Graphical user interface for Finesse simulation tool

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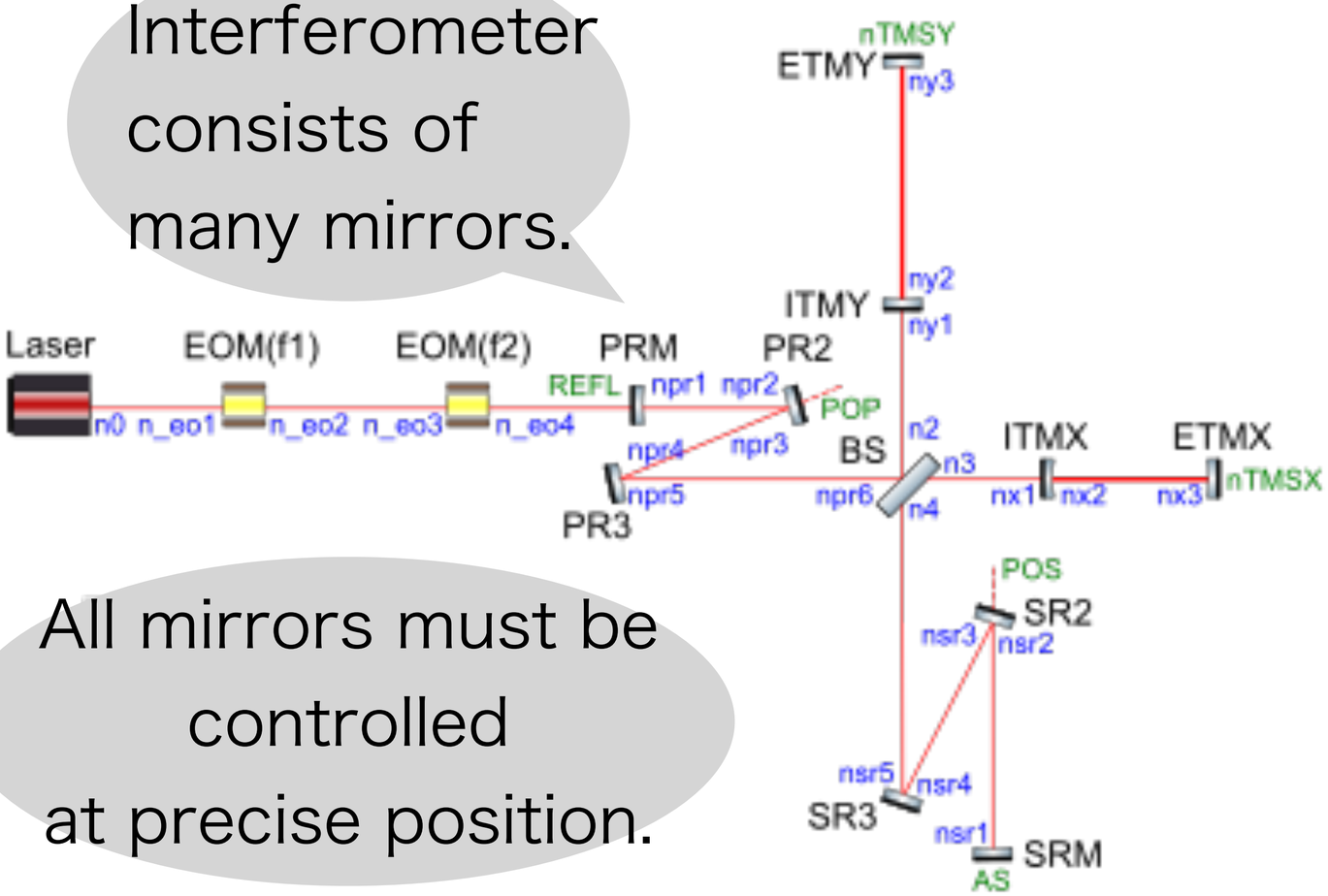
Introduction

Interferometer consists of many mirrors.



All mirrors must be controlled at precise position.

→ **Lock**

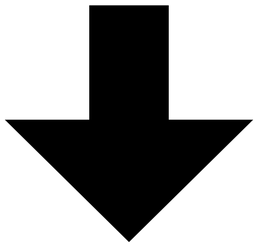
- **DARFPMI**
  (Dual Recycled Fabry-Perot Michelson Interferometer)
- The interferometer has 5 **DoF** (Degrees of Freedom) in length to be controlled.

5 DoF
- DARM
- CARM
- MICH
- PRCL
- SRCL

Motivation

- KAGRA has not yet achieved full DRFPMI locking.

  There is a demand for a tool to support the commissioning of full locking.



visually easy to use

We developed **GUI** for simulation tool.

Finesse (Frequency domain INterfErometer Simulation SoftwarE)

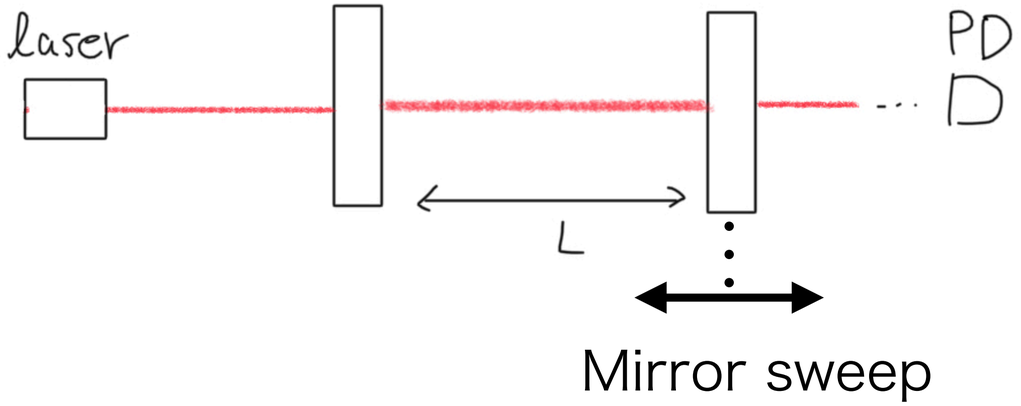
Kat format file

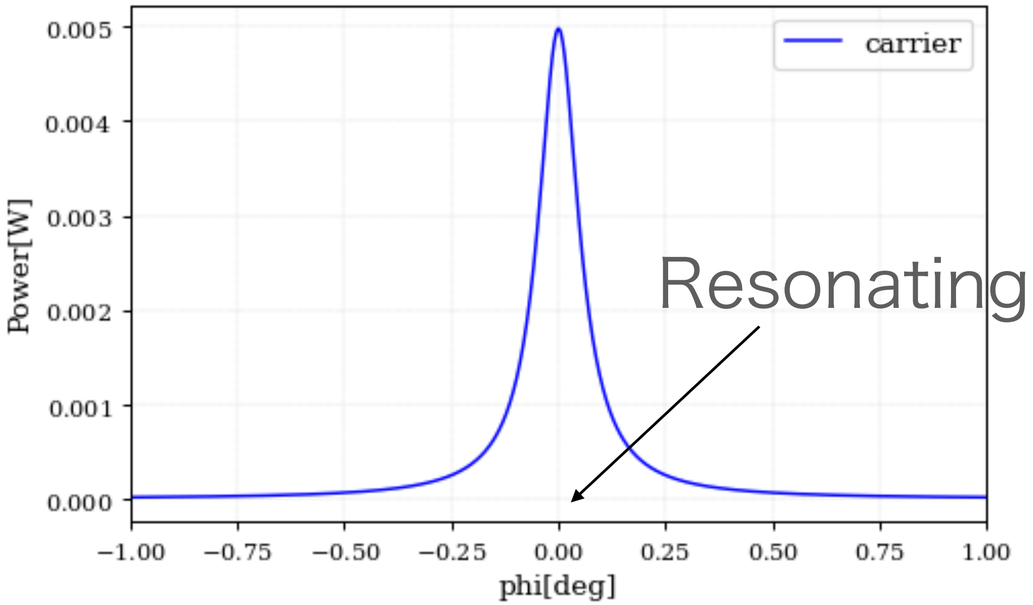
```
# DRFPMI
#
# ======== Input optics ====================
l i1 1 0 n0
s s_eo0 0 n0 n_eo1
mod eom1 $fsb1 0.3 3 pm n_eo1 n_eo2
s s_eo1 0 n_eo2 n_eo3
mod eom2 $fsb2 0.3 3 pm n_eo3 n_eo4
s s_eo2 0 n_eo4 REFL

## ======= PRC each mirror loss $prc_loss =======
# PRC
m1 PRM 0.1 4.5e-05 0 REFL npr1
s sLpr1 14.7615 npr1 npr2
bs1 PR2 0.0005 4.5e-05 0 $a npr3 npr2 POP POP2
s sLpr2 11.0661 npr3 npr4
bs1 PR3 5e-05 4.5e-05 0 $a dump dump npr4 npr5
s sLpr3 15.7638 npr5 npr6

# ======= Michelson =======
bs1 MIbs 0.5 0 0 45 npr6 n2 n3 n4
s lx 26.6649 n3 nx1
s ly 23.3351 n2 ny1

# X arm
m1 ITMX 0.004 0 0 nx1 nx2
s sx1 3000 nx2 nx3
m1 ETMX 5e-06 0 0 nx3 nTMSX
```

- We can use the tool called **Finesse**.
- Finesse is an interferometer simulation program.
- This tool calculates ISC signals in our specified interferometer configuration (**Kat format file**).
- kat format is Finesse's own format for reading configuration file.

Finesse (Frequency domain INterfErometer Simulation SoftwarE)

Example) Fabry-Perot resonator





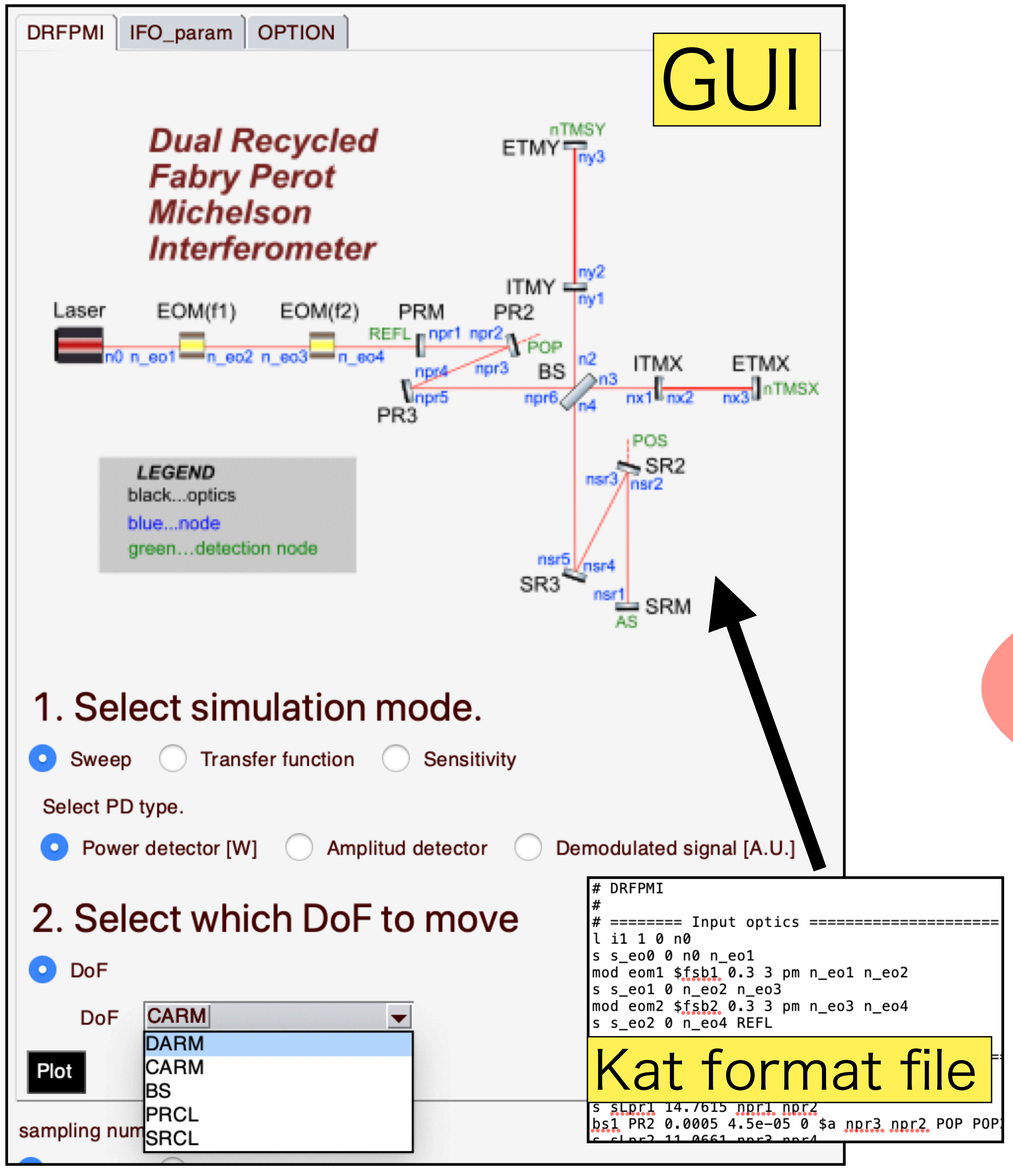
Plotting the transmitted light while sweeping microscopic mirror position of a Fabry-Perot resonator.

When the mirror is moved, the laser does not resonates and the transmitted light of the cavity is reduced.

Advantage of developed GUI

- **Previously**
  - We need to know the syntax of Finesse because the configuration file is created in Kat format.
  - We have to verify the correctness of the created models individually when we create our own interferometer models for simulation.
- **What we did**
  - We developed GUI.
    - We do not have to know the syntax of Finesse using this GUI.
  - We verified the correctness of created configuration file.
    - We've included the checked model for use in the GUI. (Chiaki's talk)

Advantage of developed GUI



We select

- DoF to move
- Ports to put PDs

visually easy to select

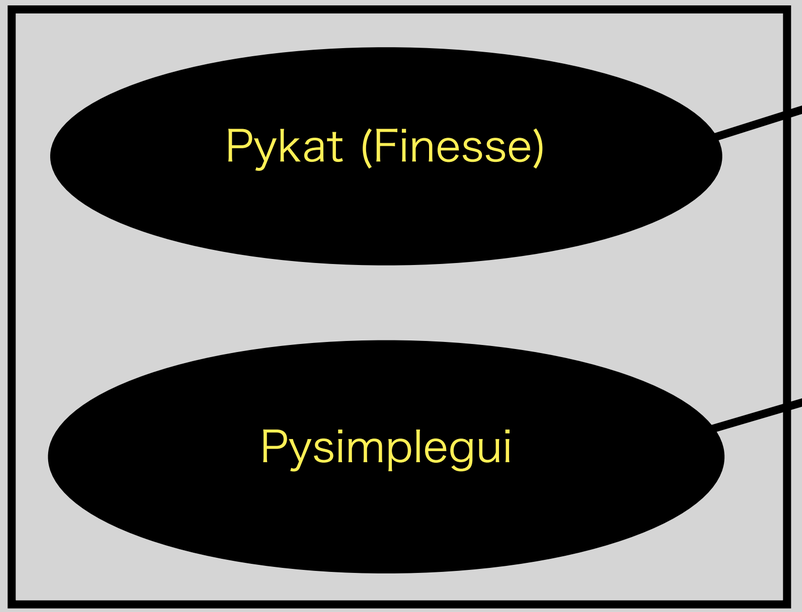
Fast

Speeding up the commissioning process

Development environment

Anaconda

Tools to manage python packages for **Windows**, **Mac** and **Linux**.



Installed using Anaconda

- This GUI works in **python**.

  → GUI works in **Windows**, **Mac**, **Linux**.

- **pykat (Finesse)**
  A package for python that allows Finesse to be used in python.
- **Pysimplegui**
  A python package for creating GUIs.
  (A wrapper for Tkinter that makes it easier to use.)

Features of GUI

1. Making GUI for Simulation modes

   - **sweep**
     we can see **power**, **amplitude** and **demodulated signal**.

   - **Transfer Function**
     we can see **transfer functions** of each modulation frequency components.

2. Making GUI for changing optical parameters

3. Export results

Power detector

1. Select simulation mode.

Sweep Transfer function

Select PD type.

Power detector [W] Amplitud detector Demodulated signal [A.U.]

no advanced settings

REFL AS POP TMSY TMSX POS

n0 n_eo1 n_eo2 n_eo3 n_eo4

npr1 npr2 npr3 npr4 npr5 npr6

nsr1 nsr2 nsr3 nsr4 nsr5

n2 n3 ny1 nx1 ny2 nx2 ny3 nx3

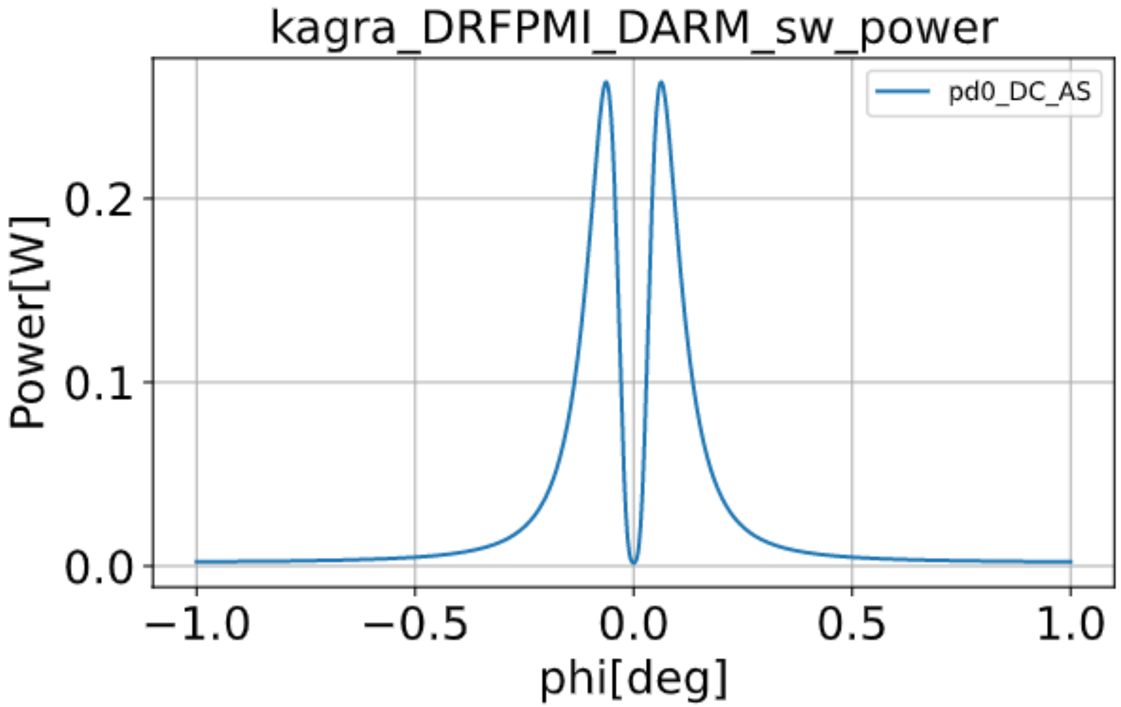
2. Select which DoF to move

DoF DARM

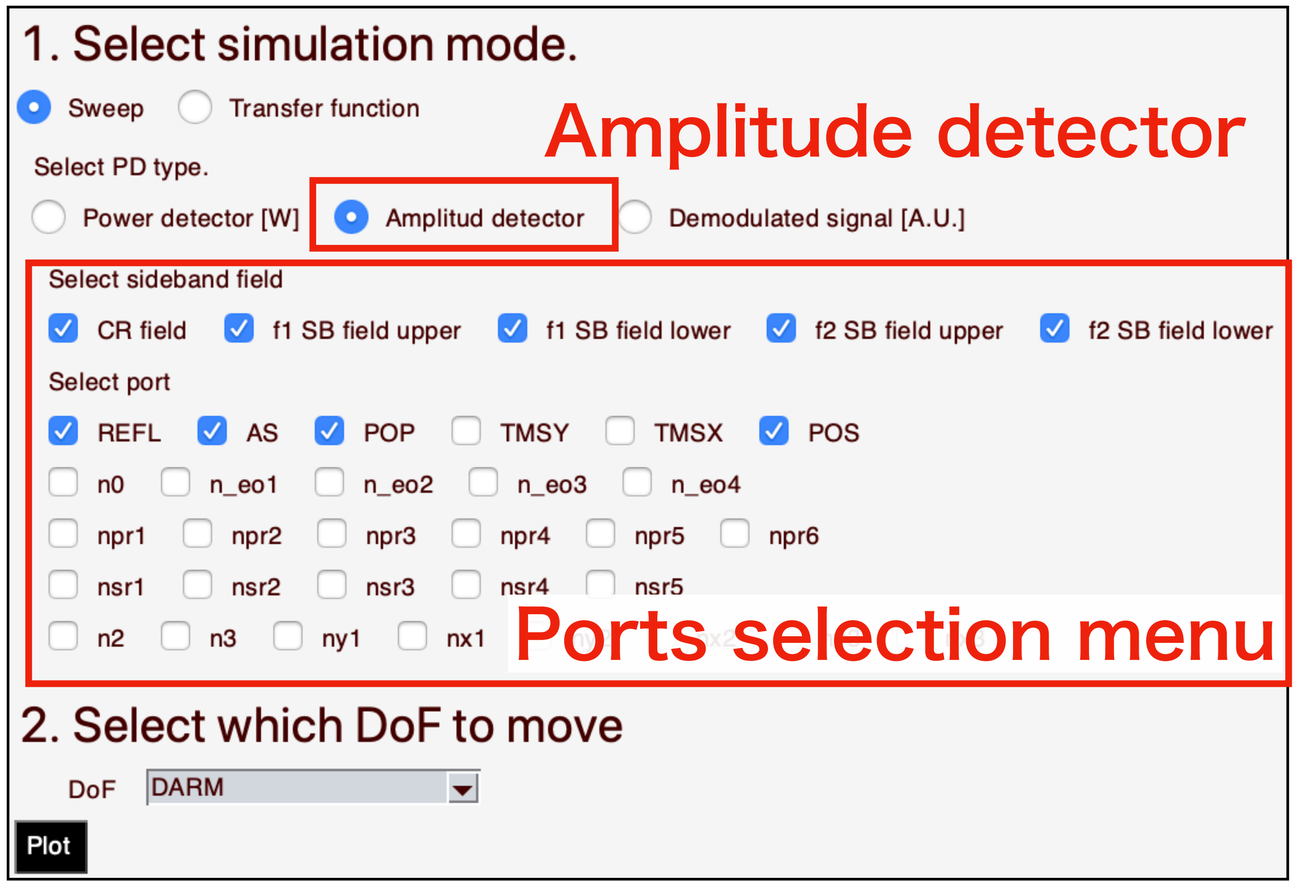
Plot

Ports selection menu

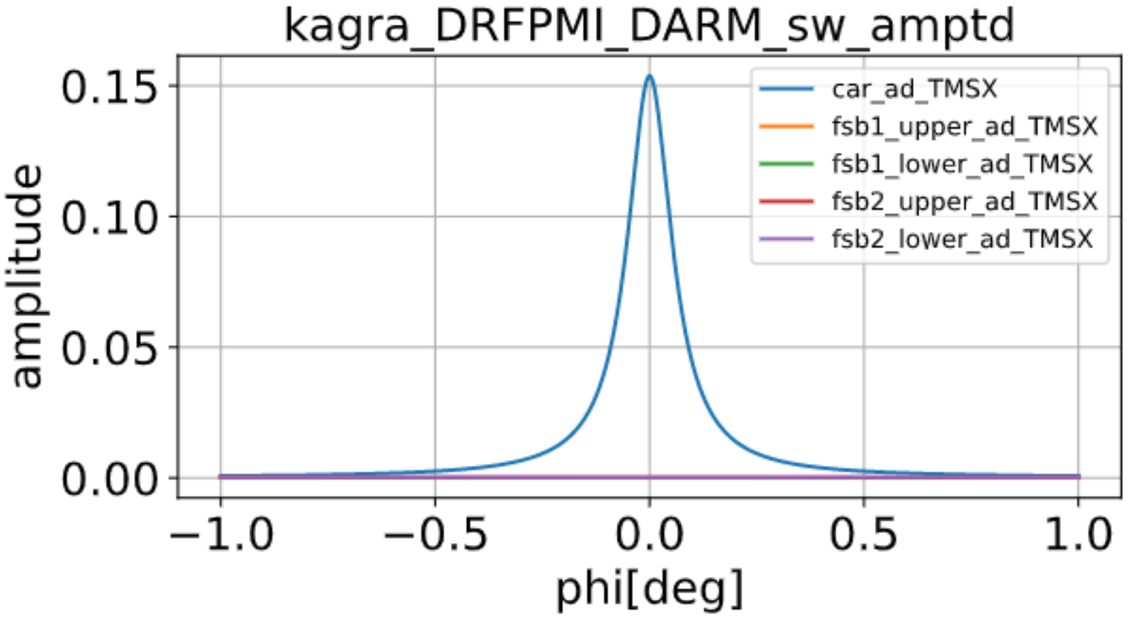
The DoF setting to sweep is **DARM** and the selected port is only **AS.**



Amplitude detector



The DoF setting to sweep is **DARM** and the selected ports are **TMSX.**



“**Carrier**”, “**f1 upper**”, “**f1 lower**”, “**f2 upper**” and “**f2 lower**” sideband fields are selected.

Demodulated signal

1. Select simulation mode.

Sweep Transfer function

Select PD type.

Power detector [W] Amplitud detector Demodulated signal [A.U.]

if select "plot separately", pd results displayed all separately.

overplot selected port output plot separately

Which phase to plot?

select "port", "demodulation frequency", "demodulation phase" - +

01	port =	REFL	demod freq =	fsb1	demod phase =	Iphase
02	port =	REFL	demod freq =	fsb1	demod phase =	Qphase
03	port =	AS	demod freq =	fsb1	demod phase =	Iphase
04	port =	AS	demod freq =	fsb1	demod phase =	Qphase

select option from list or input number directly

2. Select which DoF to move

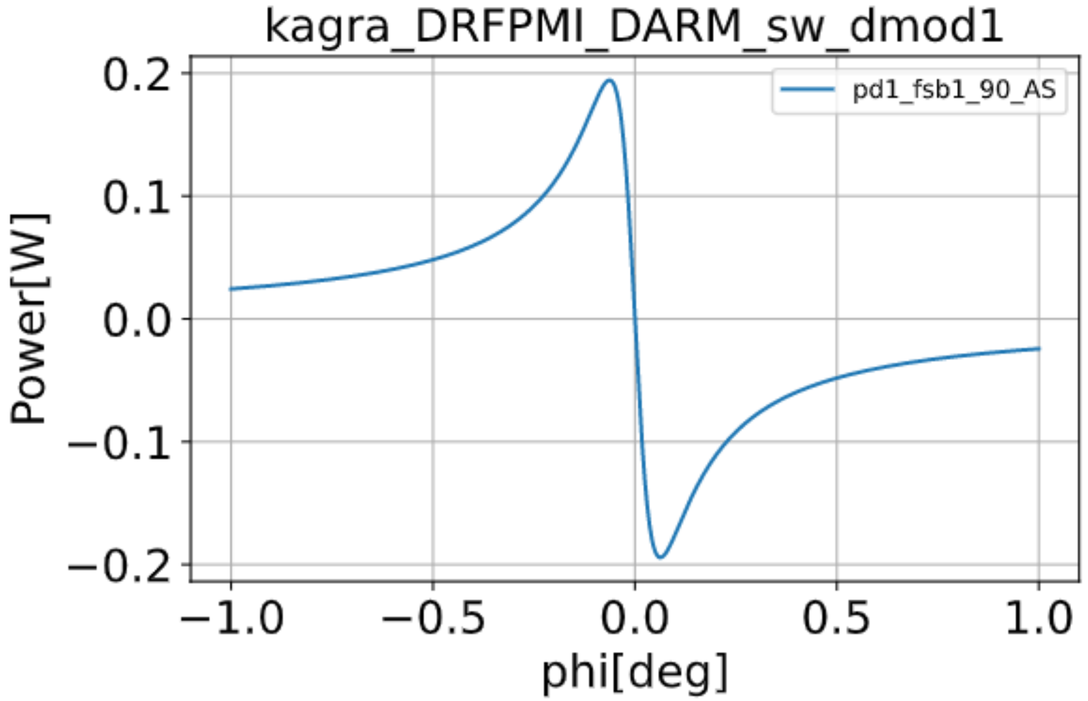
DoF DARM

Plot

additional setting menu

- Port
- Demodulation frequency
- Demodulation phase

The DoF setting to sweep is **DARM** and the selected ports are **AS**.



Demodulation frequency is **16.881 MHz** and demodulation phases is **Qphase**.

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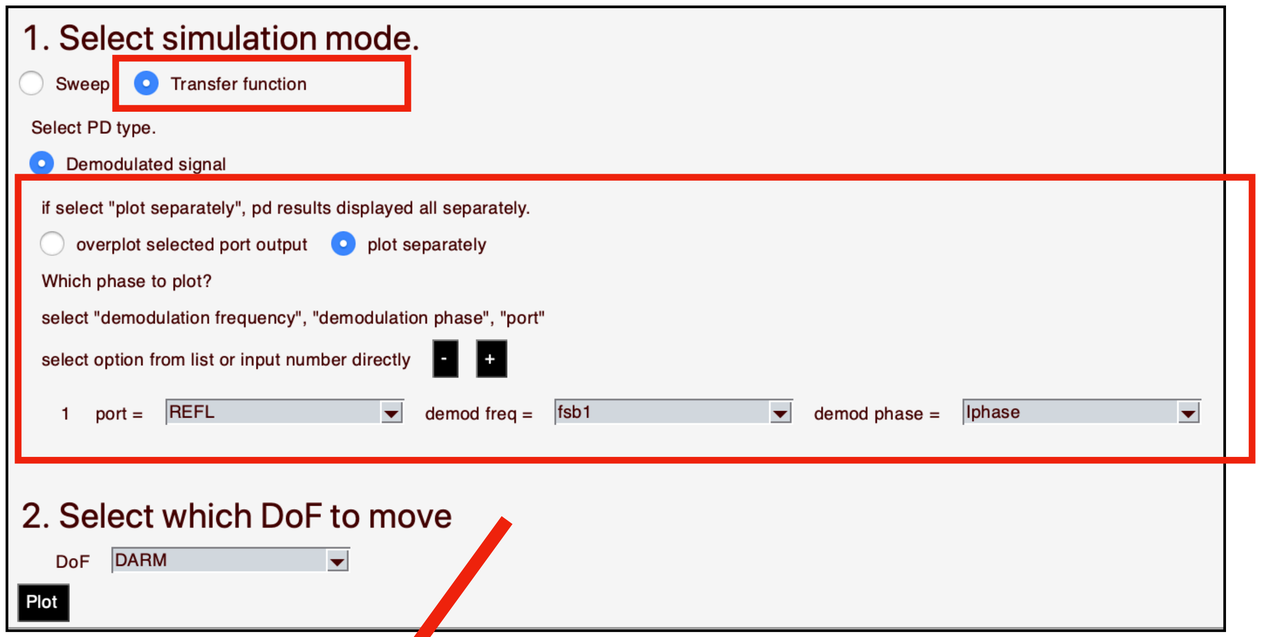
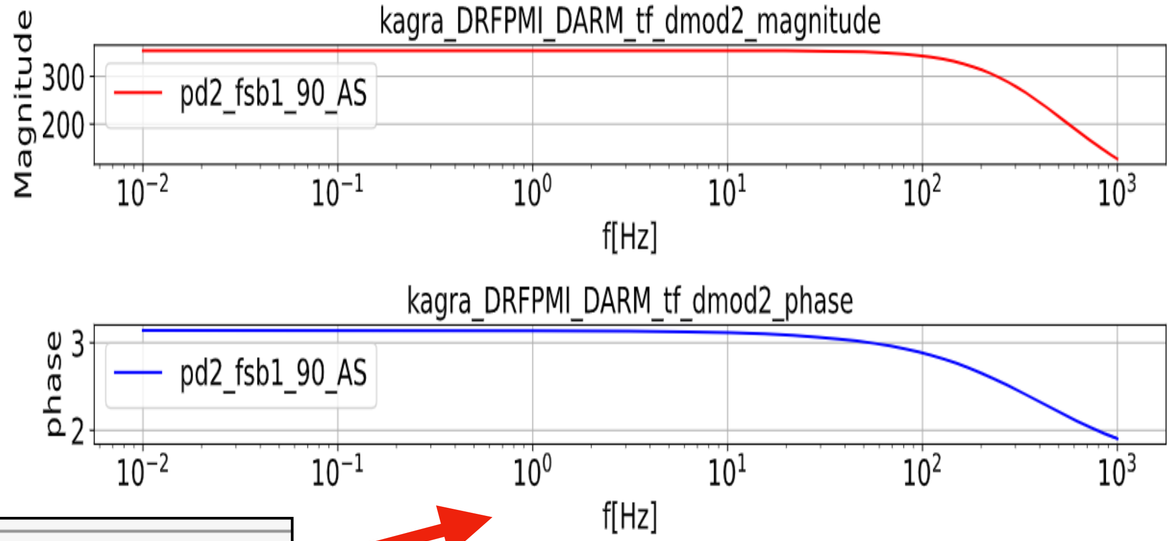
2. Making GUI for changing optical parameters

3. Export results

Transfer function

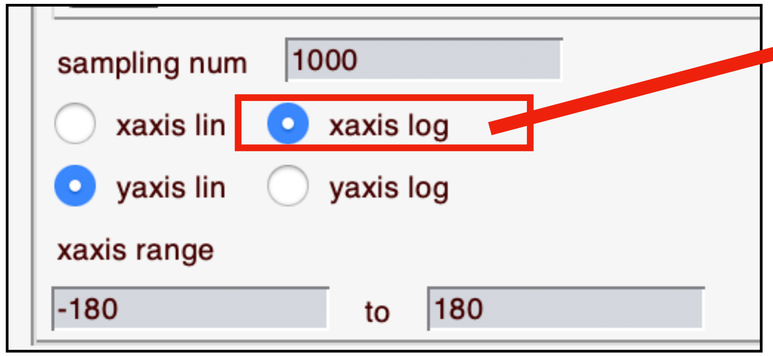


The DoF setting to sweep is "**DARM**" and the selected ports are **AS**.



additional setting menu

- Port
- Demodulation frequency
- Demodulation phase



Demodulation frequency is **f1**.
Demodulation phase is **Iphase**.

Features of GUI

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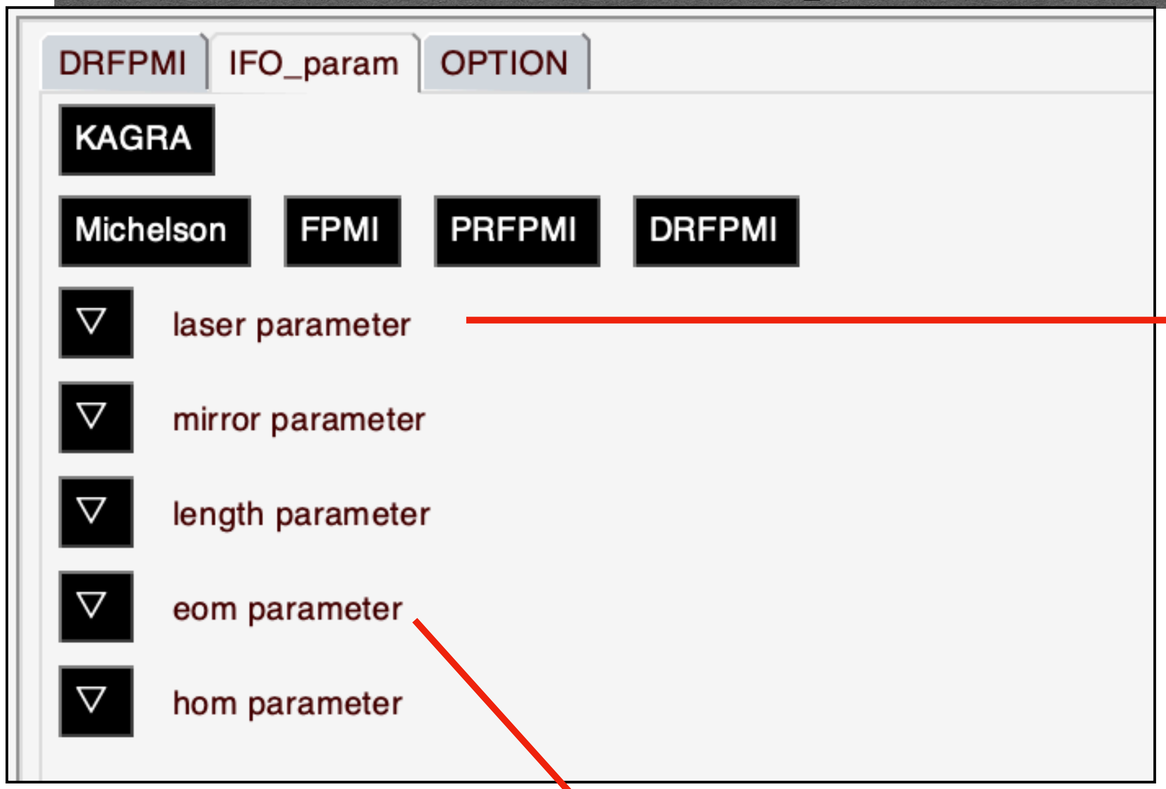
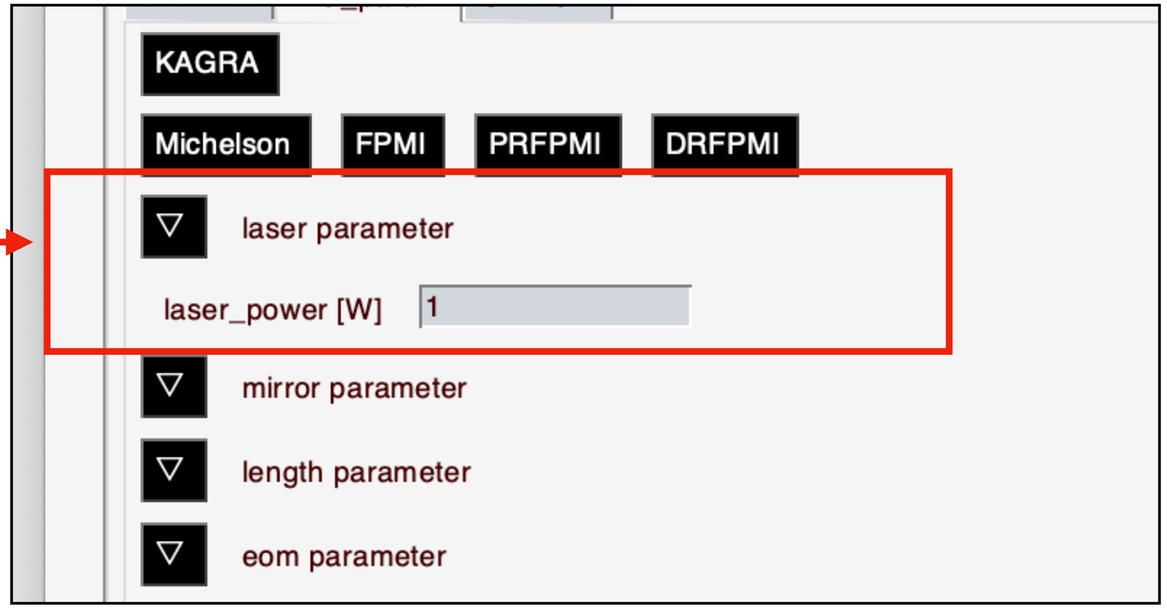
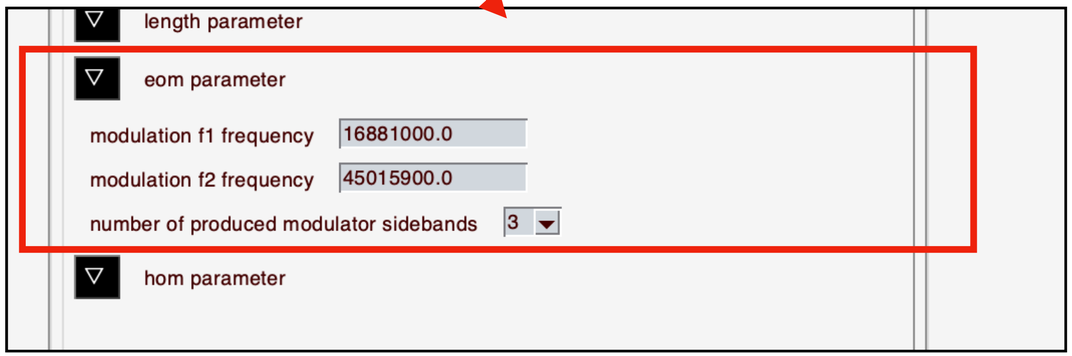
Parameter option







When option checkbox selected,
Additional menu appear.

Parameter option

laser parameter

mirror parameter

note: Reflectance and transmittance are values between 0 and 1.

BS

BS mirror power transmittance 0.5

BS mirror power loss 0

load mirror map file?

length parameter

length PR3-BS 15.7638

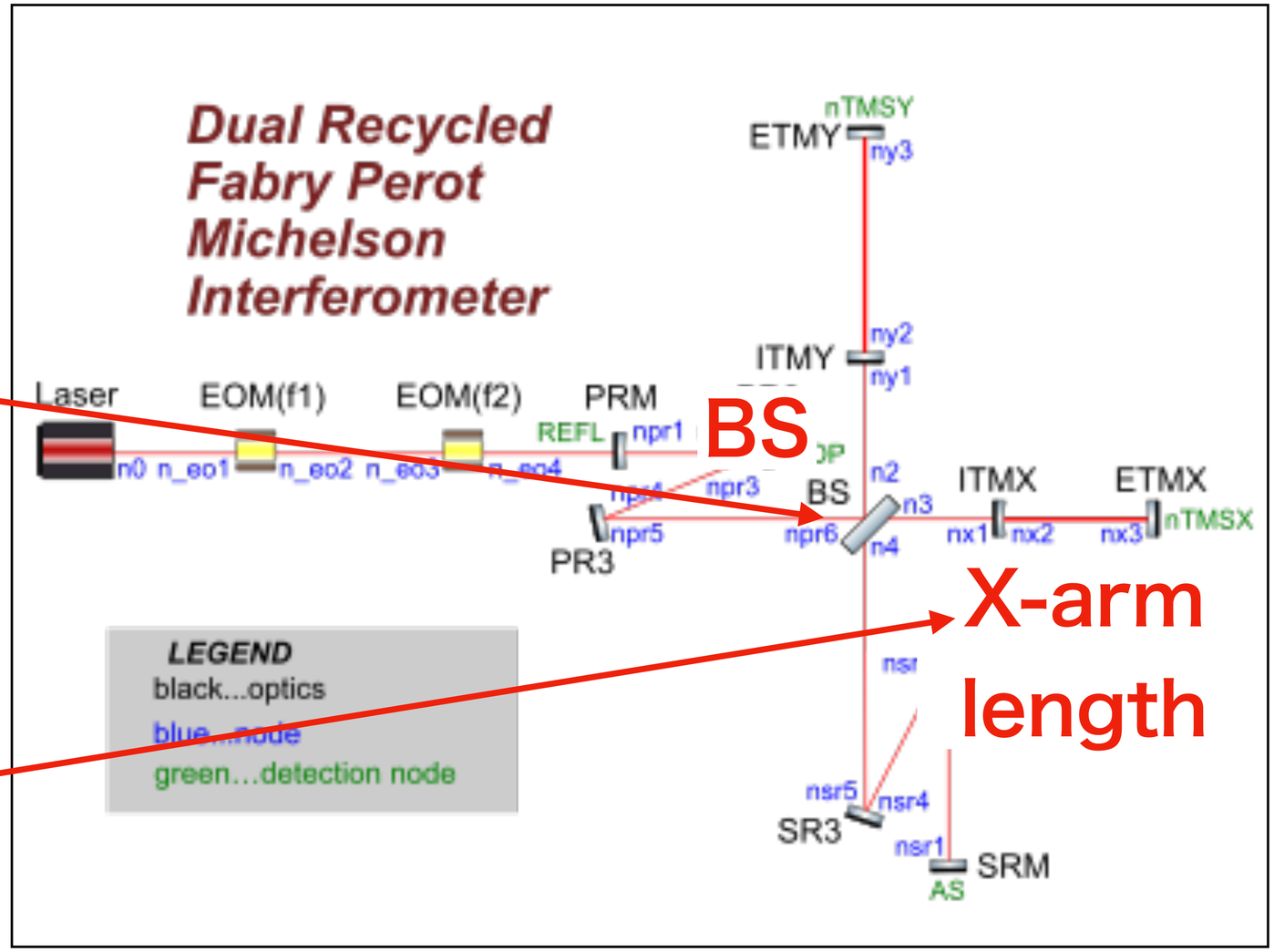
length BS-ITMX 26.6649

length ITMX-ETMX 3000

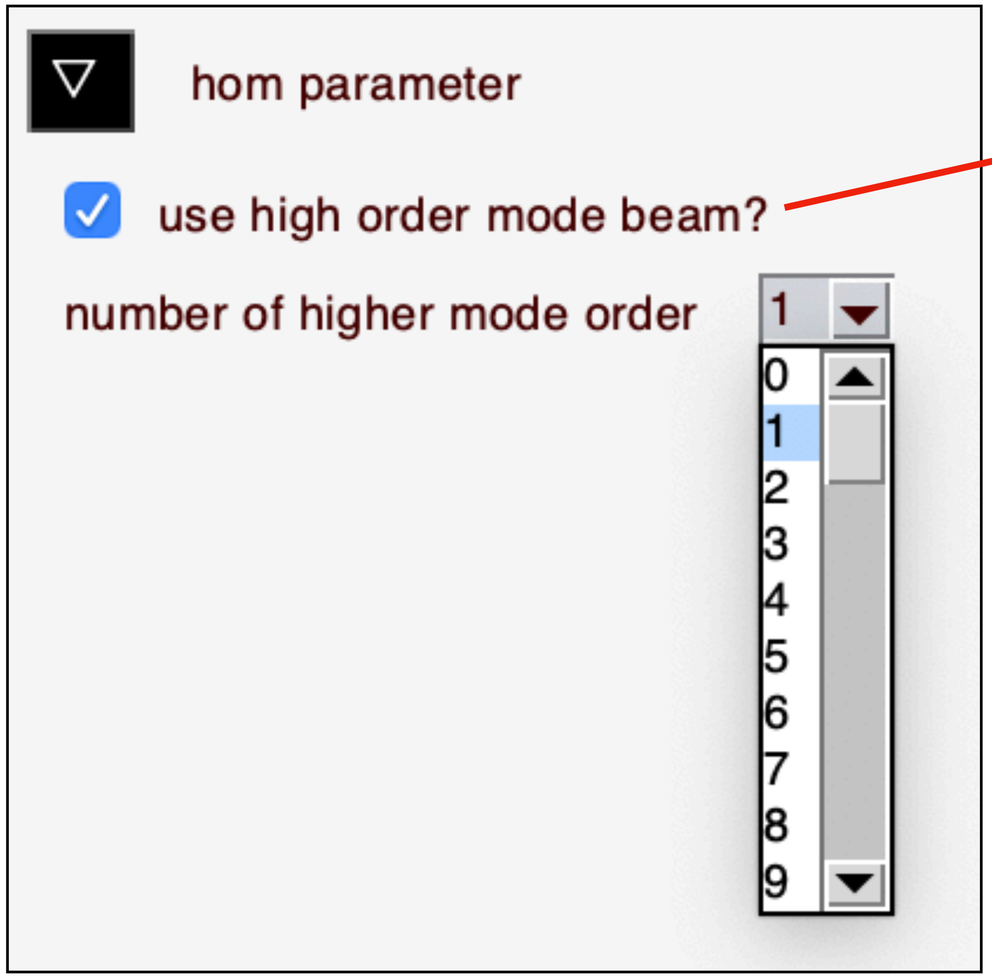
length BS-ITMY 23.3351

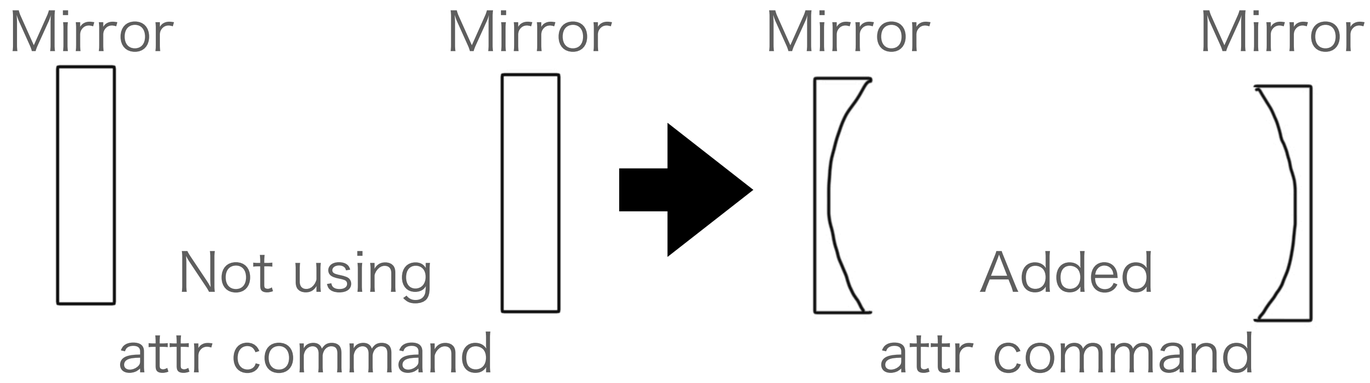
length ITMY-ETMY 3000

length SRM-SR2 15.7386



Parameter option





- The value of curvature is added to the mirror.
- The mode will be generated up to the number we select here.

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   - **Transfer Function**
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2. Making GUI for changing optical parameters

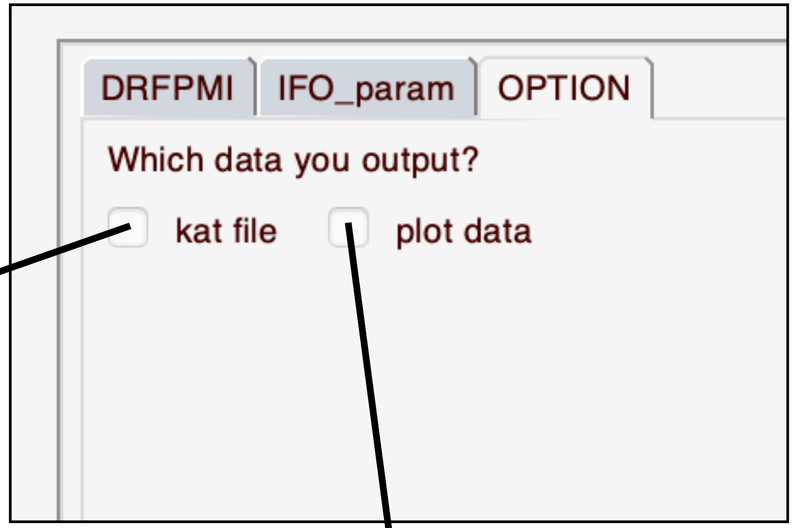
3. Export results

Export results

plot_20201104111822840030.

```
% Generated by PyKat 04.11.2020 11:18:22

l i1 1.0 0.0 0.0 n0
s s_eo0 0.0 n0 n_eo1
mod eom1 16881000.0 0.3 3 pm 0.0 n_eo1 n_eo2
s s_eo1 0.0 n_eo2 n_eo3
mod eom2 45015900.0 0.3 3 pm 0.0 n_eo3 n_eo4
s s_eo2 0.0 n_eo4 REFL
m PRM 0.8999550000000001 0.1 0.0 REFL npr1
s sLpr1 14.7615 npr1 npr2
bs PR2 0.9994550000000001 0.0005 0.0 0.686 npr3 npr2 POP POP2
s sLpr2 11.0661 npr3 npr4
bs PR3 0.999905 5e-05 0.0 0.686 dump dump npr4 npr5
s sLpr3 15.7638 npr5 npr6
bs bs1 0.5 0.5 0.0 45.0 npr6 n2 n3 n4
s lx 26.6649 n3 nx1
s ly 23.3351 n2 ny1
m ITMX 0.995955 0.004 0.0 nx1 nx2
s sx1 3000.0 nx2 nx3
m ETMX 0.99995 5e-06 0.0 nx3 TMSX
m ITMY 0.995955 0.004 90.0 ny1 ny2
s sy1 3000.0 ny2 ny3
m ETMY 0.99995 5e-06 90.0 ny3 TMSY
s sLsr3 15.7386 n4 nsr5
bs SR3 0.999905 5e-05 0.0 0.686 nsr5 nsr4 dump dump
s sLsr2 11.1115 nsr4 nsr3
bs SR2 0.9994550000000001 0.0005 0.0 0.686 nsr2 nsr3 POS dump
s sLsr1 14.7412 nsr2 nsr1
m SRM 0.8463550000000001 0.1536 0.0 nsr1 AS
xaxis sig1 f lin -180 180 1000
put pd2_fsb1_0_REFL f2 $x1
put pd2_fsb1_90_REFL f2 $x1
put pd2_fsb1_0_AS f2 $x1
put pd2_fsb1_90_AS f2 $x1
put pd2_fsb1_0_POP f2 $x1
put pd2_fsb1_90_POP f2 $x1
put pd2_fsb1_0_POS f2 $x1
put pd2_fsb1_90_POS f2 $x1
pd2_pd2_fsb1_0_REFL_16881000_0_0_0_10_0_REFL
```



testplot_202010301614.txt

```
# This is finesse result simulated at 202010301614
test plot_202010301614
# x pd1_fsb1_0_REFL pd1_fsb1_optimal8.461553655433377_REFL
-180.0 1.88273824834476e-16 1.81522769835056e-16
-179.64 -7.60717392819701e-08 -2.70653719273205e-06
-179.28 -1.54812447974865e-07 -5.4782641043678e-06
-178.92 -2.36338510303941e-07 -8.24519149016e-06
-178.56 -3.22386308977664e-07 -1.10216957213738e-05
-178.2 -4.14573530493677e-07 -1.38142324955107e-05
-177.84 -5.14536354670357e-07 -1.66279910295818e-05
-177.48 -6.23959729995999e-07 -1.94678815678871e-05
-177.12 -7.44594626232917e-07 -2.23388019188665e-05
-176.76 -8.78273052748435e-07 -2.52457439631326e-05
-176.4 -1.02692315710676e-06 -2.81938532432044e-05
-176.04 -1.19258518110045e-06 -3.11884728020025e-05
-175.68 -1.37742868596422e-06 -3.42351819140047e-05
```

Cross Check the GUI

Motivation

- Ifo-models are models written in Finesse syntax, independent from the GUI, and confirmed to be computed correctly analytically.

  We run the same simulation with Ifo-models and GUI configuration files respectively, compare the results.

- When using GUI options to set optical parameters set in ifo-model to GUI, we check if the changes are reflected in the GUI configuration file.

Method

- We use the Python package to output two configuration files.
- We plot the results of both in a single figure.

- We set the ifo-models parameter in the GUI

in the GUI options.

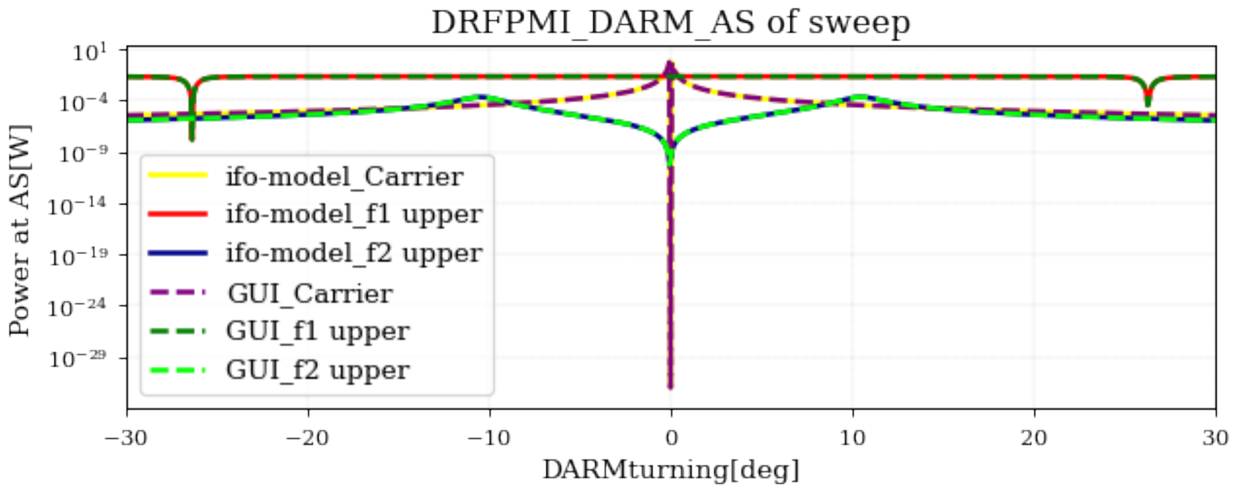
- The following conditions must be met.

(interferometer configuration, simulation mode, PD type, DoF, port put PD)

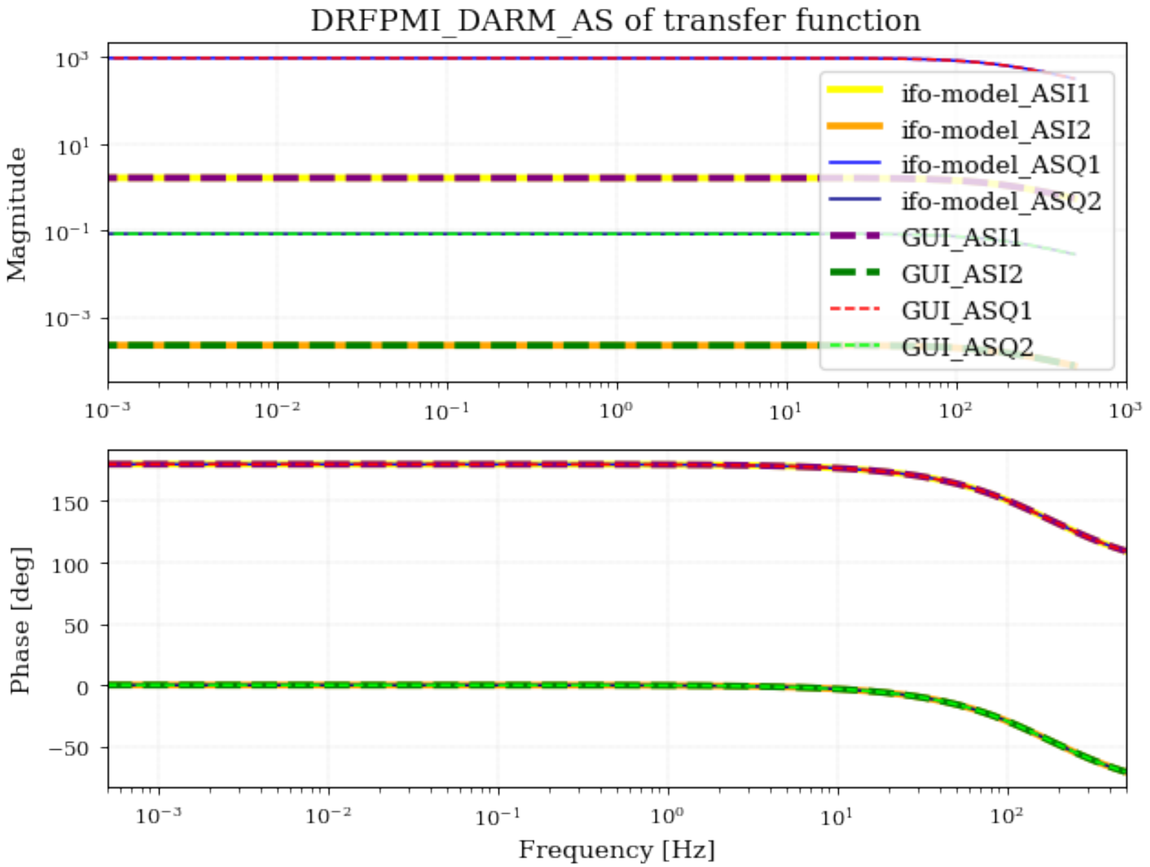
Result

Example) DRFPMI DoF: DARM port: AS

simulation mode: Sweep
PD type: Amplitude detector
(f1,f2 =sidebands)



simulation mode: Transfer function
PD type: Demodulated signal
(I=in phase, Q=quadrature phase)



• We tried most of the functions of the GUI
and found that the results of ifo-models and the GUI.
The ifo-models and GUI results matched for all simulation results.

• We looked at the output GUI configuration file
and confirmed that reflected parameters setting.

Summary

- We developed GUI that makes it easy to use Finesse for KAGRA commissioning.
- There are three types of simulation mode.
  - In sweep option,
    we can see **power**, **amplitude** and **demodulated signal**.
  - In transfer function option,
    we can see **transfer functions** of each modulation frequency components.
- Future tasks
  - Implementation of simulation mode **sensitivity**.
  - Implementation of **mirror map**.