

Preface

This book attempts to give a discussion of the physics and current and potential applications of the self-focusing of an intense femtosecond laser pulse in a transparent medium. Although self-focusing is an old subject of nonlinear optics, the consequence of self-focusing of intense femtosecond laser pulses is totally new and unexpected. Thus, new phenomena are observed, such as long range filamentation, intensity clamping, white light laser pulse, self-spatial filtering, self-group phase locking, self-pulse compression, clean nonlinear fluorescence, and so on. Long range propagation at high intensity, which is seemingly against the law of diffraction, is probably one of the most exciting consequences of this new sub-field of nonlinear optics. Because the intensity inside the filament core is high, new ways of doing nonlinear optics inside the filament become possible. We call this filamentation nonlinear optics.

We shall describe the generation of pulses at other wavelengths in the visible and ultraviolet (UV) starting from the near infrared pump pulse at 800 nm through four-wave-mixing and third harmonic generation, all in gases. Remotely sensing fluorescence from the fragments of chemical and biological agents in all forms, gaseous, aerosol or solid, inside the filaments in air is demonstrated in the laboratory. The results will be shown in the last part of the book. Through analyzing the fluorescence of gas molecules inside the filament, an unexpected physical process pertaining to the interaction of synchrotron radiation with molecules is observed. It is the excitation of the superexcited states of a molecule which undergo dissociation into neutral fluorescing parts. Thus, there is a similarity between exciting the superexcited states of a molecule through multiphoton/tunnel excitation and through one XUV-photon absorption. This phenomenon will be described in the last chapter.

Also included in the last chapter is the most recent discovery and development of filament induced anisotropy in air. Normally isotropic air becomes birefringent because of the strong field of the linearly polarized pump pulse. A probe pulse will experience the ultrafast birefringence through cross-phase modulation. Molecular rotational wave packets of air molecules are excited and aligned; they then dephase and revive after the pump pulse is long gone. The ease in detecting such revivals using a probe pulse is indeed a surprise.

Some background knowledge of the readers is assumed. This includes basic non-linear optics, the properties of femtosecond laser pulses, and multiphoton/tunnel ionization/excitation of atoms and molecules.

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