Towards New Interferometer Technology for Surface Metrology

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Abstract

There is an increasing requirement from manufacturing industries for improved technologies to measure surface topography. New instruments have to be accurate; robust to be used on the industry floor; non-invasive; automatic; and sufficiently fast to be used in real time as well as to simultaneously measure over a large area. The industrial applications are plenty:

- On-line quality control of machined parts,
- Direct feed back to the manufacturing process,
- Analysis and selection of surface texture/structure.

This paper presents new developments in interferometer techniques for new robust area-based topographic instruments.

1 Introduction

Changes in the pattern and polarization of electromagnetic wave fronts represent the most sensitive probes in physics. Electromagnetic waves may penetrate media and/or reflect on media borders with various results depending on the composition of the media and structure on the media changes. The change in electromagnetic field can be amplitude, direction, phase, and in the case of a moving reflective surface also frequency. Our toolbox to observe these changes include observations of field pattern with three dimensional position, time, frequency, and polarization.

The Photonics grouop at Halmstad University originates from radio astronomy and has more than 40 years of experience in interferometry technology from VLBI (see e.g. [1]), mm-wave interferometry, and development with the steel industry. In a rare case of technology collaboration, the Photonics group now works closely with the Functional Surface group at Halmstad University to develop surface measurement techniques. We have previously published one such development in PDI interferometry [2], Here we present other developments on robust measurement systems for direct in-line observations of industrial processes.

2 Technical development

The Halmstad group is developing a series of surface measuring technologies. Our purposes are multiple:

- understand and know the measuring instrument to first principle in order to do the best possible science on surface structure;
- develop instruments for specific industrial environment and fulfil specific industrial measurment purposes;
- ensure technology to be easily integrated to existing process controls.

2.1 Halmstad Large Area Statistic Analysis (HLAS)

In many industrial processes it is sufficient, at least at present time, to do a statistical analysis of a large scale surface. This is presently performed by visual inspection, with a human visually analyzing and giving a go or no-go. In order to avoid human bias, subjective or biological, we are developing an automatic instrument which can be used as a toolbox for controlling the polishing process towards a specific area and/or strategy or to give a go/no-go decision. Our method will not give any specific depth measures, so a final more detail off-line analysis is necessary if a quality measure is required. This development is part of the EU project poliMATIC.

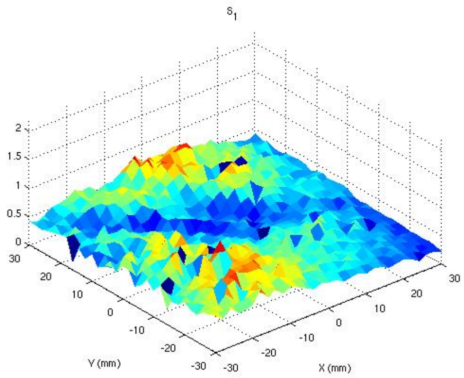

Figure 1: Statistic measurements over a polished 100x100 mm area.

Figure 1 above shows an example of measurements over a 100x100 mm area. The area has been measured as 4x4 mm sub-areas sampled at 3 mm center-to-center distance. The colors represent the ratio of incoherent scattering over the coherent reflection of each sub-area, blue is flatter and red is rougher. It is clear that the polishing is much better along a center line than at the edges.This information, together with statistical information about scratches, holes, lines, furrows etc., is anlyzed and can be fed back to the polishing process in object co-ordinates.

2.2 Halmstad White Light Interferometer (HWLI)

White light interferometers exist commercially in abundance and are frequently used in laboratory work. We decided to build our own in order to have it available as reference on the same workbench and format as our other instruments. Such an interferometer is also simple, can be built at low cost and since we are using the same camera and positional hard-ware as our other instrument we also can easily obsserve the same area and compare measurements. We have verified our HWLI as to have at least the same resolution and properties as commercial instruments. We are presently using it to measure curved surfaces, e.g. the inner lining of cylinders. The area topography is observed in Cartesian co-ordinates and then converted to cylindrical azimuth, Y-position and radial distance offset (Θ, Y, R) co-ordinates.

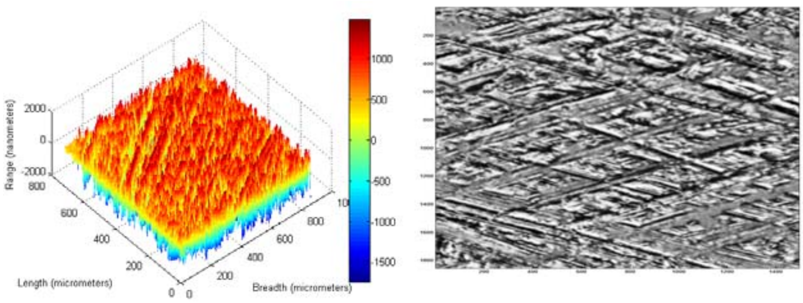

Figure 2: Topographic images of cylinder liner in Cartesian co-ordinates (left) and cylindrical co-ordinates (right) where the X-axis represents azimuth angle around the cylinder and the Y-axis represents the position along the cylinder depth.

2.3 Halmstad Polarization Phase Interferometer (HPPI)

White light interferometers have large observing range and can also be used as phase interferometers if colored light is used instead of white light. However, they have the drawback that the physical distance between the observed and reference area has to be changed. We therefore decided to develop an instrument which has the same footprint and lateral resolution as our statistic HLAS instrument and the same depth resolution as a phase interferometer but without linearly moving parts. For this purpose we have constructed a polarization interferometer where the object and reference reflected beams are in the same optical path but at perpendicular linear polarizations. The resulting elliptical polarization can then be measured at each pixel without moving parts. We use the same camera and the same objective as for the HLAS, and can in fact use the HPPI also as a HLAS. The aim is to have a combined instrument HPPI/HLAS which can be placed at long distance from the object positioned outside the process chamber. Figure 3 below shows results from experiments with a flat surface with engraved structure.

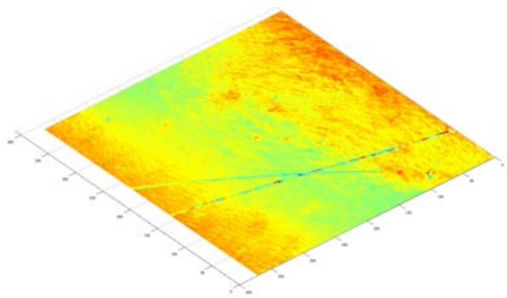

Figure 2: Topographic image of a surface with polarization interferometer (HPPI).

References:

[1] Baath et al.: “The microarcsecond structure of 3C273 at 3mm”, Astron.Astrophs., V241 (1991), L1

[2] Baath,L.B., Abu Dalou,S.K. and Rosen,B.G.: “Surface topography with PDI holography”, XII International Colloqium on Surfaces, Chemnitz, 2008