The 6th Report of Undergraduate Graduation Design

Research on laser interference & Something about programming . . .

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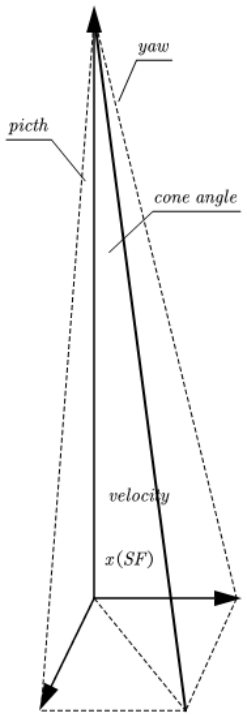
Concluding work of KBR

In the last weeks, I complaint about the lack of the attitude data for GRACE FO. But it seemed the data package of LRI includes the essential information for calculating the cone angle of one satellite, AKA, yaw and pitch angle. These two attitude angles are measured by laser interference.

The relationship between cone angle and attitude

Formula

$$tan^2(cone \quad angle) = tan^2(yaw) + tan^2(pitch) \tag{1}$$



Error propagation formula

Formula

- $$\sigma_n^2(\delta T) = \frac{1}{1 - P_n(cos\theta)} \frac{R_e}{GM} \left(\frac{r}{R_e}\right)^{2n+1} \sigma_n^2(\delta \dot{\rho}) \quad (2)$$
- $$\sigma_n^2(\delta \dot{\rho}) = \sum_{n=0}^{n} \left(\delta \bar{C}_{nm}^2 + \delta \bar{S}_{nm}^2\right) \quad (3)$$

Some news

News

- Good news:
  All the program work is finished . . . , including oscillator noise, system noise, multipath noise, error propagation and some plotting work.
- Bad news:
  - Not enough data, on the way solving.
  - Last week, I found two IEEE articles about generating noise from prescribed PSD. These two methods are complicated and absolutely more accurate than my method which is generating the signal using filtering in the frequency domain regarding the given PSD as the filter. This problem must be solved!

Code review

Frankly speaking, I didn't finish enough work last week, so here it comes . . .

In order to demonstrate explicitly, I am gonna switch to VSCODE . . .

Reference

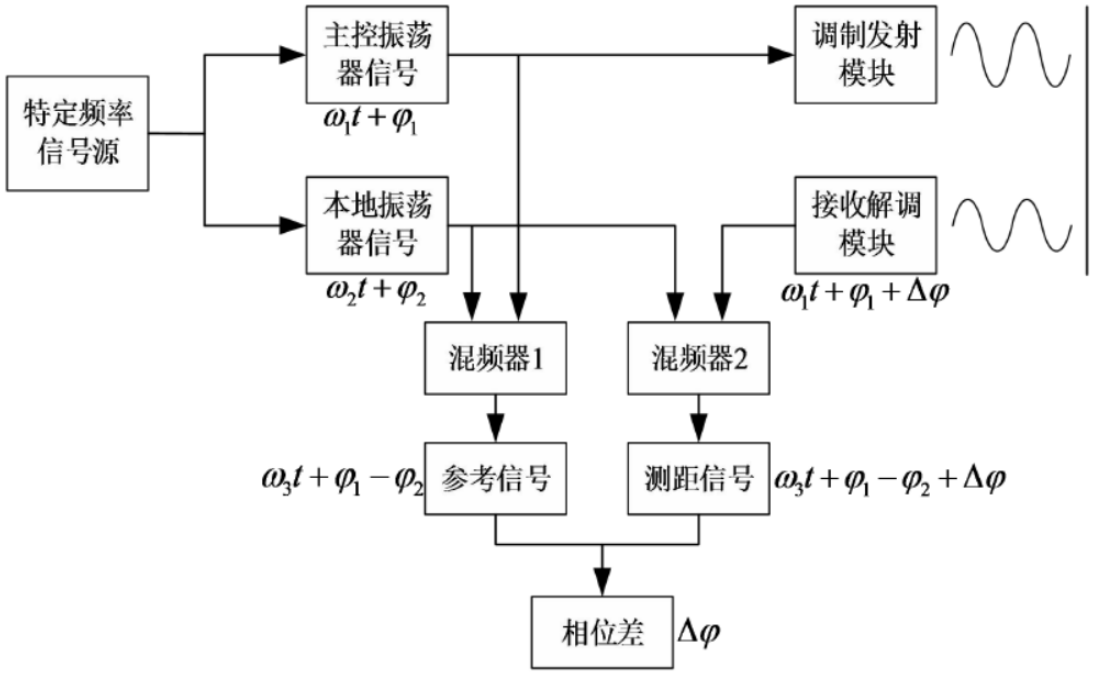
At first, I wanna read some articals or papers from Institute of mechanics, but nothing is found . . . .
So I switch to read work from Huazhong University of science and technology and Harbin Institute of Technology.

- 梁浴榕. 外差激光干涉仪中的高精度相位测量研究[D].华中科技大学,2013.
- 颜浩. 基于激光干涉的高精度多自由度光学传感研究[D].华中科技大学,2019.
- 刁晓飞. 基于空间分离的高速外差激光干涉测量若干关键技术研究[D].哈尔滨工业大学,2014.

Will ask Luo and Liu for some papers.

Difference frequency

The theorem of difference frequency

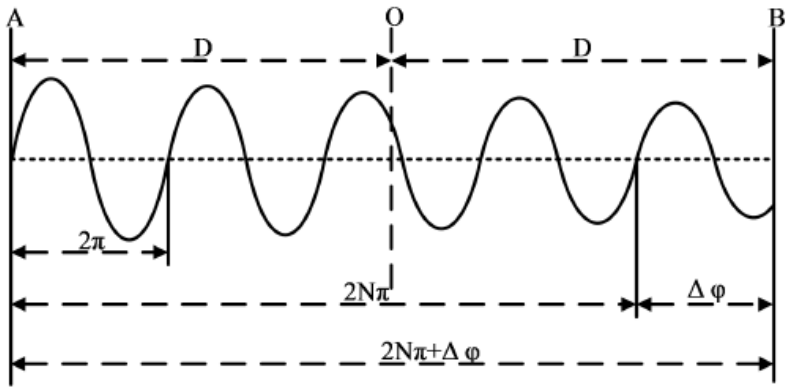


Difference frequency

Formula

- Input 1: $y_1 = A_1 sin(2\pi f_1 t + \phi_1)$
- Input 2: $y_2 = A_2 sin(2\pi f_2 t + \phi_2)$
- Back: $S_1 = A_1' sin(2\pi f_1 t + \phi_1 + \Delta\phi)$
- the mixer = multiplier + low-pass filter
- $S_{ref} = y_1 \times y_2$
- $S_{dis} = y_1 \times S_1$
- the phase difference between S_{ref} and S_{dis} is what we concerned.

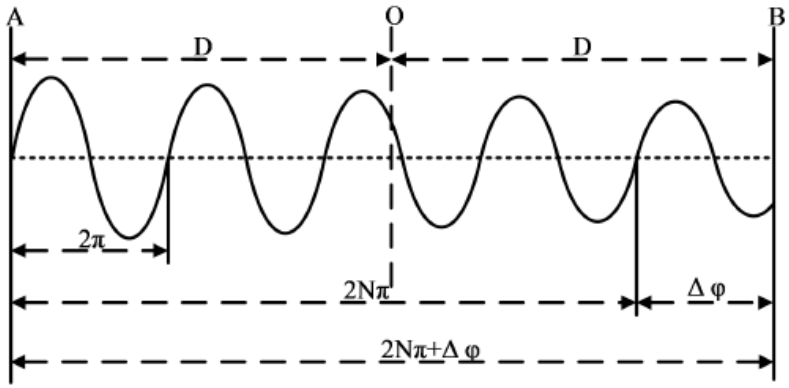
The principle of phasemetre AKA Two-way ranging



description

- Two-way ranging: the one shot the laser is the same one to process the signal
- A: Shot point
- O: Reflection point
- B: Shot point, to exhibit explicitly

Two-way ranging



Principle

- Transmitting singal: $S_1 = A_1 cos(\omega t_0 + \phi_0)$
- Received signal: $S_2 = A_2 cos(cos\omega t_0 + \phi_0 + \phi)$
- No doubt, the loss of energy must exist
- Travelling time: $t = \frac{\phi}{2\pi f}$
- Separation: $D = \frac{1}{2}ct = \frac{\lambda}{2}(N + \frac{\Delta\varphi}{2\phi})$

Two-way ranging

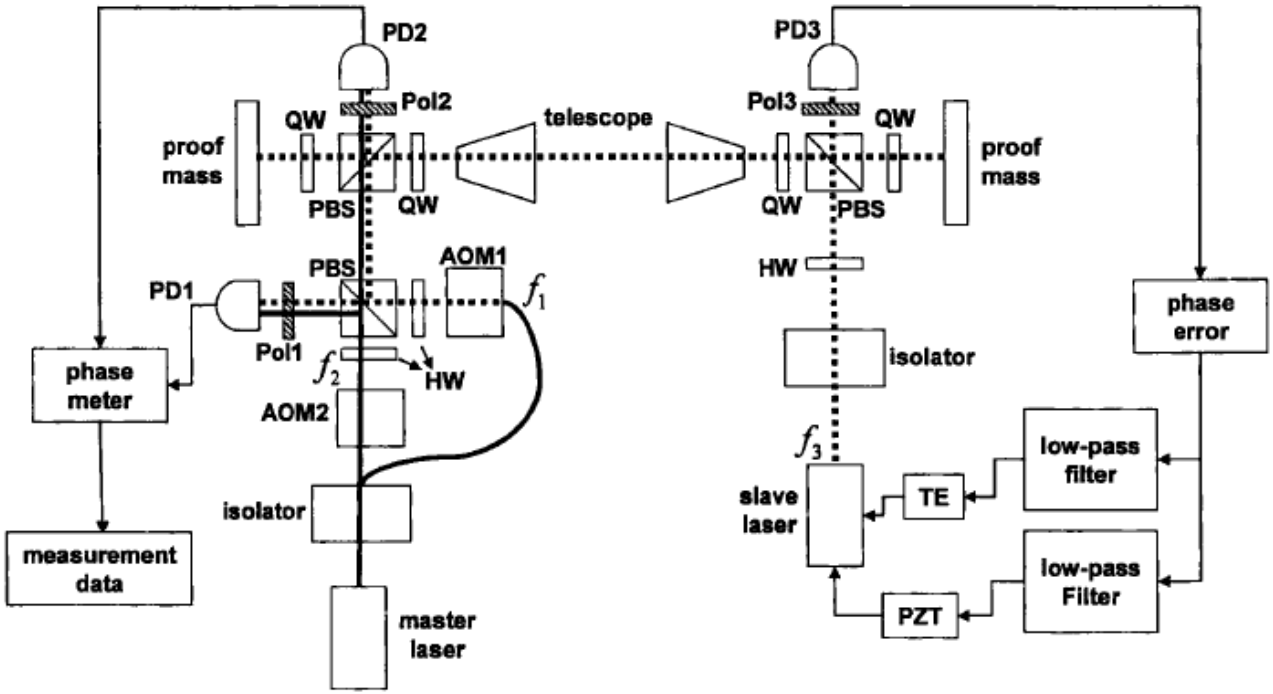


Figure: Schematic diagram

Main error sources of laser interference

Error sources

- Unstable frequency of laser beamer Transmitter, but Luo said it is NOT important
- Triple Mirror Assembly Pointing Jitter Coupling
- Unstablility because of temperature
- Additional Linear and Quadratic Pointing Jitter Coupling
- Noise from the phasemetre, can be neglected for now.

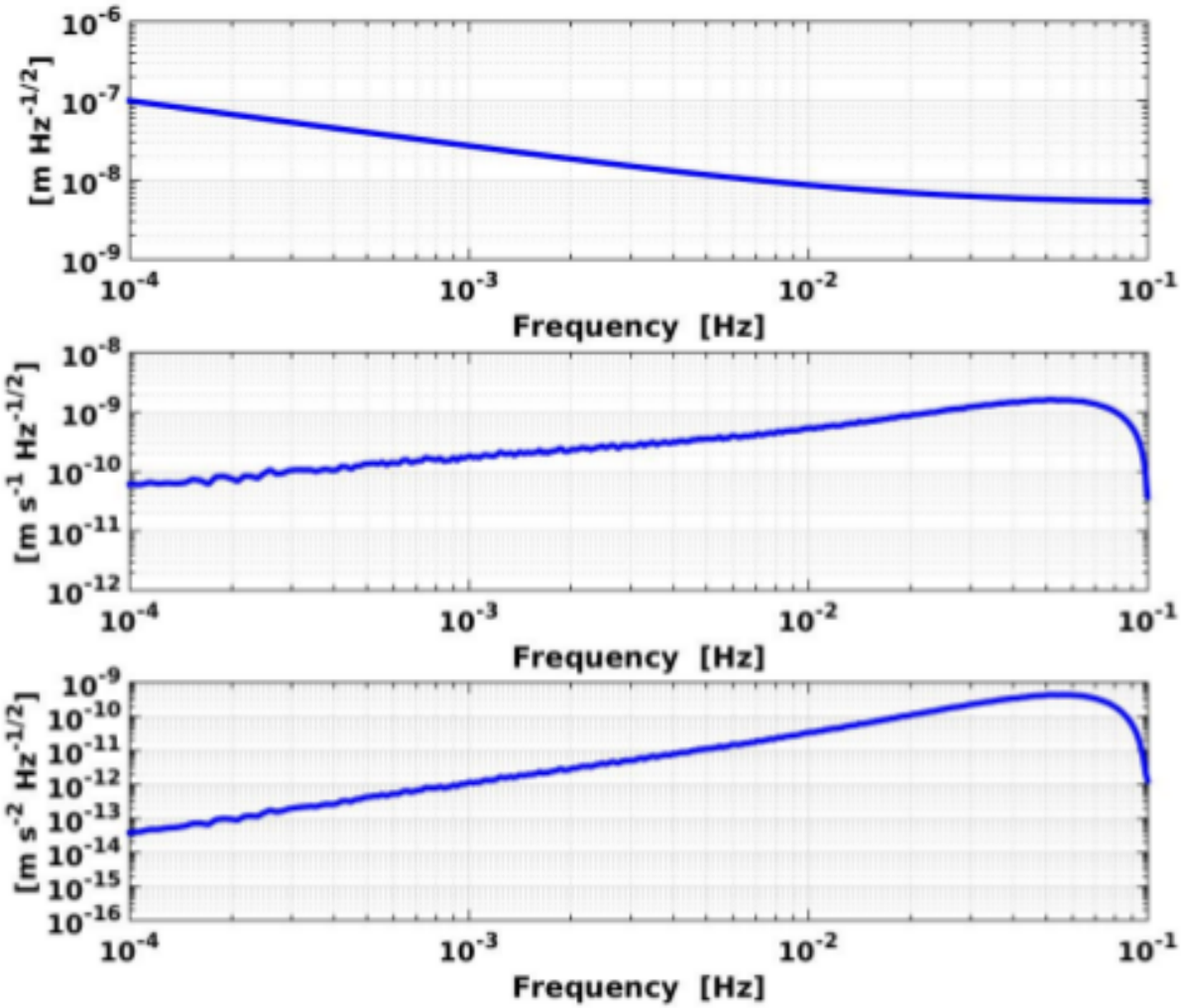
Frequency noise

Formula

According to the ground cavity performance test by JPL, the current best estimate of the ASD of the laser frequency noise for a satellite separation of 238km is:

$$\bar{\rho}_{LF}(f) = 5 \times 10^{-9} \sqrt{1 + (\frac{0.0182Hz}{f})^2} \frac{m}{\sqrt{Hz}} \tag{4}$$

ASD diagram


[m Hz^-1/2]
Frequency [Hz]
[m s^-1 Hz^-1/2]
Frequency [Hz]
[m s^-2 Hz^-1/2]
Frequency [Hz]

Problem coming . . .

This is another problem about generating noise from a prescribed ASD/PSD.
The only solution is filtering for now . . .
The theories in those two papers will certainly be useful in the future, so one of the tasks in the graduate stage is to solve this problem.

Thank you!