LITERATURE REVIEW REPORT

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There are mainly three parts and another short part of conclusion in this report. Part one gives a brief introduction on the work of literature review, part two offers a general report on the relative literature and part three emphasizes some particulars.

1. ON THE WORK OF LITERATURE REVIEW

1.1 Purpose

In order to improve a reliable measurement technique that is able to measure curved surface of products such as lenses accurately and efficiently, the group has recently decided to go in for a project "Accurate measurement of shapes of curved surface" with cooperation from Procornea, EPT and other industries. It is necessary as primary work to review relative literature so that we may learn from and find important essentials from previous and exiting research work and, as a result, benefit our research.

1.2 Methods

To search relative literature, including technical papers in journals and proceedings, theses as well as technical reports and books, we use following retrieval tools:

EI -- The Engineering Index
SCI -- Science Citation Index
TUECIS -- TUE Campus Informatie Systeem
CD-ROM -- Compact Disk for Degree Theses
ISTP -- Index of Science & Technology Proceedings
Following key words

Moiré, interferometry, 3D-shape measurement

were used as main heading keywords, and

lens, asymmetric, curved surface,
optical method, gratings

were accepted as sub-heading keywords in retrieval and searching relative literature.

1.3 The procedure

26 Nov 93 (Friday) decision to go in for the project

29 Nov - 17 Dec 93 literature retrieval, search and relative papers copymaking

20 Nov - 24 Dec 93 and review relative literature

29 Dec - 02 Jan 94

03 Jan - 05 Jan 94 writing this report

1.4 Statistical results and analysis

There are in total 137 research and technical papers, 71 theses and 11 books have been identified to be of relative to the project, most of which are in English and a few of which are in Chinese, Japanese and German respectively owing to author’s language limitation.

Table: literature retrieval statistics

<table>
<thead>
<tr>
<th>item</th>
<th>(M)</th>
<th>(C)</th>
<th>(G)</th>
<th>92-93</th>
<th>90-91</th>
<th>88-89</th>
<th>82-87</th>
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<td>34</td>
<td>90</td>
<td>57</td>
<td>27</td>
<td>19</td>
<td>34/11</td>
<td>137</td>
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<tr>
<td>thesis</td>
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<td>13</td>
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<td>23</td>
<td>21</td>
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<td>3</td>
<td>1</td>
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<td>7</td>
<td>11</td>
</tr>
</tbody>
</table>
M - most closed relative; C - closed relative; G - general

It can be seen from above table that shows you a statistical result that moiré technique and its derivatives as novel whole-field sensing methods, unlike point sensing methods as traditional ones, have been getting remarkable developments and more and more attractions to the researchers in a rapidly increasing number of industries and academic institutes.

The table says that there is a rapidly increasing trend of number of relative papers. Number of the paper during 1992-1993 is twice as much as that during 1990-1991 and triple as much as that during 1988-1989.

It should be pointed out that unfortunately, we have find no any report on the measurement of curved surface shape, such as lenses, mirrors and dies etc by moiré or its relatives of optical and mechanical means with an accuracy within sub-micron range. This may be, on other hands, fortunately offer us an opportunity to do an inventive work in our research.

2. GENERAL REPORT

2.1 Theme of the project

The production of lenses, mirrors and products with asymmetrical curved surfaces is increasing very fast, while high precision is required. Especially the production of lenses, for example, used in compact disc players, soft and hard contact lenses, and parts utilized in all kinds of recorders has expanded enormously.

The actual measurement technique to inspect these product ranges are not sufficient to satisfy the increasing demands of industry, especially the required measurement accuracy and convenience.

The aim of this research is to improve a kind of suitable measurement method for reliable and traceable use both in industry and in laboratory cases. It is possible to adapt comprehensively moiré interferometry, deflectometry, image processing, surface interferometry and 3D measurement techniques to implement the demanding but interesting research task.

2.2 Significance and importance

Workpieces with spherical and/or aspherical surfaces, as well as with other symmetrical and/or asymmetrical shapes are more and more employed in precision engineering, which are often manufactured with precision or ultra-precision cutting machines, for example "optimatic" diamond lathe by EPT. Precision measurement of such kind of curved shape is essential for precision or ultra-precision manufacturing.
The concept of measuring such kind of a component, for example, a contact lens, without any physical contact between the part and a measurement device has many attractions. Non-contact optical techniques are therefore becoming an important tool in the metrology of precision, curved surface form. Traditional measurements are based on point sensing methods and even recently developed measurement such as STM techniques are based on line sensing methods whereas the novel measurements like moiré method, are based on whole-field sensing method. In recent years, moiré technique has attracted much attention of many workers who work in the fields of both research and development, as an attractive alternative for measuring the complex shape of 3D objects. It makes possible to inspect and assure product quality on-machine and in laboratory accurately and efficiently.

2.3 Review of historical development of moiré technique

The moiré phenomenon can be readily observed when superimposing two periodic or quasiperiodic structures. The words "Moiré" is a French term for "watered" or "wave appearance". It is related to ancient clothmaking technique developed by Chinese. This word seems to be used for the first time in scientific literature in 1925. Then, starting from the fifties, moiré fringe techniques have expanded to become important metrological tools, lasting till the sixties.

During the period of recent two decades, moiré technique, with the old word "moire" in its title and completely new contents in its insides, has got a flourishing expansion by virtue of the advent of developments of modern techniques such as laser, opto-electronics, computer techniques and precision engineering. This is because that moiré method has some special advantages, such as whole-field scanning, non-contact, suitable to measure complex surface form, quantitative and tunable sensitivity.

In the light of precision lithography, phase-shifting and phase-stepping techniques, the sensitivity of moiré method, defined as a number of fringes per unit displacement, may reach up to micron order. A news report from one of a USA university in Virginia says that an ultra-high sensitivity of 17 nm per fringe contour has been made by means of refractive medium and fringe multiplication methods.

With developments of image processing technique and computer simulation, moiré technique has been found increasing applications in an expanding number of practical fields; not only in the fields of industry, such as shape and surface measurement, inspection in processing of welding, press working, hot working, powder moulding and so forth but also in the fields of human engineering, safety engineering and other aspects.

However, everything in the world has two sides. There exist some limitations to and some shortcomings with the moiré technique. The main point perhaps is that it is difficult to interpret phase information into displace information when reconstructing the shape of a measured workpiece and that at the time being, the accuracy of moiré measurement technique is within the range from several tens microns to a few microns while a higher accuracy order of sub-micron is our desire. Also, trouble may appear in image processing because of a tedious time of procedure.
2.4 Main research aspects

2.4.1 Fundamental principles

Moiré technique is a method of measuring 2D or 3D surface profile by using moiré fringes that appear when two gratings of similar frequencies are superimposed. In recent years much research has been done on its practical application, and as a result, shadow-type and projection-type moiré topography are well established. When a grating and its shadow onto the object interact to produce moiré fringes which represent height contours of the surface, a shadow-type moiré is formed. When a fringe pattern is projected onto the object, projection-type moiré fringes are obtained by comparison with a reference grating which can be made by viewing through the reference grating or by computer, storing object and reference grids in digital form, and adding or subtracting them. With both types moiré fringes become contour lines of surfaces in specific geometrical conditions. Most of reports from the reviewed literature are based on these two kinds of moiré principles.

However, the height difference between two consecutive fringes does not remain constant based on the principles. A report from South Korea is found that a new type of moiré topography where scanning a slit beam is used for illumination so that the problems associated with absolute fringe orders are eliminated, namely, the difference become constant to simplify the problem.

Two researchers from Israel proposed a method for ray deflection mapping, moiré deflectometry, which is compatible with interferometry. The information provided by moiré deflectometry is the ray deflection map of a light beam and the method is a pure ray tracing. As a result, the analysis of 3D shape may be simplified.

Usually, grids are made in parallel straight lines with equally spaced line gratings (Ronchi gratings) on a plane plate. A paper presented from Japan reports that they used a zone-plate interferometer, which is a kind of common-path interferometer and needs no real reference surface. A zone-plate is a circular grating and can be used to measure symmetrical shape parts. Also, cross grating was employed by German people with phase-shifting technique to the 2D deformation of fine fringes with up to 1000 lines per mm.

No other type of gratings has been picked up from the review.

2.4.2 Set-ups and apparatus

Numerous different optical schemes can be arranged for moiré interferometry, most of which, however, are composed of followings:

- LD or laser head as light source (0.3 - 0.8 mw)
- measurement and reference gratings
- optical elements for optical system
- CCD camera (1024 * 1024 or 4096 * 4096)
- adjustable fine motion mechanics
- TV or other monitor
- computer (486 or 386)
- a package of software
- image processor board interfaced with computer
- recorder and/or printer

among of which, the quality of light source and gratings, as well as the sensitivity of CCD camera may to a great extent determine the accuracy of a moiré measuring system.

2.4.3 Image processing technique

In many spheres of application, moiré interferometric result must be expressed in such a way that non-specialists can comprehend them or in such a way that may be combined or compared with other, non-interferometric measurements. In other words, we have to convert the fringe phase or position information into shape different data between a reference and a measured component so that the results can be presented in the required numerical or graphical form.

Another reason for the requirement of image processing technique is to adapt phase-shifting or phase-stepping technique in order to enhance the sensitivity of moiré method. Both two kinds of methods bring us a great deal of computational work for image processing.

In the early days of moiré technique, fringe pattern analysis was carried out manually. During the last two decades, however, the wide availability of digital image processing equipment has prompted a number of research groups to investigate the possibility of semi- and/or automatical analysis by means of computers.

It can be seen from the literature that there have been much attention and research onto the image processing technique, but most of them were inefficient because there is a huge amount of information stored in moiré fringe patterns. Some authors have made efforts to process moiré fringe pattern automatically, for example 4-5 (China), 10-6 (Israel), 6-2 (Hongkong) and 10-15 (UK). There is still a lot of work to simplify the problem to do. Fortunately, we found that there is a kind of image processor card, for example FG100AT board, which can be interfaced into computer to speed up and shorten the image processing procedure, appearing in market.

2.4.4 Accuracy

There may be many factors affect accuracy of a precision measurement. For example, optical influences of environmental fluctuations, system configuration, quality of employed elements and imperfection of measurement principle and computation. However, the most important factors which mainly determine the sensitivity or accuracy are the gratings and the availability to divide and then identify the fringe patterns as fine as possible.
The gratings control the sensitivity in moiré methods, the smaller the pitch, the higher the sensitivity. A fine grating is formed either by metal deposited, chemical means, or by optical method. It has been shown from the reviewed literature that the grating pitch of most gratings used were from the ten-micron order through micron order, which corresponds to sensitivity of moiré with 100 through 1000 lines per mm. The waviness of light source, 788 or 632 nm for instance, may limit to further fine gratings. A research team from Virginia of USA has created a virtual reference grating by inserting a refractive medium instead of air, thus shortening the wavelength of light. As a result, A basic sensitivity of 208 nm per fringe order has been reached.

To divide fringe pattern more and more fine, some efficient methods have been developed which with such titles as phase- shifting, phase-stepping and fringe sharpening methods. After a fringe shifting and fringe sharpening scheme was developed, Americans implemented a fringe multiplication scheme with which an ultra-high sensitivity of 17 nm per fringe contour was accomplished. This corresponds to moiré with 57,600 lines per mm. This means that an accuracy order within the sub-micron range may be reached up considering that the order of sensitivity is usually higher one order than that of accuracy.

At the same time, many authors have reported according to the review that the sensitivity order within micron range was reached up from UK (NPL, NEL, 8-2, 10-15, 7-9), USA (10-2, 4-4), China (2-3, 2-4, 14-9), Japan (10-7, 13-4, 13-2, 5-1), Korea (3-5), Israel (10-6), Germany (7-9) and France (8-4).

2.4.5 Applications

Moiré topography is able to determine the shape of an object, by pattern measuring, in a short time. Recently moiré topography has been used in various industrial fields as well as other aspects. This is because that it has superior features that point sensing measurements do not have. As it becomes popular various related techniques that fit special needs have been developed and there is the prospect that moiré technique will become a more important measurement method and strengthen its position in the near future.

It can be summarized from the literature the application cases in which we have found the application of moiré technique:

1) Experimental mechanics
   - strains and deformation measurement
   - crack length and its velocity measurement
2) Manufacturing
   - on-machine inspection
   - shaping and cutting inspection
   - inspection in CIM and automation
   - welding inspection
   - hot working inspection
   - press working inspection
   - powder moulding and ceramic working inspection
3) Dimension measurement
   - 2D or 3D shape measurement
   - surface topography
   - displacement measurement
   - water surface measurement
4) Optical testing
   - focal length of lenses and mirrors
   - refractive index of lenses and fluids
   - curvature of optical components
5) Human engineering
   - recognizing human face profile
   - dental diseases and orthopaedy
   - axial eye length measurement
6) Density field analysis in fluids
   - wind tunnels
   - flame temperature distribution
7) Thin-film
   - tympanic membrane measurement
8) Thermal lensing
9) Safety engineering
10) Others

2.4.6 Limitations

It can be drawn out from the review that there exist something that limits and obstructs the availability to further development and application of moiré method. They are:

1) Difficulty to make smaller pitch and higher quality of the grating, i.e., make higher basic sensitivity of moiré fringe patterns.

2) Complication to interpret the phase and position information from moiré fringe patterns into displacement information to reconstruct the measured profile.

3) A great amount of computational work on image processing which may take a tedious time, and

4) The main obstacle may be how to accomplish the high measurement accuracy within the sub-micron range.

3. BRIEF REVIEW OF PARTICULARS

In this part, regarding the most closed relative literature, we give a brief
3.1 Virginia Polytechnic Institute and State University

There is a robust research team in this university working on moiré techniques. There are two supervisors, Daniel Post and Robert Czarnek, in the team. They have published some books and papers on fundamental principle and their research on moiré technique since as early as 1967. Recent years, from 1988 to 1993, there are at least six people have done the research on moiré techniques, four of who work for their PhD degrees and two of who are visiting scholars from China.

They have developed a hybrid method combining moiré interferometry, high-resolution data-reduction technique, 2D data-smoothing method and finite element method to apply residual strain analysis of composites, and cruciform composite shear test.

Next, they accomplished a ultra-high sensitivity of 17 nm per moiré fringe contour by two developments. First, to create a virtual reference grating by inserting refractive medium instead of air, thus shortening the wavelength of light. As a result, A basic sensitivity of 208 nm per fringe order has been reached. Second, after a fringe shifting and fringe sharpening scheme was developed, they implemented a fringe multiplication scheme with which an ultra-high sensitivity of 17 nm per fringe contour was accomplished.

Also, they did the research on quality control of the milling process using three-dimensional vision based on the moiré interferometry technique.

Another research was on the development in moiré interferometry focus on carrier pattern technique and vibration insensitive interferometers.

Moreover, they also present the whole analysis of moiré fringe patterns by using an image processing technique.

3.2 Universitaire Instelling Antwerpen

A PhD research was centred on automated moiré topography and its application for shape and deformation measurement of the tympanic membrane. They have developed a non-contacting high resolution metrological method and an apparatus, and to use it for obtaining quantitative data of shape and deformation of the tympanic membrane. Unfortunately, they do not show their measurement accuracy in the abstract.

3.3 Universiteit Twente

Topographical measurement based on the shadow and projection moiré method was their project of research. They reported the theoretical research on the two different ways of generating moiré patterns, the condition to be made for, the construction of a moiré system for topographical measurement.

Experimental results have been compared with theoretical ones. And the
measurement accuracy was 200 microns.

3.4 Lehigh University

Some researchers were working on how to enhance moiré interferometry by digital image processing in the university. The main objective of their work was enhancement of the whole field displacement monitoring technique of moiré interferometry by the introduction of a new approach combining fractional fringe analysis and digital image processing. Applications include transient and steady state strain analysis of electronic packages, calibration of piezo-resistive, stress-chips, investigation of the thermal expansion of composite sheets used in circuit boards, and determination of stress.

3.5 Toyama University and Fuji Photo Optical Co., Ltd.

A group being composed of people from two institutes has turned their attention from line fringe to circular one. They used a zone-plate interferometer, which is a kind of common-path interferometer and needs no real reference surface. A zone-plate is a circular grating and can be used to measure symmetrical shape parts. The zone-plate used is a photo plate (Agfa1OE75) and has a pattern calculated to reproduce the shape of the designed surface. They employed 0.028 mm pitch gratings and the measuring error was less than 0.012 mm. This kind of method has been adapted in on-machine shape measurement.

3.6 Korea Advanced Institute of Science and Technology

A new method of moiré topography is suggested by them in which a slit beam is used in a scanning mode to generate moiré fringe. One remarkable feature of this method is that height difference between two consecutive fringes becomes constant so that absolute fringe orders need not be identified. This makes it possible to measure 3D surface profile in an automatic manner simply by using a computer-aided image proceeding technique.

3.7 Rotlex Optics Ltd.

The Israel people proposed a method for ray deflection mapping, moiré deflectometry, which is compatible with interferometry. The information provided by moiré deflectometry is the ray deflection map of a light beam and the method is of a pure ray tracing. As a result, the analysis of 3D shape may be simplified. This method has such advantages as fully quantitative, interferometry-compatible in accuracy and has the additional one of tunable
sensitivity, but the accuracy they made was not as high as that we desire.

3.9 Tsinghua University and Huazhong University of Sci. & Tech

There are two research groups in the two Chinese universities respectively. Based on moiré techniques, some new measurement methods have been developed for the application to strain, stress and deformation analyses in metal forming and manufacturing.

Also, some reports present there are applications of moiré technique in 2D and 3D shape measurement. The accuracy order was within ten or a few microns.

4. CONCLUSION AND PROPOSITION

1. Moiré technique and its derivatives as a kind of novel whole-field sensing, non-contact methods, have getting remarkable developments and more and more attractions to the industry and academia in recent years.

2. The most important factors which mainly determine the sensitivity or accuracy are the pitch and quality of gratings as well as the availability to divide and then identify the fringe patterns as fine as possible.

3. No any literature on the measurement of curved surface shape, such as lenses, mirrors and dies etc by moiré or its relatives of optical and mechanical means with an accuracy within submicron range has been found in the review.

4. It is proposed to order a few most closed relative theses and make a contact with the researchers, for example, Virginia, Antwerpen, NEL and NPL as well as PTB.

5. It is possible after our hard and inventive research, the aim of our research project to improve a kind of suitable measurement method for the measurement of curved surface shapes using both in industry and in laboratory cases can be accomplished.

APPENDIXES:
1. List of relative books
2. List of relative papers
4. List of relative theses (1993)

Appendix 1
RELATIVE BOOKS

1960: Guild, J: Diffraction gratings as measuring scales: practical guide to the metrological use of moiré fringes, Oxford University Press

1969: Guild, J: Moiré fringe in strain analysis, Oxford: Pergamon


1970: Dyson, J: Interferometry as a measuring tool, Machinery Public Co.


1990: Kafri, O & Glatt, I: The physics of moiré metrology, John wiley & Sons (*)


1993: Malacara, D: Optical shop testing, 2nd ed, New york: John wiley & Sons ($) 

1993: Patorski, K and Kujawinska: Handbook of the Moiré fringe technique, Elsevier Science publishers (*)


1993: Practice contact lensology, Guan Ming Daily Press Mass. (RL)
1989: Wu, S: Precision machining without precise machinery, v 38, n 1, 533 - 536

1989: Zhuang, B: Using compensated HOE in optical head, v 38, n 1, 537 - 540

1991: Zhuang, B: Noncontact optical probe with holographic optical element, v 40, n 1, 507 - 510

1992: Sohlenius, G: Concurrent engineering, v 41, n 2, 645 - 655

1993: Evans, C: Compensation for errors introduced by non-zero fringe densities in phase-measuring interferometers, v 42, n 1, 577 - 580 (*)

1993: Kunzmann, H: Scales vs. laser interferometers performance and comparison of two measuring systems, v 42, n 2, 753 - 767
1970: Meadows, D: Generation of surface contours by moiré patterns, v 9, n 4, 942 - 947

1970: Takasaki, H: Moiré topography, v 9, n 6, 1467 - 1472

1974: Bruning, J etc: Digital wavefront measuring interferometer for testing optical surfaces and lens, v 13, 2693 - 2703 (*)

1977: Indesawa, M etc: Scanning moiré method and automatic measurement of 3-D shapes, v 16, 2152 - 2162 (*)

1981: Kafri, O etc.: Reflective surface analysis using moiré deflectometry, v 20, n 18, 3098 - 3100

1982: Kim, C: Polynomial fit of interferograms, v 21, n 24, 4521 - 4525

1982: Weissman, E & Post, D: Moiré interferometry near the theoretical limit, v 21, n 9, 1621 - 1623

1983: Gasvik, K: Moiré technique by means of digital image processing, v 22, 3543 - 3548 (*)

1984: Jensen, S etc: Subaperture testing approaches: a comparison, v 23, n 5, 740 - 745 (*)

1984: Nergo, J: Subaperture optical system testing, v 23, n 12, 1921 - 1930 (*)

1984: Srinivasan, V etc.: Automated phase-measuring profilometry of 3D diffuse objects, v 23, n 18, 3105 - 3108 (*)

1984: Yatagai, T etc: Aspherical surface testing with shearing interferometer using fringe scanning detection method, v 23, n 4, 357 - 360 (*)


1987: Yoshizumi, K etc.: Ultrahigh accuracy 3D profilometer, v 26, n 9, 1647-1653 (*)

1988: Cochran, E etc: Combining multiple-subaperture and two-wavelength techniques to extend the measurement limits of an optical surface
profiler, v 27, n 10, 1960 - 1966 (*)


1988: Kafri, O etc.: High-sensitivity reflection-transmission moiré deflectometry, v 27, n 2, 351 - 353

1988: Keren, E etc.: Universal method for determining the focal length of optical systems by moiré deflectometer, v 27, n 8, 1383 - 1385 (*)

1988: Liu, Y etc.: Subaperture testing of aspheres with annular zones, v 27, n 21, 4504 - 4513 ($)

1988: Omura K etc.: Phase measuring Ronchi test, v 27, n 3, 523 - 528

1990: Kafri, O etc.: Moiré deflectometry with a focused beam: radius of curvature, microscopy, and thickness, v 29, n 1, 133 - 136

1990: Tang, S etc.: Fast profilometer for the automatic measurement of 3D object shapes, v 29, n 20, 3012 - 3018 (*)

1991: Arimoto, A: Laser scanning system using a rotationally asymmetric aspheric surface, v 30, n 6, 699 - 704 (*)

1991: Lin, D etc.: Profile measurement of an aspheric cylindrical surface from retroreflection, v 30, n 22, 3200 - 3204 (*)

1992: Creath, K etc.: Testing spherical surfaces: a fast quasi-absolute technique (a), v 31, n 22, 4350


1992: Kim, S etc.: Moiré topography by slit beam scanning, v 31, n 28, 6157 - 6161 (*)

1992: Simova, E etc.: Phase-stepping holographic moiré simultaneous in-plane and out-of-plane displacement measurement (a), v 31, n 14, 2405 - 1407

1992: Stetson, K.: Phase-step interferometry of irregular shape by using an edge following algorithm (a), v 31, n 25, 5320 - (*)

1992: Wegdam, A etc.: Projection moiré fringe pattern prediction using the optical transfer function in the presence of aberrations, v 31, n 34, 7348 - 7354 (*)

1992: Wegdam, A etc.: Simulation of shadow moiré system containing a curved
1993: Fischer, D: Vector formulation for interferogram surface fitting, v 32, n 25, 4738 - 4743 (*)

1993: Rosete-aguilar, m etc: Profile testing of spherical surfaces by laser deflectometry, v 32, n 25, 4690 - 4697 (*)


1994: Creath, K etc: Phase-shifting errors in interferometric tests with high-numerical-aperture reference surfaces, v 33, n 1, 24 - 25 (*)

1994: Elssner, K etc: Establishing a flatness standard, v 33, n 13, 2437 - 2446
1967: Post, D: Sharpening and multiplication of moiré fringes, v 7, n 4, April. 154 - 159 (*)

1982: Sciamarella, C: The moiré method -- a review, v 22, 418 - 433

1984: Morimoto, Y etc: Deformation measurement during powder compaction by a scanning-moiré method, v 24, n 2, Feb. 112 - 116


1988: Graham, S: The influence of grating characteristics on moiré fringe multiplication, Dec. 330 - 335

1988: Matthys, D: Automated analysis of holointerferograms for the determination of surface displacement, March 86 - 91

1988: Ning, P: Automatic analysis of moiré fringe pattern by using an image-processing system, Dec. 350 - 354 (*)


1993: Chang, M: Phase-measuring profilometry using sinusoidal grating, June 1117 - 122 (*)

1993: Han, B: Geometric moiré methods with enhanced sensitivity by optical/digital fringe multiplication, Sept. 196 - 200 (*)

1993: Liao, J etc.: Enhancement of the shadow-moiré method through digital image processing, v 33, March, 59 - 63

1993: Poon, C: Automated fringe pattern analysis for moiré interferometry, Sept. 234 - 241 (*)

1993: Read, D: Scanning moiré at high magnification using optical methods, June 110 - 116
1986: Hattori, S: An automatic super-accurate positioning technique using moiré interference (Bull. JSPE) v 20, n 2

1991: Kohno, T: High precision optical surface with linear detection, v 25, n 3, 237 - 238

1991: Kurata, Y: CD pickup using a holographic optical element, v 25, n 2, 89 - 92


1992: An, H: Method for machining of free formed surface by using an optical profile NC machining-- application for dental CAD / CAM system, v 26, n 4, 342 - 347

1992: Igarashi, S: 3D measurement of shape by projection method using special gratin pattern, v 26, n 2, 128 - 133 (*)

1993: Igarashi, S. etc: 3D measurement of shape using differential stereo vision algorithm, v 27, n 3, 247 - 252
TITLE OF THE JOURNAL: JOURNAL OF OPTICS SOCIETY OF AMERICA :A

1985: Keren, E etc: Diffraction effects in moiré deflectometry, v 2, n 2, 111 - 120

1990: Liu, L: Joint talbot effect and logic-operated moiré pattern, v 7, n 6, 970 - 976

1991: Asundi, A: Phase-shifting and logical moiré, v 8, n 10, 1591 - 1599 (*)

1993: Lee, K: Surface reconstruction from photometric stereo images, v 10, n 5, 855 - 867

1990: Ahmed, N etc: Miniature laser anemometer for 3D measurements, V 1, 272 -276

1990: Moore, A etc: An electronic speckle pattern interferometry for complete in-plane displacement measurement (a), v 1, 1024 -1030

1991: Kanada T etc: A three-dimensional surface profile measuring system with a specimen-levelling device (a), v 2, 191 -197


1993: Benech, PH etc: Optical non-contact transducer (a), V 4, 1222 -1227

1993: Berwood, G etc: Laser diodes for length determination using swept-frequency interferometry (a), v 4, 988 -994

1993: Bosch, S etc: A method for the measurement of reflectance of spherical surfaces, v 4, 190 -192 (*)

1993: Pretzer, G etc: High-accuracy differential interferometry for the investigation of phase objects, v 4, 649 -658

1994: Jolic, K. etc: Non-contact, optically based measurement of surface roughness of ceramics, v 5, 761 -684
1990: Downs, M: A proposed design for an optical interferometry with sub-nanometric resolution, v 1, 27-30 (a) (*)

1990: Montgomery, P: Nanoscopy: nanometre defect analysis by computer aided 3D optical imaging, v 1, 54 62 (a)

1990: Newbury, D: Microanalysis to nanoanalysis: measuring composition at high spatial resolution, v 1, 103 - 130 (a)

1991: Franks, A: Nanometric surface metrology at the national physical laboratory, v 2, 11 - 18 (*)

1993: Hosoe, S: Highly precise and stable laser displacement measurement interferometry with differential optical passes in practical use, v 4, 81 - 85 (*)
1982: Pirodda, L: Shadow and projection moiré techniques for absolute or relative mapping of surface shapes, v 21, 640 - 649
1982: Post, D: Developments in moiré interferometry, v 21, n 3, 458 - 467(*)
1985: Kafri, O etc.: Moiré deflectometry: A ray deflection approach to optical testing, v 24, n 6, 944 - 960
1989: Huntley, J etc.: High resolution moiré photography: application to dynamic stress analysis, v 28, 926 - 933
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