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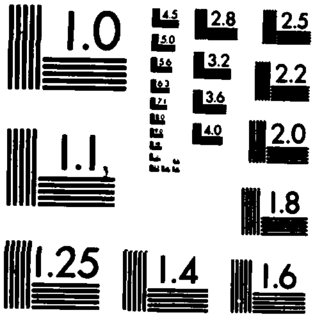

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## ELECTRON CIRCUITS: SEMICONDUCTOR LASER MULTIPLE USE INSTALLATION

by

Zhou Fangming, Fan Jinsheng and Wang Deyuan

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# ELECTRON CIRCUITS: SEMICONDUCTOR LASER MULTIPLE USE INSTALLATION

Zhou Fangming, Fan Jinsheng and Wang Deyuan

This paper presents a light source for a multiple use installation using a same-matter junction or different-matter junction GaAlAs/GaAs semiconductor laser, which has the advantages of high interference resistance, long transmission distance (tens to hundreds of meters), good security, and low power consumption; in addition, the controller of the light source has multiple usages of alarming, switching and counting. The multiple use installation can be used in control of breaking warps and counting on roving waste machines, warping machines and silk weaving machines in the textile industry; long distance speed measurement, alarming and counting in machinery, electricity and chemical industries; and alarming and control of water levels in reservoirs, rivers and water towers, as well as blockade alarming and control of important divisions.

This multiple use installation is composed of two parts--a laser emitter and a receiving device. The former component is used to produce the laser; after the receiver receives the laser, the installation completes operations of alarming, switching and counting. The skeleton diagram and circuits of the semiconductor laser emitter are shown in Figs. 1 and 2. In circuits, transistors $BG_1$ and $BG_2$ compose a push-pull type dc converter, converting low voltage direct current into alternating current. After the voltage is raised with a transformer $B_1$, a voltage doubler rectifies into a direct current high voltage. Under general situations, the voltage is between 500 and 700 volts.

The oscillator is composed of a single-action junction tube $BG_3$ and the corresponding resistors and capacitors. By changing values of $R_5$ and

$C_4$, pulse output frequency can be adjusted. The oscillation cycle of $BG_2$ is calculated using the equation $T=RC\ln[1/(1-\eta)]$. In the equation, R and C are, respectively, $R_5$ and $C_4$ in Fig. 2; $\eta$ is the voltage division ratio of the tube. Here, $\eta=0.6$, $R_5=47$ kiloohms, and $C_4=0.1$ microfarad; therefore T is approximately equal to 1000 microseconds. The triggering pulse can be coupled with $C_5$ into a control pole of controllable silicon.

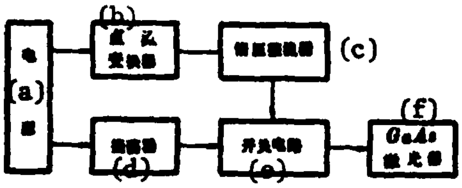

Fig. 1.
Key: (a) Power source; (b) Direct current converter; (c) Voltage doubler rectifier; (d) Oscillator; (e) Switching circuit; (f) GaAs laser.

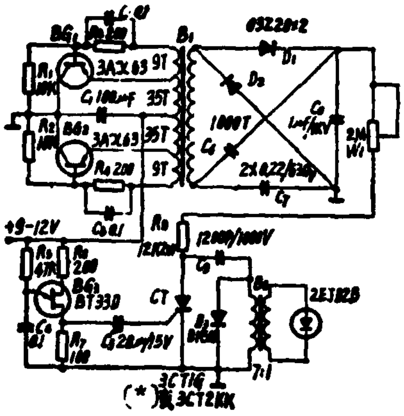

Fig. 2.
Key: (*) Or.

At the cutoff of the controllable silicon CT, the high voltage after low voltage rectifying charges a capacitor $C_9$ of anode CT. When the $BG_3$ output triggering pulse leads to CT conduction, through CT, $C_9$ rapidly discharges to the primary stage of transformer $B_2$, in forming a high tension pulse, so that the laser tube 2EJD2B (the secondary stage of $B_2$) is excited and light is emitted. If the transformer $B_2$ is dismantled and a 0.1 ohm resistance is used as load, then a pointed peaky pulse of about 10 to 90 amperes can be obtained at this resistance, as shown in Fig. 3.

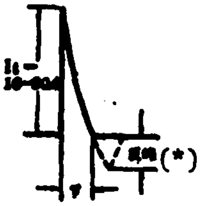

Fig. 3.
Key: (*) Negative peak.

The magnitude of the τ value of the pulse width is related to the RC time constant of the discharge circuit. R is the summation of internal resistance during conduction of controllable silicon CT and the impedance value converted from the primary stage of transformer $B_2$. By changing the magnitude of $C_9$, the pulse width can be conveniently adjusted. Worthy of attention is the fact that here the controllable silicon used is not the ordinary one, but is an element having high and intermediate power of high speed switching time. Generally, the conduction time of these elements is $t_d \leqslant 50$ to 60 nanoseconds. Of these elements, 3CT1G, 3CT2KJ and 3CT2KK have better characteristics.

If the reverse shock of the output pulse current waveform is too high (as shown in dotted lines in Fig. 3), care should be taken whether $D_2$ is misconnected or polarities are reversed. If the connection is correct and the reverse shock is high, then several diodes with good switching characteristics and adjustment of layout of the discharge circuit can reduce, as much as possible, the distributed capacitance in circuits until the waveform is satisfied.

The transformer $B_1$ adopts a twin wire parallel winding method; same-name terminals should not be confused. The primary stage uses ø0.21 mm enamel-covered wire, and the secondary stage uses ø0.12 mm enamel-covered wire for winding.

The pulse transformer is a voltage reduction type output transformer, activating the strengthening of the current. The ratio of primary and secondary stages is 7:1. $B_2$ adopts a ring-shaped ferrite magnet core of ø10xø5x5 (mm), either using MX-1000 type or MX-2000 type.

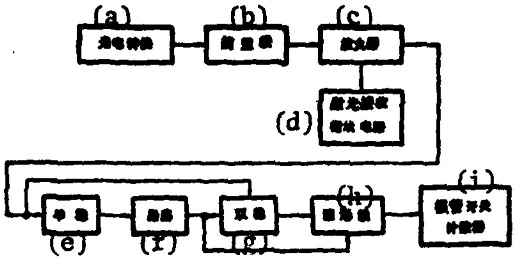

Fig. 4.
Key: (a) Photoelectric conversion; (b) Antecedent stage; (c) Amplifier; (d) Laser reception indicating circuit; (e) Single-shot [circuit]; (f) Oscillation; (g) Two-state [circuit]; (h) Rectifying stage; (i) Alarming switch counter.

In the circuit, the semiconductor laser device 2EJD2B is equivalent to a resistance of 0.1 to 0.2 ohm. Since $W_1$ and $R_8$ of charge limiting current exist in the circuit, generally frequencies are not greater than 10 kilohertz. The frequency used in this installation is 1 kilohertz.

The skeleton diagram and circuit diagram of the multiple use receiver are shown, respectively, in Figs. 4 and 5. The receiver is used to respond to 9000 angstroms light wavelength as the peak value in receiving silicon photosensitive triode 3DU5C(GB) as the photoelectric converter. The received light pulse is converted into a negative direction electric pulse signal (refer to Fig. 6A). With a transmission range of several hundred meters, the amplitude value of this signal is 0.1 to 0.3 millivolt. This weak signal is transmitted to a high input impedance antecedent amplifier. The antecedent amplifier $BG_1$ uses a junction type field effect tube 3DJ4F and the input impedance can reach 10 megaohms. The antecedent circuit has good high frequency response characteristics. By adjusting $R_5$ to have $I_D$ of $BG_1$ at 0.2 to 0.6 milliampere, then this stage can operate normally.

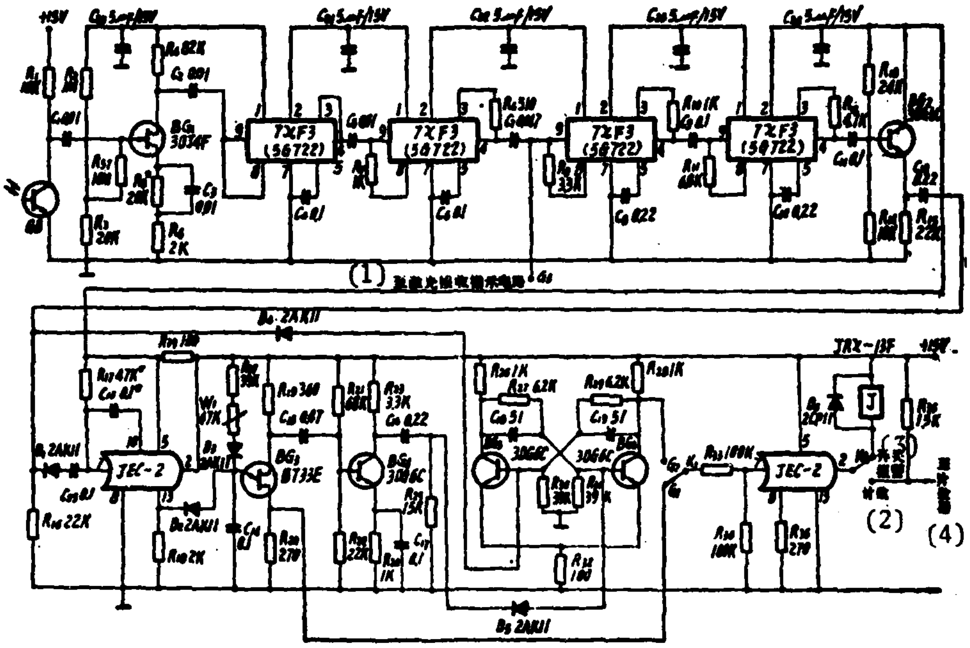

Fig. 5
Key: (1) To laser reception indicator circuit; (2) Counting; (3) Switching alarm; (4) To counter.

After the weak pulse signal passes through the antecedent amplification, it becomes a positive peaking pulse, transmitting into the pulse amplification circuit composed of four stages of a 7XF3(5G722) linear integrated circuit for voltage amplification. The 7XF3 is a negative feedback wide-band amplifier with two tube direct coupling. When used as a high increment voltage amplifier, some elements should be added externally to the circuit: (1) By additional connection of compensation capacitor $C_4$, $C_8$,

$C_6$ and $C_{10}$, the voltage increment of each stage of the circuit can reach 25 decibels (db) and the frequency band can extend from the high terminal to 100 megahertz. In order to reduce the increment at the low frequency terminal, generally the compensation capacitor is selected within the range of 0.1 to 0.33 microfarad, not too great an increment. (2) In order to reduce the negative feedback in the circuit and raise the amplification times of the close ring, between 8-foot and 9-foot of the second, third and fourth stage amplifier, it is connected externally with a resistance. (3) In order to increase the activity range of voltage output gradually stage by stage, at 3-foot and 4-foot of various stages, a resistance is connected externally. By adopting the above mentioned measures, the entire amplifier has a voltage amplification increment of as much as 100 db; this has very good response characteristics to a very narrow high frequency pulse. At various stages, a decoupling capacitor is connected in order to prevent self-excitation of the power source.

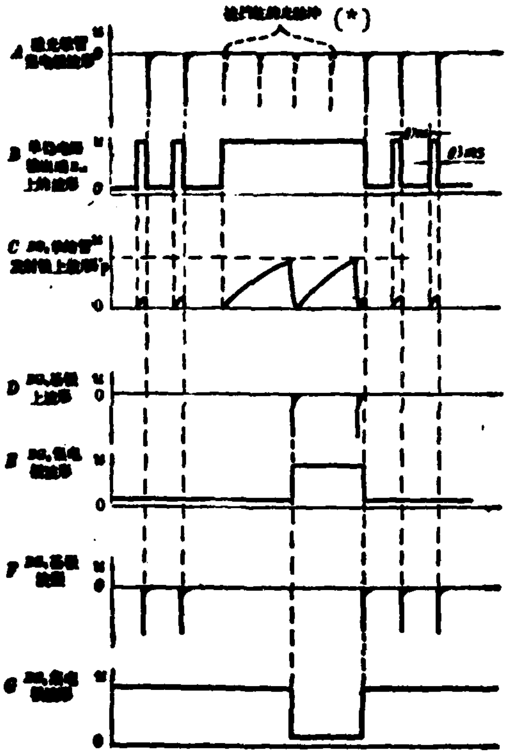

Fig. 6: (A) Silicon photosensitive tube, waveform of currnet-collecting pole; (B) Single-shot circuit, waveform at output terminal $R_{18}$; (C) Waveform of emitting pole of $BG_3$ single-action junction tube;
[to be continued on following page]

[Continuation of Fig. 6 on the preceding page]
(D) Waveform at $BG_6$ main pole; (E) Waveform of $BG_6$ current collecting pole; (F) Waveform of $BG_5$ main pole; (G) Waveform of $BG_5$ current collecting pole.
Key: (*) Blocked light pulses.

The positive pulse of output frequency (1 kilohertz) of an amplifier passes through $BG_2$ for output. After differentiating with $R_{16}$ and $C_{12}$, at one channel the negative pulse is taken out of $D_1$ and transmitted to a single-shot circuit composed of JEC-2, by synchronization of 1 kilohertz frequency as the light pulse frequency for turnover. The values of $R_{17}$ and $C_{13}$ are adjusted, so that the delay width is 0.7 millisecond and the cutoff width is 0.3 millisecond (refer to Fig. 6B). Then, only with normal light pulse input, the output voltage (approximately 1 volt of potential at the resistance $R_{18}$) of the single-shot circuit is lower than the oscillation peak value voltage $V_p$ (approximately 6 volts) of $BG_3$. Positive conduction of $D_2$ is carried out as the charge current in capacitor $C_{14}$ discharge to the ground by passing through $D_2$ and $R_{18}$. Thus, $BG_3$ is unable to initiate oscillation and there is no output signal at the $G_1$ terminal (see Fig. 6C). Another negative pulse channel after differentiation with $R_{16}$ and $C_{12}$ is transmitted from $D_4$ to the main pole (refer to Fig. 6F) of the two-state circuit $BG_5$ to reliably cut off $BG_5$, so that $DB_6$ is conducted and the $G_2$ terminal is at a low potential (refer to Fig. 6E).

By adjusting $W_1$ and $C_{14}$ to have an oscillation frequency of the oscillator of 400 to 500 hertz, it is considerably lower than the operating frequency (approximately 1/2) of the single-shot circuit. During automatic turnover of the single-shot circuit, the output terminal of the circuit has high voltage (approximately 11 volts), greater than the oscillation peak value voltage $V_p$ of $BG_3$; $D_2$ is at the reversed cutoff. Hence, passing through $W_1$, $R_{37}$ and $D_3$, the power source charges $C_{14}$ within the time duration of 0.3 millisecond (refer to Fig. 6C). As the time is very short, the peak value voltage $V_p$ of $BG_3$ has not been attained; the single-shot voltage is triggered by a light pulse of 1 kilohertz with cutoff delay. Then $D_2$ is the positive deflection and $C_{14}$ charges. Therefore, only the laser device 2EJD2B can emit light normally and the photosensitive tube can recieve it normally; $BG_3$ can be maintained without initiating oscillation and the $G_2$ terminal has no output.

When the light is blocked, there is no output of the signal pulse at the amplifying stage of the receiver, and there are no triggering pulses in the single-shot circuit and $BG_5$ main pole. The single-shot circuit turns into a stable state due to cutoff. The voltage at the output resistance $R_{18}$ of the single-shot circuit is rapidly changed to high potential, approximately 11 volts. At that time, the power source has sufficient time to pass through $W_1$ and $R_{37}$, and $D_2$ charges $C_{14}$ until $V_p$, and $BG_3$ initiates oscillation (refer to Fig. 6C). After the output negative pulse is reverse-phase amplified by passing through $BG_4$ and differentiated, the main pole of $BG_6$ is triggered (refer [illegible] Fig. 6D). Thus, $BG_6$ is turned from conduction to cutoff (refer to [illegible] 6E); i.e., the output of the $G_2$ terminal jumps to high potential from low potential.

When the object blocking off the light is removed, the photosensitive tube again receives the light pulse emitted from the laser device 2EJD2B, and the single-shot circuit is turned to cutoff from stable conduction; thus, $BG_3$ stops oscillating and the potential of the current collecting pole $BG_6$ rapidly drops; the potential of the $G_2$ terminal also rapidly drops (refer to Fig. 6E).

In order to meet different demands, the receiver circuit adopts a multi-route output. One route is the output of the $BG_6$ current collecting terminal to the $G_2$ terminal; and another route is the output (at the $G_1$ terminal) from pole $b_1$ of $BG_3$. The pulse waveform and amplitude value of outputs at $G_1$ and $G_2$ terminals are still not ideal; therefore, the pulse waveform cannot be directly used as the signal source. This requires the selection of a JEC-2 integrated block as the pulse waveform transformation circuit to transform the stage jump wave (not steep either front or rear) of the $G_2$ terminal, and the output pointed peaky pulse at the $G_1$ terminal into a rectangular pulse wave with the same amplitude value.

(A) When $K_1$ is placed at the $G_1$ terminal:

(1) $K_2$ is placed at the terminal of the switching alarm. If an object blocks the laser beam, the $G_1$ terminal has an output of pointed peaky pulse of 400 to 500 hertz. After waveform transformation, the relay J always sticks for self protection by using an indicator lamp or loudspeaker for alarming. Once the object leaves the laser beam, the receiver connects and the relay does not operate.

(2) When $K_2$ is placed at the terminal of 1.5 K resistance, an object blocks the laser beam. Thus, the waveform transformation stage will transmit the rectangular shaped pulse consistent with the $BG_3$ oscillation frequency to the counter for counting. When the object is not blocking the laser beam, the counter stops counting. Thus, the speed of an object with linear motion can be measured. For example, the length of the object is 10 meters and the oscillation frequency of $BG_3$ is 500 hertz, and the counter display (from the initial blocking of the laser beam by the object to completely free from blocking) number is 500, then the time t (=500/500 hertz = 1 second) of the object passing through the measurement point of the laser beam is 1 second; the speed of the object is s = 10 meters per second.

(B) When $K_1$ is placed at the $G_2$ terminal:

(1) $K_2$ is placed at the switch alarming terminal; i.e., the relay does not operate when there is a light pulse at the receiver. When there is no light pulse at the receiver, the relay sticks.

(2) $K_2$ is placed at the counting terminal; the counting is 1 for one blocking of the laser beam. As to whether the counting method involves counting the object blocking the light, or the times object is out of the light, the method can be selected according to the triggering requirement and various usages of the counter.

In the general situation, it is sufficient for laser repetition frequency to be at about 1 kilohertz. If the measurement speed or precision needs to be raised, the power source repetition frequency of the laser device and the operating frequency of the single-shot circuit and the oscillator should be correspondingly raised; however, the ratio between the light pulse frequency and oscillation frequency should be ensured at 2:1. Otherwise, the anti-interference characteristics of the receiver will be greatly dropped.

The light wavelength emitted by a semiconductor laser device is an invisible infrared light of 9000 angstroms; it is inconvenient in installation, adjustment, and testing, as well as operation under sunlight. Therefore, a laser indicator circuit is designed; the circuit converts the intensities of the infrared pulse laser into current to be directly indicated by an ammeter. The circuit is shown in Fig. 7. The operating principle is as follows: the amplified pointed peaky pulse charges $C_2$ through $D_1$; since the grid insulation resistance $R_{GS}$ of the field effect tube $BG_2$ is very high, the discharge constant RC is also very large. Then a positive pulse has a very steep front but very long rear edge (i.e., considerably expanding the ratio of occupied space) at the $R_5$ output; then whether the laser is intensive or weak can be indicated by the ammeter indicator. In Fig. 7, $W_2$ is used to adjust the zero point of the indicator, and $W_1$ is the maximum scale adjuster of the ammeter indicator.

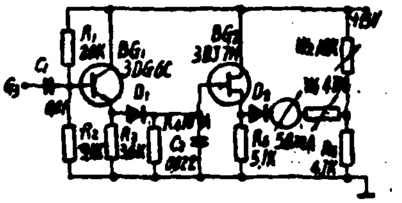

Fig. 7.

In order to adapt to long distance operation, the receiver uses four-stage amplification. If the operating distance is relatively short, the number of the amplification stages can be properly reduced. In order to sufficiently use the light energy to prevent scattering, the optical system should use lenses to focus the light beams. Generally, the transmitting and receivng lens cylinders are fitted with single sheet lenses (single convex, plain convex, or double convex) of 20 to 40 millimeters in radius to calibrate the emitted laser beam. Generally, the ratio between lens radius and the focal distance is 1:3 to 1:4; i.e., the focal distance f=80 to 120 millimeters. During installation and adjustment, the tube core of the laser device and the tube core of the photosensitive tube of the receiver should align with the lens focus; otherwise, the effective operating distance will be reduced.

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