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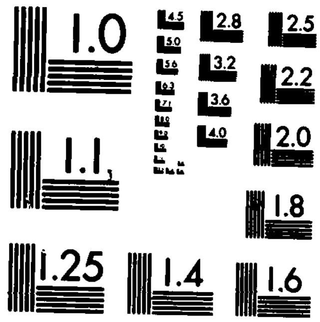
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

MULTIPURPOSE SEMICONDUCTOR LASER EQUIPMENT

by

Zhou Fanming, Fan Jinsheng and Wang Deyuan

FOREIGN TECHNOLOGY DIVISION

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ELECTRONIC CIRCUITS

MULTIPURPOSE SEMICONDUCTOR LASER EQUIPMENT

Zhou Fanming, Fan Jinsheng and Wang Deyuan

The light source of the multipurpose equipment introduced in this paper uses the homogeneous-knot or single heterogeneous-knot GaAlAs/GaAs semiconductor laser, which possesses not only high anti-noise capability, good security, long-distance transmission (reaching tens to hundreds of meters), and low electricity consumption, its controller can also be utilized for alarming, switch, counting, etc. The equipment can be used in textile industry for broken-thread control and counting, in the electromechanical and chemical industries for long-distance speed measurement, alarming, counting, etc. It can also be used in the reservoirs, along the rivers, or in water towers to alarm or control the rise of water level, and so on.

This multipurpose equipment consists of a semiconductor laser emitter and a receiver. The emitter emits the laser beam, while the receiver accomplishes the function of alarming, switch and counting after receiving the beam.

Figs. 1 and 2 show respectively the block diagram and the circuit of the semiconductor laser emitter. In the circuit the transistors BG_1 and BG_2 constitute the 'push-pull' type DC transformer, which transforms the low voltage DC currents into AC

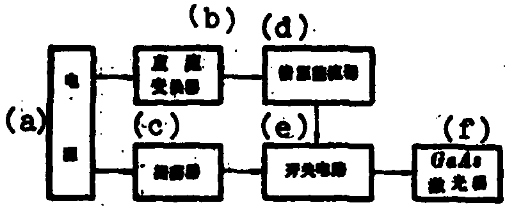

Fig. 1.

Key: (a) Electric Source; (b) D.C. Transformer; (c) Oscillator; (d) Double-Voltage Rectifier; (e) Switch Circuit; (f) GaAs Laser

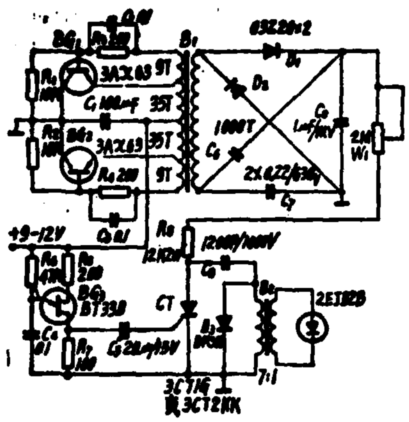

Fig. 2.

currents. The transformer B_1 then raises the voltage and 'double-voltage' rectifying the currents into high voltage DC. Under normal conditions the voltage is about 5C0 - 700 volts.

The oscillator consists of the 'single-knot' transistor BG_3 and corresponding resistor and capacitor. The output frequency of the impulses can be adjusted by means of changing the values of R_5 and C_4. The oscillating period of BG_3 can be calculated from the equation, $T=RC\ln(1/(1-\eta))$, where R and C are respectively R_5 and C_4 in Fig. 2, and η is the partial pressure ratio of the tubes. Here, $\eta=0.6$, $R_5=47$ Kohm, $C_4=0.1$ μf, therefore, $T\approx1000$ μsec. The excited impulses can reach the control electrode of the silicon controlled rectifier through the coupling of C_5.

When the silicon controlled rectifier CT terminates, the 'double-voltage' rectified high voltage charges the capacitor C_9 on the CT anode through the capacitor W_1 and resistor R_8. When BG_3 outputs excited impulses that activates CT, C_9 discharges rapidly the first-grade of the transformer B_2 through CT. This forms high voltage impulses that excite the second grade of B_2, the laser tube 2EJD2B to emit light. If we disconnect the transformer B_2, and instead using a 0.1 ohm resistor for loading, then from this resistor we can obtain a spike impulse of about 10 - 90 amp, as shown in Fig. 3.

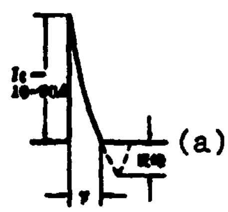

Fig. 3.
Key: (a) Anti-peak
(the dashed curve)

The value of the impulse width τ is related to the RC time constant of the discharging return circuit. R can be the sum of the internal resistance of the silicon controlled rectifier CT and the resistant value of the first-grade of the transformer B_2. The impulse width can be conveniently adjusted by changing the size of C_9. Here one should note that the silicon controlled rectifier is not those commonly used, but is those elements of high or medium power and possessing high-speed switch time; the switch-on time of these elements is about $t_d \leq 50 - 60$ nanoseconds. Those better ones are such as 3CT1G, 3CT2KJ, 3CT2KK, etc.

If the anti-impulse of the output impulse currents is too large (the dashed curve shown in Fig. 3), caution must be taken on whether D_3 is misconnected or reverse connected. If the connection is correct and there is still a large anti-impulse, one can connect several diodes of good switch quality in parallel and at the same time adjust the wires of the discharging circuit to reduce the capacity distribution of the return circuit to as small as it possibly can be, until a satisfactory waveform is reached.

The transformer B_1 uses the double-wire winding method. Be careful not to mix up the ends of the same sign. Its first-grade uses Ø 0.21 mm wire, and its second-grade uses Ø 0.12 mm wire.

The semiconductor laser element 2EJD2B in the circuit is equivalent to a 0.1 - 0.2 ohm resistor. Because W_1 and R_8 in the circuit are for charging and current-limiting, frequency is generally no greater than 10 kHz. The frequency used in this equipment is 1 kHz.

The impulse transformer B_2 is a voltage-reduction output transformer; it enhances the electrical currents. Its first- and second-grade ratio is 7:1. B_2 uses Ø 10XØ 5x5 (mm) circular iron oxide magnetic core, but it can also use MX-1000 or MX-2000.

Figures 4 and 5 show respectively the block diagram and circuit of the multipurpose receiver. The receiver uses the silicon light-sensitive triode 3DU5C(GB) as the light-electricity transformer that responds to the 9000 Å light wavelength as the peak receiving value. As shown in Fig. 6A, the light impulses are transformed into negative electric impulses; within the transmission distance of several hundred m the amplitude of these signals is about 0.1 - 0.3 mV. Such weak signals are transmitted to the high input resistance foreground amplifier. The foreground amplifier BG_1 uses knot-type field-induction tube 3DJ4F; its input resistance can reach 10 billion ohm. The foreground circuit possesses fine quality of high-frequency responses. Adjusting R_5 to allow I_D in BG_1 to be around 0.2 - 0.6 mA will put that grade to work normally.

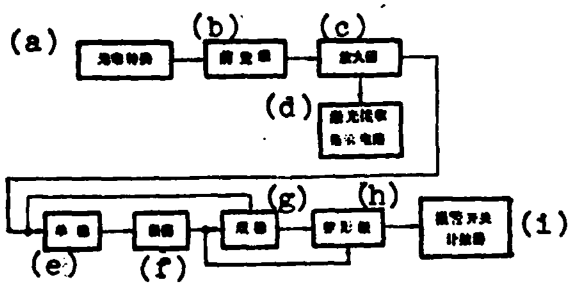

Fig. 4.

Key: (a) Light-Electricity Transformation; (b) Foreground Grade; (c) Amplifier; (d) Laser-Receiving Indicator Circuit; (e) Single Equilibrium; (f) Oscillation; (g) Double Equilibrium; (h) Waveform Rectifying Grade; (i) Switch Alarm Counter

After foreground amplifying the weak impulse signal becomes positive spike impulse, which is then transmitted to the impulse amplifying circuit that consists of a 4th grade 7XF3(5G722) linear integrated circuit for voltage amplifying. 7XF3 is a two-tube direct coupling, negative feed back, wide-band amplifier.

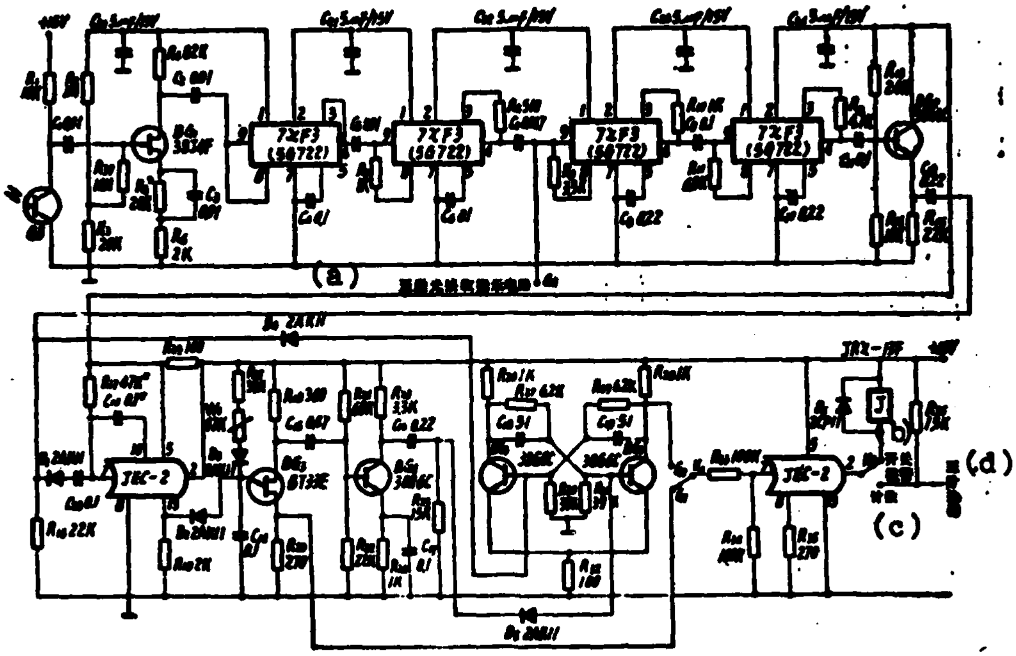

Fig. 5.
Key: (a) To Laser-Receiver Indicator Circuit; (b) Switch Alarm; (c) Counting; (d) To Counter

When it is used as a high voltage-enhancing amplifier, several elements must be added to the circuit: (1) Adding compensation capacitors C_4, C_8, C_6, and C_{10}, the voltage enhancement of the circuit of each grade can reach 25 decibels, and the upper bound of the frequency band can extend to 100 billion hertz. In order to reduce the enhancement of the lower frequency bound, the compensation capacitors are generally confined in the range of 0.1 - 0.33 μfarad and cannot be higher. (2) In order to reduce the negative feedback in the circuit to increase the amplifying power in closed circuit, resistors are connected between the 8th and 9th foot of the second, third and fourth grade amplifiers. (3) In order to gradually increase the dynamic range of the voltage output, resistors are connected to the third and fourth feet of each grade. After the above treatments, the voltage amplifying enhancement of the whole amplifier can reach 100 decibels, which will have very fine responses to very narrow high-frequency impulses. Each grade is connected with decoupling capacitor, which prevents the self-excitation induced by the electric source.

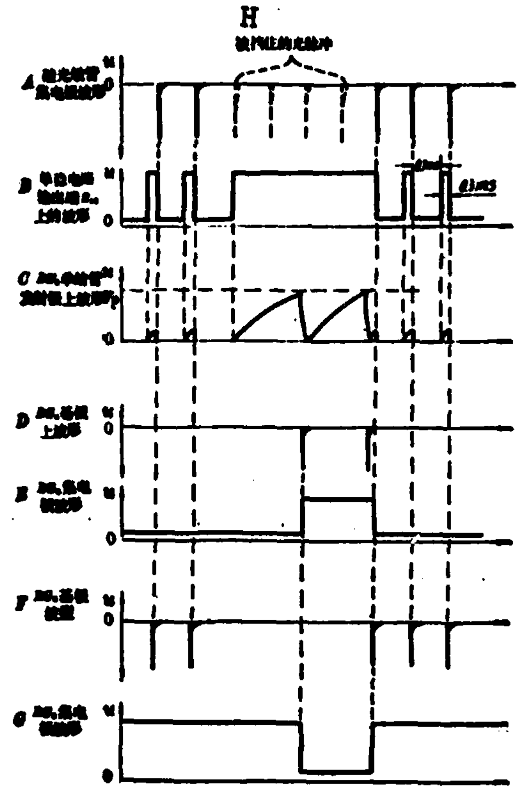

Fig. 6.
Key: A: Silicon light-sensitive integrated electrode waveform; B: Waveform at the output end R_{18} of the single equilibrium circuit; C: Waveform at the emitter of the single-knot tube BG_3; D: Waveform at the base electrode of BG_6; E: Waveform at the integrated electrode of BG_6; F: Waveform at the base electrode of BG_5; G: Waveform at the integrated electrode of BG_5; H: Shaded light impulses.

The amplifier outputs positive impulses of 1 kHz in frequency through BG_2 and then differentiated by R_{16} and C_{12}. Negative impulses are transmitted through D_1 to the single equilibrium circuit consisting of JEC-2, which synchronizes with the light impulse frequency with a frequency of 1 kHz and then proceeds to turn over. The values of R_{17} and C_{13} are adjusted to make the time-lag range to be 0.7 msec and the termination range to be 0.3 msec (see Fig. 6B). At this moment as long as there is a normal input of light impulses, the output voltage of the single equilibrium circuit (the voltage in the resistor R_{18} is approximately 1 volt) is lower than the voltage V_p of the peak oscilla ig value of BG_3 (about 6 volt). D_2 is positive conductive, the charging currents in the capacitor C_{14} go through D_2 and R_{18} and discharge to the ground. In this way BG_3 will not oscilla and no signal outputs from the G_1 end (see Fig. 6C).

The other negative impulses that were differentiated by R_{16} and C_{12} are transmitted through D_4 to the base electrode of the double equilibrium circuit BG_5 (see Fig. 6F), which causes a reliable termination of BG_5 and turns on BG_6, the G_2 end is then under low voltage (see Figure 6E).

W_1 and C_{14} are adjusted to make the oscillating frequency of the oscillator to be 400 - 500 hertz, which is much lower than the working frequency of the single equilibrium circuit (about 1/2). When the single equilibrium state automatically turns over, the output end of the single equilibrium circuit is at high voltage (about 11 volt), greater than the voltage V_p of the peak oscillating value of BG_3, and D_2 is under opposite termination. Therefore, the electric source charges C_{14} through W_1, R_{37} and D_3 in 0.3 msec (see Fig. 6C). Because the time is extremely short, the peak voltage value of BG_3 is not yet reached, the single equilibrium voltage is excited by the light impulses of 1 kHz to become terminated and delayed. Then D_2 positively deviates, and C_{14}

discharges. Therefore, as long as the laser 2EJD2B emits normally, the light-sensitive tube receives normally, BG_3 will never oscillate, and there will be no output from the G_2 end.

When the light is shaded, there will be no signal impulses output from the smplifying grade of the receiver, and no excited impulses in the single equilibrium circuit and the base electrode of BG_5, the single equilibrium circuit turns over from the termination state to the equilibrium state, and the voltage at the resistor R_{18} of the output end of the single equilibrium circuit changes rapidly to a high voltage of about 11 volts. At this moment, there is sufficient time for the electric source to charge C_{14} through W_1, R_{37} and D_2 until V_p is reached, then BG_3 starts to oscillate (see Fig. 6C). The output negative impulses, after being inversely amplified and differentiated by BG_4, excite the base electrode of BG_6 (see Fig. 6D), which causes BG_6 to turn over from conduction to termination (see Fig. 6E); i.e., the output of the G_2 jumps from low voltage to high voltage.

When the light shade is removed, light-sensitive tube again receives the light impulses emitted from the laser 2EJD2B, which causes the single equilibrium circuit to turn over again from the equilibrium state to termination. BG_3 then stops oscillation, the voltage of the integrated electrode of BG_6 drops rapidly, and the voltage of the G_2 end drops rapidly (see Fig. 6E).

In order to adapt to different needs, the receiver utilizes multiple outputs. The output is from the integra ed electrode of BG_6 to the G_1 end; the other is from the B_1-electrode of BG_3 to the G_1 end. However, the waveform and amplitude of the impulses output from the G_1 and G_2 ends are not ideal and cannot be directly used as the signals. It is therefore necessary to select JEC-w integrated blocks to be the impulse rectifying circuit, which will rectify both the spike impulses output from the G_1 end and the step waves (but both the front and rear edges are not vertical) output from the G_2 end to become rectangular impulses of the same amplitude.

1. When K_1 is placed at the G_1 end:

(1) K_2 is placed at the switch alarm end. In case there is an object that shades the laser beam, the G_1 end will output 400 - 500 hertz spike impulses. After the waveform is rectified, the relay J will then be self-protecting and continuously absorbing, and utilizing indication light of the loudspeaker for alarming.

(2) When K_2 is placed at the end of the 1.5 K resistor, the laser beam is shaded by an object. The waveform-rectifying grade then outputs rectangular impulses of the same oscillating frequency as that of BG_3 to the counter for counting. When the object is removed from the laser beam, the counter stops counting. In this way the speed of a linearly moving object can be measured. For instance, an object has a length of 10 m, the oscillation frequency of BG_3 is 500 hertz, the number of counts shown by the counter during the blockade of the laser beam by the object is 500, then the time that the object passed through the laser beam measuring point is t=500/500 hertz =1 sec, and the speed of the object is s=10 m/sec.

2. When K_1 is placed at the G_2 end,

(1) K_2 is placed at the switch alarm end. This means when there are light impulses at the receiver the relay does not move, while there is no light impulse at the receiver the relay absorbs and moves.

(2) K_2 is placed at the counting end that counts each time the laser beam is shaded. Whether the count is the number of the light shaded by the object or the number of the object leaving the light is dependent upon the excitation requirements of the counter

as well as the different usages of the equipment.

Under normal conditions the repeat frequency of the laser of about 1 kHz is sufficient. In case the measuring speed or accuracy needs to be raised, then the repeat frequency of the electric source of the laser as well as the working frequencies of the single equilibrium circuit and the oscillator need also to be correspondingly raised. However, the ratio of the light impulse frequency and the oscillation frequency must be kept at 2:1, otherwise the anti-noise quality of the receiver will be greatly reduced.

The wavelength of the infrared light emitted from the semiconductor laser is 9000 Å, which is invisible. This raises difficulty for testing the equipment or using it under sunshine. A laser indicator circuit is thus designed for this purpose. This circuit is shown in Fig. 7, which converts the intensity of the infrared laser impulses into that of electric currents which will be shown on an amperemeter. The working principle of the circuit is: the amplified spike impulse charges C_2 through D_1. Because the grid insulation resistor R_{GS} of the field induction tube BG_2 has a very high resistance, its discharge constant RC is very large. From R_5 it outputs therefore a positive impulse of a very steep front and a long rear (that greatly extended the space ratio). From this the intensity of the laser beam can then be shown through the amperemeter. In Fig. 7, W_2 is used for zeroing and W_1 is used to adjust full scale.

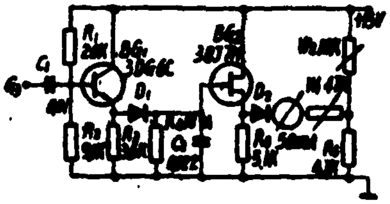

Fig. 7

In order for long-distance usage, this receiver uses 4th grade amplification. If the usage distance is shorter, the grade of amplification can be correspondingly reduced. In order to fully utilize the light energy and to prevent diffusion, the optical system needs lenses to focus the light beams. Generally the diffusion and receiving scopes use single lenses with a diameter around 20 - 40 mm (either single convex, flat convex, or double convex) to adjust the laser beams in parallel. The ratio between the lens diameter and the focal distance is about 1:3 - 1:4; i.e., the focal distance f=80 - 120 mm. During installment and adjustment the center lines of the laser and of the light-sensitive tube of the receiver must be focused at the focus of the lens, otherwise the effective distance will be shortened.

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