High performance single pulse selector for laser using avalanche transistor driver

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ABSTRACT

In this paper, high performance single pulse selectors for laser using three kinds of avalanche transistor driver are described. They have low jitter (<1ns), long life-time ($>10^7$shots), short delay time (about 20ns), high probability of selecting single pulse (100%), high signal/noise ratio of selected single pulse ($>10^3$). The amplitude stability of selected single pulse better than that of the mode-locked pulse train. Comparison of the performances of avalanche transistor driver with others is given.

1. INTRODUCTION

Selecting a single pulse from a pulse train of mode-locked laser is a key technology for high power laser. Following the fast development of mode-locked lasers, high performance single pulse selectors are required.

Usually, single pulse selector is made up of a crystal Pockels cell between a crossed pair of dielectric film polarizers. The Pockels cell is drived by a high voltage nanosecond pulse. Performances of the selectors mainly depend on the stability of the high voltage nanosecond pulse. The selector using three kinds of avalanche transistors developed in our institute can generate a very stable high voltage nanosecond pulse which has very stable amplitude,width and generated time. Various main performances of these selectors have attained or surpassed advanced world levels.

2. DESIGN AND FUCTION OF CIRCUITS

These single pulse selectors for laser consist of a photodiode detector, synchronous trigger circuit,high voltage nanosecond pulse generator using avalanche transistors,stable voltage power,crystal Pockels cell and dielectric polarizers. (see Fig.1).

PIN silicon photodiode has negative output pulses to suit voltage level of the synchronous trigger circuit. The train of laser pulses is changed to electrical pulses by the photodiode, then the electrical pulses are transmited by the coaxial cable of 50 ohm impedance to the synchronous trigger circuit.

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Synchronous trigger circuit consists of a trigger with a variable reference voltage, a pulse former and a pulse amplifier (see Fig.2). The trigger and the pulse former are made of MECL fast speed integrated circuits. The pulse amplifier is made of ultra-high frequency transistors. These circuits are very fast,so the intrinsic delay time of total synchronize trigger circuit is less than 20 ns. When one of pulses from photodiode exceeds the reference voltage level, the synchronous trigger circuit will produce a pulse which is shaped by the pulse former and is amplified by the pulse amplifier in order to trigger the high voltage nanosecond pulse generator.

Three circuits of high voltage nanosecond pulse generator using avalanche transistors are developed and applied in our work:

(1) Driver using two discrete strings of avalanche transistors (see Fig. 3).
Two trigger pulses which have a time difference trigger two strings of avalanche transistors respectively. The first string produces a negative high voltage step to open the Pockels cell, then the second string produces another negative high voltage step to close the Pockels cell. The time diference can be changed according to the requirement of users. The falling time of the negative high voltage step is 2.5ns (see Fig.4).

(2) Driver using avalanche transistor stack (see Fig. 5).
The stack is made of several strings of avalanche transistors in parallel. Comparing with the first driver, this driver is faster, because its avalanche current is increased and the equivalent resistance is decreased. The falling time of the negative high voltage step is 1ns (see Fig. 6). By using the stack, the current-handing capability is strenthened too.

(3) driver using leading-following strings of avalanche transistors (see Fig. 7)
The trigger pulse makes leading string avalanche breakdown. This is causes following string avalanche breakdown immediately. A high voltage nanosecond pulse is abtained at the output of the circuit. The high voltage nanosecond pulse has very high stability.

High voltage DC power supply has high precision and high stability. Its voltage can be adjusted from 0 to 5kv (or 6kv) . It also has a convenient output teminal in order to provide users for testing the half-wave voltage of Pockels cell.

Pockels cell using double KD*P crystals is placed in the liquid of matching refraction index to increase the transmissivity and improve the surface shape of KD*P crystals. The liquid also acts on insulation and preventing from deliquescence. The transmissivity of Pockels cell in our work is large than 90%. Two polarized prismsand and Pockels cell have a total transmissivity which is 72%.

3. TEST OF PERFORMANCES

These selectors have been used to more than ten mode-locked lasers for a long time. They have been tested by experts and professors. After through testing and using, various main performance targets are obtained below:

(1) Jitter:

The trigger pulse is connected to "EXT input " of Tektronix 7834 oscilloscope and "synchronous imput" of this instrument. Using P6015 high voltage probe, the high voltage nanosecond pulse is attenuated to 1/1000, then it is transmitted to "CH1" of this oscilloscope. After repeated exposure 60 times, a photograph is abtained (see Fig. 8). We can't see the jitter of the high voltage nanose-cond pulses from the photograph. So we deem the jitter is less than 1ns.

(2) Intrinsic delay time:

The trigger pulse is connected to "CH1" and "synchronous imput", and the high voltage nanosecond pulse is connected to "CH2" by P6015 probe. Using "ALT" mode and repeated exposure, another photograph is abtained. The intrinsic delay time is about 20ns.

(3) Signal/noise ratio of the selected single pulse:

Using photodiode detector with light attenuators,the selected single laser pulse is changed to an electrical pulse, and its amplitude is A1, making the voltage of Pockels cell zero and taking these light attenuators away, the stray light is changed to an electrical pulse, and its amplitude is A2. Ensure A1 and A2 are measured in linear area. The total transmissivity of these light attenuators is T. The signal/noise ratio is $R=A1/(A2*T)=1087$

(4) Probability of selecting single pulse:

After through testing and using for a long time the probability of selecting single pulse always is 100%. The photographs of single pulseis shown in Fig.9 and the photographs of rejected pulse train is shown in Fig.10.

(5) Life-time:

These selector have been used for a long time at repeted mode-locked lasers. The repetition of these lasers is 1 Hz to 10 Hz. Several of these selectors have operated for more than 10^7 shots,and their operation are still very well. So the life-time is more than 10^7 shots.

4. COMPARISON OF PERFORMANCES OF VARIOUS DRIVERS FOR SINGLE PULSE SELECTORS

Up to now, several kinds of driver for selector have been developed. For example, spark gap with dry Nitrogen gas[1],spark gap with dielectric film[2], Krytron tube[3],Thyrotron tube[4], planer triode[5],Photoelectronic semiconductor switch[6], avalanche transistor strings[7] and stack[8], etc.

Table 1 Shows performances of various drivers for single pulse selector,eight drivers can be divided into four kinds:

(1) Metal spark gap driver:

This kind of driver contains the spark gap with dry nitrogen gas and the spark gap with thin dielectrical film. Very high voltage and very fast rise-time are their advantages. But their jitter is very large,their life-time is very short,their probability of selecting single pulse is very low,their electromagnetic interference is very strong and they need to maintain frequently.

(2) Tube driver:

Tube drivers contain krytron switch,thyratron switch and planer troide switch. Their performances are better than metal spark gap driver,but their delay time is long and they need high voltage trigger pulse. So several stages of trigger make the circuit complex and make the jitter increased.

(3) Semiconductor switch:

Its rise-time is very fast. So it is suitable for shaping a laser pulse into perfect shape. But using it for selecting single pulse is not very suitable.

(4) Avalanche transistor driver:

This kind of driver has the least jitter. Their probability of selecting sigle pulse is the highest,their life is very long,their delay time is very short and they are suitable to high repetition lasers. The rise-time of the driver with avalanche transistor strings is not very fast, but the driver with avalanche transistor stack has very fast rise-time. So various main performances of this kind of drivers are the best in various kinds of driver.

Table 1. Comparison of the performances of various drivers

Item	Jitter	Delay time	Life	Probability of selected pulse	Amplitude of HV pulse	Repetition rate General	Repetition rate Maximum	Rise time	Refer.
Spark gap with nitrogen gas	+5ns	1ns	10^3shots	<85%	10 kv	single shot	50 Hz	<1 ns	1
spark gap with thin dielectric film	+2ns	<4ns	10^4shots	>95%	5.5 kv	single shot	2 Hz	<350ps	2
Krytron	5-40ns	50ns	10^{3-5}shots	99%	5kv	1-5 Hz	30 Hz	2 ns	3
Thyratron	5ns	70ns	10^8 shots	>85%	8kv	10 Hz	1kHz	2ns	4
planer triode			10^4h		10kv	1-10Hz	1kHz	2ns	5
Semiconductor switch					2.8kv	1Hz	12.5Hz	<1ns	6
Avalanche transistor strings	<1ns	20ns	10^7shots	100%	5-6kv	1-100Hz	1.5kHz	2.5ns	7,9
Avalanche transistor stack	<1ns	20ns	10^7shots	100%	5-6kv	1-100Hz	1.5kHz	1ns	8.9

5. CONCLUSION

these selectors in our work have been used at many mode-locked lasers for several years. They are used in those scientific research below:

(1) Selected single pulse is supplied to several stages of laser amplitier to abtain high output power.

(2) Selected single pulse triggers a semiconductor switch to shape the single pulse.

(3) Selected single pulse is applied to four-pass amplification to form a small-sized high power laser system.

(4) To select a single pulse one by one from a train of mode-locked laser, then to take photographs by streak camera to research the property of the laser.

(5) To slice a short-pulse from a long-pulse of laser oscillator.

(6) To segregation the laser pulse from reflected pulse.

(7) To dump a cavity of a mode-locked laser.

(8) To apply to regenerative amplification.

These experiments prove that the stability of selected single pulse better than that of the train of mode-locked pulses. This selector has a powerful ability to prevent interfernce, but it itself has not electrical-magnetic interference. Its volume is small, its weight is light,its performance are very riliable and it is safe for users.

ACKNOWLEDGMENTS

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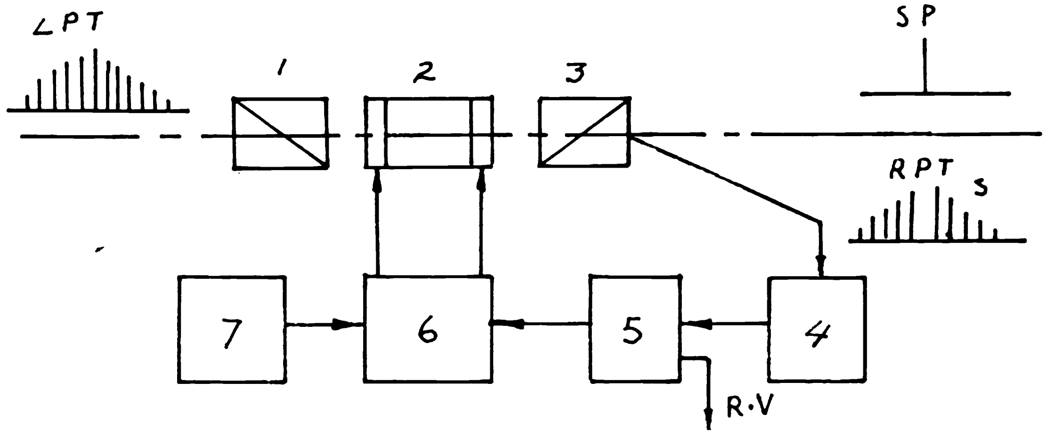

Fig.1 Principal block scheme of single pulse selector for laser
(1),(3) Polarizers, (2) Pockels cell, (4) Photodiode detector, (5) Synchronous trigger circuit, (6) High voltage nanosecond pulse generator, (7) Stable voltage power

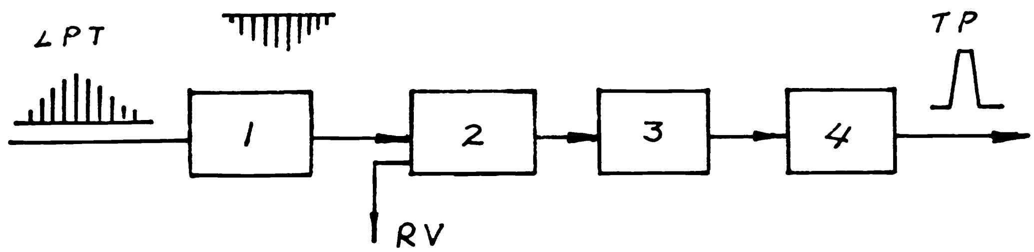

Fig.2 Block scheme of syncronous trigger circuit
(1) Photodiode detector, (2) Triger, (3) Pulse former, (4) Pulse amplifier

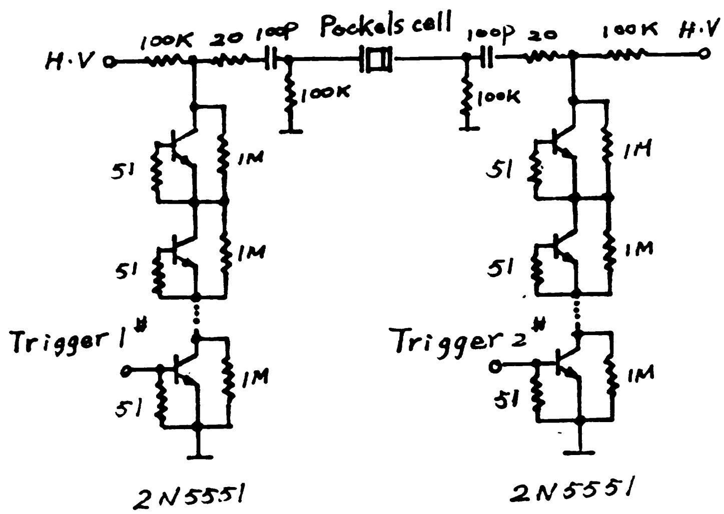

Fig.3 Circuit of the driver using two discrete strings of avalanche transistors

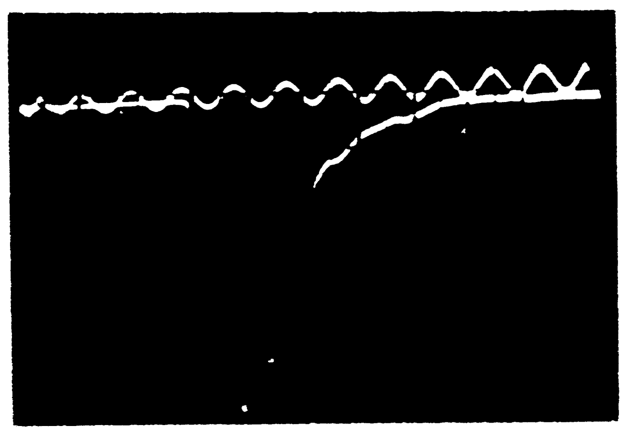

Fig.4 Falling time of the driver of using two discrete strings. The period of sine wave is 10ns

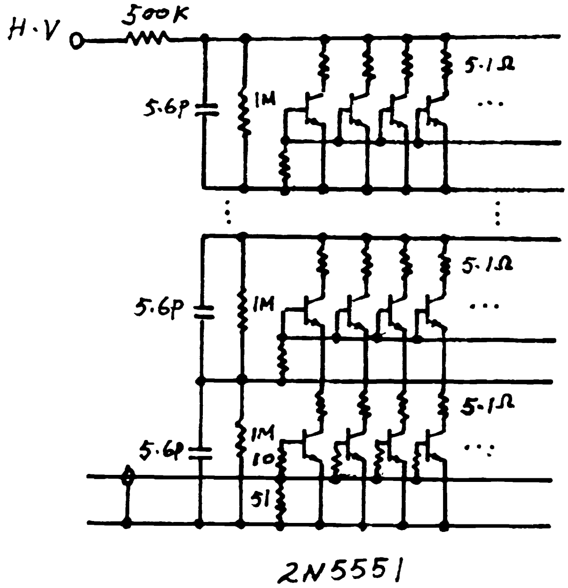

Fig.5 Circuit of the driver using avalanche transistor stack

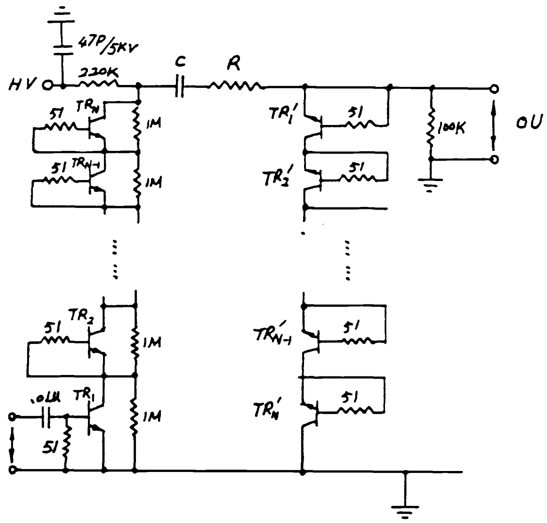

Fig.7 Circuit of driver using lead-following strings of avalanche transistors

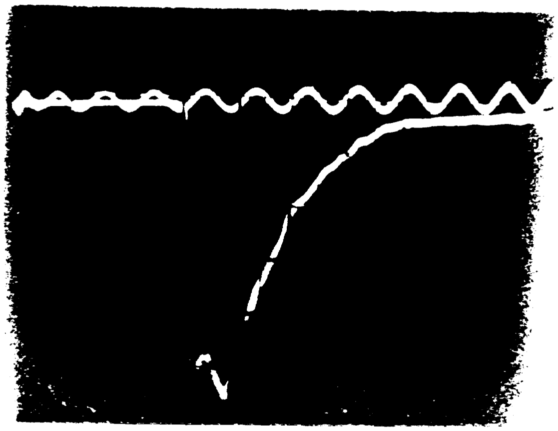

Fig.6 Falling time of the driver using avalanche transistor stack. The period of sine wave is 10ns

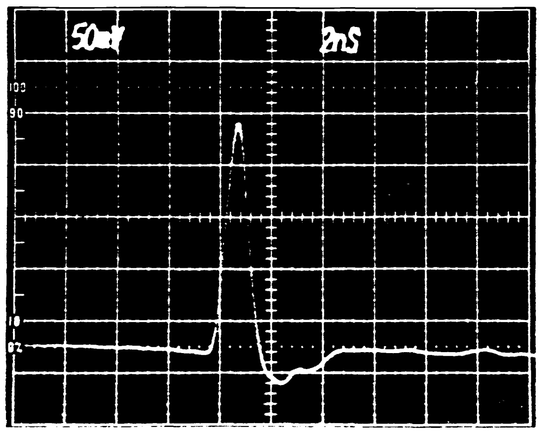

Fig.9 Wave shape of selected single pulse

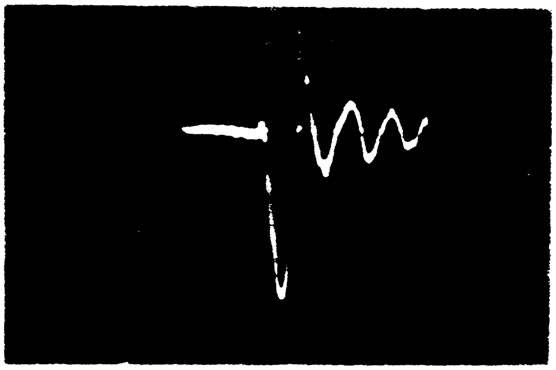

Fig.8 Wave shape of the high voltage nanosecond pulse, 10ns/div.

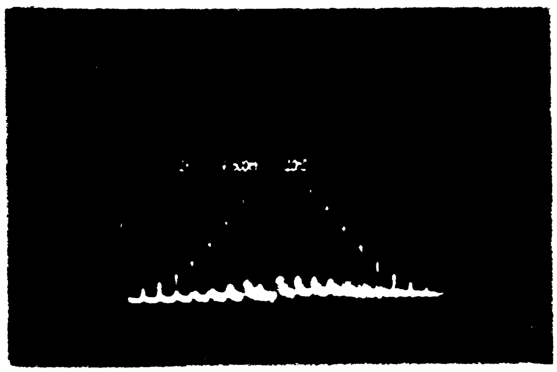

Fig.10 Wave shape of rejected pulse train