LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T060209-00-R *LIGO* October, 2006

User's manual for the AdVirgoFP package (arm cavity with high laser power) in e2e framework

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Distribution of this document:
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1 Introduction

This package consist in a Fabry-Perot cavity implemented in e2e framework : the parameters corresponds to Virgo-like arm parameters. Four directories are included in this package named «Boxes», «Data», «Figures» and «e2eBoxes». A *README.txt* file is included also.

1.1 Boxes

This directory containes the files .box used by e2e to run the program. The main box is called *AdVirgoFP.box* and it is shown in Figure (1).

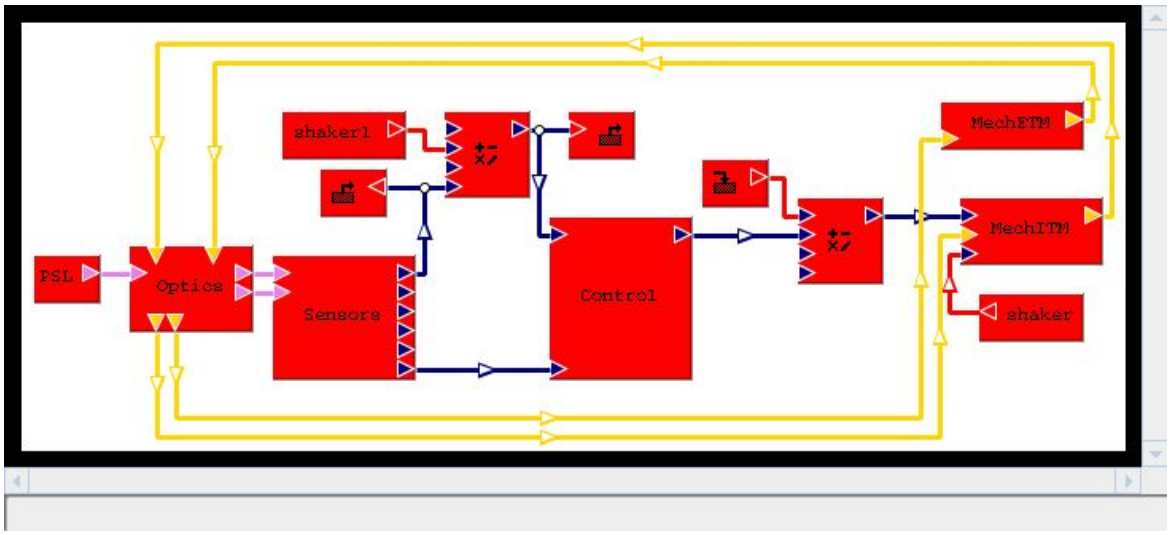

Figure 1 : AdVirgoFP.box

The *AdVirgoFP.box* includes the most important subsystems of the configuration:

- the *PSL.box*, including the laser;
- two shakers are inserted: *shaker* is used to simulate the optical response of the cavity and *shaker1* is used to simulate the open loop transfer function of the cavity.
- the core optics of the cavity is included in *Optics.box* shown in Figure (2) : a simple Fabry-Perot cavity is implemented ; the radiation pressure is added on the input mirror (ITM) and the end mirror (ETM) and a power meter has been added to monitor the arm cavity power;

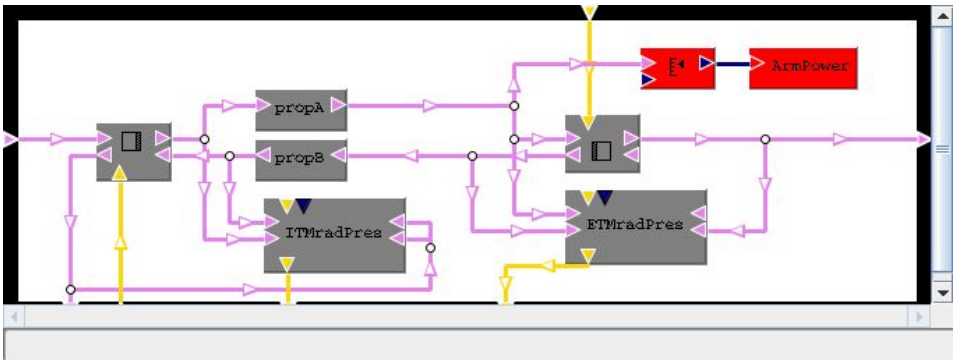

Figure 2 : Fabry-Perot cavity: Optics.box

- the photo-detectors are implemented in the *Sensors.box* file: there are detectors for the monitoring of the REFL_I and REFL_Q, i.e the reflected signal for the in-phase and the quadrature and TRANS_I and TRANS_Q, i.e the transmitted signal for the in-phase and the quadrature;
- the control system is implemeted in *Control.box* : the control system uses the REFL_I signal and it acts on the input mirror of the cavity;
- the suspensions for the two mirrors are included in *MechITM.box* and *MechETM.box* : each mirror has a dedicated box, but the setting is pretty similar. Figure (3) shows the suspension for the input mirror of the cavity (*MechITM.box*) including the connections to the control system. In this configuration the suspension is made just by a simple pendulum (7m long). Each suspension can be affected by seismic noise and radiation pressure force. The total force is sent to the mirrors to move them with a differential motion.

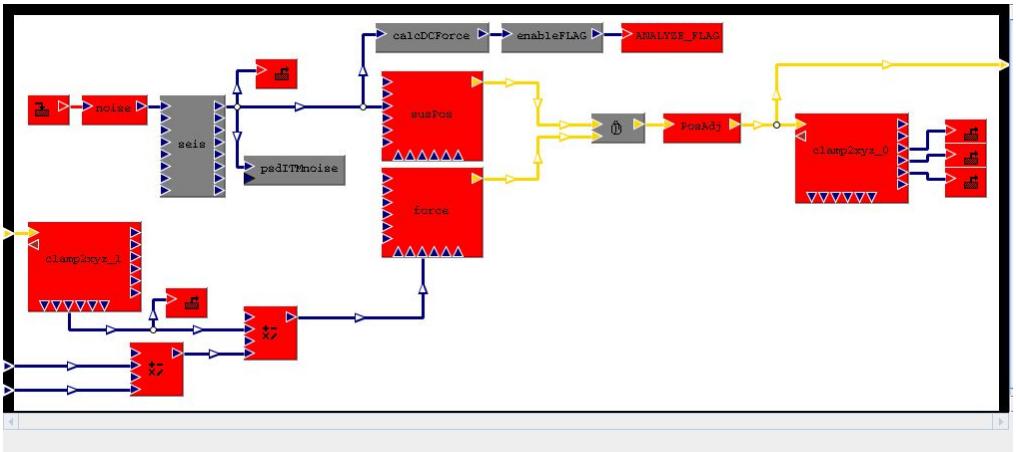

Figure 3 : Suspensions (MechITM.box)

The «Boxes» directory contains also the macro files *e2eDB.mcr* where the general parameters of the arm cavity are defined. It is possible to change most of the parameters using this macro. There are also some parameters files (.par) including values which need to change during a simulation: it is possible that some values are not fixed and need to change all along the simulation. For instance, *Lock.par* sets parameters for the simulation of the lock acquistion of the cavity in the time domain and *NoSeism.par* (no seismic noise included) sets parameters for the simulation of the optical response of the cavity (the transfer function from the input mirror positions to the error signal REFL_I) in the frequency domain.

In addition there are some input files (.in) to let run a simulation with defined options: in this way the user is not obliged to type a series of options before starting a simulation; it is worth to note that the input file for *modeler* and *modeler_freq* has different options. *Lock.in* is used to run *modeler* and uses the *Lock.par* file. *OptRespRad.in* is used to run *modeler_freq* and uses the *NoSeism.par* file. Finally, the directory «e2eBoxes» is automatically created when the simulation runs.

1.2 Data

This directory contains some results obtained with this package :

- The *Lock200Wseism.dat* data file is a simulation of 2s showing how the lock is aquired in the cavity using « modeler »: the initial velocity of the two mirrors when they are swinging is $10^{\wedge -6}$ m/s. The laser power is 200W and the radiation pressure acts on both the mirrors. The file *Lock.in* has to be used to repeat the simulation. The *Lock200Wseism.dhr* contains the names of all the ouput channels.
- The *ETMnoise.psd.dat* data file corresponds to the PSD of the seismic noise acting on the end mirror (ETM). This file is automatically created when the simulation with *modeler* or *modeler_freq* runs.
- The *OptResp.dat* data file is the simulation of the optical response of the arm cavity. The file *OptRespRad.in* has to be used to repeat the simulation. The *OptResp.dhr* contains the names of all the ouput channels.
- The *OptRespOL.dat* data file is the simulation of the open loop transfer functions of the arm cavity. The file *OptRespRadOL.in* has to be used to repeat the simulation. The *OptRespOL.dhr* contains the names of all the ouput channels.

1.3 Figures

This directory containes some figures corresponding to the described data files :

- The *Lock200Wseism.jpg* file corresponds to Figure (4) and shows the cavity power, the REFL_I error signal and the control signal during the lock acquisition of the cavity. The other channels can be plotted referring to the *Lock200Wseism.dhr* file where all the outputs are listed.

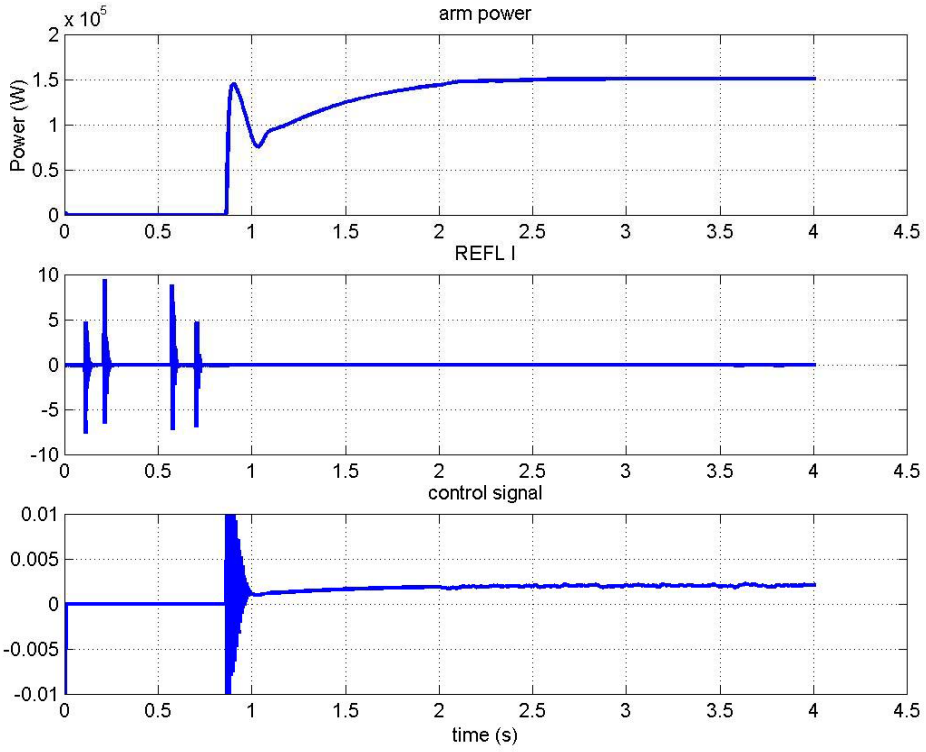

Figure 4 : The arm cavity power, the error signal and the control signal during the lock acquisition phase (between 0s and 2s) and during in-lock time (>2s).

- The *Lock200Wseism2.jpg* file corresponds to Figure (5) and shows the cavity power, the radiation pressure and the positions for the two mirrors during the lock acquisition of the cavity. The other channels can be plotted referring to the *Lock200Wseism.dhr* file where all the outputs are listed.

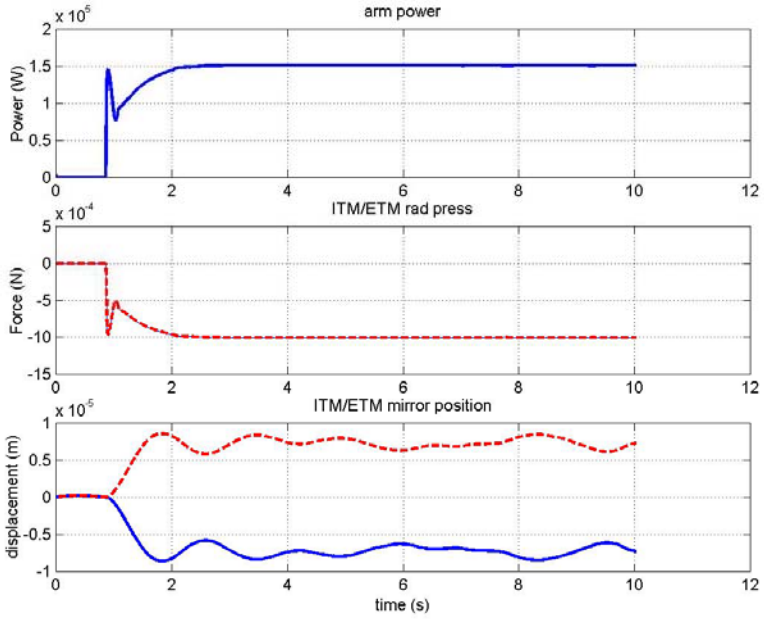

Figure 5 : The arm cavity power, the radiation pressure and the mirror positions during the lock acquisition time (between 0s and 2s) and during in-lock time (>2s).

- The *ETMnoise.jpg* corresponds to Figure (6) and shows the Power Spectral Density (PSD) of the seismic noise injected on the end mirror (ETM).

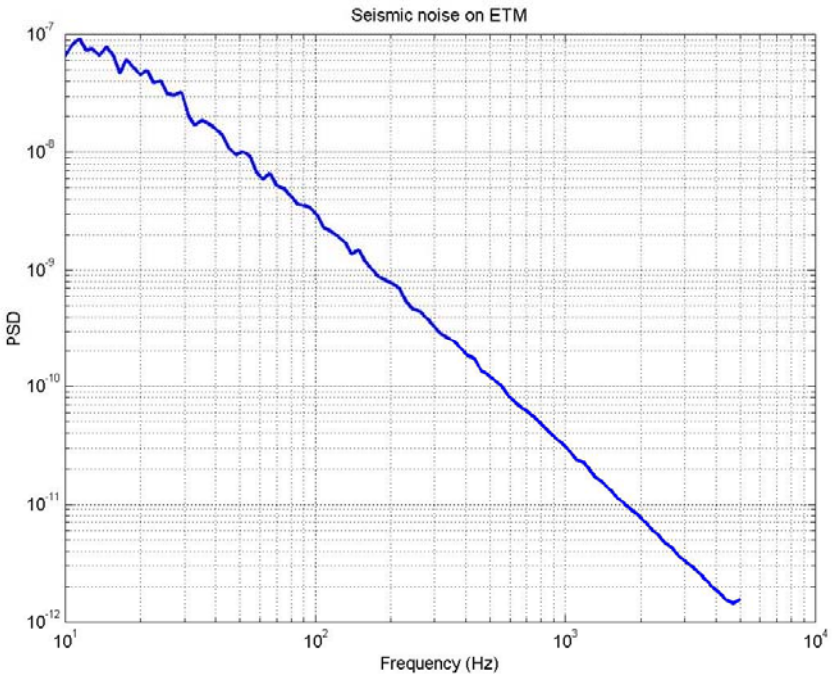

Figure 6 : Power Spectral Density of the seismic noise on ETM

- The *OpticalResponse.jpg* figure (Figure (7)) shows the optical response of the cavity obtained using the data file *OptResp.dat/.dhr* (i.e. transfer function simulation with radiation pressure on both the mirrors and control system on) compared to the data file *OptRespNoRadNoControl.dat/.dhr* (transfer function simulation without radiation pressure and control system). The file *OptRespRad.in* has to be used to run the simulation.

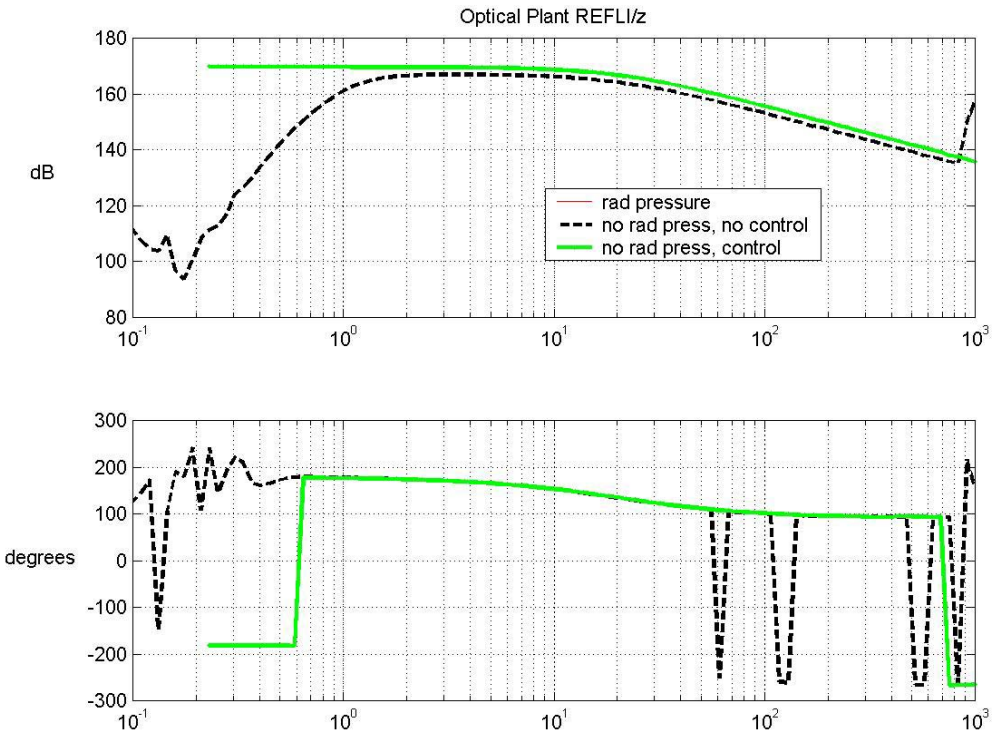

Figure 7 : Arm cavity optical response comparison without control and without radiation pressure, with control and without radiation pressure, with control and radiation pressure.

- The *OpenLoop.jpg* figure (Figure (8)) shows the open loop transfer function of the cavity obtained using the data file *OptRespOL.dat/.dhr* (i.e. transfer function simulation with radiation pressure on both the mirrors and control system on). The file *OptRespRadOL.in* has to be used to run the simulation.

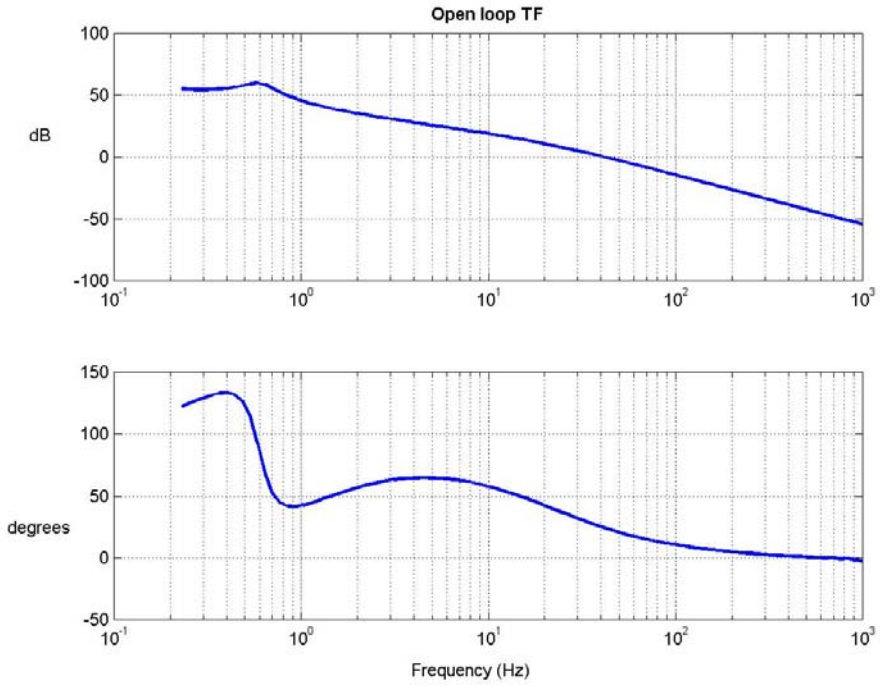

Figure 8 : Open loop Transfer function

2 How to use the existing data

To plot the time series data obtained with *modeler* one has to refer to the *Lock200Wseism.dat* file and the *Lock200Wseism.dhr* file where all the output channels are listed.

In order to plot the *Lock200Wseism.dat* file in MATLAB type the following

```
e2edataTime = load('Lock200Wseism.dat');
plot(e2edataTime( :,1),e2edataTime( :,2))
```

changing the ouput according to the channel you want to see.

To plot the data file obtained with *modeler_freq* one has to refer to the *OptResp.dat* and the *OptResp.dhr* files where all the output channels are listed. The transfer function from the displacement to the error signal is obtained with the ratio of the two output calculated by *modeler_freq*.

To plot the data file *OptResp.dat* for instance in MATLAB type the command line

```
e2edataFreq = load('OptResp.dat');
subplot(2,1,1),loglog(e2edataFreq( :,1),e2edataFreq( :,4)./e2edataFreq( :,2))
subplot(2,1,2),semilogx(e2edataFreq( :,1),(e2edataFreq( :,5)-e2edataFreq( :,3))*180/pi)
```

where the channels are defined in the *OptResp.dhr* file. The *OpticalResponse.jpg* figure shows the optical response.

The package can simulate also the Power Spectral Density (PSD) of the seismic noise acting on the end mirror (ETM) and the correspondent data file is *ETMnoise.psd.dat*. This file is automatically created when the simulation with *modeler* or *modeler_freq* runs and the default name is *AdVirgoFP.MechETM.psdETMnoise.psd.dat* (the same thing can be done for the input mirror (ITM) injecting noise on this mirror and choosing the right channel).

To plot the data file *ETMnoise.psd.dat* for instance in MATLAB type the command line

```
e2edataPSD = load('ETMnoise.psd.dat');
loglog(e2edataPSD(1,:),sqrt(e2edataPSD(2,:)))
```

when there is just one average or

```
loglog(e2edataPSD(1,:),mean(sqrt(e2edataPSD(2:end,:))))
```

when there is more than one average.

3 How to run the package

This paragraph describes how to run a simulation with *modeler* in the time domain and with *modeler_freq* in the frequency domain.

3.1 To run the simulation of the lock acquisition with *modeler* the *Lock.in* and *Lock. par* files are needed, then one can type this command line

```
cat Lock.in -| modeler –viewerOFF –thread –bin
```

3.2 To run the simulation of the optical response of the cavity with *modeler_freq* the *OptRespRad.in* and the *NoSeism.par* files are needed, then type this command line

```
cat OptRespRad.in -| modeler_freq –viewerOFF –thread –bin
```

References

- e2e website : http://www.ligo.caltech.edu/~e2e/
- the package location is on the e2e website http://www.ligo.caltech.edu/~e2e/ in the section Examples.