Preface

The aim of this book is to provide an actual collection of highlights in the technology, production, and novel applications of waveguides and other confined geometries, in particular optical fibers.

It is well known that waveguide phenomena are nowadays a textbook subject and some energy is needed to prove that waveguide problems are still of great scientific and commercial interest.

Any textbook approach should go back to the books by Theodor Tamir,[1] who always considered waveguiding as the heart of any integrated optics. It is very interesting to study the details of his first book on this subject in as early as 1975. There he dated the beginning of integrated optics to the late 1960s and mentioned as primary applications signal processing and optical communications. It is striking to note that he did not mention at this time any analytical applications (lab-on-chip) or sensors. However, he already did mention the possible chances of novel optical phenomena opened *by the concentration of high intensity fields in thin films and effects due to attendant enhancement of nonlinear and/or active properties of such films*. It should be emphasized that at least two contributions in this book deal with nonlinear phenomena in waveguiding structures and potential applications.

Contributions came from Europe, Canada, and Israel. The manuscripts have been arranged as follows:

- Theoretical considerations for semi-infinite planar waveguides. Unusual, novel ways of efficient frequency conversion in structured fibers and nanoplasmonic waveguides
- Five contributions on laser writing of waveguiding structures in various geometries and materials
- Channel formation in cluster targets as an example of self-organization of waveguiding structures

[1] Still available is the second corrected and updated edition of the book "Integrated Optics," T. Tamir editor, Springer-Verlag, Berlin, Heidelberg, New York, 1979.

- An example of a novel application of Bragg grating technology using optical fibers for 3D shape sensing

The contributions are beyond the normal textbook style, representing cutting-edge research results. A short preview/summary of some of the selected contributions is given below:

In Chap. 1 of this book radiation emerging from an open-ended waveguide is studied in theory. The idealized case of a planar waveguide open to an infinite half space is considered. An iterative scheme is constructed in analogy to the exact solution of reflection from a step-potential in one-dimensional quantum mechanics and Fresnel reflection of electromagnetic radiation from a half space. For the planar waveguide, the first step in the iterative scheme is evaluated. This yields an approximation to the radiation pattern emerging from the waveguide, as well as the amplitude of the wave reflected back into the waveguide.

Another selected example, Chap. 2, considers second-harmonic generation in a circular cylindrical waveguide with embedded periodically arranged tubelets of high nonlinear susceptibility. The configuration is similar to usual quasi-phase-matched arrangements, but places the nonlinear polarization sheet at intensity peaks of the guided fundamental wave. This leads (yet only in theory) under optimized conditions to high conversion efficiencies and hence pump depletion has to be considered in the framework of mode-coupling theory.

A major advance on femtosecond laser structuring inside optical fibers in Chap. 4 presents powerful new directions for inscribing optical, microfluidic, and mechanical structure devices in the fiber cladding that efficiently interconnect with the fiber core waveguide. This all-fiber platform circumvents tedious packaging and assembly process steps to enable highly functional photonic microsystems and lab-in-fiber devices to form into a compact and flexible optical fiber system that greatly enhances the value of today’s widely deployed fiber cables.

The modification of optical properties of dielectrics has led to the fabrication of waveguides in a variety of glasses and crystals as shown in Chap. 6. UV photosensitivity of germanium-doped glass led to a new technology of fiber Bragg gratings; now femtosecond lasers have allowed yet another aspect of laser-material interaction to be exploited, bordering in the twilight zone between optical damage and plasma formation. This not fully understood process has also led to the production of 3D waveguides and holds the promise of easing the process of waveguide fabrication in all sorts of transparent media, provided the optical loss can be tamed. At the other end of the spectrum, the brute force of carbon dioxide lasers has also been used to cut glass to form delicate, yet complex, low-loss optical devices for fast prototyping and integration. These technologies are reviewed by examining the induction of refractive index changes and waveguides in several different materials.

An unusual case of waveguide generation is discussed in Chap. 9: channel formation due to focusing of high-power laser radiation in a self-generated rare gas plasma. The discovery of a stable highly nonlinear mechanism that can compress power to a density exceeding thermonuclear values led to a new era of power compression. The associated steps, increasing by a factor of 10^{10} in power density, mark different stages of technological breakthroughs.

Chapter 10 discusses a novel method for direct femtosecond laser-based writing of Bragg gratings and micro-waveguides not only inside the core but also in the cladding of a standard telecom fiber. This enables an optical 3D shape monitoring system using just a single one-core optical fiber. For a 1.5 m long fiber, the tip position can be tracked with an accuracy of less than 1 mm for the x,y,z-coordinates. Applications of this new technology range from medical tracking systems to long-term inspection of boreholes and drilling wells in the oil and gas industry.

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Gerd Marowsky

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