S3-P-033703

NONLINEAR AMPLIFICATION OF POWERFUL TERAHERTZ PULSEES BY ELECTRON BUNCHES*

A.V. SAVILOV, Y.S. OPARINA, D.D. KRYGINA

Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia

The effect of electron acceleration in the fields of wave pulses has been well studied [1,2]. In this work, we consider a possibility to "reverse" this problem and investigate the amplification of a short powerful terahertz-frequency-range wave pulse by a photo-injector electron bunch due to the deceleration (reflection) of electrons. In this process, the initial longitudinal velocities of electrons exceed the group velocity of the pulse. Naturally, this process should be realized in a media with the "proper" dispersion, so that the group velocity of the wave pulse is small enough. The electrons catch up with the pulse, and it reflects them, so that their final velocities become less than the group velocity of the wave packet. As a result, kinetic electron energy is passed to the wave.

Since this is a principally non-linear process, amplification of very powerful wave pulses is possible. We describe an amplifier based on a principally non-linear effect of reflection of a short high-current relativistic electron bunch from the powerful wave pulse. This is effective mechanism of energy extraction by the wave from particles, when parameters of the electron bunch (initial energy spread, bunch length and emittance) haven't significant influence on the efficiency of the electron-wave interaction. We describe two schemes of realization of this process. The first one is the amplification of high-power pulses due to the almost total braking in a waveguide under effect of the non-resonant pondermotive force (Fig. 1 a). Second, the amplification of weak pulses in a waveguide immersed in the undulator magnetic field is describes (Fig. 1 b); here, the undulator resonance provides an efficient electron-wave interaction.

Results of numerical simulations on the basis of the approach described elsewhere [3,4] demonstrate the possibility to provide nonlinear amplification of powerful wave pulses by at least in order of magnitude with efficiencies of the electron-wave interaction process at a level of 10 %. The amplification is accompanied by compression of wave pulses. Several examples of complicated dynamic of the nonlinear interaction between short electron bunches and powerful wave pulses will be given in the presentation.

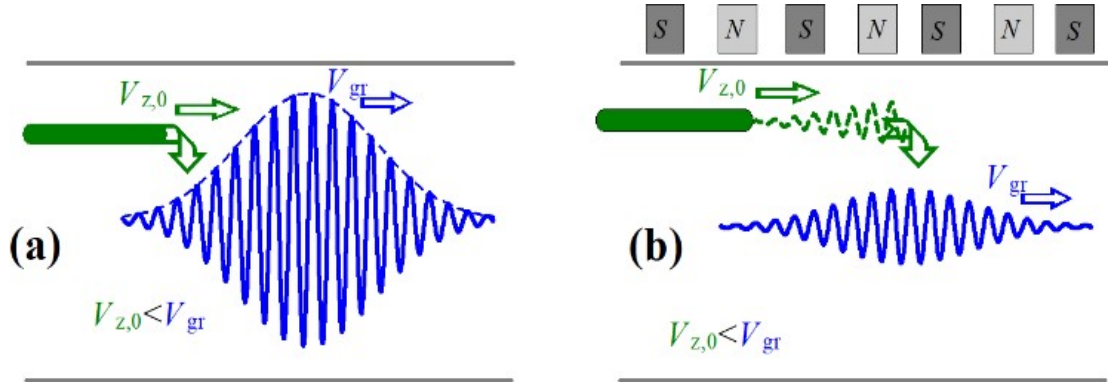

Fig.1. Non-resonant (a) and resonant (b) "reflection" of electron by a short powerful wave pulse.

REFERENCES

[1] Nanni E.A. et al. "Terahertz-driven linear electron acceleration", Nature Communications. vol. 6, p. 8486, 2015.

[2] T. Tajima and J.M. Dawson "Laser electron accelerator," Phys. Rev. Lett., vol. 43, pp. 267-270, 1979.

[3] I.V. Bandurkin, Y.S. Oparina, A.V.Savilov, "Super-radiative self-compression of photo-injector electron bunches," Appl. Phys. Letters, vol. 110, no. 26, p. 263508, 2017.

[4] Y.S. Oparina, A.V. Savilov, "Coherent super-radiative undulator emission of ultra-short THz wave pulses," Physics of Plasmas, vol. 28, no. 9, p. 093302, 2021.

* The work was supported by Russian Science Foundation (grant no. 21-72-30027).