Photoacoustic, photothermal and photochemical processes in gases

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As the number of available laser systems increases and the corresponding measurement methodologies are developed the appearance of new scientific directions based on the interaction of laser radiation with matter is observed. The book under review which could be included in the genre of collective monographs contains a review of several directions of the kind where gas media are investigated using lasers. From the multitude of physical effects arising as a result of laser action the authors of the book have selected the acoustic, thermal and chemical effects.

The book is based on lectures given by leading specialists in the field of laser physics and gas acoustics at the 49th European General Physics Seminar organized in November 1988 in the FRG. The principal attention in the lectures is directed to the effects of generation and propagation of sound waves in molecular gases subjected to laser radiation. Usually they deal with the use of resonance laser radiation whose frequency corresponds to the energy of a vibrational quantum of a molecule present in the gas being investigated, and therefore the absorption of laser radiation is accompanied by the formation of vibrationally excited molecules. The subsequent collisional relaxation of such molecules leads to a local heating of the element of volume being irradiated and can be accompanied by the generation of acoustic waves the parameters of which depend on the concentration of absorbing molecules, the times of vibrational relaxation, and also on the properties of the acoustic resonator in which the experiment is conducted. This opens up the possibility of using photoacoustic effects for detecting small admixtures of molecules, for investigating the mechanisms of vibrational relaxation of molecules and for establishing the characteristics of this process. Several sections of the book are devoted to a presentation of the theoretical bases of such measurements and contain a brief summary of the corresponding experimental results.

Another interesting possibility of using photoacoustic phenomena which is examined in detail in the monograph being reviewed is associated with the appearance of a thermal lens. The essence of this phenomenon consists in the fact that as a result of resonance absorption in a gas of laser radiation the frequency of which corresponds to the energy of a vibrational quantum of a molecule a temperature inhomogeneity arises in the gas. The gas which has such an inhomogeneity can be utilized as an optical element for controlling the direction of propagation or for focussing laser radiation. The rapid nature of the occurrence of relaxation processes and transport processes affecting the magnitude and the form of temperature inhomogeneity in a gas provides unique special features to such a method of controlling a laser beam. This opens up the possibilities of utilizing the phenomenon of a thermal lens for measuring transport coefficients in gases, for investigating the characteristics of processes of transfer of vibrational energy in collisions of molecules and for the study of near-surface and photochemical phenomena etc. All these possibilities have been realized practically, and this has been reflected on the pages of the monograph under consideration.

The photoacoustic effect serves as an effective means for the study of kinetics of gas-phase chemical reactions. Among a large number of schemes being used of the greatest interest is the study of reactions stimulated by laser irradiation. Here the laser beam plays a double role–first, as a result of its absorption in the gas excited particles are formed which stimulate the progress of the chemical reactions, and second, the heating of the gas and the change in its density and chemical composition due to the occurrence of the chemical reaction change the conditions for the passage of laser radiation. This makes it possible to utilize laser radiation simultaneously for stimulation and diagnostics of chemical reactions. A detailed review of the experiments of this kind is given in one of the sections of the book.

Two large sections of the book are devoted to the use of photoacoustic phenomena for detecting small impurities in gases. This methodology whose distinctive special feature is the use of the photoacoustic effect in combination with other more traditional methods of detecting small impurities is used in controlling the quality of atmospheric air, in the analysis of the completeness of combustion of fuel in diesel and other engines, in the study of the mechanism of metabolism in plants and living organisms. The reader is greatly impressed by the example quoted in the book of using the photoacoustic methodology in a completely automated system of monitoring the excretion of sulphur dioxide by plants on an experimental plot subjected to treatment with insecticides.

In summary it should be emphasized that this monograph by its appearance marks a definite stage in the development of investigations of photoacoustic phenomena. At this stage a displacement of the interest of investigators occurs from a study of purely physical effects and laws to the creation on the basis of these effects and laws of new measuring methodologies and the use of these methodologies for a solution of specific scientific and practical problems. This enables us to state that photoacoustics is beginning to occupy an important place among other directions based on the use of laser radiation.