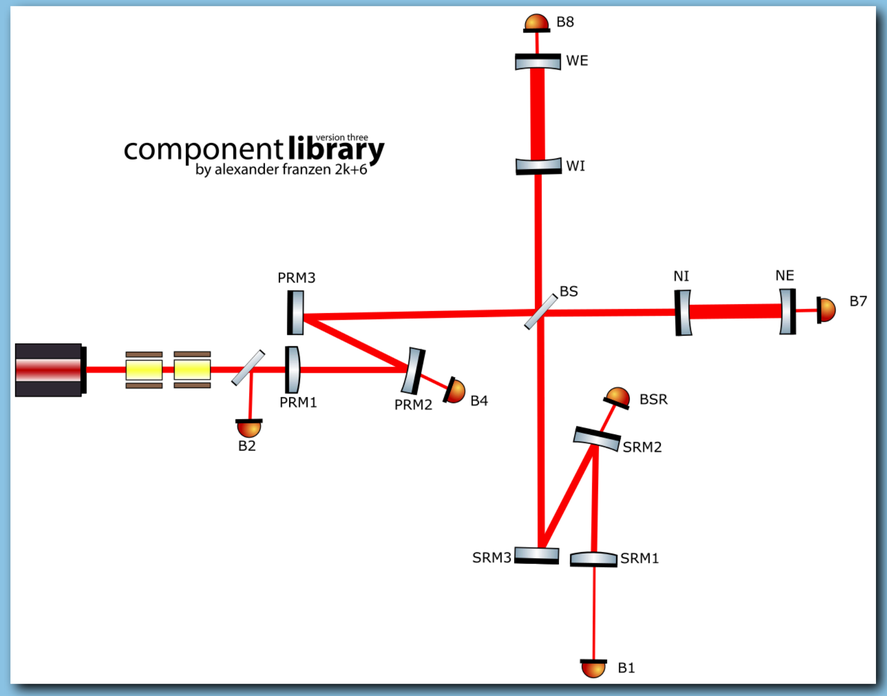
Use the experimental data to check if the simulation reproduces the interferometer



Astigmatism is observed in the arms of Virgo. In order to simulate Virgo precisely, astigmatism has to be implemented in the simulation. In the end comparison are made between the measurement and the simulation until we obtain a satisfying precision.

Future work

Simulation of the future optical layout



Future configuration of Virgo with stable recycling cavities.

In future run of Virgo, power laser will increase largely in order to increase the sensitivity.

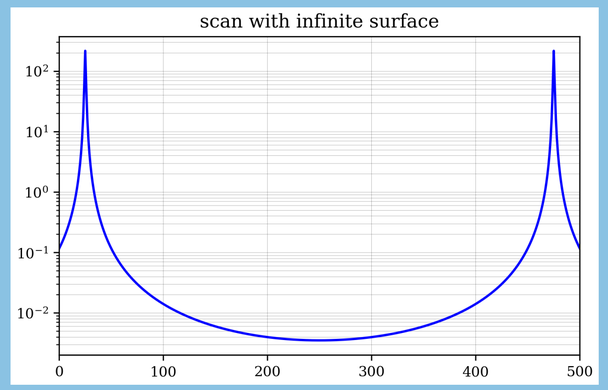
Anticipation of the effect triggered by the power enhancement need to be carried out carefully.

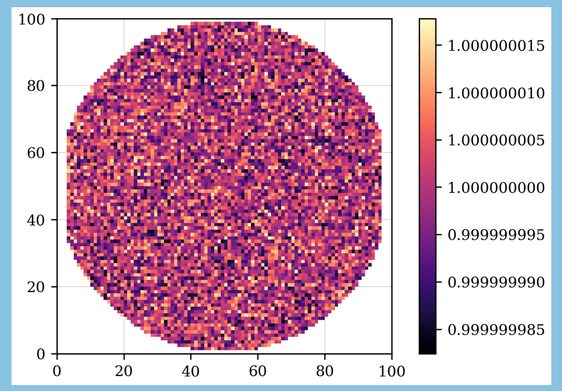
Finesse 3

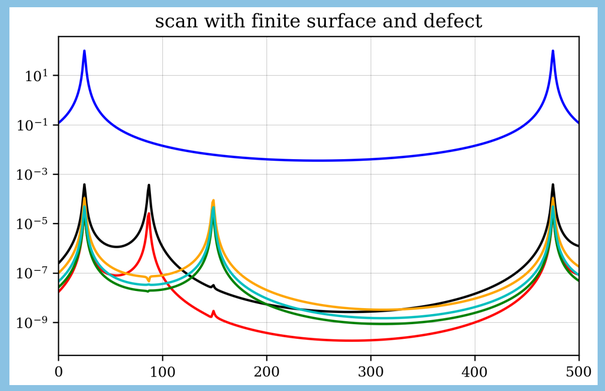
Once the current optical layout of Virgo is simulated with a satisfying precision, futur changes will be implemented in the simulation.

Future work

Mirror map, thermal effects and squeezed light.







- Here there is a simple example of a simulation of a Fabry-Perot cavity with and without a mirror map. Here adding small defect on the surface trigger Higher order modes. All the question will be how create a realistic mirror map of mirror that are not created yet, for precise simulation of stable recycling cavity for example.
- After improving the complexity of the simulation of the optical layout, the simulation of physical phenomenon can start. For exemple, the question on the impact of thermal effect and how it is related to optical defects can be studied.

Conclusion

- In the end, the aim is to obtain a precise and robust simulation.
  - Careful consideration need to be carried out concerning the requirement estimation in term of surface defect of the mirrors and thermal effect mitigation.
  - A previous work on the actual configuration is necessary in order to highlight what are the more sensible parameter in a finesse simulation when we want to produce a precise simulation of behavior of the interferometer.