Essay

The Southampton/UCL Interdisciplinary Optoelectronics Research Centre

By William A. Gambling*

1. What is Wrong with Electronics?

When the transistor was invented in the 1950s a revolution in the methods of electronic information processing was immediately foreseen. Compared with its predecessor, the electronic valve, the transistor was small, highly-efficient, and, above all, reliable. The impact of the transistor on electronics, indeed on all aspects of our lives, is so immense that it could not have been fully appreciated at the beginning of its development. Nowadays we do not rely on individual transistors but take for granted a "silicon chip" a few millimeters square containing hundreds of thousands of them. The room-size computer can now be carried in a pocket and requires no external power supply.

However, even the extremely rapid switching and processing speeds now possible with solid-state electronics are beginning to reach their limits and much research is being carried out with the aim of devising inherently faster optical methods. Furthermore, the rapid processing of information is of no avail unless the results can be transmitted at an equally rapid rate to the places where they need to be used. In the mid-1960s a critical bottleneck was developing in our ability to transmit information. For example, the number of telephones and telephone calls in the United Kingdom was doubling about every six years and it was clear that a radically new system was urgently required. A number of us began to speculate on the possibility of changing from copper wire and electrical signals to glass fibers and light. By increasing the carrier (i.e. operating) frequency from the highest then possible, namely microwaves at 5×10^9 Hz, to visible light at 5×10^{14} Hz, the capacity of a single transmission line might be increased by the same amount, i.e. by a factor of 100000. This was a radically speculative and challenging idea since the only glass fibers then available were fragile, crude and capable of propagating light over only a few meters. In fact, I was told more than once that I was out of my mind and that optical fibers would never be used.

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2. Optical Fiber Communications

However, by perseverance, innovation and some good luck, the miracle has come true and optical-fiber cables are being installed worldwide which are strong, a centimeter or so in diameter (the fibers themselves are only one-tenth of a millimeter thick), of almost infinite capacity and capable of transmission over hundreds of kilometers before amplification is necessary. Most telecommunication systems are being changed over to fibers and photons, including telephone networks (60% of trunk telephone calls in the UK are already carried by optical fibers). The first (electrical) telephone cable across the Atlantic ocean in 1958 carried 48 telephone conversations simultaneously; the last, laid in 1986, carried 4000. The first optical-fiber transatlantic cable carried 40000 and a cable planned for the Pacific ocean in 1996 will carry 600000. The use of satellites for much point-to-point communications is doomed.

3. Optoelectronics

Research in optoelectronics is advancing rapidly on many fronts, so that optics is increasingly taking over much more efficiently many of the processes hitherto performed electronically. It has been predicted that the future for optical techniques in electronics will be as spectacular in the 1990s as was the development of the transistor in electronics in the 1950s. In 1988, the Advisory Council on Science and Technology (UK) published a report in which it described optoelectronics as the convergence of electronic and optical techniques covering a broad and rapidly-expanding field of materials, devices, systems and applications. It went on to predict that over the next ten years optoelectronic devices will become commonplace, gradually replacing many purely electronic devices in a natural progression to faster communications and greater information storage capacity and processing speeds. The world market for optoelectronic applications is expected shortly to exceed £ 7 billion per annum and there have been further estimates that in Japan, for

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example, optoelectronics will form no less than 5% of the gross national product by the turn of the century.

Recognizing the vital importance of optoelectronics, the Science and Engineering Research Council (SERC) set up an Interdisciplinary Research Centre in Optical and Laser-related Science and Technology jointly at the University of Southampton and University College London, with supporting work in collaborating laboratories at the Universities of Oxford, Liverpool, Sussex and Kent. This research organization, renamed the Optoelectronics Research Centre (ORC), began life in October 1989 as a national center for research in optoelectronics. It presently employs about 80 people, has strong collaborative links with industry, and covers a range of fundamental research in physics, chemistry, biochemistry and electronics; optical and laser materials including glasses, crystals and polymers; and embracing material fabrication, fiber and waveguide fabrication, as well as biochemical materials.

4. The Optoelectronics Research Centre

The initial SERC grant setting up the ORC was £ 11.5 million for the first six years (although the budget for the current year has been reduced by 10%), whilst the University of Southampton contributed £ 0.5 million and industrial contracts provide a similar amount (over two years). The University has also provided 12 seconded staff, laboratories, accommodation and access to expensive fabrication equipment. University College London has provided refurbished laboratories and six partially seconded staff. The ORC has been established as an independent research institute at Southampton, outside the departmental and faculty system, with the Director reporting directly to the Vice Chancellor. Seconded staff have moved out of their departments into ORC accommodation but some do a small amount of teaching. Research is organized into three divisions, each headed by a Deputy Director, namely Optical Physics (Professor *D. C. Hanna*), Optical Technology (Professor *D. N. Payne*) and Optical Systems (Professor *J. E. Midwinter*, University College London).

5. Research Programs

Present research is directed towards processing optical information in communication systems, as well as simply sending it. A number of different media are under investigation including optical fibers, planar waveguides and crystals. Recently, new types of fiber laser have been invented at Southampton, together with methods of generating new and tunable wavelengths. Fiber lasers are very small, flexible, highly efficient, have very low pump-power requirements and yet are capable of producing appreciable powers.

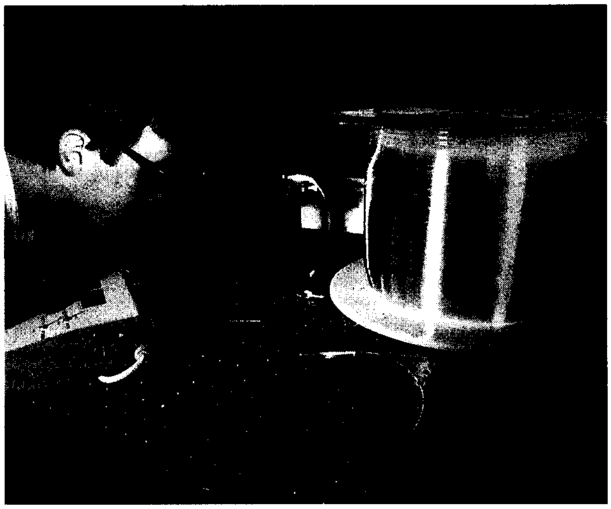

Fig. 1. Work is shown being carried out on the $Er^{3\oplus}$-doped optical-fiber amplifier, a device developed at Southampton University which has brought about a revolution in the field of optical communications. Using this device, it is now possible to exploit the extremely large bandwidth provided by the optical fiber over long-haul and inter-continental telecommunication networks. Transatlantic and transpacific links using the $Er^{3\oplus}$-amplifier are planned for the mid-1990s.

Another Southampton invention which has had a spectacular impact industrially is the fiber amplifier. It consists of a short length, ≈ 1 m, of fiber containing suitable rare-earth ions in the core which can amplify an optical signal by a

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factor of more than 1000 at an extremely low noise level, when pumped by a diode laser. It can be simply jointed into a fiber transmission line at intervals of several hundred kilometers along its length. The 1996 transpacific cable will have no electronic repeaters along its 10000 km length, only a succession of optical-fiber amplifiers.

At the other extreme (of length) optical techniques are being developed for making interconnections between silicon integrated circuits (i.e. "chips") since the vast amount of information generated can no longer be carried by electrical means. Optical fibers will penetrate into the home, carrying not only telephone calls, but data, television, "electronic" mail and newspapers. Optical techniques are starting to be used in industrial sensors where the freedom from electromagnetic interference and the absence of sparking hazards makes them particularly useful in chemical processing plants, oil refineries, fuel tanks and anywhere where there is likely to be an explosion hazard.

Already the Optoelectronics Research Centre has produced a range of new, compact, highly-efficient lasers operating at existing and new laser wavelengths. The research extends to special optical fibers and waveguides, as well as active and passive devices based on these devices, including optical biosensors. The tremendous impact of the optical-fiber amplifier invented at Southampton has already been described. Future research will continue into highly-efficient compact lasers, amplifiers and nonlinear-optical devices, in fiber, planar and miniature-crystal form for a wide range of applications and into optical interconnects, high-speed pulse generation and processing, neural computing networks and future applications of optical signal processing.

6. The Future

Optoelectronics is not just a key technology but is already generating new aspects of physics and chemistry which in turn are used in practical devices. Successful research will require interdisciplinary teams, as at the Optoelectronics Research Centre of Southampton/UCL, comprising physicists, chemists, mathematicians, electronic engineers, electrical engineers, mechanical engineers, biologists and others, with the necessary drive and imagination to probe new physical processes and to apply them. The future, in optoelectronics at least, is very exciting and will have a major impact, not only on technology and fundamental science, but also on the fabric of our society.

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