FINESSE

Numerical Modelling for Optical Design and Commissioning

D. Töyrä[1], D. Brown[1], S. Cooper[1], A. Green[1], H. Wang[1], M. Wang[1], P. Fulda[2], A. Perreca[3], H. Miao[1], C. Mow-Lowry[1], A. Freise[1]

1 University of Birmingham, 2 University of Florida, 3 California Institute of Technology

dtoyra@star.sr.bham.ac.uk

LSC-Virgo Collaboration meeting, Pasadena, March 2016

www.gwoptics.org/finesse
www.gwoptics.org/pykat
aligo-finesse@ligo.org

Frequency domain INterferometer Simulation SoftwarE

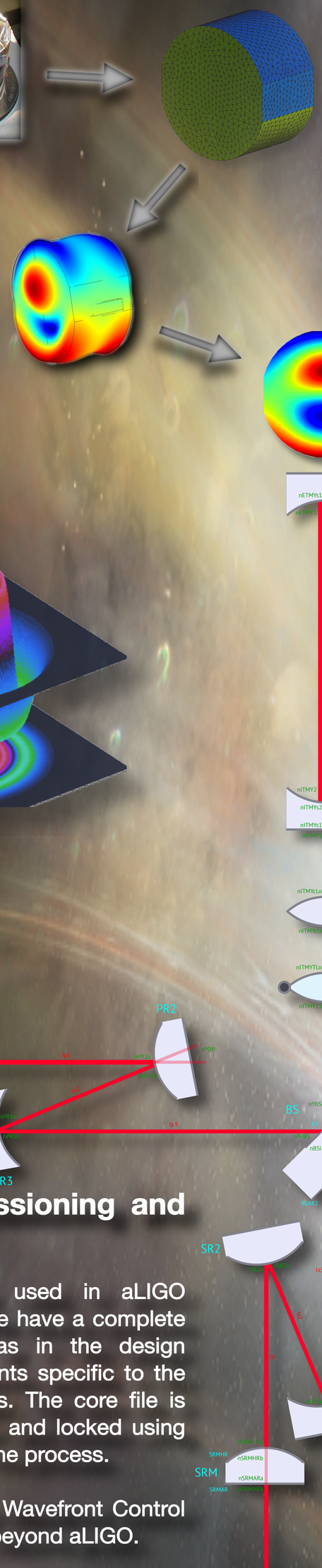
FINESSE is a frequency domain modelling tool for optical experiments, specialised at gravitational wave laser-interferometry. It is free and open source, released under the GPL license.

PyKat

PyKat is a free Python interface and set of tools for running FINESSE and for performing stand alone optical calculations. It is specialised for automating advanced optical simulations that involves multiple FINESSE runs.

FINESSE can simulate:

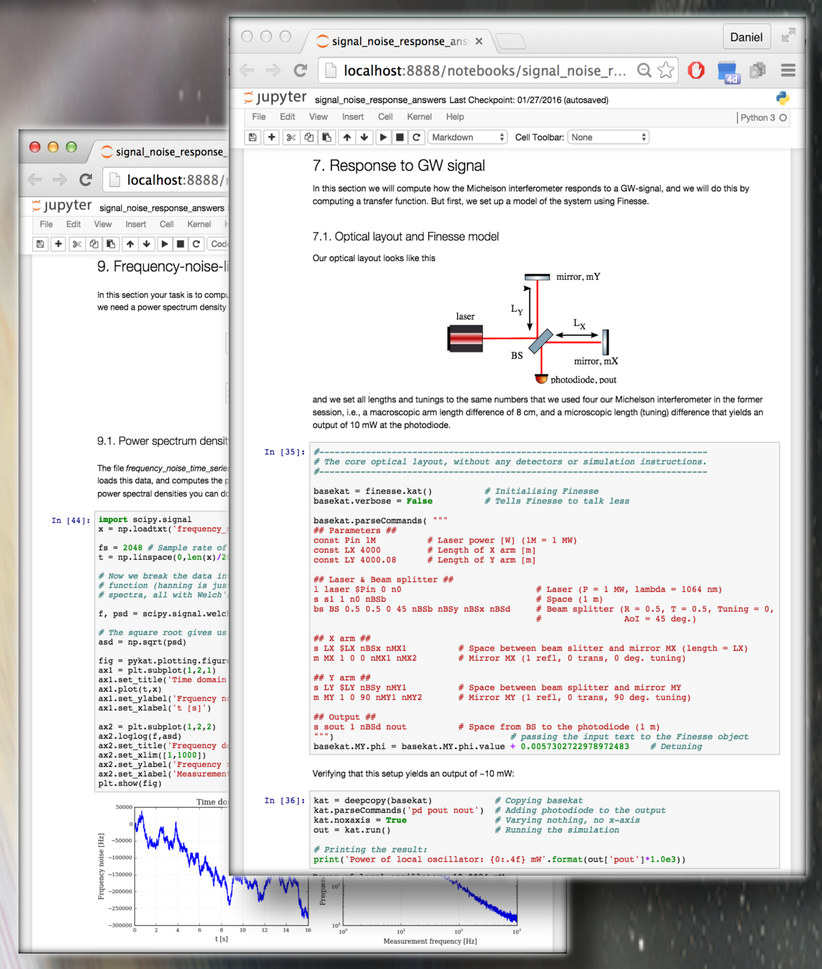
- Imperfect Beams
- Imperfect Optics
- Quantum Noise
- Squeezing
- Radiation Pressure Effects
- Parametric Instabilities
- Realistic Detectors



Online course on gravitational wave laser-interferometry

We offer a free online course on laser optics, FINESSE and PyKat, using Ipython Notebooks. The course is aimed at begginers, but also functions as reference material for advanced users. Ipython Notebook offers a new transparent way of presenting simulations and scientific results that we will use frequently in the time to come.

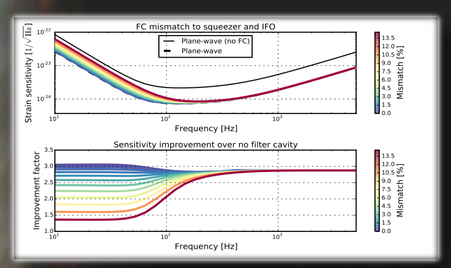
gwoptics.org/learn



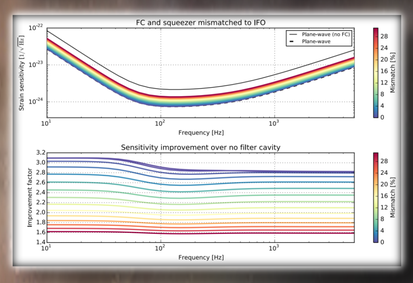
FINESSE in commissioning and design

Finesse is being actively used in aLIGO commissioning modelling. We have a complete file of the interferometer as in the design documents, as well as variants specific to the Livingston and Hanford sites. The core file is tuned to the operating point and locked using PyKat to automate much of the process.

We are also studying Active Wavefront Control (AWC) to improve detectors beyond aLIGO.



Quantum noise dependance on mismatches between filter cavity (FC), interferometer (IFO), and squeezer [2]. Here we looked at LIGO+ with a filter cavity [3] to produce frequency dependent squeezing. **Above**: The FC is mismatched to the squeezer and IFO, which are matched to each other. There is a clear improvement in sensitivity, which degrades for low frequencies with the mismatch. **Right**: FC and the squeezer are matched, but mismatched to the IFO. In this case we see a broad band drop in sensitivity.

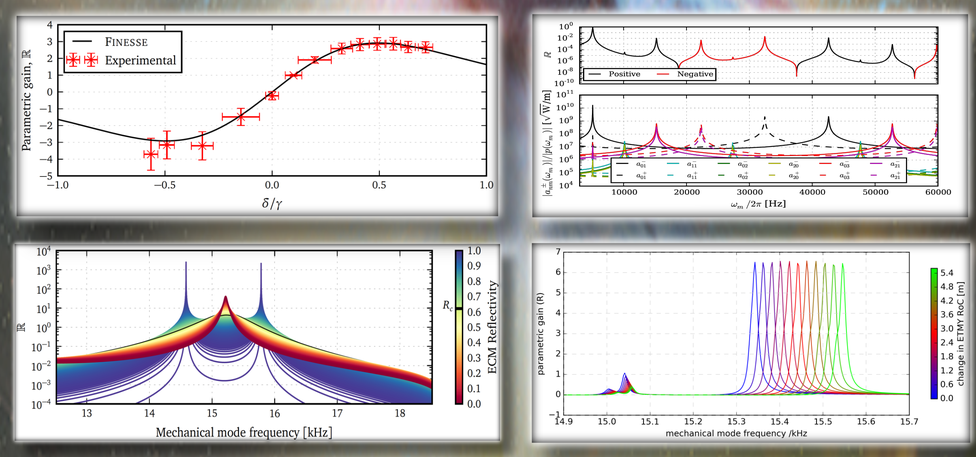


Parametric instability modelling

Parametric instability (PI) modelling been implemented in FINESSE, and this model has been successfully tested against the experimental results obtained by Corbitt *et al.* [1].

We have modelled PI for a LIGO arm using the mechanical mode thought to cause the PI seen in LIGO Livingston.

We are numericallly investigating ways of suppressing PI, currently by using an extraction cavity.



Upper left: Finesse model vs. the experiment by Corbitt et al. [1]. **Upper right:** Parametric gain in a model LIGO arm using the mechanical mode thought to cause PI in LLO, and the higher order modes thought to be involved. **Lower left:** Parameteric gain in a model LIGO arm with an added extraction cavity. **Lower right:** Parametric gain in an arm of an LLO model for different ETMY radii of curvature.

References:

[1] T. Corbitt *et al.*, *Phys. Rev. A* **74**, 021802 (2006)
[2] P. Fulda, *et al.*, dcc.ligo.org/LIGO-G1501039
[3] M. Evans *et al.*, *Phys. Rev. D* **88**, 022002 (2013)

Background picture courtesy:
Aurore Simonnet,
E/PO Sonoma State University

dcc.ligo.org/LIGO-G1600447