FORMATION OF PICOSECOND ELECTRON BUNCHES IN THE LINEAR ACCELERATOR BY MEANS OF AN OPTICAL DEFLECTOR

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Abstract

A possibility for forming trains of optical picosecond pulses by the microwave scanning of a laser beam across the adjustable diaphragm is considered. After amplification these pulses can be used for obtaining a photoemission in microwave guns.

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.1a, or the method with active mode locking (AML), Fig.1b. Both methods use the intercavity modulation of laser radiation requiring an exact adjustment and a very stable construction.

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.1c. 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. 1a](image1)
![Fig. 1b](image2)
![Fig. 1c](image3)

Figure 1: Block-diagram of forming microwave trains of optical picosecond pulses.

Fig.1a - the method with passive mode locking (PML). Fig.1b - the method with active mode locking (AML). Fig.1c - the method of laser radiation deflection.


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

![Fig. 2](image4)

Figure 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 $\alpha_{\text{defl}}$, 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 a metallic disc 4 in which radial slit diaphragmes 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 diaphragmes behind the latters a spatially- separated OPP train is formed that is converted, by lense 5, analogous to lense 3, and by DS 6, analogous to DS2, into the light beam being collinear with the axis of laser 1. Then this light beam is amplified by amplifier 7, is converted into the 3d harmonic and directed onto the microwave photocathode of gun 9.

Basic parameters of the optical pulse train include: a 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 \( n \) of the slit diaphragmes 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]:

\[
\begin{align*}
    n &= \frac{f_{mw}}{f_{scan}} \quad (1),
\end{align*}
\]

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 \( f_{scan} = f_{mw}/n \), where generally \( n>10 \), and then, after amplification and multiplication of light pulses with the help of the multiplexer by a factor of \( n \) 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 \( f = 3GHz \), the layout of the setup is considerably simpler. The block-diagram of the setup is shown in Fig.3.

**Figure 3:** Block-diagram of the setup for forming picosecond electron bunches in the electron linac. OSC - master oscillator, TWD - travelling wave deflector, L1, L2 - telescope 1:2, D - adjustable diaphragm, AMPs - amplifiers, \( \omega_3, \omega_4 \) - converter into 3d or 4th harmonics, PI - photogun, K1 - klystron, At - attenuator, \( \varphi \) - 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 \( \nu = 10 \) Hz synchronously with a klystron and generating optical pulses of a duration \( \tau = 7 \) ns and an energy of 0.03 J at a wavelength \( \lambda = 1047 \) or 1064 nm. An optical ray from the master oscillator comes into the travelling wave deflector TWD, being energized via the attenuator from the klystron. TWD performs the scanning of the ray with a frequency 3 Gzh across the adjustable slit diaphragm. The lens L1, 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 L2, with a focal distance of 60 cm and comes onto the amplifiers AMP and the frequency converter \( \omega_3 \) or \( \omega_4 \), tripling or multiplying by a factor of 4 the frequency of the master generator depending on the cathode type of the microwave gun.

The phase shifter \( \varphi \) 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 \( \tau \) depends on the relation between the laser beam diameter in the focal plane of the lens L1 and the width \( \delta \) of the slit diaphragm [1]

\[
\begin{align*}
    \tau &= \frac{T_{scan}}{2\pi N} \frac{\delta + d}{d} \quad (2),
\end{align*}
\]

here \( N = \alpha_{defl}/\alpha_{diverg} \) where \( \alpha_{defl} \) and \( \alpha_{diverg} \), are the deflection angle and the divergence angle of the laser beam, respectively. If we select the TWD length \( L = 40 \) cm and \( \delta = 2d = 0.3 \) mm, taking into account that \( F = 30 \) cm and \( \alpha_{diverg} = 0.0005 \) rad, and \( \alpha_{defl} = 2^\circ \), then \( \tau = 2.5 \) 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 \( \sim 10 \) \( \mu \)J every will follow. At the exit of the amplifier AMP, comprising three amplification cascades, the micropulse energy can be increased up to 1 \( \mu \)J \( (K_{ampl.} = 100) \). 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 \( \mu \)J that allows one to obtain the electron bunch charge of \( \sim 0.25 \) noul 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