

[54] **DEVICE FOR OBSERVING WAVEFORM
REPEATED AT HIGH FREQUENCY**[75] Inventor: **Kazuo Fujisawa**, Osaka, Japan[73] Assignee: **Osaka University**, Osaka, Japan[22] Filed: **Mar. 14, 1974**[21] Appl. No.: **450,972**[30] **Foreign Application Priority Data**

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315/30, 393; 330/4.7; 250/549, 207; 328/231[56] **References Cited****UNITED STATES PATENTS**

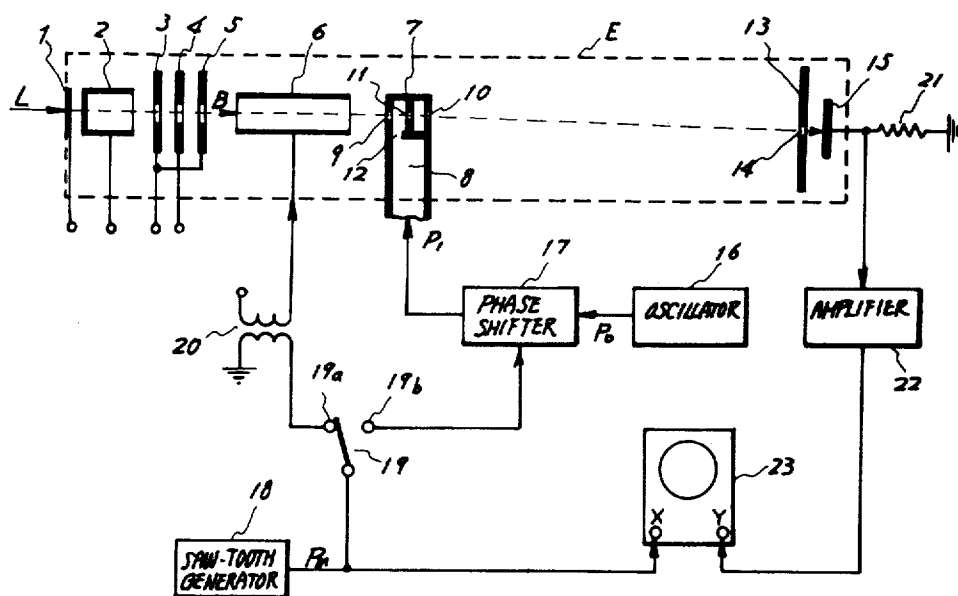
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[57] **ABSTRACT**

Apparatus for observing waveforms of extremely short duration and repeated at high frequencies wherein an electron beam is produced having a density variation corresponding to the waveform to be observed. The electron beam is deflected by a microwave voltage synchronized with the repetition rate of the waveform. A phase shifter under control of a saw-tooth generator sweeps the phase angle between the electron beam and the microwave voltage and the density of the electron beam is detected only at a predetermined deflection and displayed with the density corresponding to intensity and time corresponding to phase difference.

4 Claims, 2 Drawing Figures

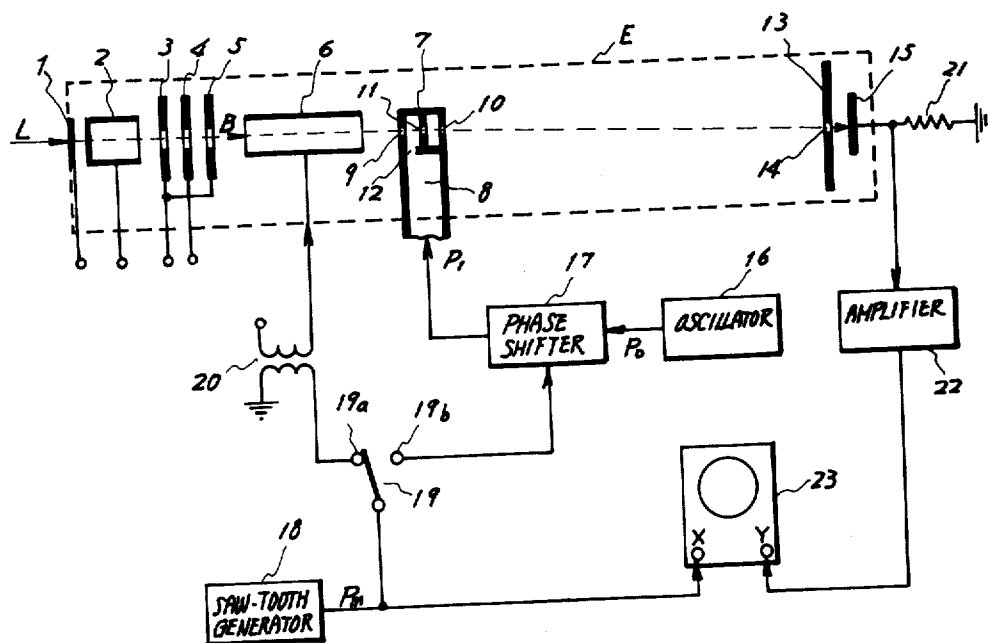


FIG. 1

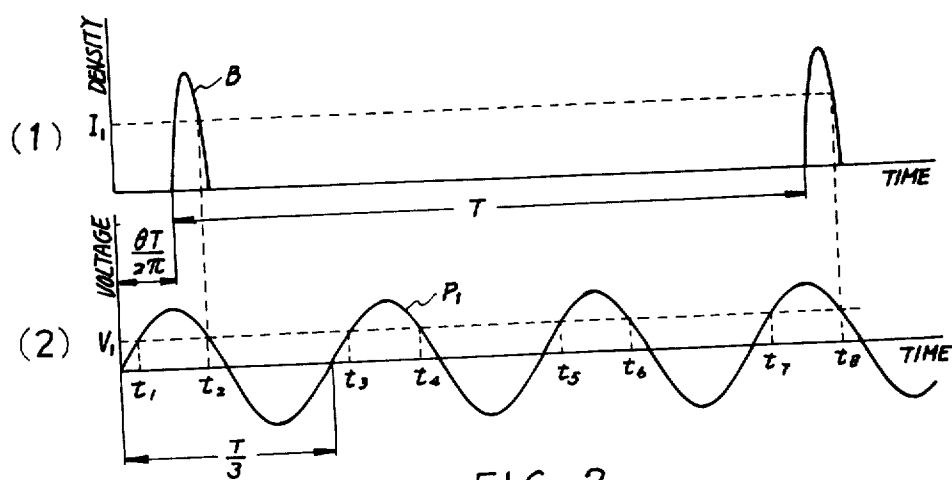


FIG. 2

DEVICE FOR OBSERVING WAVEFORM REPEATED AT HIGH FREQUENCY

This invention relates to an improved device for observing a waveform of an extremely short duration repeated at high frequency.

In order to observe a waveform of extremely short duration which is repeated at high frequency, a sampling oscilloscope has been used. In this oscilloscope, a voltage pulse which is synchronized with the waveform to be observed and varies its phase bit by bit at every cycle, is produced and the waveform is sampled during the duration of this pulse and amplified for use in waveform display. As the duration of the voltage pulse must be short as compared with the duration of the waveform to be observed, the shorter the duration of the waveform becomes, the shorter the required duration of the voltage pulse becomes. Thus, the prior techniques only enable observation of the waveforms having a duration of the order of a nanosecond at the best. With the advance of the recent laser technique, however, it has become possible to produce pulses having durations of the order of picosecond and, consequently, it has become necessary to observe the picosecond light pulses.

Therefore, an object of this invention is to provide a novel and improved device enabling display of a waveform having an extremely short duration such as of the order of a picosecond and being repeated at a high frequency.

The device according to this invention comprises means for producing an electron beam having a density variation according to the waveform to be observed, means for deflecting said electron beam under control of a microwave voltage which is synchronous with the repetition of said waveform to be observed, means for sweeping the phase difference between said electron beam and microwave voltage at a low frequency, means for controlling said electron beam only at the position corresponding to a predetermined deflection effected by said deflecting means, and means for displaying the magnitude of the electron flow collected by said collecting means along the phenomenon axis and said phase difference along the time axis.

Other features and operation of the device of this invention will be described in more detail hereinafter with reference to the accompanying drawings.

In the drawings:

FIG. 1 is a schematic sectional side view, partly in block form, representing an embodiment of this invention for observing the waveform of a high frequency light pulse; and

FIG. 2 is a waveform diagram presented to aid the explanation of the operation of the device of FIG. 1.

Referring to FIG. 1, a photoelectric surface 1 is formed on a transparent electrode (not shown) which is formed on the inner face of one end wall of an evacuated glass envelope E, and arranged to receive a light pulse L to be observed. Located in front of the photoelectric surface 1 are an anode electrode 2, lens forming electrodes 3, 4 and 5, a drift tube 6 and a reentrant cavity resonator 7 in that order. The cavity resonator 7 is coupled to a waveguide 8 through a coupling hole 12 and its inner post forms a modulation gap 11 in the center. Pin-holes 9 and 10 are formed in the walls of the cavity along the tube axis. At the other end of the envelope E, there is a masking electrode 13 having a

pin-hole 14 and an electron collector electrode 15 is located behind the pin-hole 14. The pin-hole 14 of the masking electrode 13 is positioned a specific distance from the tube axis so that only the electron beam encountering the corresponding deflection can pass the pin-hole 14 to be collected by the electrode 15.

A microwave oscillator 16 generating a proper microwave signal P_0 synchronized with the repetition of the light pulse L to be observed is connected through a phase shifter 17 to the waveguide 8. A saw-tooth wave generator 18 is connected to the drift tube 6 through a fixed contact 19a of a single-pole double-throw switch 19 and a transformer 20 and also to the control terminal of the phase shifter 17 through the other fixed contact 19b of the switch 19. The output of the saw-tooth wave generator 18 is further connected to the time axis input X of a cathode-ray tube oscilloscope 23. The electron collector electrode 15 is grounded through a resistor 21 and also connected through a high gain amplifier 22 of the phenomenon axis input Y of the oscilloscope 23.

Now, the operation of the device of FIG. 1 will be described with the aid of FIG. 2. The light pulse L incident upon the photoelectric surface 1 emits an electron beam B having a density waveform which is identical to the waveform of itself, as shown in FIG. 2 (1). The pulsed electron beam B passes through the anode electrode 2, the lens electrodes 3, 4 and 5 and the drift tube 6 and enters the cavity resonator 7 from the pin-hole 9. The oscillator 16 generates a microwave signal P_0 synchronous with the repetition of the pulsed electron beam B and accordingly with the incident light pulse L, and the signal P_0 is shifted in phase by the phase shifter 17 and applied to the modulation gap 11 of the resonator 7 through the waveguide 8 as a microwave signal P_1 as shown in FIG. 2 (2). As an example, the period of the microwave signal P_1 is selected to be one third of the repetition period T of the pulsed beam B in the drawing.

The electron beam B is deflected laterally in the modulation gap 11 by an electric field controlled by the signal P_1 and comes out of the pin-hole 10. Although most of the deflected electrons of the beam collide against the masking electrode 13 and are absorbed thereby, only the electrons passing through the pin-hole 14 are collected by the collector electrode 15. Assuming that the deflected portion of the electron beam passing through the pin-hole 14 corresponds to a voltage level V_1 of the microwave signal P_1 , the possible time points at which the electron beam passes through the pin-hole 14 are $t_1, t_2, t_3, \dots$ as shown in FIG. 2 (2) and, in this case, an electron flow having a density I_1 passes therethrough at the time points $t_2, t_4, \dots$ and is collected by the collector electrode 15 to induce a voltage drop corresponding to the density I_1 across the resistor 21. This voltage is amplified by the high gain amplifier 22 and applied to the oscilloscope 23 to effect a sweep along the phenomenon axis corresponding to the density I_1 .

A saw-tooth wave signal P_m of relatively low frequency is applied to the drift tube 6 when the switch 19 is turned to the contact 19a as shown in FIG. 1, and varies the electron speed of the electron beam B linearly. As the phase difference θ between the pulsed electron beam B and the microwave signal P_1 at the modulation gap 11 is equal to a sum of the electron transit angle from the photoelectric surface 1 to the gap 11 and the

phase shift produced by the phase shifter 17, it is swept over a specific range by the saw-tooth wave signal P_m . As easily understood from the drawings of FIG. 2, the sweep of the phase difference θ results in a sweep of the sampling time point t_2 and, therefore, in a variation of the density of the electron beam passing the pin-hole 14 in accordance with the waveform B to be observed. Since this variation is applied to the phenomenon axis input of the oscilloscope and the saw-tooth wave signal P_m is also applied to the time axis input thereof, the waveform corresponding to the waveform B to be observed is displayed on the display screen of the oscilloscope 23.

It is obvious that the sweep of the phase difference θ can be effected by directly shifting the phase of the microwave signal P_1 under control of the saw-tooth wave signal P_m . This can be attained by turning the switch 19 to the contact 19b to apply the signal P_m to the control terminal of the phase shifter 17.

As described above, the device of this invention does not need to feed the sampling voltage pulse to the outside of the envelope E and effects the sampling of the waveform to be observed within the vacuum envelope of an electron tube. Waveform observation can be done in an extremely high frequency range.

Although the above description was made in conjunction with the device for observing the waveform of a light pulse, this invention is applicable to a device for observing the waveform of a high frequency electric signal such as microwave signal by providing a suitable unit for density-modulating an electron beam with this microwave signal. Moreover, by selecting the amplifier 22 and the saw-tooth wave generator 18 appropriately, the waveform display can be effected by a mechanical XY-recorder instead of the cathode-ray tube oscillo-

scope 23.

I claim:

1. A device for observing a waveform repeated at a high frequency, comprising means of producing an electron beam having a density variation according to the waveform to be observed, means for generating a microwave voltage which is synchronous with the repetition rate of the waveform to be observed, means for deflecting said electron beam under control of said microwave voltage, means for sweeping the phase difference between said electron beam and microwave voltage at a low frequency, means for collecting said electron beam only at a position corresponding to a predetermined deflection effected by said deflecting means, and means for displaying the magnitude of the electron flow collected by said collecting means along the phenomenon axis and said phase difference along the time axis.

2. A device according to claim 1, wherein said electron beam producing means comprises a photoelectric surface formed in an evacuated envelope.

3. A device according to claim 1, wherein said deflection means comprises a reentrant cavity resonator to which said microwave voltage is applied.

4. A device according to claim 1, wherein said electron beam collecting means comprises a masking electrode having a pin-hole or slit and an electron collector electrode located behind said pin-hole or slit for collecting the electrons passing said pin-hole or slit, and said display means comprises a cathode-ray tube oscilloscope, a voltage corresponding to the electron flow collected by said collector electrode being applied to the phenomenon axis input of said oscilloscope.

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