Laser interferometric high-precision angle monitor for JASMINE

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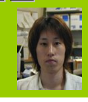


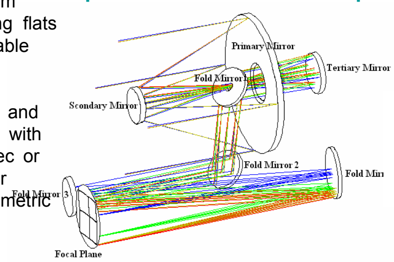
ABSTRACT

The JASMINE instrument uses a 3-mirrors optical system. The accurate measurements of the astrometric parameters requires the instrument line-of-sight highly stability and the opt-mecanical highly stability of the payload in the JASMINE spacecraft; for example, the distance of the primary mirror to the secondary mirror and the angle between two mirrors should be stabilized and the fluctuations should be monitored with the accuracy of about nm or 100 microarcsec. For this purpose, a high-precision interferometric laser metrogy system is employed. One of the available techniques for measuring the fluctuations of the angle is a method known as the "wave front sensing" using a Fabry-Perot type laser interferometer. This technique is to detect fluctuations of the angle as displacement of optical axis in the Fabry-Perot cavity. One of the advantages of the technique is that the sensor is made to be sensitive only to the relative fluctuations of the angle which the JASMINE wants to know and to be insensitive to the common one; in order to make the optical axis displacement caused by relative motion enhanced the Fabry-Perot cavity is formed by two mirrors which have long radius of curvature. To verify the principle of this idea, the experiment was performed using a 0.1m-length Fabry-Perot cavity with the mirror curvature of 20m. The mirrors of the cavity were artificially actuated in either relative way or common way and the resultant outputs from the sensor were compared.

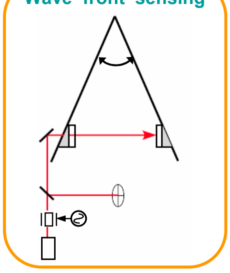
A high-precision angle monitor for JASMINE

A candidate for optics of JASMINE telescope is a modified Korsch system which has three mirrors with 4 Folding flats to fit the back focal length into available volume. The angle and the distance between the primary mirror and the secondary mirror should be stabilized and that fluctuations should be monitored with the accuracy of about 100 microarcsec or nm during the observation of 1.5 year to enable the measurements of astrometric parameters to the accuracy of 10 microarcsec.

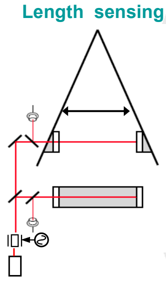
Optics of JASMINE telescope



Wave front sensing



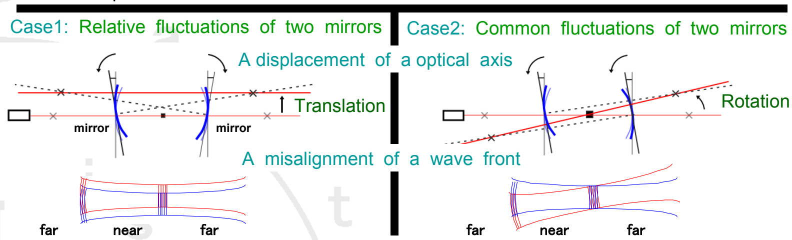
Length sensing



A high-precision interferometric laser metrology system is employed as a monitor. The metrology concept of JASMINE is based on using Fabry-perot type laser interferometer. The "wave front sensing" is a means for detecting angle fluctuations and The "length sensing" is a means for detecting distance one. The research and development of the wave front sensing method is advanced now.

The wave front sensing method

A Fabry-Perot cavity is composed of two mirrors. Those mirrors being misaligned angularly, the optical axis in the cavity causes translation and rotation around the beam waist from the incidence optical axis position. The wave front sensing can determine that the optical axis's translation and rotation.



The above figure shows there are two kinds of two mirrors motion. The one which JASMINE wants to know is case1; therefore, the response signal to fluctuations of two mirrors is detected at far field where a wave front of a reflected light from a cavity is misaligned from that of a incoming light.

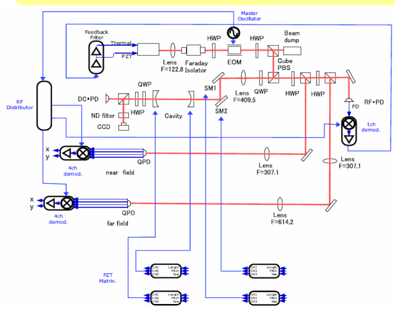
Advantage for JASMINE

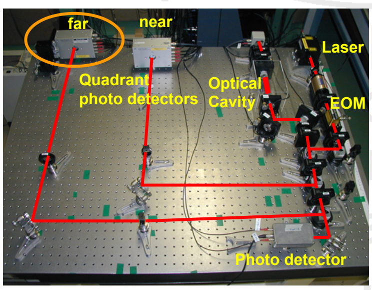
Using a Fabry-Perot cavity with the mirror curvature of long radius → The amount of translation of optical axis is **increased**. The response signal to relative fluctuations of a angle between mirrors is **enhanced**.

A Sensor can be made to be sensitive only to the two mirror's motion which JASMINE wants to know.

Verification experiments For the wave Front Sensing method

Wave Front Sensing: configuration

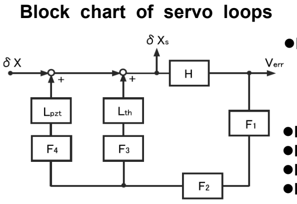




- Optical system is set on vibration isolated table(1200mm×900mm).
- The input laser is Nd:YAG laser of 1064-nm wavelength.
- The Fabry-perot cavity is 0.1m-length and formed by two mirrors which have 20m of curvature.
- Using the heterodyne detection technique the carrier light is phase modulated at 15 MHz using electro-optic modulator (EOM).
- A quadrant photodetector (QPD) is set to detect the spacial gradients in the interfering carrier and sideband and measure the magnitude of the TEM10 mode. It is called the wave front sensor.

Servo loops for cavity length control

Block chart of servo loops



sensor

- H:Fabry-perot Cavity

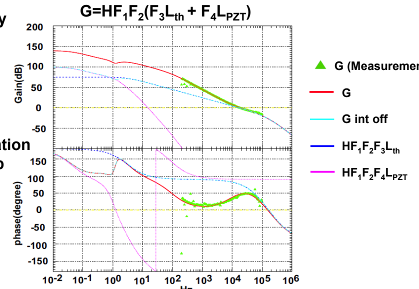
filter

- F1:Integrator
- F2:LPF fc=3Hz
- F3:Phase compensation
- F4:High voltage amp

actuator	band	range
L_{th} :Laser-thermal	~1Hz	± 10 μm
L_{PZT}:Laser-PZT	~100kHz	± 0.03 μm

Open loop transfer function G

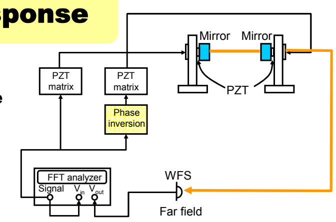
$G=HF_1F_2(F_3L_{th}+F_4L_{PZT})$

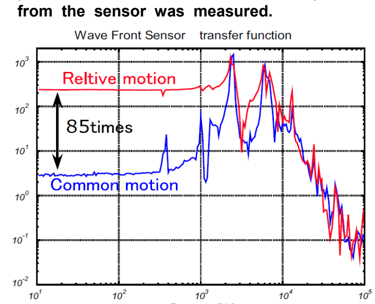


The laser beam has two control inputs: a PZT input and a thermal input. To hold the cavity on resonance for long periods of time (it is called "cavity lock") two servo loops are used for these inputs to realize fast and wide control. δX is suppressed to the level of $\delta X_s = \frac{\delta X}{1-G}$ by the control. Actually deviation from resonant length was controlled within about 1 nm.

Wave front sensor response

To verify that using a cavity with mirrors which have long radius of curvature make sensor only to be sensitive to relative angle fluctuations the mirrors of the cavity were artificially actuated in either relative way or common way by PZT actuators which were put on mirrors and the resultant outputs from the sensor was measured.

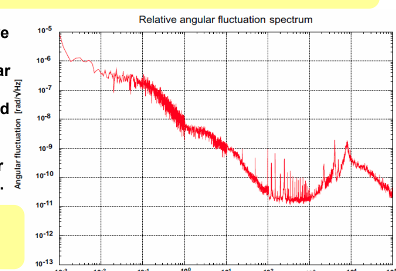




The left figure shows the measurement result at far field. A grate difference between the response to relative motion and the response to common one could be seen. The ratio of response to relative motion to response to common one was about 85 times. In high frequency band a relative motion or a common motion could not be made purely due to mechanical resonance of PZT actuator and the responses of wave front sensor to two motion were not measured.

Relative angular fluctuation spectrum

The right figure shows the relative angular fluctuation spectrum measured in the atmosphere at far field. The angular stability of the Fabry-Perot cavity was 1.3×10^{-7}rad in root-mean-square in a bandwidth of 10^{-3}Hz ~ 1Hz. Its value is 270 times the angular fluctuations limit of JASMINE now.



CONCLUSIONS

One of advantages of the wave front sensing is that using the Fabry-perot cavity composed by the two mirrors which have long radius of curvature the sensor can be made to be sensitive only to the relative angular motion of two mirrors. To verify this idea optical system using a 0.1m-length Fabry-Perot cavity with the mirror curvature of 20m was set up. A grate difference between responses to two motions of mirrors can be seen in the experiment; the ratio of the response to relative fluctuations of a angle between two mirrors to the response to common one was about 85 times.