4.3.12. OPTOELECTRONIC METHODS OF GEOMETRICAL PARAMETERS MEASUREMENTS WITH MICRO- AND NANOMETRIC RESOLUTION

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Many tasks of non-destructive testing and technical diagnostics come to measurements of different geometrical parameters of tested objects. The report concerns high-precision optoelectronic methods featuring digital processing of measuring information, providing micro- and nanometric resolution. The methods concerned are the following:

1) computer microscopy;
2) homodyne white light interferometry;
3) laser heterodyne interferometry with acousto-optic light frequency transformation.

Classical microscopy of dimensional measurements comes to aiming the microscope's sight to the points of the edge of object's image and determination of distance between the points via reading devices. Computer microscopy digitally processes the image via CCD matrix and performs software determination of distance between the points. This allows us to correct a range of microscope errors (caused by Abbe error, guide straightness variation etc), but essential part of aiming error, caused by object's edge diffraction (Fresnel diffraction). Edge position measurement uncertainty can be essentially reduced by using CCD matrix as image analyzer [1]. A zone of about 20–30 pixels is cut around the sight and electronically zoomed in 500-600 times. Thus a diffused image is displayed, representing Fresnel diffraction. Real edge's position giving the diffused image, is found by solving inverse problem of mathematical optics. The solution of inverse problem is indicated as a colored mark, that should be superposed with the sight. Results of experimental methods are presented, showing that uncertainty of edge position is decreased in at least 3–5 times.

The authors introduced this method of intellectual measurements in a range of universal and instrumental measuring microscopes, thus improving resolution.

Solution of inverse problem of mathematical optics determines the real position of object's edge. Thus intellectualization of spatial measurements takes place, improving the resolution of universal and instrumental measuring microscopes up to 1 micron and better [1].

Homodyne white light interferometry is based on locating the achromatic fringe on the measuring device's scale. Using CCD matrix allowed digital processing and filtration of interference pattern, as well as evaluation of sizes of CCD matrix pixels in relation to known light wavelengths [2].

Algorithms allowing superposition of achromatic fringe and pixels of CCD matrix are presented, providing up to 0, 001 micron resolution.

Results of introduction of this method in a number of contact interferometers calibrating end gauge blocks of A and A+ grades used as length measuring standards with 0.001 micron resolution are presented.

Laser heterodyne method is based on acousto-optic interaction and forms at acousto-optic modulator output a beam of light with new time-spatial properties.

New way of forming optical "caliper jaw" is presented, involving phase or frequency conversion of object's edge displacement [3]. The method is based on positioning the non-transparent object's edge in the laser beam Fresnel diffraction zone caused by acousto-optic modulator with ultrasonic wave propagating in it. As a result of diffraction of light by propagating harmonic ultrasonic wave, a set of plane waves in the spectrum of scattering optical radiation is formed – a set of diffraction maximums with different optical frequencies and directions. In the Fresnel zone diffraction maxima overlap forming a complicated propagating interference field, the period of which is equal or a multiple of ultrasonic wavelength, propagating through modulator. Displacement of object's edge within the Fresnel zone causes phase shift of photoelectric measuring signal, frequency of which is equal to the frequency of ultrasonic wave. Thus phase conversion of object's edge displacement takes place.

Forming acoustooptoelectronic feedback from photodetector to ultrasonic wave generator provides frequency conversion of object's edge displacement.

Partial blocking of the beam of light by non-transparent measured object causes photodetector's output signal's phase or frequency shift with carrier from several to dozens of megahertz. The experimental results or phase and frequency conversion with carrier of 8 MHz are presented. The maximal achievable sensitivity makes up 20–30 degrees per micron – for phase conversion, and 300-400 Hz per micron for frequency conversion. Applications of described "optical caliper jaw" for non-contact object measurement with object's dimensions bigger or smaller then optical beam aperture are presented. Also a phase heterodyne laser interference method is described, providing displacement measurement with resolution of 0.001 micron and better [4].

References:

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