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Integrated High-Precision Measurement of Multi-Freeform Surface Prisms

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With the advancement of manufacturing technology and the increasing application demands, optical systems are being developed towards miniaturization and high optical performance. As a crucial means to meet these demands, optical freeform surfaces offer high design flexibility, allowing the surface shape to be adjusted according to imaging requirements and overcoming the limitations of traditional spherical and aspherical designs. The introduction of freeform elements can significantly reduce the number of components in an optical system. Optical freeform prisms, as typical freeform elements, not only possess image quality control capabilities but also enable optical path folding, thereby reducing the size of the optical system. The optical performance of freeform prisms is influenced by the precision of each surface and the relative positions between surfaces. Therefore, when such devices are measured, it is essential for all surfaces to be comprehensively sampled in a single measurement process. High rotational degrees of freedom are required for the measurement system, and accurate measurement paths must be designed according to the sensor's angular characteristics. Current optical element measurement equipment can measure only a single surface. To address this, a five-axis line-scan system has been developed, and an iterative measurement algorithm has been proposed that can automatically correct the measurement path, ultimately achieving comprehensive measurement of optical freeform prisms. Additionally, the measurement errors of multi-axis systems have been theoretically modeled, and an efficient and low-cost calibration method has been proposed that effectively corrects the motion errors of the measurement system, thereby improving measurement accuracy.
