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Interferometry for Precision Measurement

Peter Langenbeck

Tutorial Texts in Optical Engineering
Volume TT94

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Introduction to the Series

Since its inception in 1989, the Tutorial Texts (TT) series has grown to cover many diverse fields of science and engineering. The initial idea for the series was to make material presented in SPIE short courses available to those who could not attend and to provide a reference text for those who could. Thus, many of the texts in this series are generated by augmenting course notes with descriptive text that further illuminates the subject. In this way, the TT becomes an excellent stand-alone reference that finds a much wider audience than only short course attendees.

Tutorial Texts have grown in popularity and in the scope of material covered since 1989. They no longer necessarily stem from short courses; rather, they are often generated independently by experts in the field. They are popular because they provide a ready reference to those wishing to learn about emerging technologies or the latest information within their field. The topics within the series have grown from the initial areas of geometrical optics, optical detectors, and image processing to include the emerging fields of nanotechnology, biomedical optics, fiber optics, and laser technologies.

Authors contributing to the TT series are instructed to provide introductory material so that those new to the field may use the book as a starting point to get a basic grasp of the material. It is hoped that some readers may develop sufficient interest to take a short course by the author or pursue further research in more advanced books to delve deeper into the subject.

The books in this series are distinguished from other technical monographs and textbooks in the way in which the material is presented. In keeping with the tutorial nature of the series, there is an emphasis on the use of graphical and illustrative material to better elucidate basic and advanced concepts. There is also heavy use of tabular reference data and numerous examples to further explain the concepts presented. The publishing time for the books is kept to a minimum so that the books will be as timely and up-to-date as possible. Furthermore, these introductory books are competitively priced compared to more traditional books on the same subject.

When a proposal for a text is received, each proposal is evaluated to determine the relevance of the proposed topic. This initial reviewing process has been very helpful to authors in identifying, early in the writing process, the need for additional material or other changes in approach that would serve to strengthen the text. Once a manuscript is completed, it is peer reviewed to ensure that chapters communicate accurately the essential ingredients of the science and technologies under discussion.

It is my goal to maintain the style and quality of books in the series and to further expand the topic areas to include new emerging fields as they become of interest to our reading audience.

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Preface

With new material added to the English translation of Chapter 7 of the German *Wirtschaftliche Mikrobearbeitung* (Carl Hanser Verlag, 2009), the author presents developments in physical, optical, and mechanical engineering over the past 60 years. The enduring impetus for this work is owed to the late, great gentleman engineer, Gordon J. Watt, with his assertion that optical wavefronts used in interferometers are complementary to the surfaces used to build air bearings. A foremost example of this statement is the fact that a plano-convex lens is confined by surfaces that are equivalent to those defining the Watt air-bearing spindle. The spindle rotor consists of a truncated hemisphere, rigidly connected to a flat disk.

Soon after the author founded Intop Entwicklungen (Baden-Württemberg, Germany) in 1972, he and G. J. Watt witnessed a sudden growth in spindle-enabling applications and new machines whose performance relied completely on low-axial-error motion (less than 5 nm) and an angular error motion of less than 0.1 arcsec. The bearing’s disk took on multiple integral functions: as a polygon wheel, as a polishing scaife for diamond tools, and as a chuck for thin substrates (memory substrates with memory scaling of 14.5). Interferometers for in-process quality control and final acceptance needed to be developed.

Increased interferometric sensitivity by multiple passes was adopted as a technique for measuring small departures from 90 deg, both for the metrology of corner cubes and for extremely sensitive tilt measurement (one of the three CCR mirrors being the front mirror on a problem spindle’s nose). Interferometric techniques that facilitated the assembly of ultraprecision machining and metrology machines (3D orthogonal) were developed.

Likewise, decreasing interferometric sensitivity made possible the inspection of nonspecular surfaces. The cost for quality control of mass-produced components (for example, water faucet ceramic seals) was substantially reduced. The inspection technique in use at the time became the standard for expedient handling of samples with interferometric precision.

This relatively recent development focused on measuring tilt error motions of air-bearing spindles, as is amply covered in this book. Tasks that
occur every day in an optical shop—such as centering and homogeneity measurement—are also extensively discussed.

The author gladly shares his recollections and experience with students, scholars, and peers but also wants to give a warning: dealing with optics every day may turn a profession into an obsession!

The author appreciates SPIE for making this publication possible. He also expresses his warm thanks to Prof. Hans Tiziani for frequent, critical discussions.

Peter Langenbeck
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