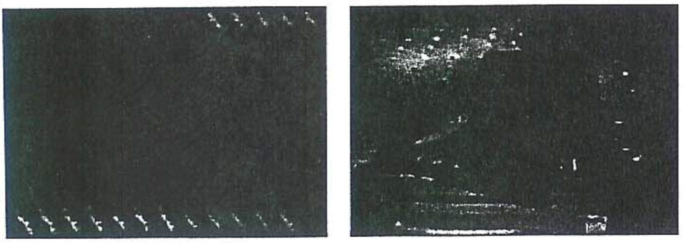
Optical control systems breed fast modulators



This polymer modulator, which operates at frequencies of greater than 100 GHz, is opening up new applications for the photonic control of millimetre-wave systems.

The optical control of systems operating above 100 GHz, which image through fog, for example, has led to optical modulators and phototransistors capable of controlling submillimetre wavelength systems, Harold Fetterman of the University of California at Los Angeles told THz 98.

The modulators are arrays of travelling wave devices based on polymer waveguides deposited on a flexible Mylar substrate. The low dielectric constant of the polymer allows optical signals to propagate inside the waveguide at the same velocity as electrical signals travel across its surface.

Each end of a polymer waveguide is integrated with an element that couples to a waveguide operating at millimetre wave frequencies. Laser heterodyning measured the frequency response of the arrays to be in the approximate range of 23 to 27 dB between 80 and 110 GHz.

Fetterman and his co-workers from Pacific Wave Industries and the University of Southern California are looking at high frequency transistors, based on a polyimide optical waveguide deposited on the active region of a heterojunction phototransistors. The researchers are working, too, on generating microwaves at 212 GHz by mixing optical signals.

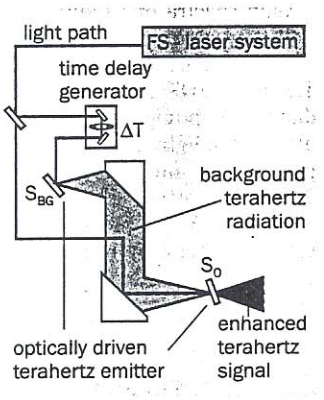
One of the potential applications of these devices is to improve the design of optoelectronically controlled terahertz oscillators, which are currently limited in their response by the speed of photodetectors and modulators.

Inversion-free gain adds energy to short pulses

Emitters of epitaxially grown InGaAs on InP emit terahertz radiation when excited by 100 fs optical pulses emitted by a commercial laser. In an experimental resonator, the emitters amplify the pulses by a factor of more than six without any need for inversion in a gain medium.

A high electrical potential on the surface of the emitters makes them act like a Schottky diode. When 800 nm pulses strike the surface, the carriers become excited and the emitted light is shifted to a terahertz signal at a wavelength of 300 µm.

Rainer Martini from the Institute for Semiconductor Electronics in Aachen explained to THz 98 how amplification without inversion helps to boost the output power of a demonstrator.



Inversionless amplification boosts the output power of terahertz emitters. The output power of the optically driven emitter S_0 is enhanced if it is illuminated by carefully synchronized terahertz pulses from a secondary emitter.

The output from a femtosecond laser is split into two. One pulse stream directly drives the terahertz emitter, S_0, while the other pulse goes to a second generator, S_{BG}, via a time delay generator.

The terahertz signal generated by S_0 is amplified by illuminating the emitter with carefully synchronized terahertz pulses from S_{BG}. If the shape and duration of the background and newly generated terahertz signals are identical then the electric fields add up and constructive interference trebles the power from S_0. Adjusting the output at the emitter, S_{BG}, optimizes the gain.

Placing the emitters in a ring cavity made from gold-coated mirrors amplified pulses by a factor of more than six. The cavity is flushed with nitrogen to reduce water absorption along the 4 m optical path.

Electro-optic guide exploits bandgaps

A lithium niobate modulator exploits periodic microstructures and the Pockels effect to operate at 100 GHz to 1 THz or faster. The device has no electrodes, which cause conduction losses at these speeds, and confines waves in a resonant cavity structure.

The structure provides the strong electric fields necessary for efficient electro-optic modulation at modest radiofrequency drive powers, says Richard De La Rue of the optoelectronics research group at Glasgow University. Scaling the structure with wavelength increases the electromagnetic confinement as frequency increases.

Proposed designs that combine guides of different geometry in short lengths show that a distributed Bragg reflector mirror stack could act as a resonator to deliver strong electric fields. For example, a six-period stack, less than 250 µm long, should provide a Fabry resonator with a Q-factor larger than the upper limit determined by propagation losses at 1 THz in lithium niobate at 77 K.

There are fabrication problems to be solved with such mirror stacks, but De La Rue suggests that photonic bandgaps and microcavities could produce antennas capable of transmitting, steering and receiving terahertz signals.

Terahertz devices start to join optics with electronics

Terahertz technology for the frequency range of approximately 100 GHz to 100 THz is blurring the distinction between electronics and optics, delegates to the IEEE's Sixth International Conference on Terahertz Electronics (THz 98) at the University of Leeds (3–4 September) heard.

An algorithm announced at THz 98 by Anthony Vickers of the University of Essex and co-workers at ENST, France, allows two diode lasers instead of one large femtosecond laser to perform pump-probe experiments.

The Essex approach is to fire a probe pulse from a second laser with an electrical signal after a variable and controlled delay. The idea is to hold the second laser diode below its threshold with a DC current and then excite it to lasing levels with a short electrical or radio frequency (RF) pulse.

There is a time lag between the edge of the drive signal and the optical pulse which depends on the level of DC bias below threshold immediately before excitation. The algorithm manipulates both RF and DC components to both time the second optical pulse and preserve its shape.

Metal-semiconductor-metal photodetectors respond best at terahertz frequencies when the contact width and spacing are equal, according to a team from Chalmers and Gothenburg universities in Sweden.

The GaAs/AlGaAs photodetectors operate successfully at terahertz frequencies with a contact spacing as large as a few tenths of a micrometre. Previously it was assumed that the spacing of planar inter-digitated Schottky contacts needed to be a few hundredths of a micrometre.

Quantum well structures based on GaAs/AlGasAs can emit in the far-infrared or terahertz region of the electromagnetic spectrum – say 300 to 30 µm or 1 to 10 THz – according to a theoretical study at the institute of microwaves and photonics at Leeds University. The design is for an active region with triple quantum wells, which have subband radiative transitions.