3.C Noncontact Electro-Optic Sampling with a GaAs Injection Laser

Due to high cost and large size of dye-based short-pulse laser systems, the application of electro-optic sampling to the measurement of high-speed electrical waveforms has been limited to a small number of research laboratories. This is unfortunate, as it means that the advantages of electro-optic sampling over direct electronic sampling are not being fully exploited. Those advantages are a very high-speed reserve (up to a few THz) and the possibility of noninvasive electric field measurement.

Here we describe an electro-optic sampling system that is compact, uses a semiconductor laser source, and supports a versatile, substrate-independent probing geometry (Fig. 27.17).

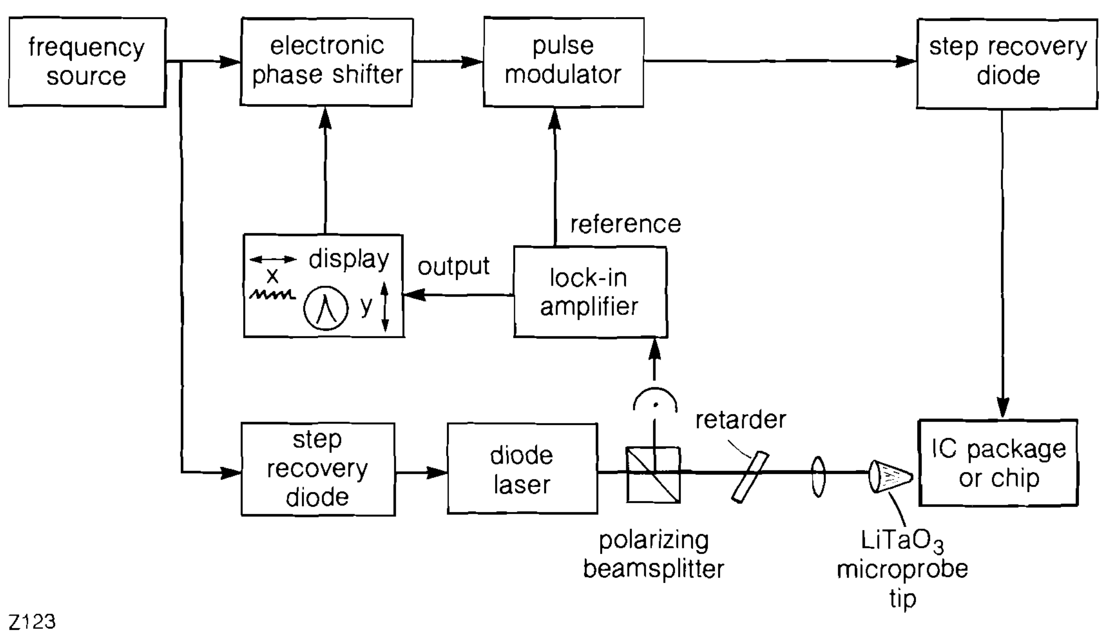


Fig. 27.17
Schematic of electroc-optic sampler with a finger probe.

The repetition rate of this system is set by a 100-MHz oscillator (though all of the system components allow greater than 1-GHz repetition rate). About 1 W of the oscillator power is used to drive a step-recovery-diode-based comb generator (Hewlett-Packard), which in turn pulses a current-biased GaAs injection laser. These 830-nm pulses (Fig. 27.18) have been time resolved on a streak camera showing less than 30-ps FWHM and a very low background level.

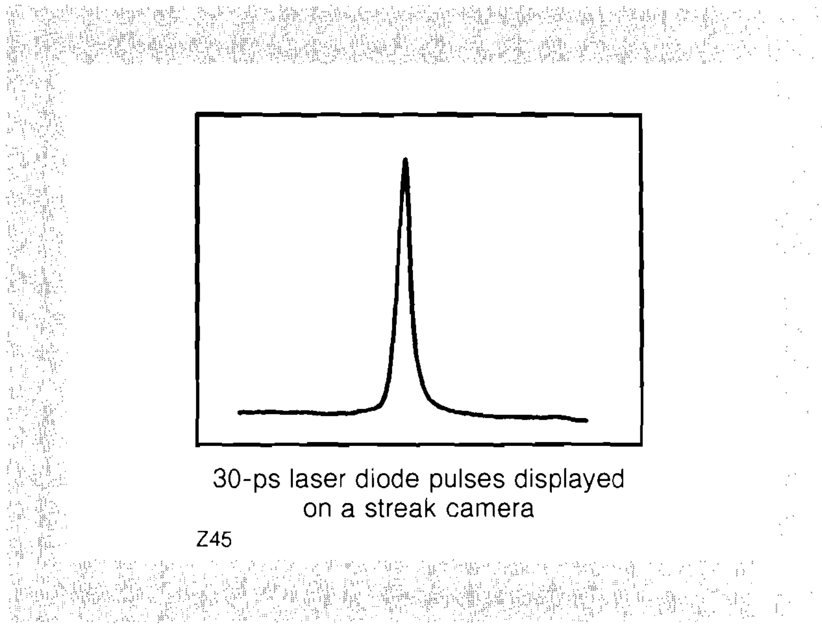
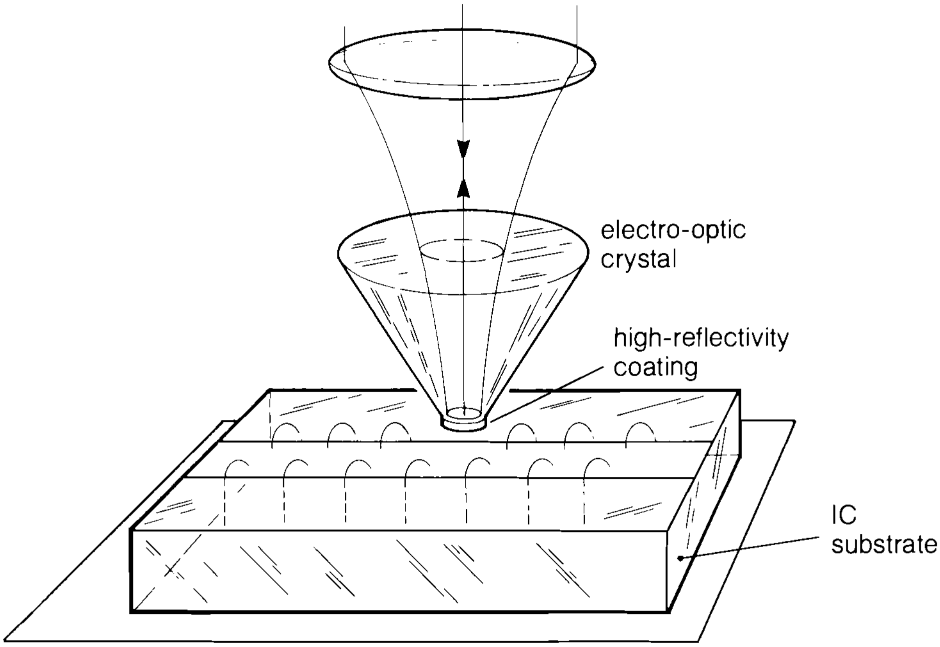


Fig. 27.18
Streak camera trace of 30-ps laser-diode pulses.

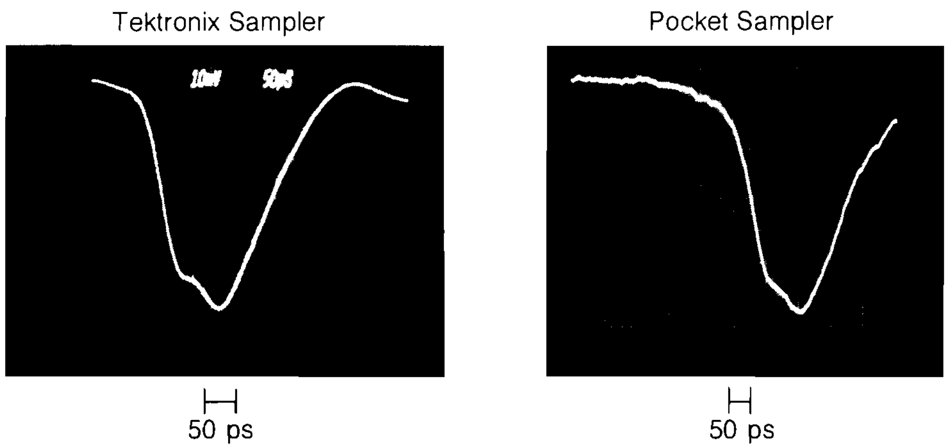
The delay necessary to scan the sampling point in time is provided by an electronic phase shifter in a second branch off the main oscillator. This device is more flexible and less expensive than the optical delay lines or two-frequency phase controllers normally used. Finally, a reflective-mode Pockels cell is used as an electro-optic modulator to provide a substrate-independent, versatile geometry for testing devices and packages. This "finger probe" (Fig. 27.19) is a small cone of electro-optic material with a very small, high-reflectivity-coated flat[2] on the tip. In use, the probe is brought near an operating electronic circuit so that the tip is immersed in the circuit's fringing fields. With all these components in place, a polarized train of short optical pulses is focused down through the back of the cone onto the tip, where the electric field induces a change in the polarization, linear with its intensity. After the light retroreflects off the high-reflectivity coating, it passes back through the optics where it is subsequently detected by a PIN photodiode and processed, using lock-in techniques. Although our experiment uses 30-ps optical pulses to sample electric fields, we could also use 100-fs pulses from dye laser sources to measure much faster phenomena because the electro-optic crystal can be transparent in the visible. This probing geometry is also compatible with the use of UV light, where submicron spot size could lead to very fine spatial resolution.

In our experiment, a small section of the ground conductor of a semirigid coaxial cable was removed and the finger probe immersed in the electric fields bridging the center conductor and the remaining outer conductor. The feedthrough from the cable was also sampled with a Tektronix sampler. These results (Fig. 27.20) agree to within 10% in time. The finger-probe "pocket" sampler has also been used to measure the fields around IC packaging pins, the fields of intrapackage connections, and the fields around package-to-chip wire bonds, as well as signal propagation and cross-talk on, and as far as 400 μm above, an alumina test structure.



Z124

Fig. 27.19
Electro-optic "finger probe."



Z125

Fig. 27.20
Comparison of electronic (Tektronix) and electro-optic samplers.

In conclusion, the ability to make noncontact measurements of electrical waveforms with 30-ps laser-diode pulses, an electronic phase shifter, and a versatile, substrate-independent probe have been demonstrated. With the availability of this inexpensive electro-optic sampling technology and the trends toward shorter pulses from semiconductor sources, it is hoped that electro-optic sampling will become available to the ordinary electronics laboratory.

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