Edited by Maximilian Lackner

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Lasers in Chemistry

Probing Matter

Volume 1

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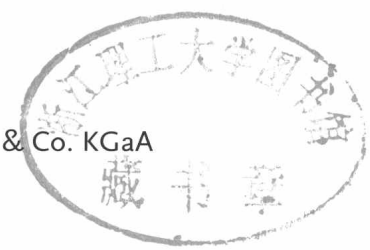

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Foreword

Dear Reader,

It is a honor and pleasure for me to give a short perspective to lasers and their applications from the chemical engineering and my personal point of view.

As we do research in the area of energy conversion, fluidized bed combustion and high temperature processes in general we develop new processes and optimize existing ones. To do this in an efficient manner it is of high importance to understand the underlying chemical mechanism and its kinetics. In practice the chemistry is closely related to heat and mass transfer phenomena and depends significantly on the temperature and mixing level of the reaction system. To probe such complex systems, it is not enough to measure the transient behavior of the key species leaving the reaction system. It is very important to obtain time – dependent information from the inside of the system, from *in situ* measurements and not only of stable final products like CO and CO_2 (if you think about combustion) but also from intermediate short-time living species as for example HCN (if you think about fuel NO_x formation) or radicals like OH.

To optimize laboratory – scale systems and to be able to transfer the data to industrial scale units the Concept of Chemical Similarity [1] is used. The concept says that it is important to investigate the chemistry under conditions which are similar to the conditions which occur in the industrial-scale system. The similarity is defined by the so-called similarity criteria. One important similarity criterion is that species' concentrations should be in the same order of magnitude and not only the final stable species but also the intermediate, short-time living species because they also affect significantly the reaction paths.

To understand such complex reaction systems we have developed new and applied existing laser measurement systems and probed our reactors *in situ* [e.g. 2]. We have adopted our reactors with quartz glass windows to allow in-line-of-sight measurements. The information obtained on for example species concentration was very important to test our simulation tools for the ongoing chemical mechanism combined with heat and mass transfer phenomena. These results led to significant improvements and understanding of the underlying chemistry and reduced significantly the risks for scale-up and uncertainties to transfer the results to industrial – scale units.

Lasers in Chemistry Vol. 1: Probing Matter. Edited by Maximilian Lackner

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Another application of such *in situ* measurements is the integration of this early information into control systems of industrial-scale units. With this early information the control system is able to respond significantly faster to changes in optimal conditions [3], for example to reduce pollutants.

As we, as chemical engineers, continued to work with lasers we used lasers not only to probe the systems to get a better understanding of the reaction mechanism we also used lasers to start our reaction systems, for example to ignite fuel-air systems under engine conditions [4] or solid reaction systems for automotive safety [5] as they can be found in airbags. We also used lasers for the cleaning of our combustion windows even under engine conditions [6]. Recently, we also applied lasers to simulate the high heat transfer rates to plastic particles as they occur in blast furnaces [7].

As we learned more and more about lasers we realized what a versatile tool they can be. Applications not only in chemical engineering and chemistry but also in medicine and biology are already daily life. Furthermore, a significant increase of laser applications can be expected in future because the possible potentials are not used by far and the development of new, robust and cost-effective laser systems is increasingly ongoing.

Such a wide range of development and application is only possible by doing research work jointly. Therefore I highly recommend to exchange knowledge and start further cooperations in the area of laser development and application. I think these books are a wonderful basis and may contribute to start and link a network of expertise.

Finally, I also want to give my sincere thanks to my colleague and dear friend Dr Maximilian Lackner who initiated and carried out *Lasers in Chemistry* for all his enthusiasm and encouragement.

Franz Winter
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Preface

Laser technology has shown a remarkably fast evolution. Lasers have found numerous applications in virtually all fields of science and engineering, harnessing the unique properties of laser light. Among these are monochromaticity, coherence, collimation and high power. In chemistry, they are also deployed in various ways, thereby improving traditional techniques or even making new ones possible.

This book is an attempt to draw a bow across the wide and exciting topic of lasers in chemistry. More than 50 authors, all renowned experts in their fields, have contributed to this work.

There is a balance between authors from academia and authors from industry.

Text books that cover the subject of 'Lasers in Chemistry' are [1–4]. Early review articles can be found in [5–7]. Several conferences have also covered the topic in its breadth, one of the first events being the Conference on Lasers in Chemistry organized by the Royal Institution, London, in 1977. The laser was soon recognized as a bright, coherent and high-resolution light source with many promising properties. However, its penetration into chemists' labs has been a comparatively slow process. The proliferation in commercial, analytical instruments is even less as discussed in [8].

This book is organized as follows: There are two volumes.

Volume 1 contains an introduction to the principles of lasers and some considerations on laser safety. Laser safety is vital and must always be kept in mind.

The focus of volume 1 is the use of lasers as probes. Various techniques are described where the laser is used to gain information on the system under investigation. The techniques can coarsely be distinguished into those based on absorption, emission and scattering. Some techniques are used for sampling or sample preparation.

Volume 2 deals with the use of lasers to start and influence chemical reactions. Among the topics are laser ignition, laser-based nano-particle formation and photochemical reactions. This volume also covers the use of lasers in neighbouring disciplines such as material processing, biology and medicine. The final chapters in volume 2 present the historic development and some trends on laser research and development. Outlook and glossary conclude the book.

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The book strives to serve different purposes:

With its scope of over 50 Chapters and the contributions of high profile authors, the book can be seen as a reference on the topic of 'Lasers in Chemistry'.

Up to date, except for conference proceedings, no similar book has been brought on the market to cover the topic in its breadth.

Thereby, the book documents the state of the art in research and development of lasers in chemistry and their use in chemical production plants. It summarizes the achievements obtained so far.

The chapters are designed in a way that they give a brief introduction to the respective topic to get new readers started, similarly to a review article.

Probably the biggest benefit will stem from stimulating new thought and ideas; Several important technologies are the outcome of a combination of existing techniques. Examples for such an outcome are hyphenated analytical methods like GC/MS. The reader of the book, being an expert in one of the fields, might discover an interesting aspect in another discipline and try to apply knowledge from there to his own work.

This cross-fertilisation might lead to totally new analytics or synthesis methods, process control applications or novel materials. Experts in various fields, though concerned with similar challenges, tend to speak a language of their own with special terms, such as 'degrees crank angle' as a substitute for time amongst engine researchers and 'wave numbers' instead of wavelength amongst spectroscopists. If this book can create some common understanding and stimulate thoughts, it has achieved its objectives.

Highlights of the respective chapters, of which there are several, are outlined in Chapter **3** for the area of lasers as probes and in Chapter 24 for lasers as reaction starters.

The authors wish the readers many fruitful insights, as they embark on a fascinating journey on 'Lasers in Chemistry'.

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