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Comparison analysis of Freetrig mode and Universal trigger mode

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This paper is about Freetriging. First, we define what is the Freetrig mode, and list its characteristics, and then elaborate the areas one should pay attention to in the selection and use of the Freetrig mode. We also discuss the current status and future applications of the Freetrig mode, and analyze its advantages and disadvantages in various situations. We use calculations to optimize the energy utilization and use experimental data to compare the performance with and without the Freetrig mode.

Key words: Freetriging , TRIG , Energy efficiency , PSO , POD , Synchronous clock

There are many ways to control ultrafast laser processing, such as: switch mode, continuous mode, PSO mode (position synchronized output) and so on, among which PSO control is more complex and requires the laser to have the corresponding interface mode with it. The laser is generally controlled by POD mode (pulse on demand) to dock the PSO, so that the laser output and the equipment motor can be precisely synchronized, thus allowing the ultrafast laser to hit on the right position.

1 Universal trigger mode

The current laser side usually uses GATE mode and TRIG mode, both of which can be used as POD to dock PSO.

GATE mode is the external control mode that uses the level signal as the light output enable to control the light output; when GATE is enabled, the laser outputs the laser pulse corresponding to the heavy frequency, and when GATE is de-energized, the laser does not output light.

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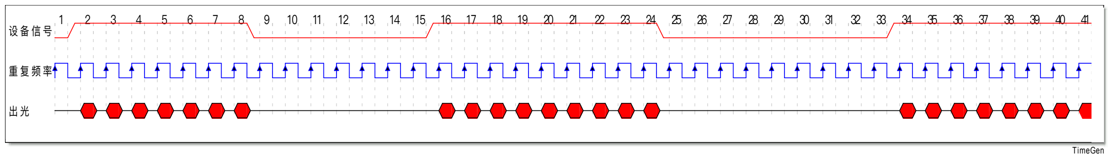


Figure 1

POD in GATE mode is to change the laser output frequency in real time by sending a command to the equipment controller during the processing operation to synchronize the laser with the position. This mode requires high matching, and it is rarely seen nowadays. Figure 2 shows the middle band of the laser re-frequency in GATE mode is set to half of the normal frequency.

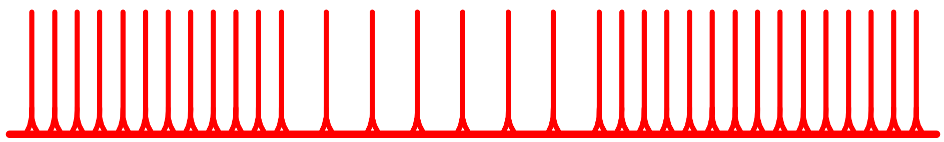


Figure 2

TRIG mode is an external control mode that uses edge triggering to control the light output. The laser system uses the external input control signal as the trigger signal, and when the rising edge arrives, the system will find the first encountered laser pulse afterwards to output out and finalize the light output operation.

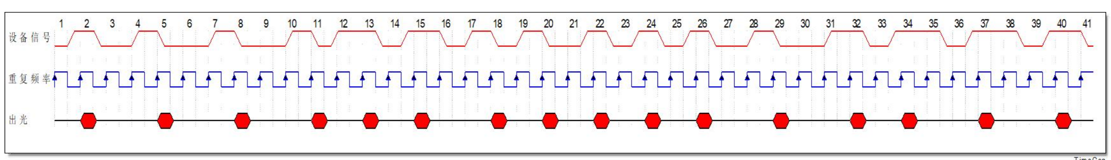


Figure 3

In TRIG mode, the POD is generated by the device controller to change the laser's output frequency in real time according to the actual situation, so that the light and position are synchronized. the POD in TRIG mode is the current common trigger mode (hereinafter referred to as the common trigger mode).

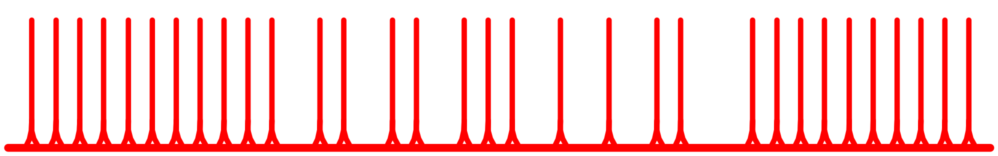


Figure 4

The application of universal trigger mode is that the device controller needs to control the X motor, Y motor and laser of the displacement stage at the same time, so that the coordinates on the stage and the laser out light are synchronized.

As shown in Figure 5: When the graph turns or crosses the corner, the rotation speed of X motor and Y motor will change, resulting in the horizontal and vertical displacement per unit time and the distance traveled in straight line movement become different. At this time, if the laser light output rate still maintains the original value, there will be uneven hitting point sparseness, affecting the processing effect.

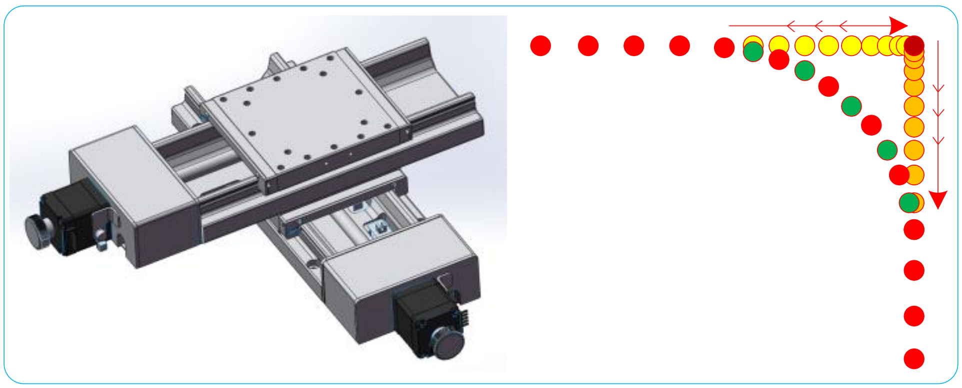


Figure 5

2 Freetrig mode

What is the name of the Freetrig mode and what are its characteristics? First of all, let's understand its definition.

FreeTrig mode, like GATE mode and TRIG mode, is a response mode of the pulsed laser to the external control signal, but this mode will output a pulsed laser with the same single pulse energy synchronized to the external control signal for any external control signal input in the rated frequency range.

From the definition of the Freetrig mode has two characteristics: synchronized to the external control signal, single pulse energy is the same.

1. synchronized with the external control signal.

The Freetrig mode can ensure the synchronization accuracy of the laser output when the frequency of the external control signal changes arbitrarily, the difference is only one oscillation frequency, for example: 20ns when the oscillation frequency is 50MHz; the synchronization accuracy of the actual output and the external control signal that can be guaranteed by the general trigger mode is determined by the value of the repetition frequency setting, and the difference between the output intervals is one repetition frequency period in the worst case, for example: 1us when the repetition frequency is Therefore, the synchronization error of the Freetrig mode is negligible compared with the universal trigger mode.

2. The energy of single pulse is the same.

Freetrig mode can guarantee the same single pulse energy for any frequency control signal. Users do not need to calculate as many parameters when choosing a Freetrig mode laser as they do when choosing a universal trigger mode, only the rated optimized frequency parameter is needed. The rated optimized frequency parameter is the highest common frequency required for processing, and the single pulse energy below this frequency is the same.

From the definition, it can be seen that using Freetrig mode processing, there is no need for the process engineer to calculate the optimized frequency, directly using the Freetrig mode timing software, or general trigger mode timing software processing can get very good processing results. Of course, the use of Freetrig mode dedicated timing software will be more able to take advantage of the advantages of the laser.

In addition, in the same laser can set several groups of Freetrig mode optimization frequency, the user according to the actual situation to choose different pulse energy of free mode processing, to make up for the lack of Freetrig mode in pulse energy.

3 Advantages of Freetrig mode

Freetrig mode single pulse energy and the highest frequency consistent, people will naturally think that the energy utilization will be very low, is this the case? The following is a concrete example to analyze and draw conclusions.
General trigger mode energy utilization is: actual frequency algebraic sum / optimized frequency
Freetrig mode energy utilization is: actual energy / corresponding re-frequency energy

This comparison may not be intuitive for you. Let's compare the energy loss in another way to illustrate the advantages and disadvantages of the two modes.

Universal trigger mode energy loss is: (optimized frequency - actual frequency algebraic sum) * single pulse energy

Freetrig mode energy loss is: actual frequency algebraic sum * (corresponding frequency energy - actual energy)

The use of universal trigger mode requires laser processing process personnel to be able to design the processing process, where the first thing to do is to determine the laser repetition frequency required for processing objects in universal trigger mode, the following is a simple example of laser parameters calculation.

Example ★: the following conditions: 4 rounded corners, the radius are 3mm, efficiency needs ≤ 0.3 seconds to process 1 piece; each piece of the perimeter of 300mm; into the filament light point spacing 5um; using universal trigger mode processing.

Solution: From the conditions it is known that.

X motor decelerates at 3mm from the longitudinal edge and decelerates to 0 at 0mm from the longitudinal edge.

Y motor decelerating at 3 mm from the transverse edge and decelerating to 0 at 0 mm from the transverse edge.

X motor accelerating at 0 mm from the transverse edge and speed accelerating to 1000 mm/s at 3 mm from the transverse edge.

Y motor accelerating at 0 mm from the longitudinal edge and speed accelerating to 1000 mm/s at 3 mm from the longitudinal edge.

① $s = 1/2at^2 \Rightarrow 0.003 = 1/2at^2$

② $at = v \Rightarrow at=1$

⇨ t=0.006s = 6ms = 6000us

1/4 circumference of a circle = 1/4 * 3 * 2 * 3.14 = 4.71mm = 4710um

Assume that the heavy frequency is equal to 200KHz, 5us out of a light, 5um spacing when straight, rounded corners 6000us/5us = 1200 light points => in the rounded corners of the light point spacing = 4710/1200 = 3.925um ≈ 4um;

Launch.

The light point spacing at a right line is 5um;

The interval of light points on the rounded corners is 4um;

The distance ratio is 5:4, and the frequency ratio is 5:4. The following can be used: Least common multiple method + enumeration method + estimation of distance.

The frequency of TRIG signal is 50KHz for straight line, 40KHz for rounded corner => 200KHz for laser re-frequency

The frequency of TRIG signal is 125KHz at the right line, and the frequency of TRIG signal is 100KHz at the rounded corner => laser re-frequency 500KHz

The frequency of the TRIG signal is 250KHz at the right line and 200KHz at the rounded corner => laser re-frequency 1MHz

The frequency of TRIG signal is 500KHz at right line and 400KHz at rounded corner => laser re-frequency 2MHz

......

Obtain the optimized frequency optional range for the above laser.

Then according to this frequency and the actual situation used in the processing efficiency (0.3 seconds a piece) compared to the needs of the selection of the appropriate optimization frequency. Finally, the optimized frequency of 1MHz is closer to the demand, of course, this is the choice based on the need to meet the linear speed of the motor ≥1250mm/s.

From the previous "example ★" we already know that the general trigger mode application is to adjust the processing frequency before the actual use of the "actual frequency" is the approximate number of the set frequency. The full frequency will not be used in the actual application. Therefore, the universal trigger mode energy loss is not the full frequency of power loss, "example ★" in the final device board using the normal frequency of 250K, while the optimized energy frequency of 1MHz, that is, less than 25% of the power utilization. Freetrig mode can be processed in the full frequency, the loss is the lower frequency than the preset frequency of the single pulse energy difference. Freetrig mode can complete processing at any frequency near the optimized frequency, the normal frequency = optimized frequency, and thus will not waste power. Optimized frequency switching function can also provide a variety of optimized frequencies for users to choose, so the power utilization Freetrig mode is more excellent than the universal trigger mode.

The actual machine test found that the Freetrig mode parameter setting is more intuitive, the same processing effect of universal trigger mode needs to go through several trial samples to get, and the Freetrig mode can keep the processing effect unchanged when adjusting the processing speed arbitrarily.

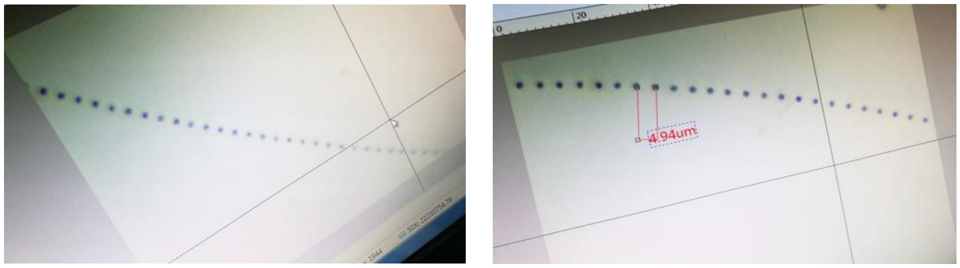


Figure 6

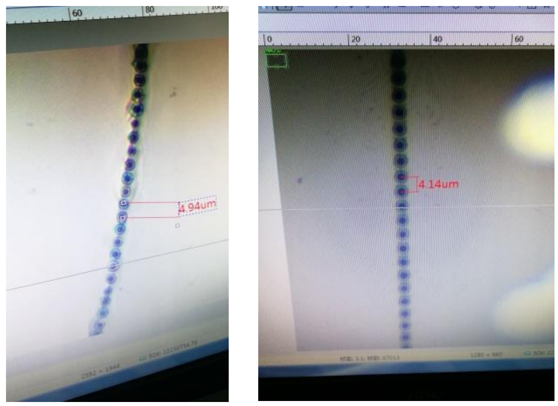


Figure 7

When writing the processing script for the device control board, the correlation between motor acceleration and laser light output is less, and only the linear distance of adjacent light pulses need to be considered, so the freedom of script design is greatly improved.

Currently, with the expansion of laser processing application fields and scale, the advantages of the convenience of the Freetrig mode in the application are becoming more and more prominent, and there are already many laser applications trying to use this approach. In the future, with the continuous maturity of laser design technology and the increasing demand for application accuracy, the Freetrig mode is likely to replace the universal trigger mode as the mainstream control mode for lasers.

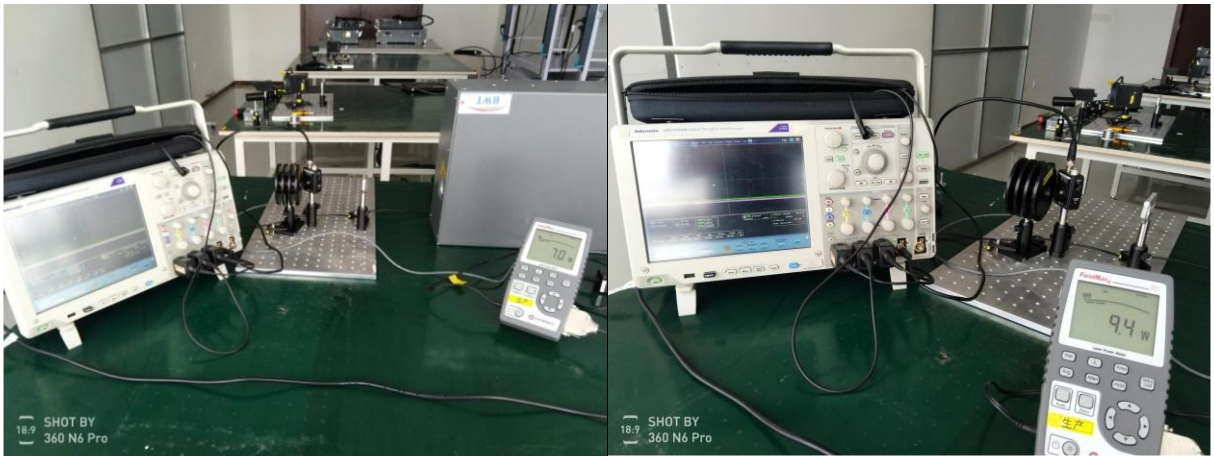
According to the above comparative analysis, we get the following comparison table of Freetrig mode and universal trigger mode.

Table 1

	Universal trigger mode processing	Freetrig mode processing
1	synchronized error is a re-frequency period	synchronized error is one oscillation cycle
2	Trig signal triggers the laser's re-frequency and then the light comes out	The Trig signal generates the laser's re-frequency output
3	Equal energy for a single pulse during processing	Equal energy of single pulse during processing
4	Very good energy stability	Good energy stability
5	Higher single pulse energy	Equal energy for all single pulses
6	The minimum common multiple of the trig frequency is set to the laser's refrequency for graphic processing	As long as trig is less than the laser's optimized frequency
7	The processing point spacing is a multiple of the set refrequency	Processing point spacing is arbitrary time
8	Energy utilization is: algebraic sum of actual frequencies / optimized frequency	Energy utilization is: actual energy / corresponding re-frequency energy
9	Good processing results	Excellent processing results
10	Low technical difficulty in implementing this module for lasers	Technically more difficult for lasers to implement this module
11	Larger design effort for process engineers	Less design work for process engineers
12	Relatively low price of the laser	Relatively high price of lasers
13	All models currently available on the market	Few models are currently available on the market
14	Most current equipment boards support this feature	Specific equipment boards can be used perfectly for this function
15	Optimized frequency affects power when multiplying applications	No loss of power for frequency doubling applications
16	Trig signal and re-frequency are not synchronized when the error is a fixed re-frequency period	Trig signal and re-frequency are not synchronized when the error is one oscillation cycle

4 Implementation of Freetrig mode

There are many methods to achieve Freetrig mode in laser: feedback method, frequency method, power method, proportional method, saturation method, hybrid method, etc. The applicable methods are different for different architecture design of laser, and the hybrid method is used by Caplin Laser. The following is a set of picture records of our company's frequency sweep test on Freetrig mode.


18:9
SHOT BY
360 N6 Pro
7.0
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