a field effect transistor with a 0.1 μm gate. The inability of the electrons to be scattered by phonons when dealing with picosecond time scales makes the electrons travel faster — ballistic regime — and can give most impressive maximum operating frequencies, perhaps beyond 100 GHz.

In looking to the new future of submicron devices, materials growth particularly in the compound semiconductors, will play a key role. This topic was reviewed by R.W. Brander and M.M. Faktor of the British Telecommunications Research Laboratories. Brander clearly came down, in the presentation, on the side of expecting molecular beam epitaxy to give the best technique for controlled and selective material growth, at least in the future. The problems of throughput that may trouble mass production were not emphasised by Brander, but were of concern to P.J. Daniel (Philips' Research Laboratories, Redhill) in his careful comparison of photolithography and electron-beam lithography. While conceding that the electron beam has clear advantages over photo-lithography in the diffraction limitations, in spite of back scattering of electrons blurring the edges, Daniel believed that the problems of speed of writing for raster or vector scanned e-beam machines would remain. If true, this could have serious consequences on the commercial exploitation of the new physics of sub-micron devices where e-beams may be essential rather than as at present, used to help in discretionary wiring of VLSI.

Indeed the practical difficulties of reducing dimensional tolerances to increase packing densities while maintaining yield in VLSI production processes, may have accounted in part, for the greater interest in vertical integration which appeared in papers time and again. For example, J. Lohstroh (Philips' Research Laboratories, Eindhoven) in his review paper indicated how vertical integration was helping the packing density of bipolar devices and also reducing the power consumption to meet the requirements of VLSI, even with 3 μm minimum detail. Vertical integration appeared again in the opening review paper of the conference from J. Tihanyi (Siemens, Munich). Tihanyi showed how the VMOS, which originally had the V standing for the shape of its special groove, now had the V standing for vertical. Vertical integration had given Siemens a process whereby MOS power devices could be made with reverse hold off voltages of around 1000 V, with on-conductances of over 100 Siemens (to quote Tihanyi's pun). Bernd Hoefflinger of Dortmund University again echoed some of these ideas about vertical integration in discussing enthusiastically the virtues of CMOS. On listening to Hoefflinger's technology which combines bipolar and MOS in an appropriate blend of planar and vertical integration, one is led to believe that CMOS will give the ultimate in flexibility of design from high speed, low power, through to high voltage, if required; an exciting prospect for VLSI.

Special mention must be in order for the contribution of Cyril Hilsum, (Royal Signals and Radar Establishment, Malvern). Hilsum was described by Walter Merz as the "father" of ESSDERC, having played an important role in forming ESSDERC ten years ago and guiding the conference through all the intervening years. In a relaxed mood before the conference outing to the Yorkshire Moors, Chatsworth House or the beautiful York City, Hilsum gave a colourful discourse on solid state displays. He showed, for example, a unique photograph of a 512 x 512 matrix CdS display from the Kirin Inst. of Physics, Chang Chun, but pointed out that it emitted only 1 ft lambert, some 30 times less bright than a television set. However, the future was brighter than that and liquid crystals had made a dramatic advance in reliability with the production of improved materials. Improved materials would again lead to colour being added to liquid displays without the rapid bleaching of some of the present methods. The next ten years he promised would not be dull.

To a man who is interested in the physics of novel devices, one likes to think that ESSDERC will report on them. The invention of such novel devices is slowing down but it was a pleasure to hear that J. Shannon's (Redhill) Monolithic Hot Electron Transistor, which was first reported in the *IEE Journal on Solid State and Electron Devices,* was continuing to do well. Its "camel" diode emitter-base indicated satisfactory transport of the hot electrons and gave promise for future high microwave developments. G.G. Bloodworth's (York) fascinating rotating domain magnetometer continues to provide interest and the explanation of the physics of his device is now much clearer.

ESSDERC then is very much alive as nearly 300 delegates, from 25 countries, know. Like Hilsum's promise for displays, the next ten years will not be dull.

Next year's ESSDERC will be held from September 14-18 at Toulouse and again the Symposium on Technology will be held in parallel. General information for ESSDERC '81 may be obtained from:

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J.E. Carroll, Cambridge

ESCAMPIG

The Vth European Conference on Atomic and Molecular Physics of Ionized Gases, ESCAMPIG was held in Dubrovnik 1-3 September. This conference is now well established and the organizers, R. Deloche and R.K. Janev, chose to include several new topics related to the same central theme. This year, for the first time the collisional properties of Rydberg states (F. Gounand) and laser induced inelastic collisions (C. Manus) were presented.

Due to their large size and the weak binding of the outer electron, Rydberg atoms are very sensitive to external perturbation. Gounand gave a very enlightning survey of the collisional properties of these very high atomic excited states, underlining the importance of their role in astrophysics and in laser isotope separation.

Currently the most widely studied process is the total collisional de-excitation (quenching) of a well-defined Rydberg level. Two-step selective excitation of alkali states, for example, is reached by pulsed dye lasers. Large depopulation cross-sections are generally observed (10^{-13} — 10^{-12} cm^2). The most interesting behaviour is exhibited by the n dependance. At rather small values of n, the cross section increases with n, reaches a maximum, then decreases for still higher n values. It was also shown that the position of the maximum shifts to higher n values when the mass of the perturber increases. These findings of the Saclay and S.R.I. groups seem to emphasize the dominant role of the electron perturber interaction. although in other situations the influence of the ionic core may be more important.

Due to the importance of the subject, this talk was followed by a workshop opened by Deloche, who presented a general account of the various reactions that involve Rydberg states, such as the ionizing processes observed by R.F. Stebbings and A.N. Klutcharev. Deloche also discussed the present situation of the theoretical models and their ability to describe the experimental findings.

The growing importance of laser isotope separation has been very often emphasized. N.V. Karlov presented a very clear survey of the basis and possibilities of such a field. For a great number of atoms, an enrichment of a factor of 100 or even higher has already been obtained. A selective first step laser excitation carries the desired species into a well defined state. The second photo-excitation step may be a Rydberg state that is field-ionized by a static electrical field, the resulting ion being captured and extracted. One other very interesting possibility for the second step, according to Karlov, would be an autoionizing state.

Laser chemistry and laser isotope separation have given a new stimulus to dissociation spectroscopy of molecules. C.B. Collins has demonstrated a remarkable method based on two-photon absorption that occurs through a resonant intermediate state, unstable against dissociation on the time scale of the two-photon process. The resulting products of the dissociation are photo-excited to Rydberg states that can be readily ionized for detection. In the case of caesium dimers two relatively broad absorption bands were found, corresponding to the population of the two fine structure components of the 5^2D states. The respective influence of predissociation and dissociation was demonstrated.

It is well known that the formation and loss rates of cluster ions play an important role in aeronomy. D. Smith presented a survey of very recent results, performed by a temperature variable selected ion flow tube, on the measurements of rate coefficients for many association reactions of several ion species such as NO^+ or CH_3^+. Relevance to interstellar molecular synthesis was also discussed. Two-body and three-body ion-ion neutralisation has been carefully and systematically observed, and the relevance of these data on atmosphere de-ionization was discussed. This field is developing at an impressive rate.

J. Uhlenbusch described his new results on production of plasmas by CW lasers. Such discharges, called continuous optical discharges (COD), are produced without any electrodes and are characterized by a low level of impurities. They seem to be very well suited for plasma chemical applications as well as welding, cutting and tempering. The COD plasma is obtained by focusing the beam of a powerful CO_2 laser into a high pressure chamber (up to several hundred bars). By using very refined optical diagnostics, the main characteristics of the plasma have been carefully measured over an electron density range from 10^{17} – 10^{18} cm^{-3}. T_e varies over 13000-22000 K.

F. Howorka presented the situation of our knowledge of transport of ions in gases under the influence of electrical fields. The Innsbruck group has actively contributed to this area. Among many interesting developments, Howorka demonstrated how exact mobility measurements allow the determination of the interaction potential of ions drifting in a given gas.

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C. Manus, Gif-sur-Yvette

Laser Doppler Anemometry

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(Respectively, Institute for Applied Physics and Max-Planck Institute for Research on Fluid Dynamics)

In the past few years, laser applications of increasing complexity and sophistication have begun to make their way from research to development laboratories and from there into engineering practice, industrial production and marketing. Laser Doppler anemometry is a case in point. In what follows, basic principles, the state of the art and some typical applications will be reviewed. Apologies are made to laser Doppler specialists for what may seem to be a disregard for many of their ingenious schemes and inventions, but interested readers may go more deeply into the subject by consulting references 1, 2 and 3.

The Beginning: Optical Heterodyning

During the development of the first gas lasers, beats between adjacent longitudinal modes were observed. For an $L = 1$ m long laser, for example, the beat frequency is $c/2L = 150$ MHz, and it is due to laser modes which differ by 1 in the number of half wavelengths in the standing wave pattern between mirrors. This suggested that with laser beams of adequate spectral purity and wavefronts sufficiently parallel to one another, differences between optical frequencies could be obtained much like intermediate frequencies are obtained by heterodyning radio frequencies. Further exploration of this possibility led to the evolution of heterodyne spectroscopy. Laser light impinges on a sample from which Stokes or anti-Stokes shifted light is scattered through Rayleigh, Brillouin, or Raman effect. Superposition of scattered light with part of the original laser light on a photodetector results in an electrical signal at the difference frequency.

H. Z. Cummins, one of the originators of heterodyne spectroscopy, also initiated laser Doppler anemometry. In 1964, he and his coworkers directed a laser beam at particles that were being carried along by a laminar fluid flow. Owing to the particle velocity, the scattered light frequency was Doppler shifted. Superposing the scattered light with part of the original laser beam on a photodetector, they observed Doppler frequency shifts in the kHz range. They moved the spot from which scattered light was collected relative to the flow geometry and, in this way, were able to trace out the parabolic Poiseuille velocity profile, characteristic of laminar flow in round tubing.

The heterodyne method used in laser velocimetry, in the jargon of the field, is called the reference beam method. In association with modern optical and electronic equipment, it is popular for a number of applications, but it suffers the drawback of low sensitivity. For heterodyne detection, scattered light and the original beam should have coplanar wavefronts over the area of the photodetector. That can be accomplished only for a small detector area or, equivalently, for small acceptance aperture.

Other methods of laser velocimetry do not depend on optical heterodyning directly. Their modus operandi may be discussed on the basis of seemingly different, yet fundamentally equivalent principles.

Basic Principle: Time-of-Flight Measurement

In any kind of velocimetry, a distance is marked by elements of the apparatus and the time that the object under study takes to travel that distance is measured. Dual focus velocimetry utilizes two focal regions of laser beams as sketched in Fig. 1. Typical dimensions are 10 μm for the beam diameters at their waist and 300 μm for their separation. These beams represent light gates. If a particle (city air or clean water usually contain enough particles for the purpose, otherwise artificial "seeding" may be called for) passes both focal regions in succession it will cause a burst of scattererd light in each. Photodetection is arranged to receive light signals from both focal regions in separate channels and the time of passage is equal to the time delay between pulses. The time difference may be obtained for example, by a time-to-voltage converter (originally developed for nuclear physics instrumentation) or by cross correlation. The fast digital electronic correlator used for this purpose will be discussed below.

Fig. 1. — Principle of laser dual focus velocimeter.