Methodological demonstration of laser beam pointing control for space gravitational wave detection missions

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Introduction
The angular jitter of the transmitting light will cause phase noise \( \delta \phi \) due to the geometrical distortion of remote telescope [1, 2]:

\[
\delta \phi = \frac{1}{32} \frac{2\pi}{\lambda} d D^2 \theta_{dc} \delta \theta
\]

where \( \theta_{dc} \) is the static offset error in the pointing, \( \delta \phi \) is the pointing jitter, \( D \) is diameter of telescope, \( d \) is amplitude of curvature error in the wavefront and \( \lambda \) is laser wavelength. To achieve the desired beam pointing stability, active feed-back beam pointing control system is required. A demonstration of such system is performed, where Differential Wave-front Sensing (DWS) technique[3] is used to sense the beam pointing jitter.

Experiment setups

DWS techniques

\[
\delta \phi \approx \frac{16 r}{3 \lambda} \alpha = k \cdot \alpha
\]

where \( \alpha \) is the relative wave-front tilt, \( r \) is the beam radius, \( \lambda \) is the laser wavelength and \( k \) is the conversion factor.

Calibration

The conversion factors for yaw and pitch motion can be obtained from linear fitting curve:

\[
k_{yaw} = 5703 \text{rad/\text{rad}}
\]

\[
k_{pitch} = 4790 \text{rad/\text{rad}}
\]

Results and discussions

Conclusions

A methodological demonstration of laser beam pointing control system for space gravitational wave detection missions has been accomplished. Pointing jitter of 50 rad is produced to simulate the situation of eLISA or future satellite gravity missions. With beam pointing control system turned on, the stability of beam pointing direction can be kept at 80 nrad/√Hz and 90 nrad/√Hz at frequencies from 1 mHz to 1 Hz.

References