It seems to be worthwhile to give a short summary of the above conference as the object dealt with in this symposium is surely of common interest.

Laser physics has developed in the last few years very rapidly into an important and very large field of research. The great number of publications concerning this subject makes it almost impossible to survey all the developments in this field. Only special symposia can help to overcome this difficulty.

The selection of papers presented at the Conference in BERN was remarkably good. 80 o/o of the conference time was reserved for invited review papers concerning the main fields of laser physics and were given by authors of high reputation. The rather few short communications were delivered in parallel sessions and their subjects were selected from the aspect of completing invited papers in some details. The following main subjects were discussed:

1) Laser physics in general
2) Solid state lasers
3) Gas lasers
4) Injection lasers
5) Chemical lasers
6) Applications

1. Laser physics in general

With the first paper, G.T. di Francia presented a general introduction in laser physics, beginning with the fundamental problems of this field. It followed a general review of laser physics, experimental techniques and a short survey of laser application. Already this paper pointed slightly to the fact that the results of present work and probable results of current work are not expected to be as sensational in general as were the first publications concerning optical masers. As a matter of fact,
laser physics seems to have reached a stage where research is mainly engaged in details. The more theoretical part of laser research, especially, is up against considerable difficulties. Complete explanation for many effects and properties of lasers and laser light are still sought. One review paper, some short communications and remarks in many discussions showed in which direction theoretical work is concentrated: namely, properties of the cavity, non-linear theories and effects, wave propagation on different media and coherence phenomena. Only some questions of these complex problems were discussed in detail. A rather hard point for explanation turned out to be the so-called spiking of the output light. A lot of work was spent on that matter, but really satisfactory explanations of this effect have not been given until now. The reason for these difficulties can be seen in that this spiking obviously depends on various properties of the laser arrangement. For example it is certainly influenced by the quality of the active material. It was shown that in very good samples of CAWO$_4$:Nd$^{3+}$ crystals with relatively few impurities the spiking becomes much more regular than in crystals grown with less care. An interesting point of view was shown in a paper where the author discussed the possibility of a connection between spiking and density fluctuations (ultrasonic waves) in the crystal samples. Experiments confirmed that internal modulation of laser oscillation is possible by applying ultrasonic vibrations to the laser rod. This fact could not only give an explanation for the spiking but could also have applications in the field of communications.

It was quite interesting to hear a talk about the influence which optics still has on laser research. H. de Lang from the Philips research laboratories presented this paper and touched on 3 main fields where optics is closely connected with laser physics. For each of these fields he discussed an example. Geometrical optics was involved in the discussion of 3- and 4-mirror laser arrangements. That could be made in order to increase the "active" surface of the cavity relative to the total surface. (In the two mirror arrangements of a Fabry-Perot interferometer this "active" surface is about 10% of the total). 3- and 4-mirror arrangements for gas and solid state lasers were discussed. The use of such arrangements will decrease the cavity losses. For investigations involving interferometric spectroscopy a scanning confocal interferometer was shown and its properties discussed. This instrumental arrangement seems to be very useful for...
analytical investigations of laser light and its properties. Zeeman splitting for example has been studied with this instrument. Phase conditions in standing and travelling waves and the modulation of laser light can be investigated using various laser arrangements with polarizing media within or outside the laser feed-back.

2. Solid state lasers

An instrument of great importance for investigations in various fields of physics turned out to be the giant pulse laser. Further development of this laser type was reported in this conference. Remarkable is the new Q - switching technique by means of so-called passive Q - switches. The previous giant pulse lasers were normally operated with Kerr-cells as light switches. The inconvenience of Kerr-cells soon gave rise to a search of other switching techniques. Light switching by rotating prisma was and still is very successful in operation. The new Q - switching technique, developed during the last year, briefly works as follows: within the feedback of the laser is placed a material which absorbs strongly the wave-length at which the laser is operated. With increasing intensity this absorbing material is itself pumped and when the point is reached where the population of this material becomes inverted the filter is switched very rapidly (within some ns) to transmission of the laser light because the absorption has become negative. During the quenching period the active material of the laser was pumped to a high level of inverted population and now the giant pulse emerges through one mirror. It should be noted that after a short time when the absorbing material has by itself emitted so many photons (stimulated by the passing light pulse) that when restitution of the normal population has taken place the shutter is closed again. The shape of the emerging pulse therefore shows steep slopes on both sides, in contrast to the shape from a Kerr-cell or rotating prism switched pulse which shows only short risetime. The advantage of this new technique is mainly in its easy handling.

One of the most important and interesting applications of the giant pulse laser is its use for investigations of stimulated Raman scattering. This effect has been observed in a series of materials using either a technique with the sample within the laser feedback or outside in the focused beam. Stokes, as well as
Anti-stokes-lines could be observed. At the moment work in this field is mainly concerned with the explanation and the development of the theory, but conformity of the latter with the experiment is not currently very good.

Although the series of materials in which successful laser operation has been reported becomes always longer, the position of Ruby as the most often used material is still uncontested. This arises from the fact that the output power and energy of lasers operated with other materials (mostly rare-earth doped ionic crystals) is still very low. An exception perhaps is the glass laser, using neodymium glass as the active material, because its output energy may be fairly high. Indeed nothing essentially new from the field of solid state lasers was reported at the conference in Bern. Some details and technical problems were discussed, but only for glass lasers more time was spent on their properties and practical usefulness.

3. Gas lasers

It was also not surprising that no sensational news about gas lasers was reported, since it has recently been apparent that technical development has reached a stage of stagnation. However, that does not mean that gas lasers have lost something of their importance for practical applications as well as for investigations in physics. Gas lasers are extremely useful for fundamental research of basic physical processes such as the mechanism of laser action, analysis of laser light, tuning experiments, interferometric investigations, and also their applications as physical standards. Further applications can only be expected if the search for new systems with higher energies and (or) power output is successful. From these investigations spectroscopy may expect valuable data and information.

4. Injection lasers

Since the time when laser action in a p - n - junction of gallium arsenide was first reported, various other compounds (\( \text{III}_A \text{V}_A \text{; IV}_A \text{; VII}_A \text{ compounds; } \text{SiC} \)) proved to be capable for operation as injection lasers, but Ga As (F) - compounds still command the main interests. Injection lasers can be operated continuously, but only at very low temperatures, (liquid helium). For higher temperatures only pulsed...
techniques are possible since the threshold depends very strongly on the temperature and that means that the current density which is necessary for laser action is increased very rapidly with rising temperature (about 4 orders of magnitude between the temperature of liquid helium and room temperature). The efficiency of injection laser is not as high as mentioned in the first rather optimistic publications, but lies in the range of 5 - 8 %. This quite considerable value is possible since radiative recombination seems to occur with 100 % efficiency. Increase of the current density in a junction does not raise the intensity of the single lines, but increases only the number of lines within a frequency range, which is roughly given by the width of the normal emission (100 - 200 A). It should be noted that besides the well known emission in the red region a weak emission in the blue range has been observed.

Apart from these more experimental aspects, much work is being done to give a better understanding of recombination in junctions because it is not exactly known between which levels transitions occur. These investigations and the results of various other problems will be of great interest for solid state physics.

5. Chemical lasers

A new possible laser type is the so-called chemical lasers. This laser could possibly be an arrangement in which the inversed population is produced only as the consequence of chemical reactions. For example two gases could react in a flame in this way that the secondary product appears in two states between which radiative recombination is possible. Inverted states in various compounds are known (some for a long time) and they are mostly produced in atomic flames. But although calculations concerning this matter are rather optimistic, successful laser operation has not yet been reported.

6. Applications

An important point of the programme of this Conference was the discussion of laser applications. A pure technical matter and therefore of rather small interest for physics is its application as machining tool. Hole drilling and
similar operations are done indeed but the practical usefulness is limited by the low total energy of the laser output and the low repetition rate. More interesting is its use for evaporating of materials in the focused beam. The energy concentration in this point is very high and the material is vapourised immediately. This technique is mainly used for spectroscopic investigations. It should be noted that lasers are also used for measuring optical properties of plasmas.

It is impossible to make an exhaustive list of all the applications of lasers which utilise the source of light with remarkable properties like coherence, narrow frequency range, high energy concentration and extremely high power density or photon density respectively, but it is obvious that these properties are of much higher value for application in fundamental physics research than for more practical aims.

Laser application in the field of communication will also in the near future be rather moderate, even when all problems of modulation etc have been solved satisfactorily. Long range communications in the atmosphere based on visible or infra-red laser light will be impossible. Even communications over short distances will be problematic since besides normal limitations in clear air, (absorption, scattering and turbulence), weather conditions cannot be controlled. In free space communication over rather short distances (within the solar system) could be possible, but over very long distance communications in the wave-length-range of the H - 21 cm - line should be far superior. Terrestrial communications over short distances using a sort of light guide (optical fiber rods or hollow wave-guides), could be worthwhile if one really needs the extremely high information carrying potential of the laser light.

Laser applications in the field of medicine are not expected to become very important.

Conclusion

The Conference presented an unusually well planned selection of papers so it was possible to get a very good survey of the important fields of laser physics. The conference showed that the time where sensational reports and speculations about lasers hunted each other has definitely gone. It also turns out more and
more that its practical application will be rather limited. This fact surely is of importance for the commercial point of view but does not bother physics itself. The laser will also in future be an unusually important instrument in fundamental research of physical processes. Reasons for the limited practical applicability are obvious: The rather low energy output and the low repetition rate of pulsed lasers. The most optimistic estimations of possible output energies lie in the order of $10^3$ Joule. It is not even clear how this value should be achieved. Normal lasers have a typical output energy of some Joules. The continuously operated lasers have a typical output power of $10^{-3}$ Watt. As these facts cannot be altered one can expect that for application in fields where some energy is needed, like treating material or for military aims, lasers will be unimportant.

What results and new possibilities can one expect from further research? One of the main problems naturally will be the further development of laser techniques and materials. With already known and available laser materials the attainable limits are indicated. Besides the above mentioned energy problems the question of power flux is of great interest since investigations of non-linear effects are only possible if high power densities are available. In a focused beam power densities of, say, $10^{13}$ W/cm² and perhaps more are attainable, and hence, of course, very high electromagnetic fields. With a new technique where several lasers are operated in a file, pulse lengths as short as some $10^{-10}$ s should be attainable, (present giant-pulse-lasers about $10^{-8}$ s) and with that a still higher power flux.

Great progress is to be expected from the development and application of new laser materials. The development of lasers with higher energy output is only possible if the pump efficiency could be increased. This could be attained, if, for example, a compounded material could be developed in which the pump light becomes absorbed in two or more different absorption bands and the energy is then transferred to a common level from which radiative transition to a ground level is possible. Another more promising possibility seems to be the use of rare-earth doped organometallic compounds imbedded in a liquid or plastic like material. In such complexes inner molecular energy transfer occurs whereby the energy which is absorbed in a broad band of the molecule is transferred to the rare earth ion which becomes excited and emits its narrow emission lines. It is
a pity that nothing about the work in this field was reported in the Conference in Bern although some time ago successful laser operation in a similar material has been reported.

It does not seem to be very probable that laser materials with considerable output energy in the visible wave-length range or up to the ultraviolet range will be found in the near future. It is perhaps easier to do the step to the X-ray or γ-ray range, but there exist only abstract speculations.

It remains to have a look at the foreseeable applications of lasers. As already mentioned above the practical or technical application will be limited. In the field of treating materials lasers will certainly not displace tools like electron beams. In the field of communications lasers could attain some importance for short range communications when their high carrier potential is really needed. For the measurements of short and long distances and geographical surveys, lasers have already attained and will attain still more importance.

In many fields of research one will find possibilities of laser application but this surely will not be comparable with the importance lasers have for fundamental research in physics.

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N.B. The proceedings of the Conference are being published.

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