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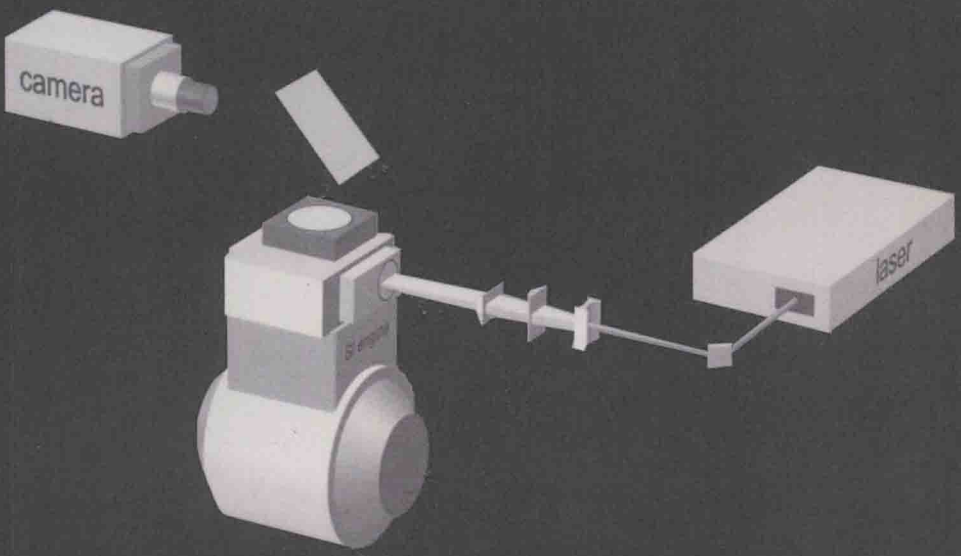

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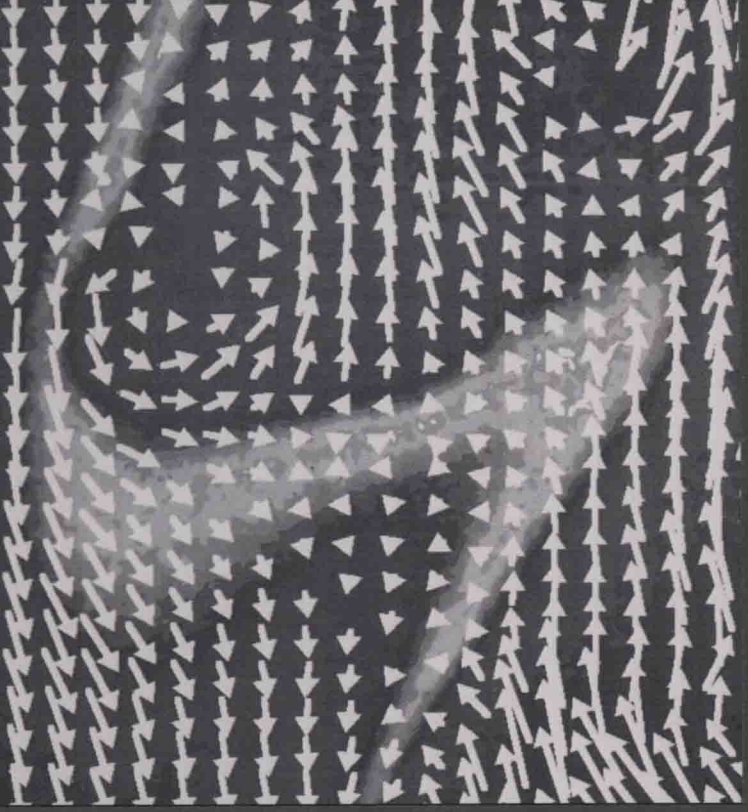

Presenting a through overview of the applications of modern laser-based diagnostic methods to practical combustion problems, this book forms a link between applied laser physics and combustion engineering. Laser-based diagnostics provide important tools to probe the harsh, high-temperature, and often high-pressure environment of modern combustion systems. The book begins with recent advances in laser-based measurement techniques including cavity ringdown spectroscopy and laser-induced incandescence. This is followed by specific diagnostics applications to important combustion problems such as soot formation and catalytic combustion. Practical combustion applications are addressed including internal combustion engines and gas turbines with a focus on specific needs for characterization of fuel injection and the development of combustion control sensors.The book concludes with perspectives for diagnostic-driven solutions to some important topics including monitoring and mitigating the environmental and public health impact of combustion.

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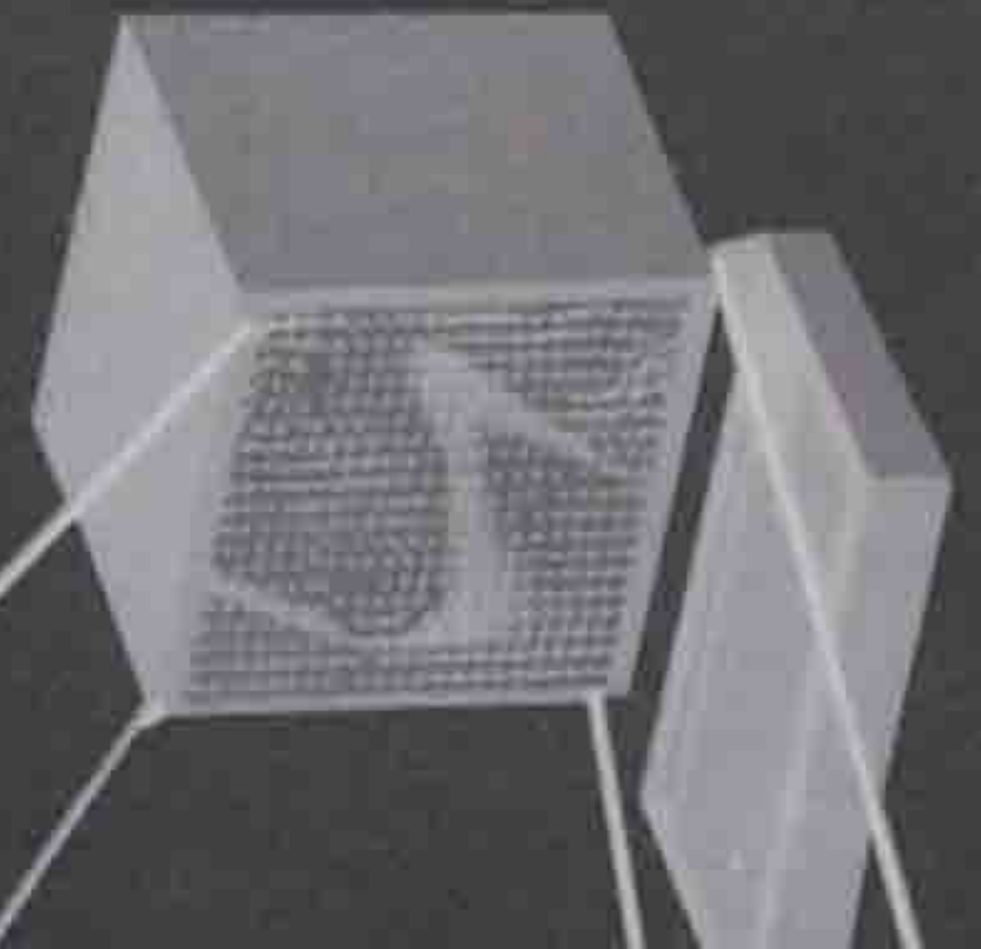

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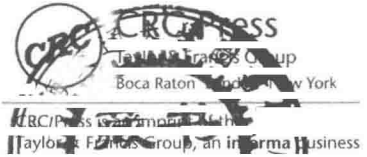

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To Eva and Klaus

and

To Sean, Ryan, and Robin

About the Editors

Katharina Kohse-Höinghaus, Dr. rer. nat., has extensive experience in the use of laser diagnostics to unravel the chemistry important in combustion, chemical vapor deposition, and biological systems. As a Member of the Technical Staff at the German Aerospace Research Center, she conducted sabbatical research at Stanford University, and SRI International in the USA, and ONERA in France. She won a Heisenberg Fellowship in 1993, and in 1994, was appointed as full Professor of Chemistry at the University of Bielefeld, Germany. Prof. Kohse-Höinghaus is a colloquium chair for the 2002 International Combustion Symposium, a member of the editorial board of *Combustion and Flame*, and served as the Chair of the 1999 and vice Chair of the 1997 Gordon Research Conference on Laser Diagnostics in Combustion.

Jay B. Jeffries' Ph.D. career has focused on the development of laser-based diagnostics for practical applications, especially combustion, plasmas, and the atmosphere. In 2000, he joined the High Temperature Gasdynamics Laboratory, in the Mechanical Engineering Department at Stanford University, after 17 years in the Molecular Physics Laboratory at SRI International, and 3 years as a Research Assistant Professor at the University of Pittsburgh. He is a past chair of the Fundamental and Applied Spectroscopy Technical Group and the Optical Physics Division of the Optical Society of America. He serves as a Topical Editor for the *Journal of Applied Optics*. Dr. Jeffries was the Chair of the 2001 and vice Chair of the 1999 Gordon Research Conference on Laser Diagnostics in Combustion.

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Preface

This book provides a pedagogical overview of the current state-of-the-art in the development of laser-based optical methods for the solution of fundamental and applied combustion problems. Laser-based diagnostics provide important tools to probe the harsh, high-temperature, and often high-pressure environment of modern combustion systems. These diagnostic measurements enable tests of fundamental understanding of combustion as well as enable empirical strategies to maximize the combustion efficiency and minimize the pollution of the combustion effluent from practical combustion devices.

This book gives a snapshot of the available diagnostic methods and their typical applications from the perspective of leading experts in the field. Teams of authors, sometimes from different groups, have written chapters with the intention to provide an educational approach to the subject, cutting-edge application examples from the research of their own and other groups, an acute literature survey, and well-balanced guidelines for current applications as well as indications of unsolved problems or of further perspectives.

The first part reviews the most widely used laser-based diagnostic techniques. Methods to detect trace concentrations of intermediate species in the chemical mechanism are reviewed in detail; laser-induced fluorescence, nonlinear optical methods, and cavity ringdown spectroscopy are highlighted. The current status of soot monitoring with laser-induced incandescence is presented with a focus on quantitative calibration. Temperature is an important combustion parameter, and fundamentals of accurate temperature measurements are discussed. Practical combustion is dominated by the interaction of chemistry and fluid mechanical transport; laser-based imaging techniques are an important tool to understand laminar and turbulent combusting flows. Chapters on flow-field diagnostics and multidimensional diagnostics attack the problems of spatially and temporally resolved combustion measurements.

The second part focuses on the current state-of-the-art application of these laser-based techniques to practical combustion problems. Chapters

on rich flame chemistry and on polycyclic aromatic hydrocarbons (PAH) and soot monitoring apply laser-based diagnostics to the important class of fuel-rich flames. This discussion naturally leads into chapters on two-phase fuel flows and fuel sprays in engines, followed by a detailed application of laser diagnostics to pollutant formation in engines. Catalytic combustion, fire suppression, combustion control, and gas turbine diagnostics round out Part II.

The final part discusses unsolved combustion problems and how laser-based measurements have the potential to provide the understanding needed to find solutions for these problems. We discuss the needs for diagnostic measurements to attack currently unsolved problems in detailed chemical modeling, gas–surface catalytic combustion, active combustion control, and commercial gas turbines. The book concludes with three chapters discussing the impact of toxic combustion effluent emissions on the atmosphere and two promising diagnostics schemes to provide the needed tools for in-situ monitoring of trace toxic species in the atmosphere; finally, a perspective on anticipated developments and emerging techniques is given.

Each chapter is written as a stand-alone contribution, providing an educational, concise and timely review of the present status of techniques, applications and perspectives. Cross-referencing to other chapters is provided throughout to allow for additional in-depth information related to individual chapters. The book may thus be used in different ways: by reading from start to end as a detailed course in combustion diagnostics, by reading individual chapters as a source of reference, or by browsing through different sections as a source of ideas. We intend to provide the active combustion research scientist with an understanding of the quality and content of the measurements from a variety of laser-based techniques. The book also provides supplemental reading to graduate courses in combustion and experimental methods in mechanical engineering. The laser-diagnostics specialist can learn the strengths and weaknesses of the various laser-based techniques, and the serious student can quickly get an up-to-date status of laser-based combustion measurements.

As we developed the program for the 1999 Gordon Research Conference on Laser Diagnostics in Combustion, we recognized the incredible progress in the application of laser-based measurement tools to combustion problems. During the summer of 2000, Professor Norman Chigier suggested that Katharina Kohse-Höinghaus might author or edit a diagnostics book. His subsequent encouragement of our book ideas led us to begin to enroll the author teams during the International Symposium on Combustion in Edinburgh.

We must acknowledge a great many people who have made this book possible. First, we thank the forty-six contributing authors whose names appear in the contents; not only did these experts provide the text of the book, but they met our very aggressive publication time schedule. In addi-