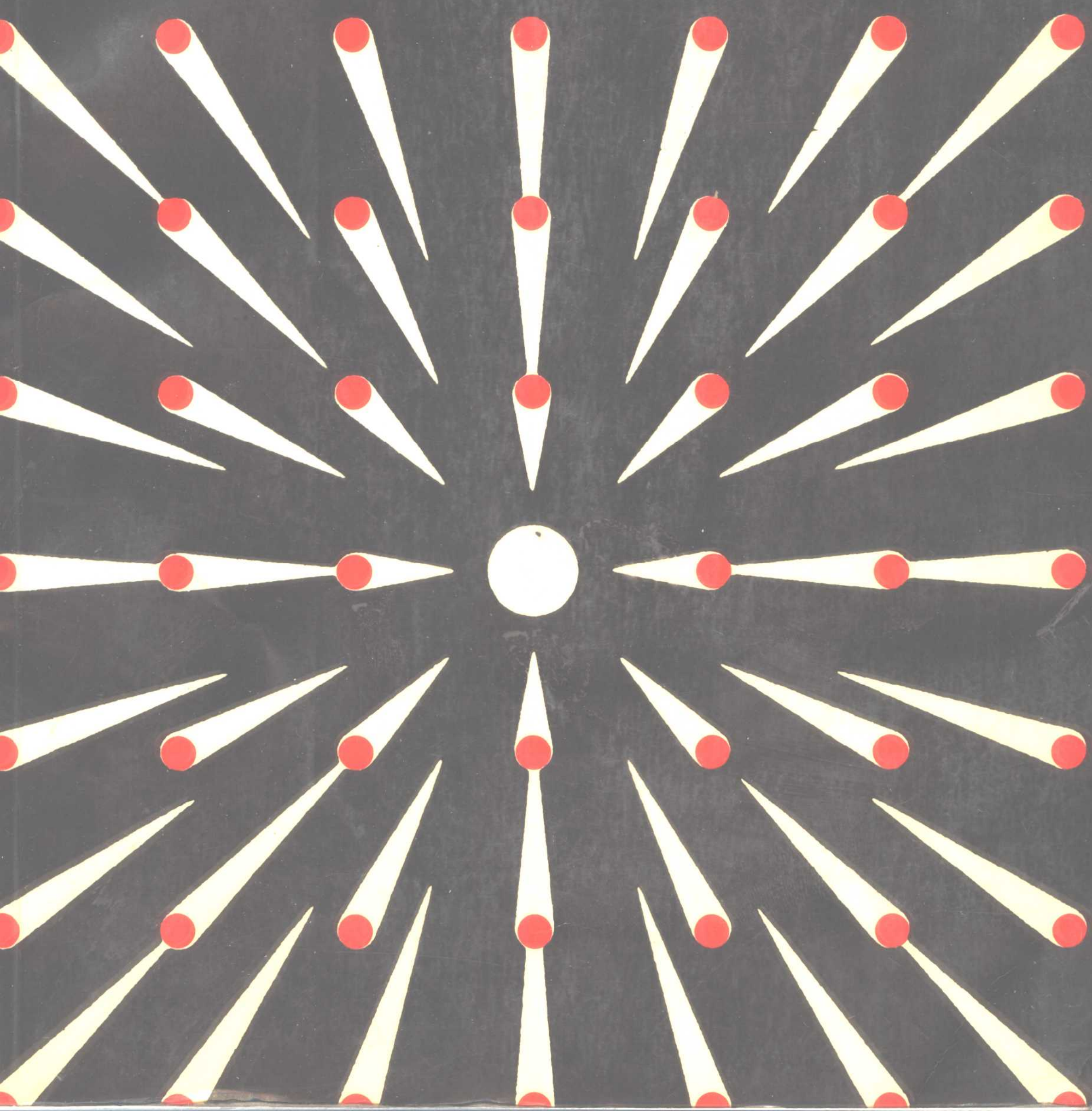
LASER 79 OPTO-ELECTRONICS

Munich 2/6 July 1979

Conference Proceedings

Edited by

Professor Dr W Waidelich



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FOREWORD

The special properties of laser radiation, such as monochromaticity, coherence, beam concentration and high power density, open up for the laser completely new, undreamt of applications in science and technology alike. Since the laser was discovered, in 1960, an ever-increasing number of applications have been found for it in the most diversified fields of endeavour. Despite this, its wider possibilities are still by no means fully recognized or exhausted.

The prerequisites for further rapid development lie firstly in lasers themselves. Further development is continually taking place in the design of new systems and two areas in particular that are worth mentioning are tunable lasers and the widening of the spectral range beyond the visible. Secondly, vital progress is being made in the field of optical components, where above all, fibre optics comes to mind. Then, last but not least, there are the advances in electronics, as manifest in new components and techniques.

The generation of laser radiation is in itself an opto-electronic process, but the name LASER OPTO-ELECTRONICS is meant to express the fact that a multiplicity of new applications are emerging through the combination of laser radiation with electronic systems. Examples of LASER OPTO-ELECTRONICS in this sense are the numerous new techniques in laser opto-electronic measurement technology and in optical communications engineering.

The biennial LASER OPTO-ELECTRONICS Conference and Trade Fair organized by the Münchener Messe- und Ausstellungsgesellschaft mbH is intended to convey both to experts and users, the latest progress in this rapidly expanding field. The focal point of the scientific Conference lies in the presentation and discussion of the latest research findings and possible applications; whilst in the Trade Fair, components and systems already on the market are exhibited.

This combination of theory and practice and the resulting interactions have proved outstandingly successful. The Munich concept of Conference and Trade Fair has shown itself to be the right one and has made LASER OPTO-ELECTRONICS into the largest and most important international event of this kind.

LASER OPTO-ELECTRONICS 79 opened with an anniversary lecture by Professor Goldman, the founder of laser medicine. In his lecture 'Sturm and Drang in the development of lasers for the good of man', Leon Goldman, who has always been identified with the use of lasers for the benefit of humanity,presented a heuristic vision of a better world.

I should like to express the hope that the scientific papers collected in these Conference Proceedings will foster and encourage continued successful work in the field of laser opto-electronics.

Thanks are also due to IPC Science and Technology Press Limited for their excellent presswork and speedy publication.

Prof. Dr. W Waidelich
Munich
September 1979

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STURM UND DRANG IN THE DEVELOPMENT OF LASERS FOR THE GOOD OF MAN

L. Goldman

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After the initial struggles and confusions, the laser has reached maturity for its current phase of lasers-for-the-good-of-man. For the future, there are limitless applications which could make possible Goethe's dream of one world. This can come if Goethe's attitude to science is accepted, "a guiding beacon for the humanist to-day."

In the early developments of the laser, there was great pressure to try to look for applications and great anxiety about death rays. One wondered what to do with this new darling of physics. Perhaps Goethe, had he been present at the infancy and the early growth of the laser at that time, would have been able to forecast early the brilliant future for laser biology and medicine and other developments for the good of man. With his interest in colors, he would have said much about the fascinating colors of the laser. He was, also, a pioneer in physiological optics, although he considered mathematics to be an intruder in physical optics.

The laser was born at a time when initially only industry and the military were interested primarily in the laser. Those, unfamiliar with the laser, believed its frantic search for applications was hopeless. Many years ago, in the United States, at a White House sponsored laser conference at LaJolla, California, specific recommendations were made for research and development for many applications for lasers for the good of man. Soon all these dreams, resolutions and even specifics were filed away and forgotten. Struggles for interest and for support for basic research in biology and medicine were made frequently and often in vain.

Gradually, there were spin-offs of crumbs picked up on the sidelines for use in biology and medicine and soon, some applications, especially in communications and information handling eventually were available for the good of man.

Fortunately, disinterest and lack of funding in basic research, in contrast to applied research, is slowly disappearing, although still too slowly. Fortunately, also, much current fundamental research is being done in Europe and Russia. It is difficult to imagine how any area of modern life can be disinterested in the laser. This includes the true basics of food, shelter, learning, transportation, culture, including education, art, music, and especially, health.

The fundamental applications of laser communication and information-handling obviously have the greatest potential for a smaller world, more interesting, and more important, and much more interested and concerned about one's neighbors. Again, communications and information-handling are still confined mostly to industry and the military. These systems, as yet, have not been applied, for example, for the development of better health care, or even for culture. For example, will the laser help us to get digital image processing so we can record early changes in the size and mass of cancer in computer programming? Such data will be of great value in cancer treatment and cancer control programs.

The next broad fields of concern for the good of man are, of course, laser biology and medicine. It is still not realized how important are the needs for basic research in biology, if only for a better understanding and the development of more effective laser safety programs. Otherwise, such safety regulations as are developed, result from mostly uncontrolled anecdotal reports of trial and error technics, mostly from library science and, consequently, a complete ignorance of the long-term effects. Again, only by detailed studies of the biology of reactions in the living tissues of man, can we give advice about proper laser safety programs for the operators, and also for the public.

The fields of non-ionizing radiation are receiving considerable interest at present, not only as regards treatment, so-called photo-therapy, but also as concerns the continued exposure of the public in those countries where protection of the public is of some interest and concern. The laser is an important modality of modern photo-therapy.

So, there should be encouragement of the new laser biology in terms of molecular biology, which includes fluorescence microscopy, cytofluorometry, microsurgery even of chromosomes, and an extraordinary array of new spectroscopic technics, from Raman and Rayleigh spectroscopy, to photo ionization. Molecular laser biology includes the development of test systems for the effects of lasers on living tissues as cells, tissue culture, chloroplasts, and including also, controlled safe studies on the tissues of both animal and human.

At the introduction of each new laser system, not only for laser medicine and biology, there is first, of course, the development of a so-called preliminary laser safety program. Then for biology and medicine, begins the detailed study of laser biology and then, laser medicine. A current example of this should be the investigation of the rare gas halides, the molecular halogens and the mercury halides for biological studies for safety then for applications in biology, for laser chemistry, for spectroscopic technics, and then for diagnostic technics and even for communication systems. An example of the latter application would be the mercury halides, 400 - 600 nm, for underwater communications.

What will research in laser driven inertial confinement fusion offer to the biologist and physician besides, eventually, increased energy for his daily life? Will this be only for the soft x-ray phase, as Battelle has shown, for rapid motion radiography or for cancer therapy, or just for studies in radiation? From the Nd laser in the laser fusion project, there are now studies, with good controls, of x-ray diffraction available for biology and medicine.

Following the developments of laser biology, there will be then the investigations for laser surgery and laser diagnostic medicine. Flexibility, sterilizability, reliable preformance standards, safety measures are all concerns about research and development of laser surgical instrumentation. As always, suitable controls are necessary for the specific situation to determine whether it is necessary to use the laser. All this will develop eventually more effective and more economical laser instrumentation for those conditions for which the laser is indicated. Whether there ever will be international standardization and regulation of such medical devices, as WHO desires, is not known.

We repeat, ad nauseam, that the laser industry must be interested in the development of laser biology and laser medicine. Market research indicates now that there is increasing interest at least among the biologists and physicians. One sees now some interest in the development of so-called medical divisions of laser companies. Hopefully, in addition to interest, funds will be provided for this assumed low priority area of laser application. Should we, in biology and medicine, be satisfied with our current court favorites, helium-neon, argon, krypton, ruby, neodymium, CO_2 ?

Should more investigations be done with dye lasers in biology? Should investigations be developed for research and development of "flexible" economically pulsed CO_2 for laser surgery? Should more studies, be done such as are being done here in Germany, be with holmium and CO lasers? Should there be more extensive studies in laser endoscopy, diagnostic and surgical, for the lungs, chest, the bladder, rectum and colon, and for vascular surgery? Should studies in laser molecular bioengineering be expanded for cytogenetics? Should the initial and important studies of the laser as an immuno-suppressive agent be expanded for increased direction clinical applications? All these are challenges for youth interested in science, and incidentally, for the laser industry. The new Journal of Laser Surgery and Medicine will continue to echo these challenges.

Other facets of lasers for the good of man include, as indicated, the fields of sociology, education, entertainment, art and music, all associated with better lives of communication and more effective information handling.

The theory of Einstein, the later developments of Townes, Schawlow, Basov, Prokhorov, and others have given us a new modality with limitless applications. In our present period of what has been called The Period of Science and Anxiety, lasers-for-the-good-of-man will do much for our Age of Science and will help to reduce our Age of Anxiety to tolerable levels, levels which Rosenfeld calls, "A Healthy Anxiety." What Goethe claimed as one of the principal functions of natural science, can be applied to the laser, "to provide life in its ceaseless evolution with new techniques of warding off what is harmful and promoting what is useful." These words should be, not only for us as technicians, who, often alas, know everything about techniques except their order in the universe, but also for man as a whole. As for the laser, to-day, there is no greater challenge to the spirit of adventure and also invention.

TRENDS IN OPTOELECTRONIC COMPONENTS

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The paper describes the state of the art of the most important optoelectronic components: LED's, laser diodes and detectors. A discussion of promising applications for these devices leads to goals for future development activities in optoelectronics.

1 INTRODUCTION

Today, next to integrated circuits optoelectronic components are the main contributors of innovation in semiconductor technology. Of decisive importance to the success of optoelectronics was the fact that it was possible to develop material and device technologies for the binary and ternary III-V semiconducting compounds GaAs, GaP, $GaAs_{1-y}P_y$ and $Ga_{1-x}Al_xAs$ which resulted in economically viable production methods. With these four materials the wavelength range from λ = 0.56 µm (green) to λ = 0.95 (near IR) can now be covered (Fig. 1). With the addition of two somewhat more complex quaternary III-V compounds $Ga_{1-x}Al_xAs_{1-y}Sb_y$ and $In_{1-x}Ga_xAs_{1-y}P_y$ this range can be extended to approximately 3.8 µm (Fig. 1). One might expect that suitable production methods will be found for these materials as well. For λ > 3.8 µm there are no suitable III-V compounds and here one has to rely on II-VI or IV-VI semiconductors (Fig. 1). $Cd_{1-x}Hg_xTe$, $Pb_{1-x}Sn_xTe$, $Pb_{1-x}Sn_xSe$, and $PbS_{1-y}Se_y$ do, however, fulfill all technological prerequisits for successful device development /1/. Up to the present only for the wavelength range λ < 0.56 µm (blue and shorter wavelength) has this problem not been solved. For the materials with the most chance of success SiC, GaN and $ZnS_{1-y}Se_y$ suitable production methods are lacking.

On the basis of these established technologies, with the exception of the last case, the most interesting device developments will be discussed in this paper and along with new applications the most important development goals will be indicated.

2 EMITTER

2.1 Light emitting diodes for indicators and displays

The most common materials for todays LED's of different colors are summarized in table 1. For a long time the most economically important material was $GaAs_{0.6}P_{0.4}$ which can be grown on GaAs substrates by vapor phase epitaxy (VPE) at reasonable cost. The LED's are constructed as shown in Fig 2a. In the meantime GaP substrates can be produced cheaply and their use is increasing. The LED construction is modified as shown in Fig. 2b. Typical chip dimensions are 0.4x0.4x 0.2 mm^3. Taken as a whole the achievable luminous output for the various colors hardly differs. It is to be expected that the ratio of luminous output to electrical input power for production LED's of all colors will not exceed 0.5 lm/W. With this value the red to green emitting diodes will have reached an acceptable level. Of course, blue LED's representing the third basic color would be of interest and they exist as laboratory samples. However, the technological level reached would be unsuitable to large scale manufacturing. P-N junctions can still not be achieved in GaN, and in SiC a process for the reproducible and economical production of large, high quality substrates is lacking. In $ZnS_{1-y}Se_y$ neither the question of how to form a p-n junction nor what substrate to choose has been answered. We do not see any practical solution for this problem and we feel increasingly doubtful that there will be blue emitting diodes in the same price category as red, yellow or green.

With the available LED's, even lacking the blue color, arrays can be built and used in a great variety of ways. The advantage of these displays over other solutions (for example plasma displays) can be found in the comparatively high luminous density of the picture elements. More complex displays for alhpanumerics can be realized