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# LONG DISTANCE MEASUREMENT WITH SUB-FEMTOSECOND TIMING RESOLUTION FOR FORMATION-FLYING SATELLITE MISSIONS

## Abstract

Formation-flying satellites will perform future space observation missions such as detection of the background glow of X-rays and search for Earth-like planets. This concept of using multiple satellites for synthetic aperture imaging requires controlling the position and orientation of each satellite precisely to a reference satellite. For the purpose a suitable means of absolute distance measurement at long range is crucial, which should be not only precise but also fast enough to feedback measured distance for real-time control. In response to the metrological demand in future space missions, competitive research work is being conducted worldwide to investigate several optical measuring alternatives. Time-of-flight measurement using laser pulses enables identification of a long distance without ambiguity, but the achievable resolution reaches only a few micrometers at best due to the limited bandwidth of electronics available to resolve the time difference between pulses. On the other hand, optical interferometers are capable of providing sub-wavelength resolutions, but the ambiguity range is very narrowly confined to a single wavelength, permitting only relative measurements. Multi-wavelength interferometry is considered a potential way of achieving the demanded precision and speed in absolute distance measurements. Another attempt is adopting femtosecond lasers to come up with new measurement methods of absolute distance by taking the advantage of the broad spectral range, high frequency stability and RF beat signals of high accuracy of the stabilized frequency comb.

In this paper we propose a nonlinear intensity cross-correlation technique that enables performing absolute distance measurements based on the multi-heterodyne principle. The time difference between ultrashort pulses is traced with precision of less than 1 fs, which corresponds to a sub-micrometer resolution in distance. The ambiguity range is extended to 30 km simply by tuning the repetition rate of the femtosecond laser with reference to an atomic clock of time standard. Sampling time related to the measured data update rate is enhanced to 1 ms by implementing a real-time lock-in scheme. Furthermore, by using fiber-based femtosecond lasers as the light sources enables fulfillment of the important auxiliary requirements of compactness, reliability and low power consumption.