Determine the energy of the impulse scheme for electrical excitation laser type "double impulse"

Svetoslav T. Ivanov, Yanca N. Kissova

Determine the energy of the impulse scheme for electrical excitation laser type "double impulse"information from the paper. (Svetoslav Ivanov, Yanka Kisova). *In most lasers with optical excitation essential element of the emitter except the active environment and optical resonator is a converter of electrical energy in the exciting light radiation - gas discharge or halogen filament lamps, and semiconductor LEDs and others. To obtain a high-energy (~100-300J) impulse with a steep front is suitable scheme excitation type "double impulse" proposed and investigated in this article. Described the principle of operation of the scheme and is composed substitutional electrical circuit. The analysis of resonant processes in both resonance loop lamp power supply, is defined the maximum number of inclusions flash lamp. Alleging is the equation for the total energy of the double pulse in substitutional scheme for electrical excitation laser of the type "double impulse".*

Определяне енергията на импулса в схема за електрическо възбуждане на лазер тип “двоен импулс“ (Светослав Иванов, Янка Кисова). *При повечето лазери с оптично възбуждане съществен елемент на излъчвателя, е преобразувателят на електрическата енергия във възбуждащо светлинно лъчение посредством газоразрядна лампа. За получаване на високо енергиен (~100-300J) импулс със стръмен фронт е подходяща схемата за възбуждане тип “двоен импулс“ предложена и изследвана в тази статия. Описан е принципът на действие на схемата и е съставена заместваща електрическа схема. Представени са симулационните резултати от проведеното изследване на преходните процеси. При направеният анализ на резонансните процеси в двата контура, които захранват лампата, е определен максималния брой включвания за импулсната лампа. Изведено е уравнението за пълната енергия на двойния импулс в заместващата схема, за електрическото възбуждане на лазер от вида „двоен импулс”.*

Introduction

In most lasers with optical excitation essential element of the emitter except the active environment and optical resonator is a converter of electrical energy in the exciting light radiation - gas discharge or halogen filament lamps, and semiconductor LEDs and others. Unlike coherent sources for excitation gas discharge flash lamp are significantly cheaper and available. They allow to be inflated larger volumes active environment. Main purpose of this type of source is pumped dye active dye environment [1]. The main interest in lasers with solutions of organic dyes is related to their ability to generate radiation with gradual adjustment of the wavelength in a wide spectral range, reaching 100 nm for an active solution. A characteristic requirement for excitation lamp is radiating energy to be short (~ 10μs) impulse with a rapid increase in the front. Only in this case reaches the required power of the exciting radiation for generation and reduces the deleterious effect of the settlement of the triplet level and created in Thermo illumination inhomogeneities. To obtain a high-energy (~100-300J) impulse with a steep front is suitable scheme excitation type "double impulse" proposed and investigated in this article. The purpose of research done is to create an equivalent circuit of a test device and do computer simulations of the transients, which then can be described analytically.

Principle of operation of the scheme for electrical excitation laser type "double impulse"

The principle scheme for implementing a method for managing a "double impulse" excitation of the laser gas discharge flash lamp is shown in Fig. 1.

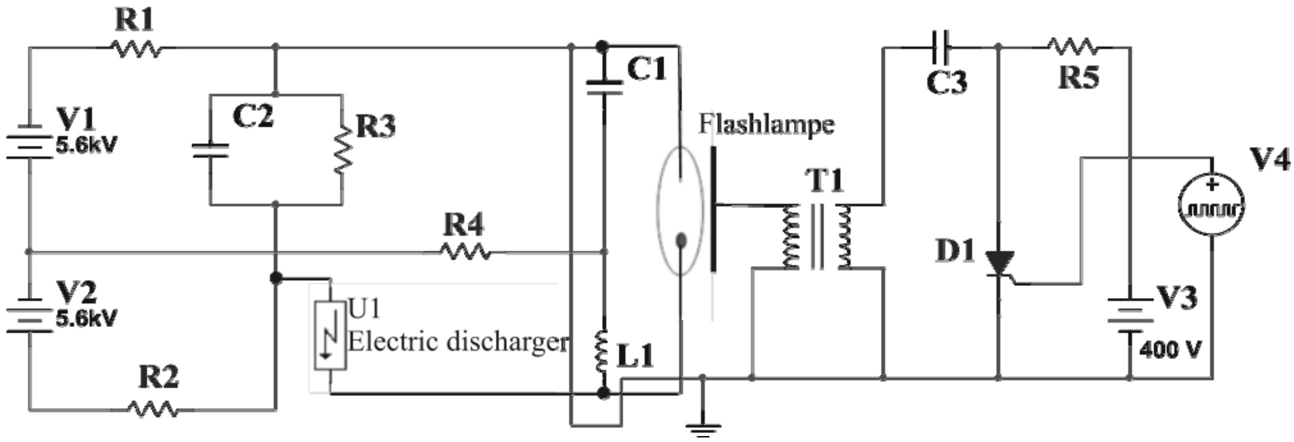

Fig. 1. Scheme for electrical excitation laser type "double impulse".

The function of this electrical circuit is to provide a powerful impulse discharge in the lamp, in which the gas is pre-ionized by an external ignition. Ignition device needed to set up the initial ionization of the gas in the lamp comprises: a transformer T_1, capacitor C_3, resistor R_5, thyristor D_1, *DC* power source V_3 and generator of control impulses V_4. By thyristors D_1 at a desired moment the capacitor C_3, which is pre-charged to a voltage of the *DC* power source V_3, is diluted in the primary winding of the ignition transformer T_1. The resistance of the lamp falls and accumulation capacitor C_1 is diluted through it. As a result of the discharge radiates powerful impulse duration determined by the capacity of the accumulator capacitor C_1 and the inductance of the discharge circuit L_1. Specificity in the design of the scheme is the selection of their values and voltages power sources in it in order to obtain without relaxations maximum effective transmission of energy from the accumulator capacitor to light. It is used as working gas of pure xenon with a pressure dependent on the diameter of the lamp [2], [3].

The accumulated capacitor C_1 is connected in parallel to the first power source V_1, which has a value 5,6kV. The discharge of the accumulator capacitor C_1 form prior to ionization low-energy impulse which provides intense ionization of the lamp. Breakdown voltage of the surge arrester U_1 is selected so that, before the discharge of the capacitor C_1 the voltage between its electrodes is less than the breakdown voltage. In the scheme it has value 7kV. During this charge voltage arrestors U_1 is constantly increasing and at a given time it reaches the required value to provide breakthrough. Then starts discharge of the condenser C_2, which is included in parallel with the two power sources V_1 and V_2 and is charged to a voltage 11,2kV. Thus, the second major high-energy impulse begins with a steep front (~ μs). The intense pre-discharge protects the lamp from damage and provides a very steep front of the main impulse. This scheme on impulse pumping is very suitable for the excitation of dye lasers. The steep leading edge is required to climb faster the active particles of the upper laser level, which in dyeing environments is short lived (~ ns, it is not metastable). Furthermore, the excitation impulse is short in order to avoid the possibility of settlement of the triplet levels settled also and absorb some of the emitted laser generation. In scheme under consideration the length of the double impulse is 26μs. The internal resistance of the power sources V_1 and V_2 in the scheme type "double impulse" are respectively R_1 and R_2. Discharge circuit inductance L_1 has a value of 10μH. This value is small, so as not to hinder the rapid growth of the leading edge of the impulse discharge of accumulated capacitor C_1. The dye environments amplified in a wide spectral range and generation can be modified by "selective resonator", in which one of the resonator reflectors reflect a wavelength [4].

Figure 2 shows a substituent sheme for electrical excitation of a laser-type "double impulse”. It consists of two resonant loops. The first includes a capacitance C_1 with a value of 1μF, resistor R_6 with the value of 1Ω and two inductors L_1 and L_2 with a value of 10μH. In the scheme used impulsed discharge lamp is represented by consistently included inductance L_2 and resistor R_6 [5], [6]. The moment of the inclusion of the capacitor C_1 in the scheme is simulated by switching S_1, which replaces the control circuit and the arrester U_1 in the real circuit (Figure 1) is replaced by the switch S_2. The inclusion of two charged capacitors C_1 and C_2 provide the initial conditions of the transition process.

At the moment t = 0 the switch is closed S_1 (Figure

2). In the scheme includes a capacitor C_1, which is charged to a voltage 5,6kV and managed by the impulse generator V_4 (Figure 1). The scheme consists only of *I*-primary circuit because the switch S_2 is open.

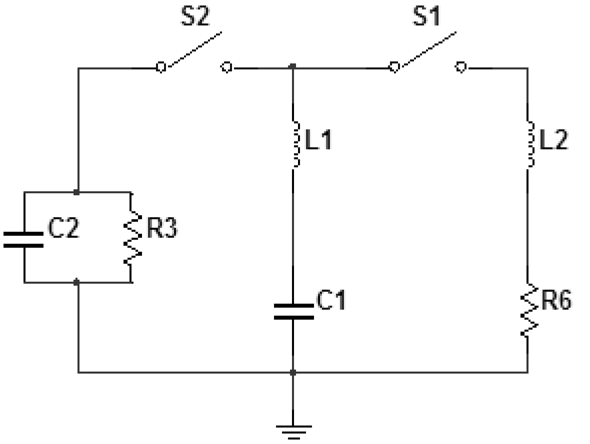

Fig. 2. Substituent scheme for electrical excitation laser type "double impulse".

The capacitor C_1 is diluted to a voltage approximately 4,4kV, when closed, and the switch S_2. In the circuit includes the capacitor C_2, which is charged to a voltage 11,2kV. His inclusion is about 5µs after power capacitor C_1, which is the time required for the appearance of the main high-energy impulse with a steep front impulse lamp whose control scheme is considered [9]. This delay time of the switching of the switch S_2 to simulate the operation of the surge arrester. The scheme comprises more than two loops, the second loop includes the C_2, connected in parallel to the resistor R_3 = 1,1GΩ, and inductor L_2, connected in series to the resistance R_6.

At the time of inclusion on the second loop current through the lamp has a value of about 840A. This value is determined by the simulation of transients made by the software Multisim. Fig. 3. shows the change of current through the flash lamp and I_{L2} form of voltage on capacitors connected in parallel to the power source: U_{C1} and U_{C2}.

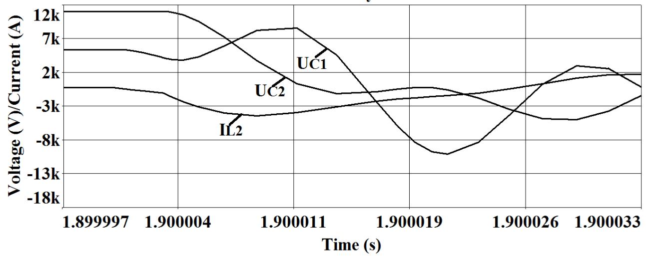

Fig.3. Graphs of $I_{L2}(t)$,$U_{C1}(t)$ and $U_{C2}(t)$.

The graph in Figure 3 shows the change of current through the flash lamp I_{L2} before and after inclusion of the second power source V_2. The amplitude value reached by this current at the second current impulse is approximately 4,1kA. From research done shows that the minimum period for switching the lamp is determined by the charging time $t_{charg.}$ capacitor C_2 after current impulse. Therefore, the maximum frequency of operation of the flash lamp calculated by the formula:

(1) $$f_{\max} = \frac{1}{t_{charg.}}, \text{ is } f_{\max}=2{,}41\text{Hz}.$$

Design of power supply for flash lamp

In order to design a power supply for flash lamp is necessary to know the parameters of the lamp and the impact they have on the maximum value of current energy released and the shape of the impulse. Other factors such as the borders of destroy (explosion) and lamp life should also be taken into account. With respect to the length of the impulse and impulse value energy should be borne in account the following considerations: too small impulse length can cause the lamp to become untransparent and absorb a significant percentage of light energy; too long impulse is inefficient because the stored energy leads to rapid aging of the electrodes of the lamp and therefore the lifetime of the lamp; too much energy in one impulse can significantly reduce the life of the lamp or in extreme cases destroy it. Therefore, it is necessary to quantify the maximum permissible impulse energy. It is calculated by the formula: too short a impulse length can cause the lamps to turn opaque and reabsorb asignificant percentage of the light energy; too long a impulse is inefficient because the stored energy in the disk decays faster than the lamps can replace it; too much energy in a single impulse or on a repetitive basis can significantly reduce the life of the lamp or in extreme situations, destroy it. This last limit,quantified as single shot explosion energy E_{exp} is given as:

(2) $$E_{\exp} = 2.10^4.l.d.\tau^{0,5},$$

where *l* is lamp length, measured in cm, *d* is lamp diameter, measured in cm, too. The time constant of an electrical circuit *τ* is given as:

(3) $$\tau = \sqrt{LC},$$

where L and C are respectively the inductance and capacitance in the discharge circuit of flash lamp. The approximate number of shots before failure is given as:

(4) $$N = \left(\frac{E_{\exp}}{E_0} \right)^{8,8}$$

where *N* is the approximate number of shots before failure. *Eexp* is the single shot explosion energy limit. E_0 is the energy at which the lamp is actually being operated. The graph of this relationship is shown in figure 4 below.

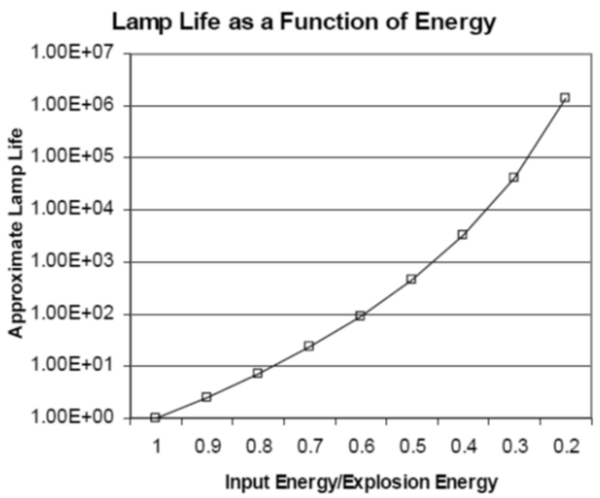

Fig.4. Expected number of lamp shots as a function of lamp energy versus explosion energy.

These factors are important and cannot be ignored, because flashlamp failure can result in catastrophic consequences to the laser disks in an amplifier.

Equations for the first resonant circuit of substitutional scheme for electrical excitation laser type "double impulse" with a discharge lamp

Select the time constant τ of the resonant circuit to be around 17% of the impulse duration t_p, for which the contour is t_p = 26μs [7,8]. Then τ is obtained:

(5) $$\tau = 0,17 t_p = 4,47.10^{-6} s^{-1}$$

According to the formula (2) for the explosion energy is obtained E_{exp} = 355,2J at *l* = 12 cm and *d* = 0.7 cm of flash lamp in the scheme "double impulsee". Selects energy at which the lamp is actually being operated E_0 be about *4,4 %* от explosion energy E_{exp}:

(6) $$E_0 = 0,044.E_{\exp} = 15,68J$$

According to the formula for the capacity of capacitor

(7) $$C = \frac{2E_0}{V_0^{\ 2}}$$

Having in mind that the voltage that includes a first resonant circuit is a V_0=5,6kV, of capacity in the resonant circuit is get value C=1.10^{-6}F.

According to the formula (3) oscillating circuit inductance is calculated as follows:

(8) $$L = \frac{\tau^2}{C} = 20.10^{-6} H$$

In the first resonance circuit full inductance *L* is $L=L_1+L_2$. Because the inductance of the flash lamp is L_2=10μH, for the inductance of the discharge circuit get value L_1=10μH. Those values of the considered variables according to formula (4) the approximate number of approximate number of shots before failure is $N \sim 10^{12}$.

Equations for the second resonant circuit of substitutional scheme for electrical excitation laser type "double impulse" with a discharge lamp

The second resonance circuit shall be included in the circuit with a delay of about *5μs* after the first. Is selected the time constant τ of the resonant circuit to be around 26% of the impulse duration t_p, for which the contour is t_p = 21μs [7,8]. Then τ is obtained:

(9) $$\tau = 0,26 t_p = 5,46.10^{-6} s^{-1}$$

Using formula (8) for capacity in the second resonant circuit is calculated by the formula :

(10) $$C = \frac{\tau^2}{L} = 3.10^{-6} F$$

According to formula (2) for the explosion energy is obtained at E_{exp} = 392,6J, *l* = 12 cm and *d* = 0.7 cm of flash lamp in the scheme "double impulse". Given that the voltage that includes a second resonant circuit is V_0 = 11,2kV, energy at which the lamp is actually being operated, lamp energy where it actually works E_0 is given by:

(11) $$E_0 = \frac{CV_0^2}{2} = 188,2J$$

Those values of the considered variables according to formula (4) the approximate number of shots before failure is $N \sim 103$.

Total energy of the double impulse E_0 in substitutional scheme for electrical excitation laser type "double impulse"

The total energy of the double impulse E0 in the substitutional scheme for electrical excitation laser type "double impulse" is calculated by the formula:

$$E_0 = \frac{C_1 V_1^2}{2} + \frac{C_2 V_2^2}{2} + \frac{L_1 I_1^2}{2} \quad (12)$$

where C_1=1µF, C_2=3µF, L_1=10µH, I_1 is the current through the inductance L_1 currently in t = 5µs, where in the circuit include the second loop and has a value of about 800A. В този момент кондензаторът C_1 е разреден до напрежение V_1=4,39 kV. Напрежението на втория кондензатор е V_2=11,2 kV. При тези стойности на величините за енергията на “двойния импулс“ се получава стойност E_0=201 J.

Conclusion

Substitutional scheme is composed of driver for electrical excitation a laser type "double pulse". It consists of two resonant circuits. This scheme allows for the simulation study of transition processes in pulsed excitation light. In the equivalent circuit is turned on and the equivalent circuit of the flash lamp composed by authors. Proposed is a methodology for designing a power control scheme for flash lamp. Transient processes were analyzed in two resonant circuits. They are composed equations describing the energy input on the lamp by two sequentially resonant circuits. Alleging is the equation of the total energy applied to the light of the two pulses. An analysis is made of the duration of the operation of the lamp depending on the energy of the ruling impulses.

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