A Giant Step: from Milli- to Micro-arcsecond Astrometry
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Laser interferometric high-precision geometry (angle and length) monitor for JASMINE

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Abstract. The telescope geometry of JASMINE should be stabilized and monitored with the accuracy of about 10 to 100 pm or 10 to 100 prad of rms over about 10 hours. For this purpose, a high-precision interferometric laser metrology system is employed. Useful techniques for measuring displacements on extremely small scales are the wave-front sensing method and the heterodyne interferometrical method. Experiments for verification of measurement principles are well advanced.

Keywords. instrumentation: interferometers, techniques: interferometric, telescopes

1. Introduction

Next-generation astrometry satellite missions will measure parallaxes, positions with the accuracy of 10 microarcsec. So the optical component of their telescope should be stabilized and its fluctuations should be monitored with high accuracy. In JASMINE(Japan Astrometry Satellite Mission for Infrared Exploration) which is one of next generation astronomical satellite missions astronomical parameter is derived by the frame linking method, and It is necessary to suppress fluctuations of frame expansion or distortion according to the temperature changing during the observation as much as possible; the telescope geometry, the distance of primary mirror to secondary mirror and the angle between two mirrors, should be stabilized with the accuracy of about 10 to 100 pm or 10 to 100 prad in root-mean-square over about 10 hours; moreover, the fluctuations should be monitored with such accuracy. For this purpose, a high-precision interferometric laser metrology system is employed.

2. Concept of high-precision geometry monitor

One of the available techniques for measuring the fluctuations of the angle is a method known as the gwave front sensingh using a Fabry-Perot type laser interferometer. 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. The heterodyne interferometrical method is useful for the measurement of longitudinal fluctuations. Moreover, this technique easily can measure displacements of two or more degree of freedom because the measurement signals can be detected without controlling optical path length with actuators. Therefore, displacements in some parts of telescope can be measured at the same time using this method.

3. Performance tests

To verify the principles of these ideas, the experiments were performed.

(*a*) The wave front sensing output signal 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 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; the sensor had good response only to relative motion.

(*b*) The heterodyne interferometer output signal The calibration of the PZT actuator movements which was attached to the target mirror was done by using four 2.5m heterodyne interferometers to test the operation with them. The calibration values for longitudinal, horizontal and vertical motions could be measured with the same accuracy to about nm.

(*c*) The noise behavior of the interferometer Figure.1 shows the wave front sensor and heterodyne interferometer noise spectrum measured in the atmosphere without temperature control system. The smooth lines show the measurement value for root-mean-square from 1kHz to each frequency. The geometry monitor stability was 13.5 nrad in the direction of the angle and 10.4 nm in the direction of the length in 1000s. The monitor instability depends on a thermal drift in low frequency band, so we plan to make interferometers compact and to introduce a temperature control system.

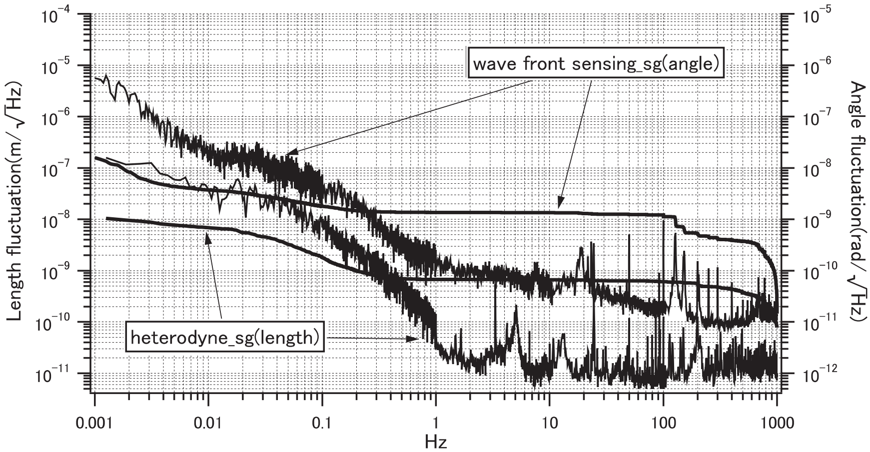

Figure 1. Two types Interferometers noise spectrums: the wave front sensor and heterodyne interferometer. The smooth lines represent root-mean-square values from 1kHz to each frequency.

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