Institute of Physics, Adam Mickiewicz University of Poznań

Main Achievements in Non-linear Optics and Quantum Electronics

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Research work in Optics is carried out at the Institute of Physics of the Adam Mickiewicz University at Poznań by three groups of scientific workers. One of these groups specializes in non-linear optics, another is active in the field of quantum electronics, whereas the third group works on selected problems of physical optics.

Hereafter, the main achievements of all three groups are presented concisely.

Non-linear Optics Division

(Head — Prof. Dr. S. Kielich)

This group has been working on a variety of problems in non-linear optics during the last years. Among the most important results, the following are worth reporting: A statistical-molecular theory of non-linear changes in electric and magnetic permeability induced by intense light beams [1], as well as a theory of optically induced electric [2] and magnetic anisotropy [3], have been elaborated. The influence of powerful laser light beams on the Faraday effect [4] was explored, and the phenomenon of non-linear optical activity was theoretically anticipated previous to its experimental detection by Vlasov and Zaitsev in 1971 [5].

The role of various statistical fluctuational processes associated with optical birefringence [6], as well as the part played by non-linear variations in refractive index [7] were investigated. The dependence of the optical Kerr effect in benzene and nitrobenzene on temperature was measured by having recourse to laser techniques [8]. Also, the non-linear optical polarizability of molecules exhibiting low anisotropy was measured using similar techniques [9].

A complete quantum-mechanical theory of interaction between strong electromagnetic fields and atomic multipoles in isotropic and crystalline bodies was published in [10]. This theory was then applied to analyze optical harmonic generation processes and frequency mixing of laser beams. Independently, it enabled an analysis of multi-photon emission and absorption. In particular, the detailed conditions of frequency mixing and optical harmonic generation were studied in electrically polarized samples [11], in magnetized samples, as well as in ones polarized simultaneously by crossed electric and magnetic fields [12]. By group theory, the non-zero and independent components of the non-linear magneto-optical susceptibility tensor have been determined for all crystallographic classes [12, 13]. It has been, moreover, theoretically predicted that the possibility exists of observing certain new non-linear magneto-optic phenomena in the Voigt and Faraday configurations [13]. The results of this work are of considerable importance in determining the operation régimes of diverse parametric electro-optic and magneto-optic devices for use in light modulation, and the like.

The quantum-mechanical theory of multi-photon Rayleigh and Raman scattering of light [14, 15] was extended and the scattering effect itself was proposed for application as a means for the investigation of such effects as: atomic and molecular non-linear polarizability, short-range order structures in liquids [15, 16], and rotational structures of hyper-Raman scattering spectra [17]. These papers stimulated the development of the non-linear molecular spectroscopy now under study in numerous scientific centres (especially, in the U.S. by Terhune, Maker and Peterson; in France by Lalanne and Martin; in Great Britain by Long and French). Finally, non-linear variations in Rayleigh scattering caused by electro-optical reorientation of molecules and macro-molecules were examined. These investigations make it possible to determine in a new way the sign of the optical molecular anisotropy [18].

Quantum Electronics Division

(Head — Doc. Dr. F. KACZMAREK)

The scientific activity of this group was concerned with the following problems:

Research on the theory of multi-photon ionization in gases in the presence of the optical fields of laser light was undertaken, which led to an estimation of the ionization probability for the hydrogen atom and hydrogen-like ions [19]. Recently, an interesting calculation has been made concerning the influence of the state of polarization on the multi-photon ionization probability [20].

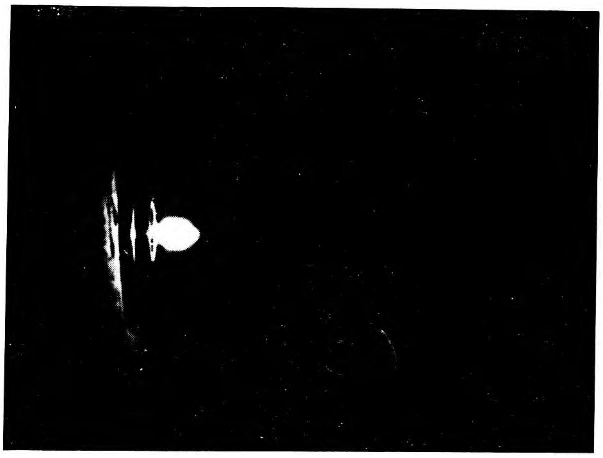

Fig. 1. Electric breakdown of air when focusing a giant pulsed ruby laser beam (Institute of Physics, A. Mickiewicz University)

The experimental activity of the group was devoted to the phenomenon of photo-ionization and breakdown in regions where a laser beam propagates in a fluid and is incident on a fluid-solid or air-solid boundary [21]. This phenomenon plays an important part in the investigation of light propagation in dielectrics, in particular in the phenomenon of self-focusing and self-trapping of laser beams, these two phenomena being currently under study in this group [22].

As a contribution to the problem of pico-second light pulse generation, a possibility to exploit the optical orientation effect from molecules (optical Kerr effect) was investigated. These studies are carried out in a wide range of temperatures for fluids of anisotropically polarizable molecules [23, 24].

A device has been constructed with the aim of examining light amplification in excited gases. The amplification measurements of selected spectral lines can be used to determine the possible applicability of the latter to laser action [25]. As far as gaseous lasers are concerned, various prototype devices of He–Ne lasers (of outputs ranging from 1 to 150 mW) argon lasers and lasers based on metal vapours have been constructed [26]. Tens of such devices have

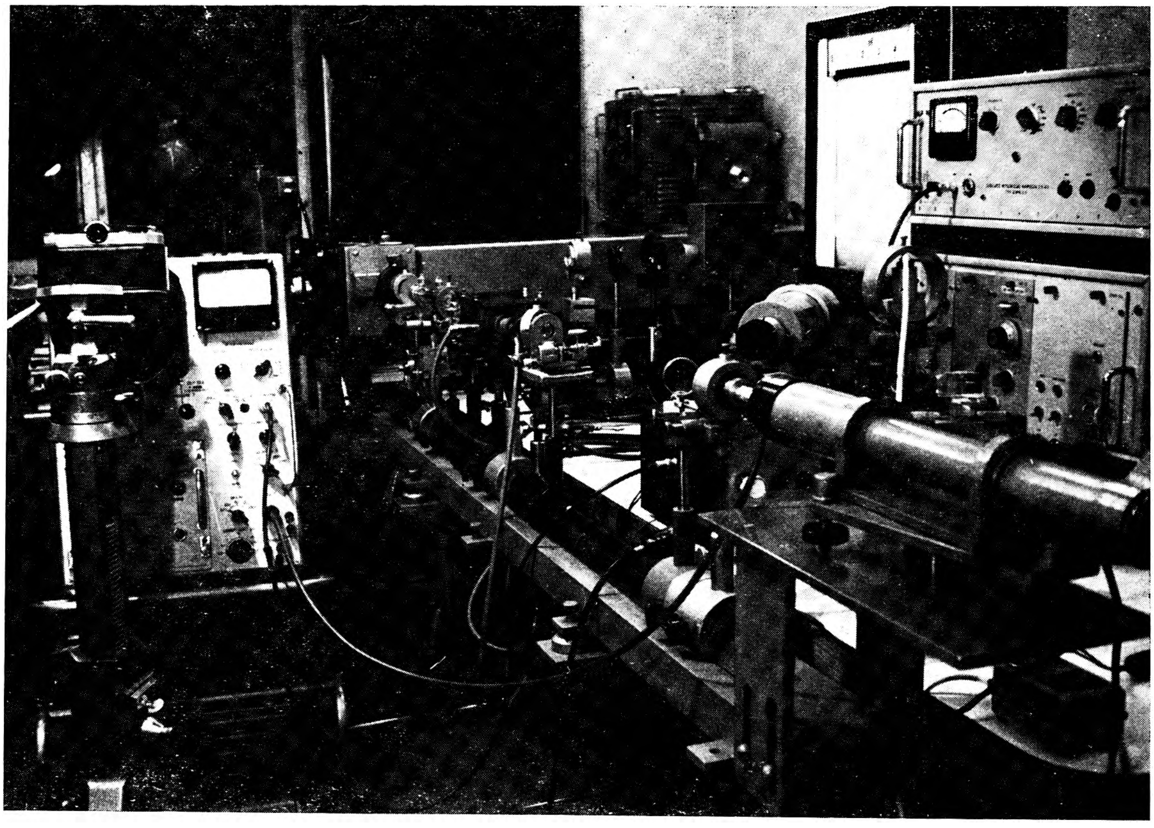

Fig. 2. Raman laser built in the Institute of Physics, A. Mickiewicz University in Poznań. The prism spectrograph in the rear and the oscilloscope to the left serve for the determination of radiation properties of the laser

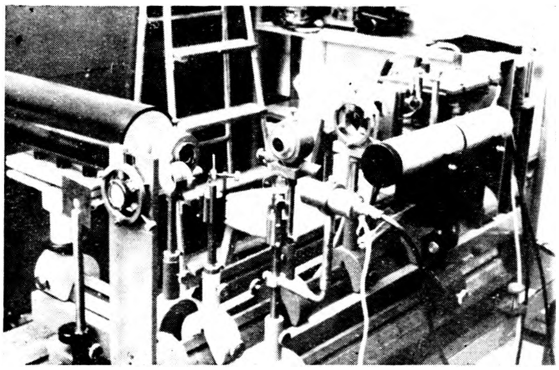

Fig. 3. Apparatus for studying the optical Kerr effect built in the Institute of Physics, A. Mickiewicz University. To the left — He-Ne measuring laser, to the right — Q-switched giant pulse neodymium: glass laser

been produced in the Experimental Workshops of the Adam Mickiewicz University at Poznań for use in numerous scientific institutions in Poland.

A thorough investigation of stimulated Raman scattering in fluids has been made mainly for samples located within a ruby laser resonator without Q-factor modulation [27].

As a result of this work, a utilizable model of laser has been realized, which operates under conditions of free emission and is characterized by high energy conversion from the exciting beam into the Raman lines and especially into Stokes lines. Another result of the experimental study of stimulated Raman scattering consisted in the determination of the influence of certain organic liquids (benzene, toluene and others) on neodymium laser output [28]. This enabled to design a high power laser model, which permitted the study of certain non-linear phenomena, such as hyper-Raman and second-harmonic scattering [14], and the generation of harmonics induced by an external electric field [11].

Rayleigh light scattering was also investigated. A device equipped with a He-Ne laser and heterodyne detectors was constructed, permitting exact determinations of the light depolarization ratio in liquids [29]. The optical Kerr effect in macromolecular systems as well as in pure organic liquids was studied in the presence of powerful pulses from a giant neodymium laser. Also, some classical measurements of electro- and magneto-optical effects were performed for those systems [30].

Much time was devoted to a systematic study of the changes in transmission and reflectivity of liquids caused by irradiation with powerful laser pulses [29, 31]. For this purpose a measuring device for light reflectivity and transmittance determinations in liquids was constructed, enabling to perform measurements in the presence of running as well as standing light waves.

Two other prototype devices, constructed by the Quantum Electronics Group, were: a pulsed energymeter for solid state lasers with a measurement range of 1 to 10 J, and one for gaseous He-Ne 10 mW lasers.

A new discharge tube technology for He-Ne lasers of durability of the order of 10,000 hrs was elaborated, and the design of the electrodes patented [32].

Optics Division

(Head — Doc. Dr. M. Surma)

The main emphasis in the research work of the Optics Group is on experimental methodology combined with the designing of experimental setups and devices for use in the investigation of various electro- and magneto-optical effects (the latter in the presence of strong magnetic fields), electrostriction, electrocaloric effect, and magnetic saturation [33].

In particular, an original pulse technique has been elaborated, which can be employed for the measurement of the optical rotatory power angle in a way extremely suitable for the electro-optical study of the Cotton-Mouton and Faraday effects in the presence of very intense magnetic fields. An advantage of this technique lies in the elimination from the measuring procedure of the necessity of scaling the recording electronic-optical device.

By applying a pulsed magnetic field of a strength up to 30 T, the Cotton-Mouton effect for various types of dipole liquid solutions in a non-dipolar solvent was investigated. The results of this research have extensively supplemented our knowledge of intermolecular interactions in liquids [34]. In addition, these experiments offer the possibility of comparing the theory of the Cotton-Mouton magneto-optic effects with the experimental results [35].

At the present time, a device for investigation of the Kerr electro-optical effect based on the differential method is being put into operation. A unique combination of very low electro-optical birefringence detection and measurement in liquids with the application of a laser light source, allows to determine effects by three orders of magnitude smaller than when using traditional techniques.

Finally, a unique optical measuring method for electrostriction and the electrocaloric effect in liquids [36] has been worked out. This method exploits pulsed electric fields and electro-optical detection.

It has already found wide application in the study of electrostriction and the electro-optical effect in liquids under very difficult experimental conditions.

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