OPTICS '84: Emerging Technologies

Optical Signal Processing

Electro-Optic Analog-to-Digital Converter

Analog-to-digital converters are needed to convert voltages occurring in an analog world to digital codes that can be stored or processed in digital computers. In applications such as spread-spectrum communications and radar, there is a need to A/D convert signals whose bandwidths exceed the limits of conventional all-electronic A/D converters.

A device has been demonstrated that can convert 500 MHz bandwidth analog waveforms with four-bit resolution at a 1 Gsample/sec rate.

The A/D converter scheme depends on the periodic variation of the output of a guided-wave interferometric modulator with both voltage and electrode length to perform the conversion and on the availability of short optical pulses to perform the analog sampling. A comb-generator-driven diode laser emits $<$120-ps-wide pulses at a 1000-MHz rate.

The optical pulses are coupled to a LiNbO$_3$ chip, and the optical modulator outputs are coupled to a Si avalanche photodiode.

Techniques to stabilize the LiNbO$_3$ based modulator array have been demonstrated. These include "thermal fixing," which has reduced the susceptibility of the devices to detrimental photorefractive effects by a hundred-fold and autocalibration circuits which periodically calibrate the A/D converter against residual photorefractive effects, thermal effects and mechanical alignment drift. These efforts have resulted in stable and very useful signal processors.—**R.A. Becker**, Lincoln Laboratory, M.I.T., Lexington, Mass. This work was sponsored by the Departments of the Navy and the Air Force.

References

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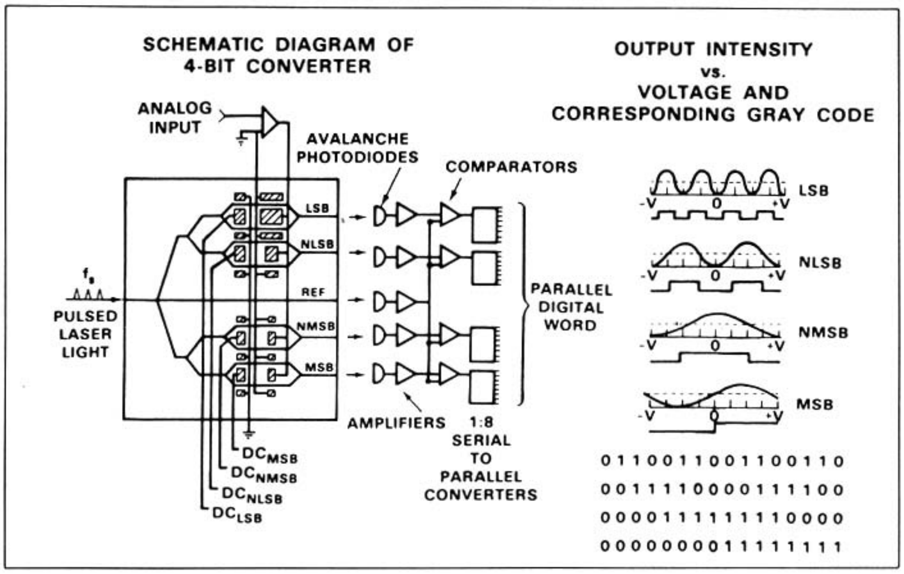

Figure 1. Electro-optic A/D converter.

Quantum Well Optical Modulators And SEED All-Optical Switches

When thin (e.g., 100 Å) layers of the semiconductors GaAs and GaAlAs are grown alternately one on top of the other, many interesting physical effects result. One is a new electro-absorption mechanism which can be used for high-speed optical modulators or low-energy all-optical switches compatible with laser diodes.

Electrons and holes are confined within the GaAs layers ("quantum wells"), which are so thin that the motion and energies become quantized like those of particles in a very small box. One consequence is that sharp exciton peaks, corresponding to confined electrons and holes orbiting around one another, can be seen at room temperature in the optical absorption spectrum. Such features can usually only be seen at low temperature in bulk semiconductors.

Recently it has been found that these peaks can be shifted to longer wavelengths by applying moderate electric fields (10^4-10^5V/cm). This shift is exceptional because it can be larger than the exciton binding energy and yet the exciton peaks remain well resolved. In excitons in bulk semiconductors, even at low temperatures, or even in atoms, the corresponding Stark shifts can normally only be $\sim<10\%$ of the binding energy before field ionization broadens the resonance so much that it essentially ceases to exist.

One reason for this difference is that the "walls" of the quantum wells (i.e., the GaAlAs layers), inhibit the electrons and holes from being ripped apart by the electric field.

When $\sim$100 such layers are grown (i.e., $\sim {}^1\mu$m total thickness), the optical absorption at the exciton resonances is large (e.g., $\sim$50%). Consequently, for a wavelength just longer than the exciton resonance position where the material is normally transparent, applying the electric field shifts the exciton resonance and markedly reduces the optical transmission, giving an optical modulator only $\sim$1 μm thick. This modulator is compatible with laser diode sources (e.g., at $\sim$850 nm). 133 ps operation has been demonstrated, limited only by simple packaging time constants, and fundamental limits are expected to be much faster.

Light absorbed in the quantum well material also gives rise to a photocurrent. This can be used to advantage by incorporating a large resistor in series with the material and the bias supply. Then any photocurrent gives a voltage drop across the resistor, hence reducing the voltage across the quantum well material.

By appropriate choice of wavelength, this results in an increase in absorption, hence giving more photocurrent and establishing a positive feedback loop which can lead to switching. There can therefore be a critical optical intensity at which the quantum well transmis-