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# TIP-TILT SPATIAL STABILIZATION FOR GROUND-TO-SPACE LASER LINKS

**Abstract**

Phase-stable free-space laser links, especially from ground to satellites, will enable improvements in applications ranging from relativistic geodesy and tests of fundamental physics, to precision navigation and coherent optical communications. However, the phase stability, and so measurement precision and data rates, of free-space laser links are severely limited by beam wander and phase fluctuations caused by atmospheric turbulence.

Piston mode effects of turbulence cause variations in the optical path length of the laser signal, introducing phase noise, while higher-order effects of turbulence lead to spatial variations, or beam wander, leading to intensity fluctuations and signal fading at the receiver.

We have previously demonstrated an optical phase-stabilization system that suppresses the piston mode phase noise effects by reflecting a portion of the laser signal back from the receiver to the transmitter where a phase-locked-loop detects and corrects for the phase variations by adjusting the transmitted frequency, effectively correcting the doppler shift caused by the optical path length change. In order to supress beam wander and reduce intensity variations which lead to drop-out of the coherent laser link we have developed terminals with active tip-tilt optics.

The light reaching the terminal is collected by a telescope and half of the light is split off and directed to a quad-photodiode. PID control loops drive a fast-steering mirror to centre the beam on the quad-photodiode. Here we present the characterization of the performance of this active-optics system over a 2 km horizontal link. The tip-tilt control effectively suppresses intensity uctuations in the received light at frequencies below a few tens of Hz, resulting in far fewer link drop outs and producing a more robust laser link for metrology and communications.

In future, we are working with the support of the SmartSat Coorperative Research Centre [https://smartsatcrc.com/] to combine the phase stabilization system and active optics terminals in order to demonstrate optical fibre-like data transfer rates over 10 km horizontal and 5 km vertical links through the turbulent atmosphere.