SEMICONDUCTOR LASER PROPERTY TO FORM INTERRUPTING RADIATION AT THE MOMENT OF SWITCHING ON AND SWITCHING OFF OF THE PUMPING ELECTRIC CURRENT

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Abstract

Semiconductor laser property to form interrupting radiation at the moment of switching on and switching off of the pumping electric current, belonging to a field of semiconductor lasers physics is described. An amplitude modulation of radiation during the moments of switching of a pumping electric current has coherent character. The average period of fluctuations is determined by tens femtoseconds, the whole process duration is some tens picoseconds. The device can be used for the noncontact high-speed precision control of geometrical parameters of the items, various defects definition in optically transparent products. The result of the research is a basis for new directions in a laser tomography, the measuring technique, use of this property will essentially simplify laser and fiber-optical gyroscopes.

Keywords: Semi-conductor laser, coherently modulated radiation, laser tomography, laser and fiber-optical gyroscopes

INTRODUCTION

The research belongs to a field of semiconductor lasers physics. The Italian scientific school considered the semiconductor laser radiation process under the effect of a pumping pulse by an electric current in the form of smooth increasing of the radiation power and its smooth termination, and both processes occurred to some delay in relation to corresponding fronts of a pumping pulse. The noticed delay was explained Svelto (1989) by ultimate electric capacity of multilayered structure of the semi-conductor laser.

Theoretical researches V.P. Gribkovsky (1988) of transient process of semiconductor lasers did not reject its undulating character.

The research result consists in the following - transient process of the initiation and the termination of the semiconductor laser radiating under the influence of a pumping pulse by an electric current occur undulating, both processes possess high repeatability for each laser and take a time interval in some tens picoseconds.

The scientific and practical significance of the received result consists in possibility to use both transient processes as the modulated high-frequency signal in echo-scanning systems of the thin transparent structures, in fiber-optical and laser gyroscopes for precision measurement of time delays of two investigated signals on the resonance effect basis of coherent modulating oscillations.

RESEARCH RESULT SUBSTANCE

Transient processes of the initiation and the termination of the semiconductor laser radiating under the influence of a pumping pulse by an electric current occur undulating. Both the initiation process of the laser radiation and process of its termination possess high repeatability that is these oscillations accordingly coherent at consecutive laser pumping pulses. Transient processes of the initiation and the termination of the semiconductor laser radiating occupy a time interval in some tens picoseconds.

PROOFS OF RESEARCH RESULTS RELIABILITY

For the purpose of the experimental proofs reduction uniquely confirming result reliability, the optical measurement method of a transparent objects thickness which is based on the applied measuring device and is recognized by the invention № 2414680 priority from December, 18th, 2009. In figure 1 the device is schematically represented by which the measurement method of a transparent objects thickness is implemented.

The device includes the semiconductor laser 1, which radiation, having reflected from a mirror 2, falls into measurement object - a glass plate 3. Diffuse reflected radiation from this plate 3 "is collected" by condenser 4 and it is focused on a sensitive photodiode cell 5. The signal from the photodiode through the gate circuit 6 and 7 connects to the generator 8, control assembly outputs 9 are set up into the other gate circuit inputs. The generator output 8 is attached to the laser input 1 and to the complementing counter input 11 through the gate circuit 10, into the second input of the gate circuit and the set input to «0» counter 11 corresponding control assembly outputs 9 are connected. The counter overflow output 11 is attached to the trigger "reset" input 12, and its set input is connected to control assembly output 9. The unity trigger output 12 through the gate circuit 13 operates connection to complementing counter input of result 14 generator output of the stable frequency 15. Set input to «0» and input Reverse of the result counter 14 are connected into control assembly outputs 9. The output code of the result counter 14 is an output of the whole device.

The device operates as follows.

The generator 8 applied in this circuit possesses ability for increase its period on delay size of only one system front (increase or fall): the laser 1 - radiation - the photo diode 5 the gate circuit 6 or 7 - and again the generator 8. The measured front selection is executed by a control assembly command, putting the gate circuit 6 or 7 into operation. If the gate circuit 6 switches on then to the period of the generator 8 delay time of a signal increase front from the photodiode, counted from a signal increase front of the laser start, is added. If the gate circuit 7 switches on then the period of the generator 8 increases by delay time of the fall front of the photodiode, counted from a signal fall front of the laser start. Proper period of the generator is selected 10 MHz, the output signal is close to a meander.

At starting connection to the generator 8 of delay of one of measured fronts is carried out, i.e. the enable potential applies only to one of two gate circuits 6 or 7. The steady mode of generation in system is established: the generator 8 - the laser 1 - radiation - the photodiode 5 - the gate circuit 6 or 7 - the generator 8. The further work of the whole circuit is connected with a time interval forming and filling it by pulses of stable frequency from the generator 15. The control assembly nulls counters 11 and 14, then it establishes to «1» trigger and enable the periods counter filling of the laser start 11. The trigger 12 through the gate circuit 13 enables the result counter filling 14 with pulses from the stable frequency generator 15. In this case the score is performed in a direct direction. Arithmetically it looks so:

T – free period of the generator 8,

tz – a delay of the selected front of the vibrating system,

n – periods quantity of the vibrating system,

F – the generator frequency of stable frequency 15 (it is applied – 100MHz).

As after the checking n periods the counter 11 resets the trigger 12 in «0» and stops generator pulses entry of standard frequency 15 on the result counter 14 so its condition is equal:

$$N1 = (T + tz)*n*F$$

In a following cycle of the device operation the photodiode output 5 is disconnected from the generator 8, therefore free period of the generator 8 equal T is installed. The result counter 14 is installed into the countdown (reverse) and the time interval from n the periods of the generator 8 is again formed. As the result counter 14 is switched on into the countdown so in the end of the second cycle of the device operation its state will be:

N2 = (T + tz)*n*F – T*n*F = tz*n*F.

In our device F = 10^8 Hz, n = 10^7 then n*F = 10^{15}, therefore the number on the result counter 14 is equal to a front delay expressed in femtoseconds. The same method delay time of an optical system of the second front is measured.

Measurements process was carried out in a following order. As a measurement object the set of the plane-parallel glass plates having equal refractive index and increasing thickness value from 0,9mm to 5,99mm was used. The delay time indications of both fronts for plates of an each thickness value were performed. As a result of repeated measurements the following regularity is determined. The fronts delay time of laser switching on and switching off under plates measurement by thickness from 0,90mm to 4,78mm has undulating character. At the same time the graph of the delay time fluctuation of both fronts for plates more 4,78mm in the thickness has a monotonous nature. The switching on front delay time decreases, as the basic power of the radiation accepted by a photodetector is reflected from a front plate side which, in this case, approaches to laser system, i.e. the way passed by radiation decreases. The switching off front delay time increases, as the radiation power, which still go on to keep a photodetector in the switched on state, even after the stopping of the laser radiation, comes from a back side of a plate. As the plate thicknesses increase, front transmission time of radiation roll-off also increases, that causes a time delay increase of this front.

The front time graph of the laser switching on under plates measurement by thickness from 0,90mm to 4,78mm has the minimum values under plates thickness: 1,77mm, 2,52mm, 2,94mm, 3,90mm and the maximum values under plates thickness 2,26mm, 2,84mm, 3,82mm, 4,48mm. Between the given extreme points there is a smooth variation of the front delay time. The front time graph of the laser switching off has opposite nature to the previous graph. So to plates thickness values to which in the previous graph the minimum values of delay times have corresponded, in the given graph the maximum values of delay times corresponds and on the contrary.

The same researches are carried out with three sets of optical systems (the laser - the condenser - a photodetector). Nature of the received results is identical, however concrete values of extreme points are various for each semi-conductor laser. For visualization of research results following graphs are given. The graph of glass plates thickness which were consistently used in 12 experiments is shown in the figure 4. The graph of front delay variation of signal increase, corresponding to the sequence of before pointed experiments is shown in the figure 3. The graph of signal fall front variation is shown in the figure 2. In the figure 5 the graphic image of prospective transient process of switching on and switching off of the semiconductor laser which has to cause the step variation of fronts delays of its operation found out as a research result is presented.

CONCLUSION

Such measurement result is possible only in case transient processes of the initiation and the termination of the semiconductor laser radiating under the influence of a pumping pulse by an electric current occur undulating, besides, each process has not less than four waves, duration of each transient process is some tens picoseconds. This conclusion is logical, as the reflected radiation from a glass plate represents two signals, the first signal is reflexion from a front side of the plate, and the second signal is reflexion from a back side of the plate. If the plate thickness is so small, that time shift between the reflected signals does not exceed transient process duration then on the sensitive platform of the photodetector there is radiation intensities composition of both reflected signals. As a result of such composition the photodetector will operate when the first result of radiation intensities composition of two signals will exceed a threshold of its operation, the next falls and hits of a total signal intensity will not affect on a photodetector as response of the last does not allow to reproduce such high-frequency signal. As consequences of this composition are the graphs described before. If the plate thickness provides time shift between the reflected signals sufficient that transient process of one signal is under the effect of constant radiation intensity of the second signal then the measurement graph nature will have a monotonous type.

References:

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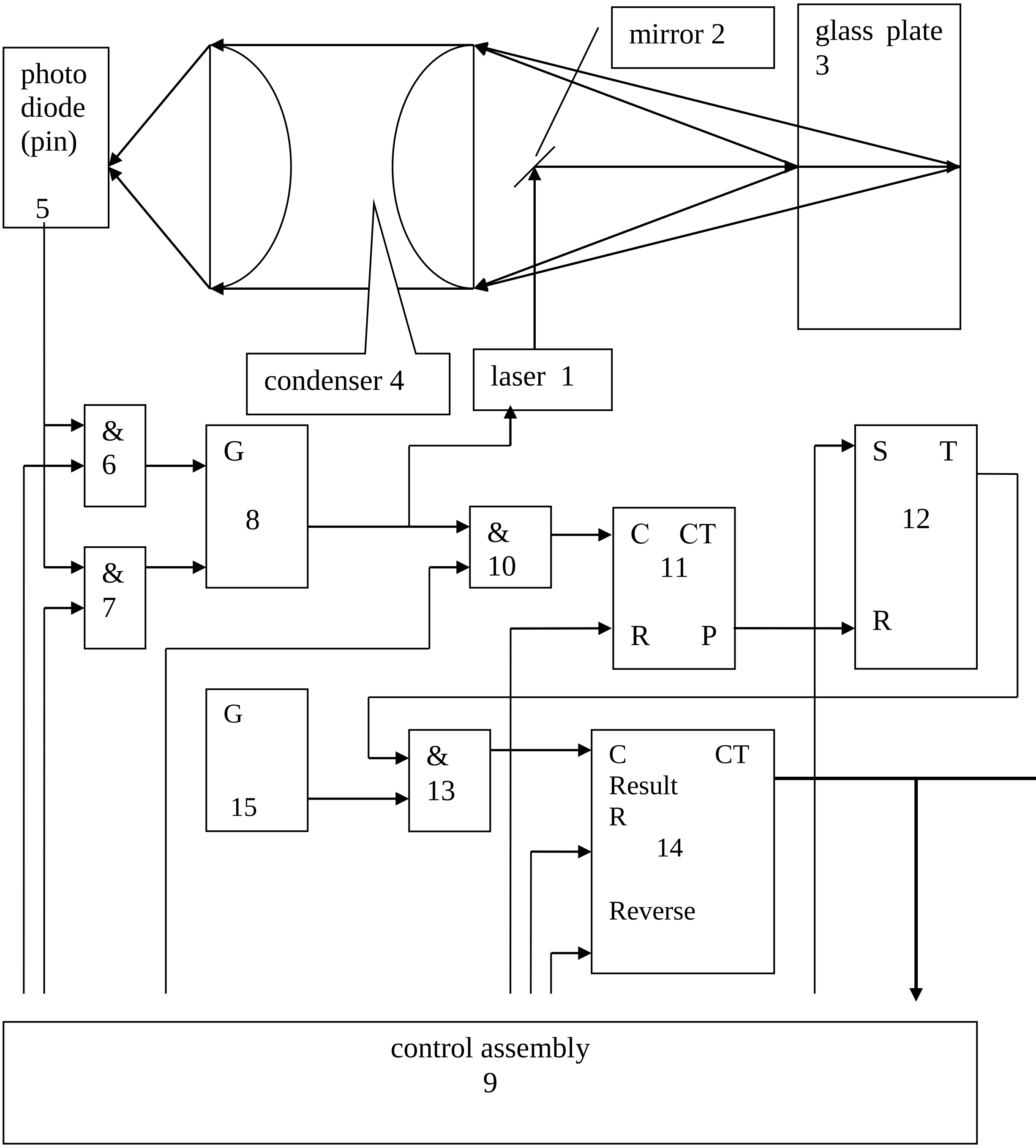

Fig. 1 The device is schematically represented by which the measurement method of a transparent objects thickness is implemented

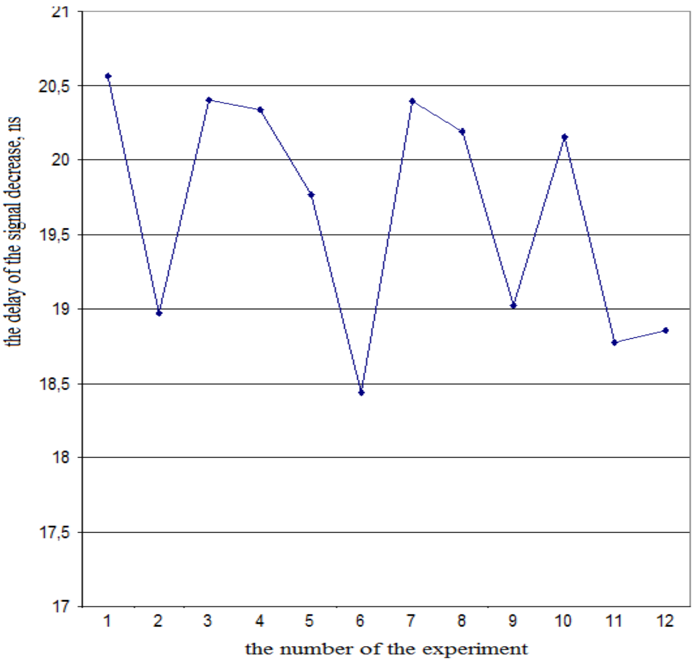

Fig. 2 The front delay variation of signal decrease

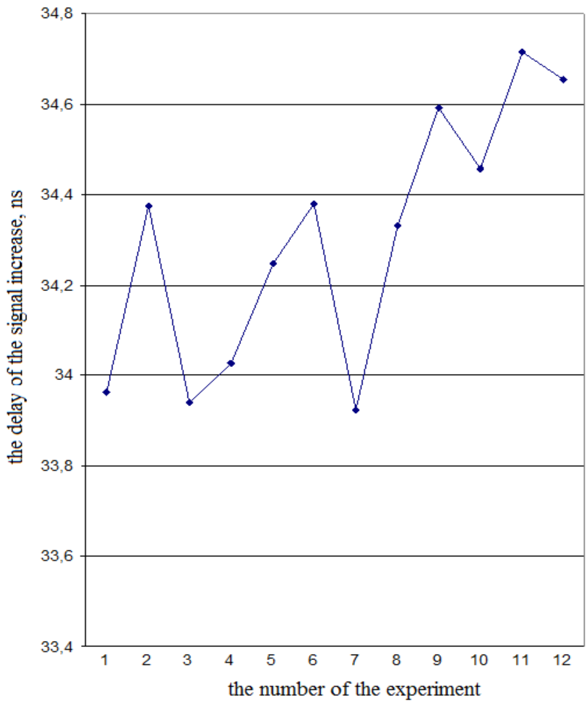

Fig. 3 The front delay variation of signal increase

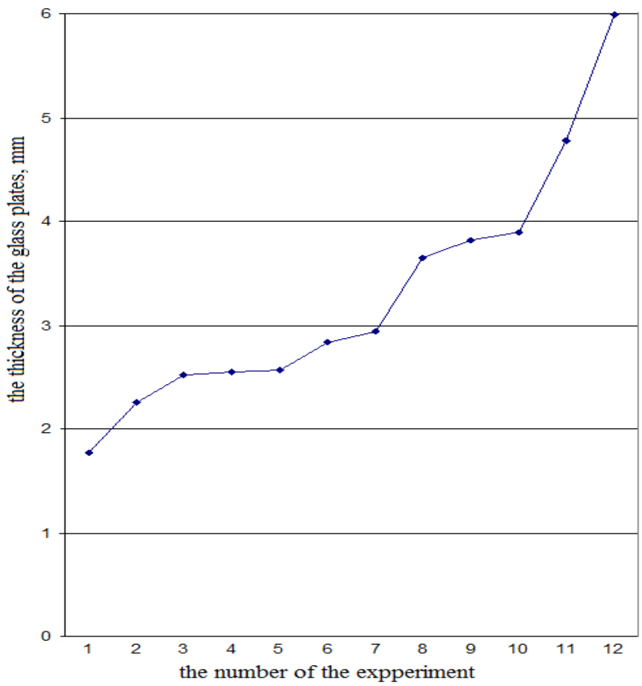

Fig. 4 The glass plates thickness

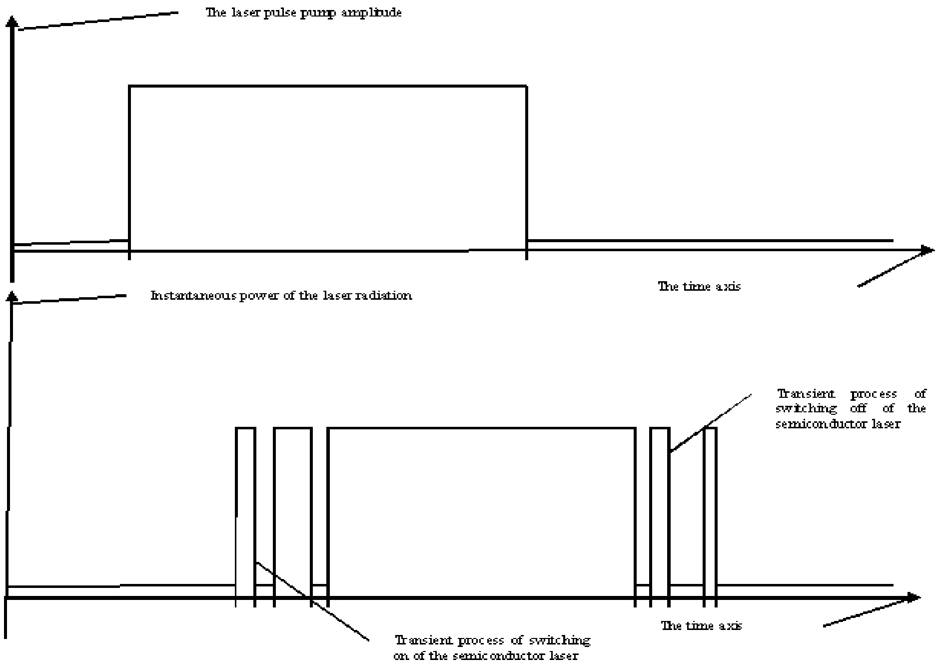

Fig. 5 Transient process of switching on and switching off of the semiconductor laser