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An Absolute Femtosecond Rangefinder for Metrological Support in Coordinate Measurements

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Abstract : In the modern world, there is an increasing demand for highly precise measurements in various fields, such as aircraft, shipbuilding, and rocket engineering. This has resulted in the development of appropriate measuring instruments that are capable of measuring the coordinates of objects within a range of up to 100 meters, with an accuracy of up to one micron. The calibration process for such optoelectronic measuring devices (trackers and total stations) involves comparing the measurement results from these devices to a reference measurement based on a linear or spatial basis. The reference used in such measurements could be a reference base or a reference range finder with the capability to measure angle increments (EDM). The base would serve as a set of reference points for this purpose. The concept of the EDM for replicating the unit of measurement has been implemented on a mobile platform, which allows for angular changes in the direction of laser radiation in two planes. To determine the distance to an object, a high-precision interferometer with its own design is employed. The laser radiation travels to the corner reflectors, which form a spatial reference with precisely known positions. When the femtosecond pulses from the reference arm and the measuring arm coincide, an interference signal is created, repeating at the frequency of the laser pulses. The distance between reference points determined by interference signals is calculated in accordance with recommendations from the International Bureau of Weights and Measures for the indirect measurement of time of light passage according to the definition of a meter. This distance is D/2 = c/2nF, approximately 2.5 meters, where c is the speed of light in a vacuum, n is the refractive index of a medium, and F is the frequency of femtosecond pulse repetition. The achieved uncertainty of type A measurement of the distance to reflectors 64 m (N•D/2, where N is an integer) away and spaced apart relative to each other at a distance of 1 m does not exceed 5 microns. The angular uncertainty is calculated theoretically since standard high-precision ring encoders will be used and are not a focus of research in this study. The Type B uncertainty components are not taken into account either, as the components that contribute most do not depend on the selected coordinate measuring method. This technology is being explored in the context of laboratory applications under controlled environmental conditions, where it is possible to achieve an advantage in terms of accuracy. In general, the EDM tests showed high accuracy, and theoretical calculations and experimental studies on an EDM prototype have shown that the uncertainty type A of distance measurements to reflectors can be less than 1 micrometer. The results of this research will be utilized to develop a highly accurate mobile absolute range finder designed for the calibration of high-precision laser trackers and laser rangefinders, as well as other equipment, using a 64 meter laboratory comparator as a reference.

Keywords : femtosecond laser, pulse correlation, interferometer, laser absolute range finder, coordinate measurement
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