LASER SYSTEM OF MICROWAVE PICOSECOND PULSE TRAINS USED FOR EMISSION INITIATION IN THE PHOTOGUN

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The scheme of picosecond pulse train formation by scanning of a laser ray across the adjustable diaphragm by means of a microwave traveling-wave optical deflector is presented. After amplification and conversion these pulses can be used for photoemission obtaining in photoguns.

PACS: 29.27 Fh,41.85.Qg

As a rule, to form trains of optical picosecond pulses (OPP) designed for obtaining a photoemission in microwave guns, one uses the method with passive mode locking (PML), the block-diagram of which is shown in Fig.1,a, or the method with active mode locking (AML), Fig.1,b. Both methods use the intercavity modulation of laser radiation requiring an exact adjustment and a very stable construction.

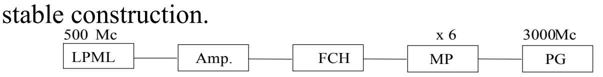

Fig. 1a

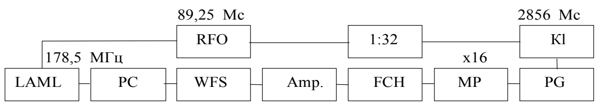

Fig. 1b

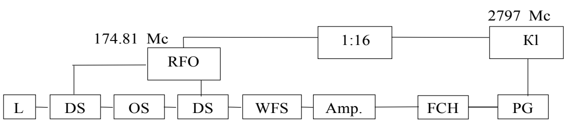

Fig. 1c

Fig.1. Block-diagram of forming microwave trains of optical picosecond pulses.
Fig.1,a - the method with passive mode locking (PML).
Fig.1,b - the method with active mode locking (AML).
Fig.1,c - the method of laser radiation deflection.
Designations: L - laser. LPML - laser with PML, LAML - laser with AML, AMP - amplifier, FCH - frequency converter into harmonics, MP - multiplexer, PG - photogun, RFO - radio-frequency oscillator, Kl - klystron, PC - pulse compressor, WFS - waveform shaper, DS - deflector system, OS - optical system

In paper [1] the authors consider the method of OPP formation being not inferior by parameters than previous method, but more simple by design and construction and more profitable economically. The block-diagram of the method offered is presented in Fig.1,c. As a master oscillator one can use either a pulsed laser, as in the first case, or a continuous-beam laser, as in the second case. The radiation from the laser is directed into the deflector system (DS) consisting of deflectors with vertical and horizontal deflection, after into the optical system composed of two lenses and a disk (placed between them) having cut slit diaphragms, then again into the analogous DS, after that the formed train of optical pulses is amplified, is converted into the third harmonic and directed onto the photocathode of the microwave gun energized from the klystron. This scheme, similarly to the previous one, is designed in order to separate the 16th klystron subharmonics and to synchronize its operation with a high-voltage radio-frequency oscillator from which DS are energized.

The layout of the setup for forming OPP trains is shown in Fig.2.

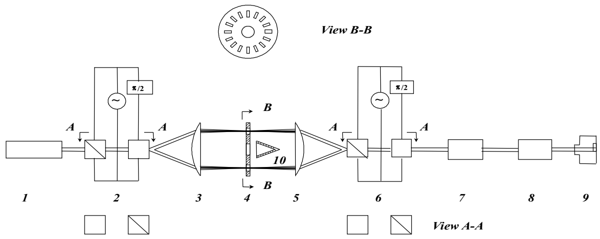

Fig.2. Setup for forming OPP by the deflection method. 1 - laser; 2, 6 - deflector systems; 3, 5 - lenses; 4 - disk with radial slit diaphragms; 7 - amplifier; 8 - converter; 9 - microwave photogun; light trap

This layout shows also the laser and the DS in more detail. A circular laser beam scanning is reached as a result of applying the driving sinusoidal electric voltage, being phase-shifted by $\pi/2$ as compared to the voltage at the first deflector. At the DS output there is formed a laser light beam, deflected from the axis by an angle α_{defl}, which rotates about the cone. By means of the lens 3 the rotating laser beam is collimated and focused in the plane B-B. In this plane placed is the metallic disc 4 in which radial slit diaphragms and hole in the middle are cut. The hole is used to pass a nondeflected laser beam into the light trap 10. During rotation of the focused laser beam over the slit diaphragms behind the latter a spatially- separated OPP train is formed that is converted, by the lens 5, analogous to the lens 3, and by the DS 6, analogous to the DS 2, into the light beam being collinear with the axis of the laser 1. Then this light beam is amplified by amplifier the 7, is converted into the 3,d harmonic and directed onto the microwave photocathode of the gun 9.

Basic parameters of the optical pulse train include: a pulse frequency, as well as, duration and energy of a pulse in the train. It is obvious, that the frequency of microwave pulses f_{mw} is determined by the frequency of deflector system scanning and by a number **p** of the slit diaphragms on the circle. To provide a given frequency of the train f_{mw} a necessary number of radial holes is determined by the formula of [1]:

$$p = f_{mw}/f_{scan}\,, \tag{1}$$

where $f_{scan.}$ is the frequency of circular scanning of the deflector system.

A peculiarity of work [1], as well as, of all the standard schemes of OPP formation consists in that the radiation of the master optical generator is either modulated, or scanned at a frequency $f_{scan.} = f_{mw}/p$, where generally p>10, and then, after amplification and multiplication of light pulses with the help of the multiplexer by a factor of p the frequency is increased up to f_{mw}.

In the present work, due to the condition that the laser beam scanning is performed at the klystron frequency f =3 GHz, the layout of the setup is considerably simpler. The block-diagram of the setup is shown in Fig.3.

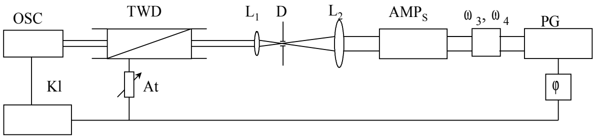

Fig.3. Block-diagram of the setup for forming picosecond electron bunches in the electron linac. OSC - master oscillator, TWD - travelling wave detector, L1, L2 - telescope 1:2, D - adjustable diaphragm, AMPs - amplifiers, ω_3, ω_4 - converter into 3d or 4th harmonics, PG - photogun, K1 - klystron, At - attenuator, φ - phase shifter

As a master oscillator OSC one can use a pulsed Q-switched laser with an active element Nd:YLF or Nd:YAG, being triggered with a repetition rate ν = 10 Hz synchronously with a klystron and generating optical pulses of a duration τ = 7 ns and an energy of 0.03 J at a wavelength λ = 1047 or 1064 nm. An optical ray from the master oscillator comes into the traveling wave deflector TWD, being energized via the attenuator from the klystron. TWD performs the scanning of the ray with a frequency 3 Ghz across the adjustable slit diaphragm. The lens L_1 with a focal distance of ~30 cm converts the light beams scanned by the deflector into ones being parallel to the optical axis of the system and being convergent into the plane of the diaphragm D. The laser beam after passing the diaphragm D is collimated by the lens L_2 with a focal distance of 60 cm and comes onto the amplifiers AMP and the frequency converter ω_3 or ω_4, triplicating or multiplying by a factor of 4 the frequency of the master generator depending on the cathode type of the microwave gun.

TWD is a multiple-prism system made on the base of electrooptical crystals having a considerable electrooptical effect. To such crystals pertaining are the crystals of a tetragonal symmetry 42m: KH_2PO_4(KDP), KD_2PO_4 (DKDP), NH_4 H_2PO_4 (ADP), as well as, the crystals of a trigonal symmetry 3m: $LiNbO_3$ and $LiTaO_3$.

For pass-through deflectors the deflection angle α is determined by the formula:

$$\alpha = tg\beta\, n^3 r_{ij} E, \qquad (2)$$

where n is an index of crystal refraction, r_{ij} is an electrooptical coefficient, E is an electric field strength, β is an angle at electrooptical prism top.

Achievement of a large angle α in the pass-through deflectors is hampered by the phenomenon of total internal reflection limiting tgβ by a unit. To exclude the total internal reflection, the prisms are dipped into the immersion, the refraction index of which is close to the quantity n. Thus, the value of tgβ can reach 8-10 [2]. Optical and electrooptical parameters of crystals, usually applied in deflectors are given in Table.

Optical and electrooptical parameters of crystals ADP, DKDP, KDP, $LiNbO_3$ and $LiTaO_3$

Crystal	Electrooptical constants			Index of refraction		Effective electrooptical constants
	$r_{41}10^{12}$ *m/v*	$r_{63}10^{12}$ *m/v*	$r_{33}10^{12}$ *m/v*	n_0	n_e	$n^3 r_{ij} 10^{12} m/v$
ADP	24.5			1.48	1.52	83
DKDP		26.4		1.47	1.51	90
KDP		8.6		1.47	1.51	32
$LiNb0_3$			35.8	2.176	2.18	371
$LiTaO_3$			30.08	2.28	2.2	351

It is seen from the table that the large deflection angle α can be obtained on the crystal of a trigonal symmetry having a high value of the effective electrooptical constant $n^3 r_{ij}$. For crystals of the 42m symmetry n = n_o, and for crystals of the 3m symmetry n = n_e.

The phase shifter φ is used for shifting the phase of microwave radiation taken from the klystron. The phase is selected so that the maximum of microwave power be coincident by the phase with the photocurrent pulse on the photocathode of the gun. In this case, the photocathode pulse, generated due to the reverse run of the laser beam across the diaphragm will be in the opposite phase with a maximum value of the microwave field and will be not captured by this field. The light pulse duration τ depends on the relation between the laser beam diameter in the focal plane of the lens L_1 and the width δ of the slit diaphragm [1]

$$\tau = \frac{T_{scan}}{2\pi N} \frac{\delta + d}{d}. \qquad (3)$$

Here N = $\alpha_{defl}/\alpha_{diverg}$, where α_{defl} and α_{diverg}, are the deflection angle and the divergence angle of the laser beam, respectively. If we select the TWD length l = 40 cm and δ = 2d = 0.3 mm, taking into account that F = 30 cm and α_{diverg}, = 0.0005 rad, and α_{defl} =2°, then τ = 2.5 ps will be obtained. At a macropulse duration of 7 ns and a micropulse repetition rate of 3 GHz, behind the diaphragm, 20 light micropulses of an energy ~10 μJ every will follow. At the exit of the amplifier AMP, comprising three amplification cascades, the micropulse energy can be increased up to 1 mJ ($K_{ampl.}$ =100). After conversion of the optical radiation into 3d or 4th harmonics one can obtain the light pulse energy on the photocathode of the order of 10 μJ that allows one to obtain the electron bunch charge of ~0.25 ncoul at a quantum efficiency of a copper photocathode $\eta = 10^{-4}$ on the wavelength of 266 nm. The advantages of the scheme offered for formation of optical pulses are:

1) possibility to form micropulses of any required duration in the wide range from subpicosecond to tens of subpicoseconds;

2) possibility of obtaining two or more pulses during the microwave period due to the installation of several diaphragms in the D plane.

REFERENCES

1. V.S. Dyomin, A.A. Chertkov. *Formation of a train of microwave optical picosecond pulses for obtaining the photoemission in microwave guns*. Proc. of the Conference on Charged Particle Accelerators. Protvino. 1994, v.3, p.103-111.
2 A.B. Van’kov, V.M. Volynkin, A.A. Chertkov. Electrooptical deflectors of optical deflection for the intense laser radiation // *Izvestiya Akademii Nauk SSSR, Ser. Phys.* 1991, v.55, №2, p.253-259.

ЛАЗЕРНАЯ СИСТЕМА СВЧ-СЕРИЙ ПИКОСЕКУНДНЫХ ИМПУЛЬСОВ ДЛЯ ИНИЦИИРОВАНИЯ ЭМИССИИ В ФОТОПУШКЕ

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Представлена схема формирования серии пикосекундных оптических импульсов путем сканирования лазерного луча с помощью СВЧ-дефлектора бегущей волны по регулируемой диафрагме. После усиления и преобразования эти импульсы можно использовать для получения эмиссии в фотопушках.

ЛАЗЕРНА СИСТЕМА НВЧ-СЕРІЙ ПІКОСЕКУНДНИХ ІМПУЛЬСІВ ДЛЯ ІНІЦІЮВАННЯ ЕМІСІЇ В ФОТОГАРМАТІ

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Приведена схема формування серії пікосекундних оптичних імпульсів шляхом сканування лазерного променя за допомогою НВЧ-дефлектора бігучої хвилі по діафрагмі, що регулюється. Після підсилення і перетворення ці імпульси можна використовувати для одержання емісії в фотогарматах.