InGaAs and InAlAs, are further extending the limits of solid-state capabilities in a range of areas from extra-high frequency (EHF) power and photonics to energy conversion applications to a host of military systems.

Published in *Electronic Engineering Times*, July 17, 1989.
Indium phosphide speeds past GaAs

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The fabrication of state-of-the-art high-speed electronic and optical devices requires not only high-quality substrates, but also that the growth upon these substrates of highly uniform epitaxial layers with precisely controlled physical and electronic parameters such as thickness, carrier concentration, carrier mobility and layer smoothness. In some applications, only a single layer may be required while in others, extremely complicated structures containing thousands of layers are necessary.

Rapidly maturing epitaxial techniques, such as organo-metallic chemical vapor deposition (OMCVD) and gas-source molecular beam epitaxy (GSMBE), are now making possible the InP-based structures that are needed for the advanced devices awaited by the military community.

InP is an attractive material for microwave and millimeter-wave power transistors because of its higher peak electron drift velocity, thermal conductivity and breakdown field as compared to GaAs. In addition, the surface properties of InP make using the metal-insulator-semiconductor field-effect transistor (MISFET) very attractive. Unlike GaAs, it exhibits the channel carrier accumulation and large positive gate voltage swings while keeping gate leakage current extremely small.

InP MISFETs developed by the Naval Ocean Systems Center (NOSC) and by Thompson-CSF have demonstrated power output of 4.5 W/mm of gate width at 46 percent power-added efficiency at X-band. This is more than three times the power per unit gate width ever reported for GaAs-based FETs.

More recently, a collaborative effort between Texas Instruments and NOSC has resulted in 16-micron gate-length InP MISFETs demonstrating 1.8 W/mm at 30 GHz with the highest reported value for GaAs-based FETS is 1 W/mm at that frequency. Under dc conditions, these devices exhibit drain current drift to channel resistance, 

CAD voyages through 'virtual reality'

By Richard Doherty

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In the meantime, Autodesk and other computer graphics companies are working on viewer technologies that provide finger-pressure feedback proportional to the "force" the user is exerting.

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Wearing stereoscopic goggles and sensor-laced gloves, teleporters on Earth might be able to see through a robot's eyes and manipulate objects with robotic hands located thousands and even millions of miles distant. Fisher has worked closely with engineers at VPL Research Inc. (Palo Alto, Calif.) to create a 15-sensor DataGlove that translates hand and finger movement into 8-bit video as delivered to a custom interface.

VPL's Jared Lanier is working as a consultant with Autodesk. He's responsible for translating laboratory brain-glove sensor systems into large-scale commercial products. He was the catalyst behind the licensing of Mattel Toys' Power Lights con-

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Higher Power Transistors to Play in X-band

InP extending solid state's range

Continued from page 31.

Apparently the presence of an RF signal has a stabilizing effect on the interface states. Power output for these devices drifted no more than 2 percent over a test period of 167 hours (about one week) of continuous operation. Military systems that will benefit from the availability of higher-power X-band transistors will, for example, include missiles, radar, decoys and jammers. Extended the frequency range into a band will add satellite communications to the list.

In the past several years, the millimeter-wave frequency range however, similar structures based on InP have demonstrated approximately 50 percent higher frequency operation. Cornell University has reported 1/10-micron-gate InGaAs/InP MODFET structures with a current gain cut-off frequency (fT) of 170 GHz. What's more, General Electric has reported InAlAs/InGaAs/Pn lattice matched ¼-micron HEMT devices demonstrating extrapolated maximum frequency of oscillation (fMAX) of 380 GHz. Similar structures using strained non-lattice-matched (pseudomorphic) channel layers and 1/10-micron gate lengths have been reported by Hughes Research Laboratories. The Hughes devices have demonstrated an fT of 210 GHz and amplifier circuits employing these structures have exhibited noise figures of 0.8 dB with 9 dB gain at 60 GHz. Hughes also reports capacitively enhanced logic delays per stage of 6 ps at 24.5 mW per gate for ring oscillators using similar HEMT structures.

In addition to field-effect transistors, InP-based heterostructure bipolar transistors (HBTs), the fastest of which are the high electron mobility transistors called HEMTs or MODFETs. Recently, MODFETs, a few hundred GHz has received have demonstrated excellent results. Non-lattice-matched (pseudomorphic) channel layers and 1/10-micron gate lengths have been shown to improve performance. InP-based high-speed, high-speed optical links (OEICs) will soon greatly impact photonic systems ranging from fiber-optic telecommunications and signal processing to fiber-guided missiles. Photonic structures on InP lattice-matched to InP substrates operate through the 1.55-micron wavelength attenuation minimum (≈ 0.12 dB/km) of silica optical fibers. GaAs-based structures are limited to 0.65 micron radiation (25% of the 1.55-micron wavelength range) and, therefore, are more limited in their potential for use in optical fiber systems. InP technology makes possible direct fiber-optic light transmission over distances more than an order of magnitude greater than can be achieved with GaAs-based devices. AT&T Bell Laboratories has recently reported an InGaAs PIN photodiode/InP junction field-effect transistor (FET) OEIC receiver operating with a sensitivity of -32.9 dBm at a bit rate of 200 Mbit/s with a bit error rate of 10⁻¹⁰ at a wavelength of 1.55 micrometers. Meanwhile, researchers at Fujitsu have reported an InGaAs/InAlAs/InP OEIC receiver demonstrating a bit rate of 2 Gbit/s with a -18.5 dBm sensitivity, with a bit error rate of 10⁻¹⁰ at 1.3 microns.

InP-based devices and circuits are especially well-suited for space applications because of their high tolerance for the radiation environment in space. InP solar cells are already being applied in the radiation environment of space, and, according to Irving Weinberg of NASA Lewis Research Center, one year's data on InP solar cells tested on satellite LEO-3 has shown that there is no degradation in the performance of these devices.

Laboratory data indicates that for 10 years in orbit, InP solar cell efficiencies are expected to degrade by only 3 percent, while GaAs the degradation should be approximately 16 percent and for Si cells about 25 percent. NASA Lewis has reported air mass zero total area efficiencies of 18.8 percent in InP homojunction solar cells fabricated for them by Solar Corp. using OMCDV and ion implantation techniques. Theoretical modeling predicts efficiencies of 21 percent can be achieved on InP cells.

High-speed optical links (OSLs) can increase the performance of many military signal-handling systems. One approach to OSLs is the use of the quantum-confined Stark effect in multi-quantum-well (MQW) layers with charge-coupled devices (CCDs) used to spatially program the electric field across an array, thereby providing control of the transmitted light intensity.

Military systems that will benefit from the availability of higher power X-band transistors will include missiles, radar, decoys and jammers. From approximately 30 GHz to a few hundred GHz has received increased attention. Solid-state devices and arrays operating at these frequencies will have applications, such as advanced missile systems, space and covert communications, radar, active tank defense, smart munitions, and GaAs and Si electronics.

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