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B—2—3 Fourier Transform Optical Imaging Using SAW Memory-Correlator

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Recently, various kinds of optical image line scanners by surface acoustic waves have been reported.[1-7] In this paper, we describe a new method of Fourier transform optical imaging with the use of wideband memory-correlator,[8] in which a short light pulse acts to store a chirp surface wave signal and an optical pattern in the semiconductor surface.

We have reported in the previous paper[8] that by using a short light pulse surface wave signals including chirps can be stored in the storage centers at the semiconductor surface and the stored signals can be read out as a correlation signal with a reading signal sent after storage. If the semiconductor surface is illuminated with the light pulse whose spatial intensity is modulated by an optical pattern f(z) corresponding to one line of the image, the stored chirp surface wave signal in the semiconductor surface can be written as

$$f(z)\ W\cdot e^{j\{\omega_0+\mu(-\frac{z}{v_s})\}(-\frac{z}{v_s})}, \qquad (1)$$

where ω_0 is the center frequency, μ the chirp rate and v_s the surface wave velocity. After this storage process, by sending a reading chirp signal $R\ e^{j(\omega_0+\mu t)t}$ with the same chirp rate as used in the storage, a correlation output

$$F(t) \sim \int f(z)\ W\cdot e^{j\{\omega_0+\mu(-\frac{z}{v_s})\}(-\frac{z}{v_s})} \times R\cdot e^{j\{\omega_0+\mu(t-\frac{z}{v_s})\}(t-\frac{z}{v_s})}\,dz$$

$$= WR\cdot e^{-j(\omega_0+\mu t)t}\int f(z)\ e^{j\frac{2\mu t}{v_s}z}\,dz \qquad (2)$$

is obtained at the semiconductor electrode. As is seen in Eq. (2), the envelope of the correlation output F(t) is the spatial Fourier transform of the optical pattern f(z). Thus, the stored optical image can be simply read out as the Fourier transformed signal. In order to get the real image, we put the transformed signal into another matched filter or a spectrum analyzer, in which the inverse Fourier transform is achieved. In this method, the resolvable minimum spot size d_s is determined by the total bandwidth of chirps Δf, i.e.,

$$d_s = v_s/\Delta f\ . \qquad (3)$$

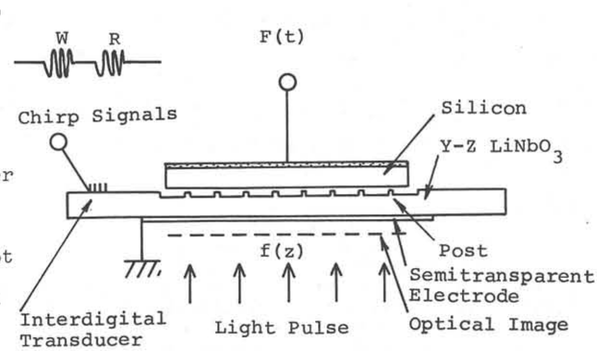
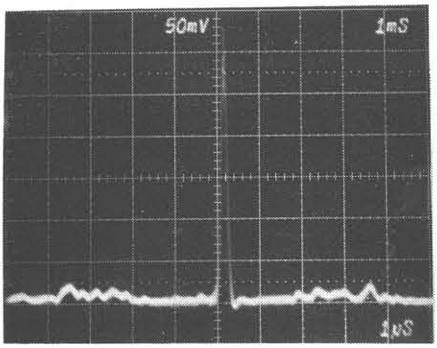


Fig. 1 Schematic configuration

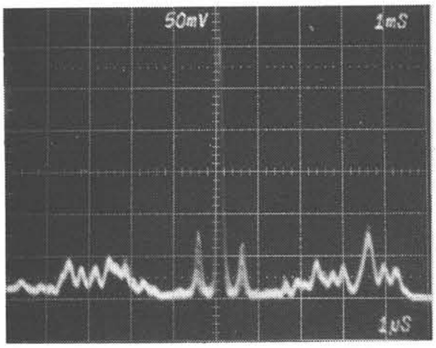
The resolution is increased with the total bandwidth of chirps.

The use of this Fourier transform method instead of a short scan pulse method has a possibility to construct an optical imager with an enhanced signal-to-noise ratio, to eliminate shot noises and redundant signals in the image.[5]

We have fabricated a memory-correlator as illustrated in Fig. 1 to demonstrate this method. A 2 cm long n-type silicon slab with a resistivity of 130 Ω-cm was placed on the Y-Z $LiNbO_3$ delay line, on which posts of 5 μm in diameter were made by the ion beam etching technique[9] in order to obtain an uniform air gap along the interaction length. A light pulse from a GaAs laser diode was used as a light source to project the image on the silicon surface. The pulse duration and the peak power were about 500 pS and 1 W, respectively.



(a)



(b)

Fig. 2 Fourier transform signals obtained from (a) an uniform light illumination and (b) simple grating image.

The output Fourier transform signals obtained from a uniform light illumination and from a simple 10 period grating with a 2 mm spacing as an image are shown in Fig. 2(a) and (b), respectively, by using 10 MHz 6μS chirps with 110 MHz center frequency. The center peak shown in Fig. 2(b) corresponds to the zero spatial frequency component and two main lobes which appear near the center correspond to the periodicity of the grating. In this experiment, surface states were used as storage centers.

In conclusion, we have demonstrated the direct Fourier transform of the optical image by using the memory-correlator in which an optical image is stored with a chirp surface wave signal. This device is considered to be useful for optical image signal processings with large signal-to-noise ratio and wide dynamic range.

References

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