Faculty of Electrical Engineering & Computer Science
Master Degree Course Electronics Engineering, MSc EE

HSB
Hochschule Bremen
City University of Applied Sciences

Master 2017

Jan Schulze

Measurement of Strongly Curved Surfaces by Multibeam Reflective Experimental Ray Tracing.

ABSTRACT - Masterthesis

Many different properties of optical components can already be measured by experimental ray tracing (ERT). In this work it is applied to the two-dimensional reconstruction of specular surfaces. A surface under test (SUT) is scanned by a ray and the direction of the reflected ray is determined by detecting its position in two different detector planes. In order to be able to retrieve the gradient of the surface at the measured positions, the direction of the incident ray also needs to be known. A method to find the angle of the incident ray using an etalon is thus proposed. From the gradient data of the SUT its shape can be determined by numerical trapezoidal integration in the coordinate system (CS) of the incident ray. This CS transformation is necessary because the position of the point of reflection on the SUT is dependent on the surface height for incident rays that are not orthogonal to the scanning direction.

A problem that is faced when using ERT for specular surfaces is the limited dynamic range regarding the measurable slopes. In order to eliminate this problem multiple incident rays are used for different slope regions on the SUT, so that strongly curved surfaces can be measured. For each incident ray one surface profile is reconstructed. These profiles are then combined by fitting them to the expected surface.

In simulations the principles of the calibration of the incident ray and the surface reconstruction by dual-beam ERT are confirmed. The influence of uncertainties in the parameters regarding the etalon used for calibration is investigated along with the effect of falsely detected incident angles on the surface reconstruction. Large surface deviations are shown to deteriorate the quality of the stitching of the profiles reconstructed from data of each incident ray.

An experimental setup is built to test the calibration and surface reconstruction procedures. The calibration of the incident beam exhibits a good repeatability with standard deviations of less than 0.03° for ten measurements per incident beam. Two surfaces with circular cross-sections and different curvatures are reconstructed by dual-beam ERT with deviations to the expected surface of a few µm. However, it is shown that these residuals are mostly caused by the experimental setup or the reconstruction method. Measurements of the centroids of each reflected beam in multiple detector planes also show deviations to the expected linear propagation. Although different possible error sources are investigated, the reasons for these deviations as well as for the different shapes of the residuals for each incident beam are not yet identified.