SUPERCONTINUUM GENERATION IN OPTICAL FIBERS

The optical fiber based supercontinuum source has recently become a significant scientific and commercial success, with applications ranging from frequency comb production to advanced medical imaging. This unique book explains the theory of fiber supercontinuum broadening, describes the diverse operational regimes and indicates principal areas of applications, making it an indispensable guide for researchers and graduate students.

With contributions from major figures and groups who have pioneered research in this field, the book describes the historical development of the subject, provides a background to the associated nonlinear optical processes, treats the generation mechanisms from continuous wave to femtosecond pulse pump regimes and highlights several important applications. A full discussion of numerical methods and comprehensive computer code are also provided, enabling readers to confidently predict and model supercontinuum generation characteristics under realistic conditions.

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Preface

Spectral broadening and the generation of new frequency components is an inherent feature of nonlinear optics, and has been studied in both bulk media and optical fiber waveguides since the 1960s. However, it was not until the early 1970s that the mechanism was widely applied to provide an extended "white-light" source for time resolved spectroscopy, which was later coined "a supercontinuum" by the Alfano group. Subsequent developments in the late 1970s in low-loss optical fibers with conventional structures for telecommunications led to the introduction of fiber as an ideal platform for supercontinuum generation. At the same time, the development of optical soliton physics throughout the late 1980s and early 1990s laid the theoretical foundation and established all the experimental mechanisms required for the production of this versatile source. Despite this progress, however, extensive laboratory deployment remained inhibited by unwieldy pump sources and unreliable system integration.

The advent of photonic crystal fiber in the late 1990s, together with developments in efficient high power and short pulse fiber lasers, fuelled a revolution in the generation of ultrabroadband high brightness optical spectra through the process of supercontinuum generation. Experiments using photonic crystal fiber in 1999–2000 attracted widespread interest and excitement because of the combination of high power, high coherence and the possibility to generate spectra spanning more than an octave. Moreover, the design freedom of photonic crystal fiber allowed supercontinuum generation to be optimized to the wider range of available pump sources, and experiments reported broadband spectra covering the complete window of transmission of silica based fiber using input pulses with durations ranging from several nanoseconds to several tens of femtoseconds, as well as high power continuous wave sources. Supercontinuum generation in PCF was rapidly applied to a range of fields including optical coherence tomography, spectroscopy, and optical frequency metrology and, indeed, this latter result was explicitly cited in the award of the 2005 Nobel Prize in physics.

These results have since led to a huge research effort studying nonlinear spectral broadening in PCF, and have also renewed interest in similar nonlinear phenomena in standard optical fiber. Recent results have provided new insight into the spectral broadening mechanisms, tailored supercontinuum properties to specific applications, and extended supercontinuum generation into new fibers and waveguides using engineered dispersion profiles and/or non-silica materials. Improvements in numerical modeling techniques have also led to remarkable agreement between theoretical prediction and experimental realization.

This progress has of course been well documented in the archival literature, but researchers are now facing the problem that there is no single resource that explains the physics of fiber supercontinuum generation, describes the important properties of new fibers and waveguides, and outlines the features of supercontinuum generation relevant to specific applications. Our aim with this book is to address this problem explicitly through a series of invited papers written by experts familiar with all aspects of this field: the fundamentals and recent developments in supercontinuum generation physics, the different possibilities raised by the availability of new fibers and materials; and the diverse applications where supercontinuum sources can be used.

The book begins with two chapters describing the historical development of the field preceding a concise introduction to nonlinear fiber optics and the numerical modeling of supercontinuum generation. This is followed by a chapter providing an overview of the fiber supercontinuum generation processes under a wide range of conditions. These first four introductory chapters are aimed to ensure that the book is self-contained and accessible to advanced undergraduates and beginning doctoral students requiring a broad introduction to the field. The most significant technical content of the book appears in the subsequent chapters where various aspects of fiber waveguide properties and fiber supercontinuum processes are described in detail by researchers who have been responsible for seminal contributions to the field.

At this point it is perhaps appropriate to add a short word about citing the work in this book. Books and monographs sometimes develop the tendency to become general references that are cited in lieu of the original literature. Whilst this can sometimes be useful, it can also sometimes be detrimental in hiding the contributions of primary journal papers and the original authors. As a solution to this problem, we wish to suggest that readers please take due care that they do not forget to cite the primary literature where appropriate. When material is described both in the primary literature and in this book, there is of course the possibility to cite both.

In closing, we wish to say that we have been very fortunate in being able to include chapters from pioneering and leading research groups from across the world, and we are very grateful to all contributors for their agreement, their effort and their patience. We hope that this book and the excellent contributions that we have been lucky enough to solicit from our colleagues will allow professionals to develop their research even further, and students to enter this field more effectively.