LASER MECATRONIC INTELLIGENT SYSTEMS FOR MEASUREMENT AND INTEGRATED CONTROL WITH APPLICATIONS IN INDUSTRIAL AND METROLOGICAL PROCESSES

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Abstract – The scientific paper presents in synthesis integrator mecatronic concept and principles and constructive mecatronic solutions regarding laser HIGH-TECH intelligent mechatronic systems for measurement and integrated control with high precision for intelligent measurement technique with industrial and metrological applications: displacement inspections (vertical, horizontal), surfaces profile, surface micro-geometry, geometry aligning, surface macro-geometry, guidance axes rectilinearity etc., for different materials (from optical glass, magnetic steel, aluminum etc. (in optical disks industry for information storage and etalon masks, in electronic industry of chips, in precision mechanics and mechatronics industry etc.)), for dimensional measurements, positioning and accuracy, in industrial HIGH-TECH domains (computer science) and in metrological laboratories of measurements and testing, through scavenging / scanning with laser fascicle.

Key words: laser high-tech intelligent mechatronic systems, measurement and integrated control

In order to approach and develop the mechatronic intelligent systems and concepts in HIGH-TECH measurement processes, as a result of a complex documentary and research study we are going to present the integrator mechatronic concept for laser type intelligent and integrated measurement technique.

Laser measurement principle can be used in several domains of intelligent measurement technique, where there are determined technical-functional parameters imposed in certain conditions.

This laser measurement principle is based on various conversion methods of mechanical measure:

(a) as converting vertical displacement of a measurement indicator, into a interference fringe displacement of a laser interferometer, according to figure 1, where is materialized optical path variation from laser interferometer as a result of interference fringes displacement.
Laser mechatronic intelligent systems for measurement and integrated control with applications in industrial and metrological processes

(b) as conversion of horizontal displacement (horizontal position) of a measuring (positioning) indicator, based on a laser semiconductor, into an interference fringes displacement resulted from light diffraction through a holographic network.

In both cases can be used laser interferometers characterized by coherence of laser sources and by resolution of nanometers order.

Laser interferometers types use a heterodyne method with Zeeman laser with two wave lengths, or a method with acoustic-optic element with 1/8 phase information, with a polarization fascicle divisor that can detect three or four signals with different phases with 90 or 180 degrees, determining the length of requested displacement.

Due to the nanometric precision of these interferometers there is obviously identified the need for air refraction index correction that can be usually modified in a 1 to 10⁵ ratio.

Therefore as method of exceeding this event, is either the use of the method of refraction index calculus and correction by simultaneous measuring of air temperature / pressure / humidity, or using a gases refract-meter which reduces correction in a 1 to 10⁸ ratio.

(c) as using conversion of profile measure for ultra precise surfaces realized, into an interface fringes scanning of wave front, according to figure 2, where is materialized a relatively stable interferogramme;

In measurement process using interferograms, these interferograms, corresponding to each scanning position, there are detected through a CCD camera, whose signals are processed using a digital computer, and there are histogrammed into a map of measured surface profile with a nanometric precision.

Due to the measurements and experimentations in measurement processes, it was determined that the temporary scanning of the fringes is affected from mutual displacements, vibrations, but also air turbulences between interferometry and surface of profile that it is measured.

To improve the measurement processes, is proposed, as result of laboratory study, to use a diphase interferometer – Simultaneous Phase Shift Interferometer, SPSI, in general conceptual schemes of measurement systems, according to figure 3, where there are precise materialized phase measurements in dynamic environments, with fast modified fringes.
Laser mechatronic intelligent systems for measurement and integrated control with applications in industrial and metrological processes

In measurement process of processed surfaces profiles, system concept contains as laser source, a He-Ne laser with a single stable frequency, as imagine system, for CCD cameras, with interference fringes, diphased with 90 degrees from each other, by polarization techniques, realizing a synchronized diaphragm (at 0.1 milliseconds), which simultaneously creates four fringes of high contrast and measuring “surface height”, with a precision of 10 nm level.

(d) as converting roughness measurement conversion (micro-geometry) of processed surface, into a detection of focusing point error “optical tool”, by using astigmatism methods, of critical angle and cutting edge.

In figure 4, is shown the principle of critical angle method in “interference profile-meter” system.

In micro-geometry measurement process, the measured surface by using optical tool principle with critical angle method, is positioned in lenses focus (in B), where laser light passes through objective lenses, is transformed in fascicle with parallel beams, fascicle that passes through total reflection prism, that being placed and oriented, so the light is reflected at critical angle, where is obtained the same level of intensity for incident light, on two photodiodes, and the defocalized signal becomes zero.

In the moment when measuring surface is
positioned in closed \( A \) field (divergent) and close to lenses system, light fascicle diverging after passing through lenses, and situated on the upper side of the optical ax, reaches the prism at a smaller angle than the critical angle, determining light refraction, at the lower side of optical AX, is completely reflected at a large incidence angle, resulting a difference in output signal of photodiodes and in this way generating a defocalized signal.

In the moment when the surface to be measured is positioned in C field (convergent), distanced from the lens, is realized a phenomenon opposite to the one in A field (divergent), obtaining a signal with an opposite sign.

For an increasing of measurement precision of processed surface micro-geometry, it is recommended to use other types of interference profile-meters, as shown: in figure 5 – laser interferometer with optical sensor HIPOSS type – High Precision Optical Surface Sensor, with an objective of 0.6 NA and resolution of 0.2 nm, which possesses a semi-transparent mirror which divides the optical path in two prisms with total reflection that divides the indicators, resolving the bending effect of surface to be measured.

In figure 6 – laser interferometer of heterodyne with circular scanning with a vertical resolution of 0.1 nm, which possessed a Wollaston prism that divides by polarization a laser fascicle with two wave lengths, divided Zeeman type, in two fascicles, measurement fascicle focalized on a point on a circular rotary surface and respectively reference fascicle which is fixed on rotation center; further, reflected fascicles are recombined by a prism and generates a interference signal due to path difference of fascicle.
(c) as converting electronic chips alignment displacement or photoelectric incremental masks, into a displacement of interference fringes on a laser base (He-Ne).

In figure 7 is showed the principle of a system for aligning with laser for etalon chips and masks.

Laser fascicle illuminates the alignment drawing of etalon chip/mask, by a projector lens; diffracted light fascicle from the plaquette and returned along the same optical path, is divided by the fascicle divisor to system indicator; the spatial filter stops diffracted light of zero order, eliminating the faults from the fascicle strongly deteriorated because of surface roughness and due to the irregularity of the drawing; the signal is scanned by the platform displacement and the signal from the indicator is interpolated from the platform interferometer fringe signal, when is made the detection with precision of drawing center.

In figure 8 is showed the processing of the aligning signal of the etalon chip/mask.
The conceptual system of the interferometer system of the chip/etalon mask aligning, is showed in figure 9, where laser fascicles are modulated optic-acoustic (AOM) with $f_1$ and $f_2$ frequencies, which are reflected by a projector lens, under reticule and then projected on the plaquette; the aligning drawing as network shape from the plaquette is illuminated by two laser fascicles from two different directions.

The processing and shaping principle of the LIA optical signal is showed in figure 10.

The aligning process of the chip / etalon mask, also contains the interference of the diffracted fascicles (on the network), order $+1$ for $f_1$ and $f_2$. 
Laser mecatronic intelligent systems for measurement and integrated control with applications in industrial and metrological processes

order for $f$, thereupon a frequency heterodyning takes place, where heterodyne frequency phase $f_h = (f_1 - f_2)$ will vary with relative positions displacements of the alignment drawings and laser fascicle.

Reference signal $f$, is processed using a reference signal generator, and the difference between $f$ and $f_h$, corresponding to the displacement of the aligning signal from reference position, determines platform movement, reducing phase difference to zero and in this way realizing aligning chip/ etalon mask.

The results of the test with interferometer system with laser (LIA) are given in figure 11.

Fig. 11

(f) as converting circular displacement (of revolution) of a measurement indicator, based on a mecatronic system with laser, into a interference fringes displacement resulted from light diffraction by a holographic network. According to mecatronic system with laser, is obtained, with a nanometric precision, the measurement of the deviation from ovality and/or micro-geometry (roughness), as there are showed in figure 12.

Fig. 12
as converting displacement (in plan) of a indicator based on a laser interferometer with laser, into a interference fringes movement, to determine linearity (in plan), of the surface (in plan).

For the mentioned determinations, there are conceived and recommended, complex mecatronic systems in 3D, that have in their structure interferometer sensor with laser, as follows:

- in figure 13, is showed the concept of system / installation for 3D measuring.

![Fig. 13](image1)

- in figure 14, is showed the concept of mecatronic system for 3D measuring of a optical disk surface smoothness.

![Fig. 14](image2)

In perspective, laser technique is continuously developed by small wave lengths generation (sub-micron) with potential possibilities of direct processing by using photons and for processing various materials at atomic level, for developing in perspective, of new technologies regarding the intelligent measurement technique and the intelligent mecatronic systems/equipments/installations of high complexity and nanometric precision.
References