Alignment Sensing and Control for LCGT

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Abstract:

LCGT(Large-scale Cryogenic Gravitational wave Telescope) is a Japanese 3km interferometric gravitational wave detector which started construction last year at Kamioka[1]. LCGT is unique in that it cools test masses to cryogenic temperature(20 K) to reduce thermal noise. Other advanced technologies such as underground construction, high power laser, RSE configuration, etc. are also applied and they help LCGT detect gravitational wave from binary pulsars more than 250 Mpc away.

In order to achieve such a high sensitivity, angular motions of mirrors of the interferometer must be finely controlled. However, the alignment control will be one of the most challenging issue because of angular instability of the arm cavities and high degeneracy of alignment signals from each mirror. Also, complexity of the LCGT suspension due to mirror cooling makes this issue more challenging.

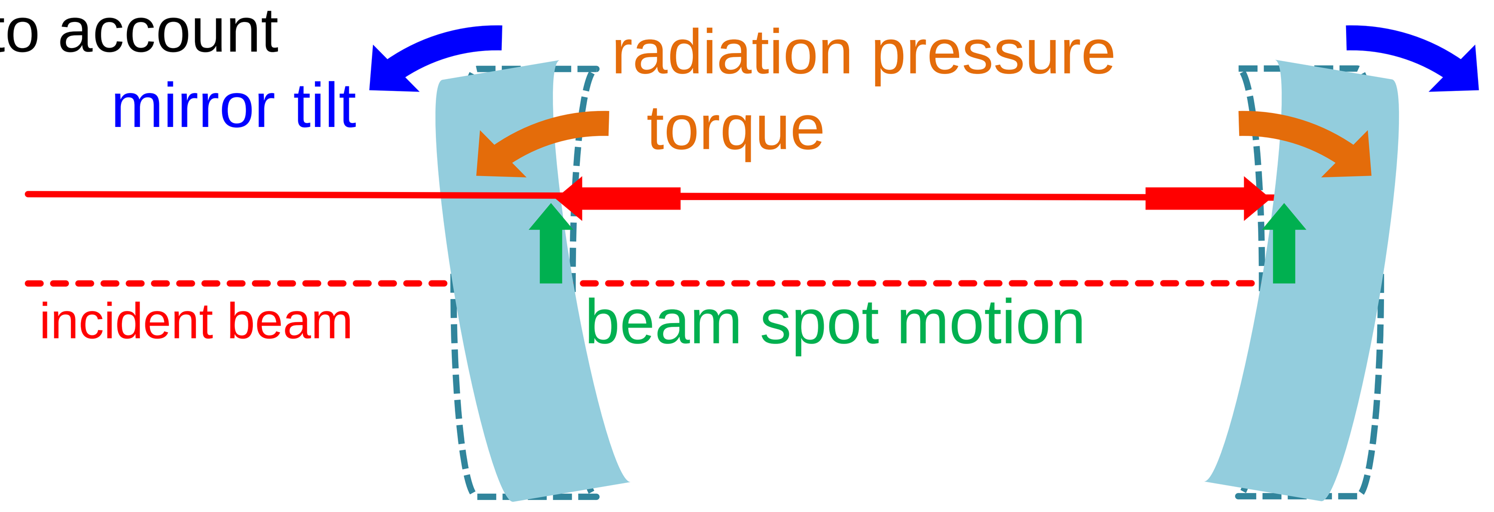
We will present current results from a model that we developed for modeling alignment sensing and control(ASC) scheme for LCGT.

1. Why ASC is Challenging

Angular instability of the arm cavities

- high intra cavity power (400 kW)
- radiation pressure torque works as positive(or negative) feedback for angular motion of the mirrors[2]

⟶ opto-mechanical response of the mirrors must be taken into account

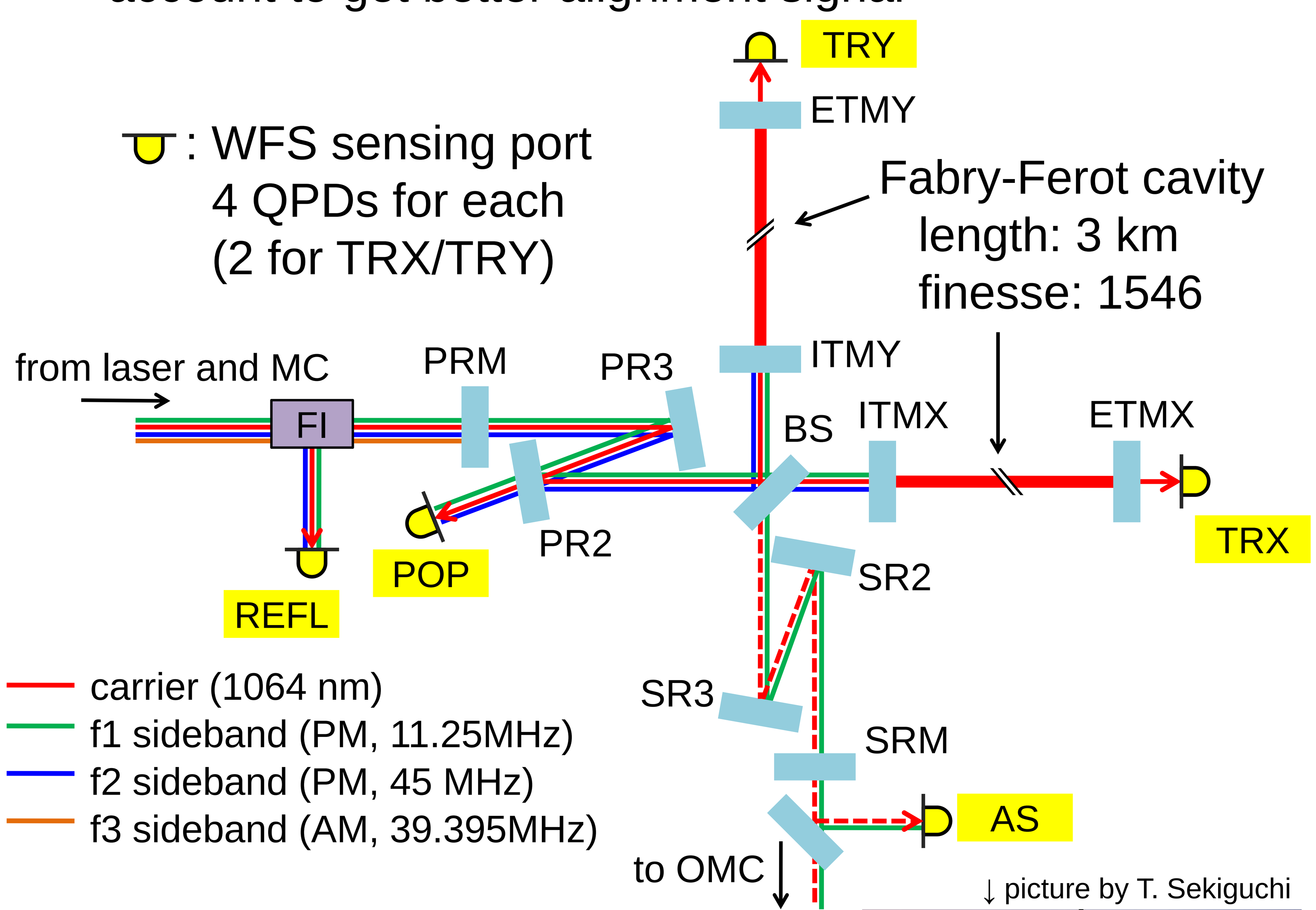


Complexity of the interferometer configuration

- RSE, recycling cavity folding
- pitch/yaw of 11 mirrors must be controlled
- WFS signal from each mirrors are highly degenerated[3]

⟶ use simulation tool for simulating the IFO response

⟶ not only WFS, but also local sensors must be taken into account to get better alignment signal

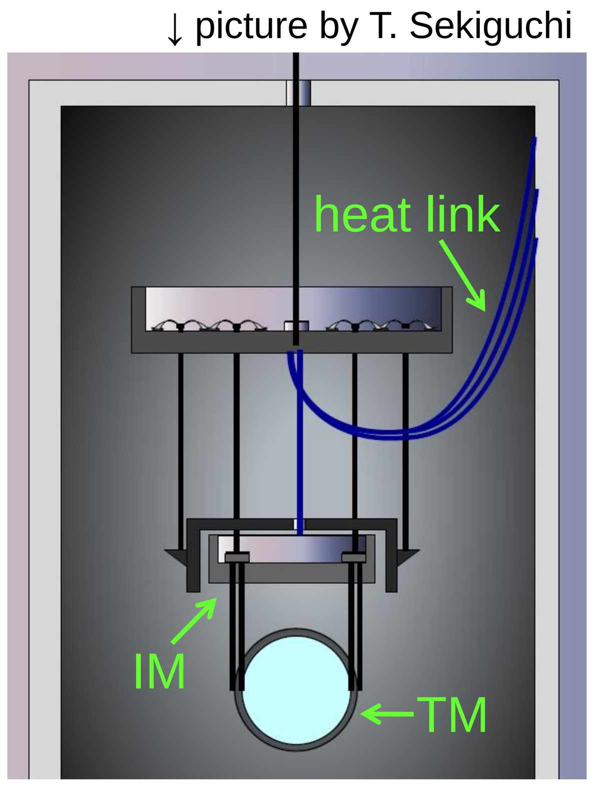


LCGT cryogenic suspension

- test mass(TM, 20 K) is suspended by 4 sapphire rods from intermediate mass(IM) ; “marionette”
- IM is suspended by 1 wire from SAS (5 filter stages)
- possible vibration from heat link

⟶ intensive cooperation with vibration isolation group

↓ picture by T. Sekiguchi



2. Modeling of ASC for LCGT

Modeling of LCGT

- 3D rigid body model in Mathematica
  for simulating mechanical response of LCGT suspension
- Optickle[4]
  for simulating opto-mechanical response of LCGT interferometer in frequency domain(including radiation pressure effect)

⟶ we design ASC by using results from these tools

Designing ASC control loop

- select WFS signal extraction ports
- calculate a matrix that diagonalize sensing matrix
- design control filters that suppress angular motion but not introduce sensor shot noise to mirrors
- calculate residual angular motion and beam spot motion on each mirrors
- evaluate angle to length(detector sensitivity) coupling

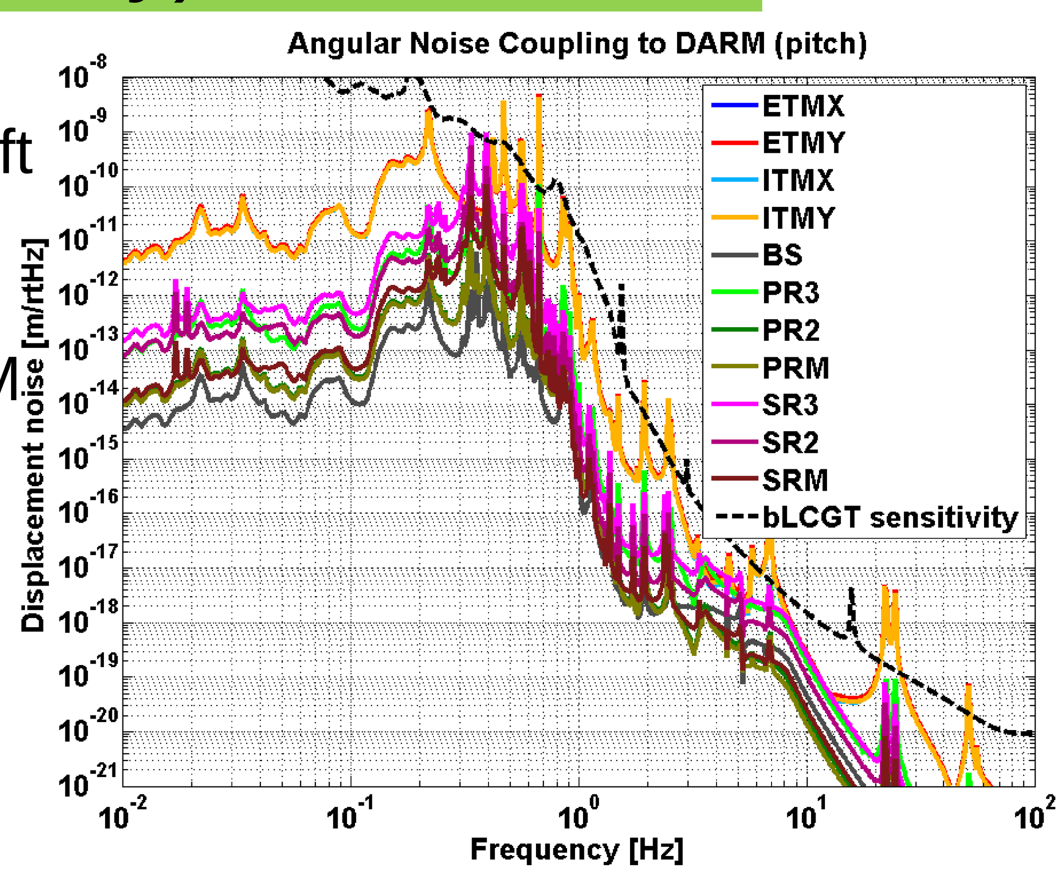
⟶ we developed a tool for calculating these

3. Result (preliminary)

- WFS loop is calculated
- WFS only works as a drift control (UGF ~ 0.1Hz)
- peaks at ~ 20 Hz come from resonance of TM-IM
- these peaks cannot be suppressed by WFS

⟶ feedback for vibration isolation group

⟶ local damping is in need



4. Summary and Plans

Summary

- developed a tool for designing ASC
- decided to use WFS as a drift control (DC to ~ 0.1 Hz)

Plans

- refine suspension design
- consider local damping and evaluate noise from it

References

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