The benefits of coherence for quality control: Trends and breakthroughs in fast digital holography

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Abstract

Interferometers have been used for quantitative surface inspection of high-quality objects long before digital image processing became possible. However, deployment of this technology was limited since most technical objects have surface roughnesses exceeding visible wavelengths and, furthermore, single-wavelength interferograms are not sufficient for inspection of objects with steep steps exceeding about one micrometer. Employing sequentially multiple wavelengths, the interferogram at a *synthetic wavelength,* corresponding to the beat frequency, can be *computed*. By choosing the wavelength separation, any unambiguous depth measurement range can be selected. The combination of more than two laser wavelengths allows cascading of the measurement ranges, increasing the ratio of measurement range and accuracy. All this is facilitated by the processing of the individual interferometric patterns, i.e. by digital holography.

An application using three wavelengths is presented where a 500-µm height range is covered unambiguously with sub-micron repeatability. For every laser wavelength, three images are acquired, i.e. nine images – each with 9 megapixels – are taken. Using a CoaXPress camera, all data is acquired in less than 70 ms. An interferometric sensor is in principle affected by object motion during acquisition, but for this very short timeframe, the required stability can be guaranteed even in real manufacturing environments and using a non-sophisticated handling system. Finally, 81 million pixel values must be combined for each measurement. To achieve this in synchronization with a 1-Hz

production cycle, all phase-extraction computations and some filtering operations are performed in parallel using CUDA-programming on a consumer graphics card. In the presented application, multi-wavelength holography is used for inline detection of defects on coin-size objects. The height of defects with 60 µm lateral footprint is measured with sub-micron repeatability.

Overall we demonstrate that the recent advances in data acquisition and parallel processing have made holography a viable technique for high-throughput 100%-inspection in manufacturing environments.

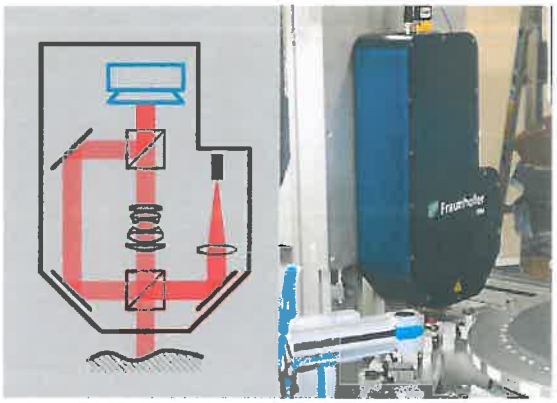

Figure 1: Simplified sketch of a multi-wavelength interferometer (left) and application in inline inspection (right).

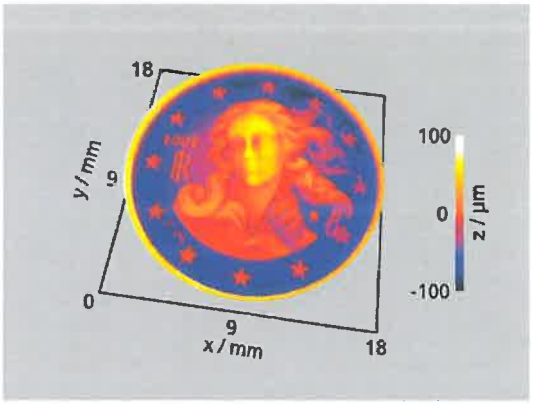

Figure 2: Measured topography of an Italian 10-cent coin. The sensor delivers 9 million 3D points with sub-micron repeatability at repetition rates of up to 10 Hz.