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# POINT-TO-POINT STABILISED OPTICAL FREQUENCY TRANSFER WITH ACTIVE OPTICS

**Abstract**

The phase-stabilised transfer of optical-frequency signals over free-space laser links, particularly between ground stations and satellites, will enable advances in fields ranging from high-speed space-to-ground optical communications and geodesy with optical Doppler orbitography, to tests of General Relativity and fundamental physics. Atmospheric turbulence induces phase perturbations of the transmitted optical signals, which severely limits these applications. Usually systems for stabilising optical transmissions against the deleterious effects of turbulence have been demonstrated over folded links. This allows the transmitter and receiver to be located physically close to each other, simplifying the process of evaluating the stability performance of the transfer. However, such an experimental setup does not resemble true frequency transfer between physically separated sites. We present results from a recent demonstration of phase-stabilised optical frequency transfer over a 300 m, point-to-point free-space link at the Centre national d'études spatiales (CNES) campus in Toulouse. Each optical terminal in the free space link included an active tip-tilt stabilisation system that was used for link acquisition and tracking. The performance of the free-space transfer was measured by a comparison against a separate optical-fibre-based phase-stabilised system operating between the terminals. Using the combined phase- and tip-tilt-stabilisation system, we demonstrated a fractional frequency stability of $4.3 \times 10^{-18}$ at 1 second of integration, which decreased to $3.5 \times 10^{-19}$ after 2 minutes of integration. This represents 4 orders-of-magnitude improvement over the unstabilised transfer stability of $5.5 \times 10^{-18}$ after 1 second of integration. With the phase stabilisation system operating, and tip tilt system disengaged, the phase stability was measured to be $1.55 \times 10^{-17}$

after 1 second of integration. This indicates that the use of the tip-tilt stabilisation system improved phase-stabilisation performance by a factor of three. The tip-tilt terminals also reduced the magnitude of intensity fluctuations over the link, eliminated the common phenomenon of deep-fading, and allowed continuous link operation during measurements lasting several hours.