Special Section Guest Editorial: Advances in Optical Measurement for Geometrical and Mechanical Quantities

Haojie Xia,[a] Liandong Yu,[b] and Lianxiang Yang[c]

[a]Hefei University of Technology, School of Instrument Science and Opto-electronics Engineering, Hefei, China

[b]China University of Petroleum, Qingdao, China

[c]Oakland University, Rochester, Michigan, United States

The Special Section on Advances in Optical Measurement for Geometrical and Mechanical Quantities considers the field of measurement and instrumentation as a broad range of research ranging from developments, concepts, and approaches for new devices, systems, and applications to engineering implementations. Measurement and instrumentation have played an important role throughout modern production and manufacturing engineering, through supporting both the traditional field of manufacturing and the emerging field of micro/nanotechnology. Precision measurement and instrumentation have gained much greater prominence in the last decade in the areas of high-precision production and manufacturing, and thus the developments of new and improved high-precision processes and machines. Many advanced technology products depend entirely on one or more components being manufactured with tolerances or dimensions in the micro- or even nano-range. This makes optical measurement an imperative tool for precise and accurate micro- and nano-measuring. Developments of novel lasers and novel devices, e.g., microcavity systems, and the required measurement performances pose challenges to new generations of researchers in this field and promote continuous research in both fundamental theories and practical applications of optical measurements.

In addition to applications of absolute distance measurements, optical measurements have also found many applications in many other fields, e.g., fast and accurate shape measurements by speckle pattern interferometry, Talbot imaging, gear pitch rapid measurements, and precise laser beam positioning. All of these fields and many other areas of optical measurements are covered by the International Symposium on Precision Mechanical Measurement held every other year. With the first held in August 2001, the conference was organized by Dr. Liandong Yu and celebrated its 10th anniversary in 2021. This special section serves as a forum to share the latest advances in optical-based precision measurement and instrumentation in high-precision production and manufacturing engineering and other related fields.

This special section comprises 12 papers that cover various topics, including microscopic measurements for lengths, angles, and coordinates, intelligent measurements and instrumentation, optical property measurements of solutions, optics-related micro/nanomeasurements and devices, optical sensors, and image processing. Many advanced technologies are also introduced, such as phase correction methods in speckle pattern interferometry, harmful gas measurements with a microcavity platform, and defect detections for specular surfaces based on deflectometry and deep learning.

Among the papers that focus on defect detections, Wang et al. reported a novel approach for identification and elimination of overexposed areas based on polarized optics in a speckle pattern interferometry system. In traditional methods, it is difficult to rotate the box and adjust the angle, and the negative effect of specular reflection on interferometric measurement results is significant. The novel approach discussed in this paper used a polarization optical system to reduce the overexposed area in the imaging field of view and obtains the speckle pattern interferometry measurement results without overexposed points. The method was applied to detect the defects of carbon fiber honeycomb panel and laminate panel placed in the pressure control box, and the experimental results show that the proposed method can extract and eliminate the overexposed area effectively.

Jang et al. reported a precise and stable laser beam positioning method with a high scanning speed by using a pixelated binary grating (PBG) based on a compact on-off state digital micromirror device (DMD). The overall procedure for PBG pattern generation was described, analyzed, and experimentally verified. The beam scanning was accomplished by the on–off control of diffraction grating patterns on the DMD, which was designed based on the grating equation under the Fraunhofer approximation considering aliasing, the blaze angle effect, and diffraction efficiency. The parallel measurement of absolute distances to three retro-reflectors was performed successfully via repetitive beam positioning using the PBG. This confirms that the PBG on the DMD can be applied to diverse scientific and industrial applications such as precision LIDAR, three-dimensional calibration of precision machines, and high-resolution laser patterning.

Shi et al. focused on another application of optical measurement in their paper. They developed a novel gear pitch rapid measurement method based on a point laser sensor. As the pitch deviation is an important index to evaluate the quality of the gear, it is important to measure and evaluate the deviation precisely, and it takes a long time with the traditional contact measurement approach, which limits the measurement efficiency seriously. This paper proposed a highly efficient method for gear measurements based on the point laser sensor. The calibration model of the sensor and the system, the effective acquisition of the tooth surface data, and the computation model were established. Experimental results were compared with those of the gear measuring center P26, which demonstrated the feasibility and effectiveness of the proposed optical method for the gear pitch measurements.

Wang et al. proposed a highly sensitive electrolytic copper (Cu) detection method using nanoparticle enhanced laser-induced breakdown spectroscopy (NELIBS) for metal smelting process. The experimental results showed that the Cu spectral line intensity of NELIBS increased by 5.5 to 9.4 times compared with typical LIBS without nanoparticles. The results showed that the ability of LIBS can be improved effectively with the nanoparticle enhancement method to detect Cu. Therefore, this work provides a promising method to detect Cu in the metal smelting process.

We appreciate the remarkable contributions of all authors of this special section and look forward to their further contributions to a future section on the same topic.

The state-of-the-art progress in the field of optical measurement and the related applications presented by these papers will be beneficial for researchers and engineers in optical engineering and related areas.