Coherent Optical Doppler Orbitography

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Motivation
Current microwave-frequency techniques for orbital determination (e.g. PRARE) are able to measure relative velocities with a precision of around 1 mm/s [1]. Greater precision is desired for improved calculations of orbital parameters and thereby a better understanding on the International Terrestrial Reference Frame [2]. Doppler orbitography at optical wavelengths has the potential to drastically improve the precision of these parameters.

Experimental Setup
We experimentally demonstrated a free-space Doppler measurement using a 193 THz (1550nm) continuous-wave laser over horizontal links up to 2.2 km in length. Horizontal links between 2 km and 5 km have previously been estimated to have similar total integrated turbulence as ground-to-space links [3-4]. Our system uses a coherent optical carrier round-trip phase measurement to determine the Doppler shift between the optical transceiver and reflector target that result from their relative motions as well as turbulence of the intervening atmosphere. It can then feedback to the outgoing to optical carrier to stabilise the phase fluctuations of from atmosphere [5].

Demonstrated Performance
For the 2.2 km link, the measured uncertainty in the relative velocity is 2 μm/s at 100 s of integration. Our system can also suppress short-term fluctuations to improve the measured uncertainty to 1 nm/s at 100 s. We expect similar performance for space links.

Future Ground-to-Space Link
The system is power limited due to beam divergence to 40 km; we are working towards a 350 km+ link by increasing power from 30 mW to 1 W and reducing beam divergence by using a larger transceiver. A ground-to-space demonstration is planned for late 2019. A chip rate can also be modulated onto the carrier for absolute distance.

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References

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