Abstract

Four Decades of Solid State High Performance Devices

By

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The past forty years have seen an explosion in not only the research on high performance devices, but the rapid translation of that research into applications that today touch an ever increasing portion of the world's population. Three pioneers of this research, Lester Eastman, Nick Holonyak Jr. and Herbert Kroemer, were born were all born in 1928 and they along with a large number of their graduate students have been instrumental in furthering this work. All three of these researchers were involved in III-V semiconductors in the 1960s, but with different focuses. Their initial work as well as that of their peers in lasers, heterojunctions and microwave sources provided the basis for the topics of interest at this year's Lester Eastman Conference

The first decade of work (1966 to 1975) on microwave devices was largely concentrated on two terminal devices with various researchers increasing the frequency and power output of devices that were primarily oscillators. Oscillators, primarily Gunn Effect, were quickly converted into several practical devices and provided the sources for the first police radars that have become an accepted part of life. Silicon bipolar transistors were limited at that time to below 4 GHz so some microwave work was done on microwave amplifiers using negative resistance devices, but the two terminal amplifier work was to be quickly replaced with three terminal devices.

Nick Holonyak, Jr. at both General Electric and after 1963 at the University of Illinois was a leader in III-V heterojunctions and in 1960 was the first to grow $GaA_{1-x}P_x$ to construct visible-spectrum lasers. He was the inventor of the first practical LED, the red diode that was initially converted into numerous displays.

The second decade of work (1976 to 1985) was highlighted by the rapid development of Field Effect Transistors (FETs), hetrostructures and the introduction of the quantum well laser. The FET exploded into applications with the largest usage being FETs fabricated with GaAs. The continued development of fabrication techniques into the sub-micron region permitted the frequency of operation of FETs of all types to continually increase. The availability of three terminal microwave and mm-wave devices also increased the emphasis on microwave and mm-wave integrated circuits as the operation of commercially available devices rapidly exceeded 20GHz. In addition to reception of television signals broadcast via satellite, this technology was deployed as microwave links for checking credit cards at gas stations long before internet connections were readily available for the same purpose.

The third decade of development was characterized by the commercial communication using “wireless” techniques. Establishing a connection was the goal in the years from 1986 to 1995. This focused research into the areas of power devices for transmitters and low cost receivers as the pager became a very common device. At the same time the fiber optics industry was maturing into a mass producer of transmission cable and supporting devices to compete with wire and wireless based communication.

A parallel development during the decade from 1986 to 1995 was the power of the personal computer. As the desktop computers developed in computing speed and memory capacity, the communication methods using wire line were typically not powerful enough or had insufficient bandwidth to support multiple users. The deployment of fiber transmission lines not only created a market for light sources, but the microwave components used to modulate the light sources.

Being connected was not enough in the most recent decade (1996 to 2005). That decade could be characterized as a search for bandwidth and power. The easiest method to create bandwidth is to increase the frequency of operation and thus the continued the emphasis on higher frequencies and the emerging research in terahertz devices. Power is most important in high density urban environments to increase the dynamic range of devices to prevent interference between the multiple signals sharing both the physical connections (wire and fiber) as well as the mobile wireless connections. Light sources and detectors have not been neglected in the push for greater transmission capability. The development of additional sources of light to fully utilize the “dark” portion of fiber optic cable continues.

The author will include as part of this presentation references to several applications as well as offer some concluding projections on potential future developments.

Note: It was suggested to me by Lester Eastman that I should submit an abstract for an invited paper on my reflections of 40 years of high performance devices since I was his first graduate student in the area of solid state microwave devices. I received my M.S. degree in 1966 and a Ph.D. in 1968 from Cornell University.