

# Generation of Cherenkov Superradiant Pulses with Correlated Phases Defined by Sharp Edges of High-Current Electron Bunches

I.V. Zotova<sup>1</sup>, N.S. Ginzburg<sup>1</sup>, A.A. Golovanov<sup>1</sup>, M.I. Yalandin<sup>2</sup>, V.V. Rostov<sup>3</sup>

<sup>1</sup>Institute of Applied Physics RAS, Nizhny Novgorod, Russia

<sup>2</sup>Institute of Electrophysics, UB RAS, Ekaterinburg, Russia

<sup>3</sup>Institute of High-Current Electronics, SB RAS, Tomsk, Russia

**Abstract**— Recently coherent summation of several SR pulses generated in parallel channels has been demonstrated in X- and Ka wavelength bands. This possibility is caused by picosecond stability of explosive emission from a cold cathode and strong correlation of phase of the SR pulses with respect to the leading edge of the electron bunch. In fact stimulated SR emission is initiated by spontaneous emission from bunch leading edges. In report we describe results of recent experiments and develop a theoretical model which covers both spontaneous and stimulated Cherenkov emission.

## I. INTRODUCTION

Recently significant progress has been achieved in generation of electromagnetic pulses in centimeter and millimeter waveband based on Cherenkov superradiance of extended electron bunches moving in periodical slow-wave structures [1]. Generated pulses are characterized by record-breaking (gigawatt) peak power and ultra-short (subnanosecond) duration. In experiments the high reproducibility of SR pulses has been observed (Fig.1a) that is caused by the correlation of phase of a radiated SR pulse with the sharp edge of a current pulse. In fact, spontaneous emission of the electron bunch edge serves as the seed for SR processes. It gives rise to the stimulated emission including electron self-bunching and subsequent radiation of the short high-power electromagnetic pulse. If identical current pulses are sent simultaneously to several channels, identical SR pulses will be generated and the coherent summation of their amplitudes is possible (Fig.1b). Recently it has been experimentally demonstrated in X- and Ka-band [2,3]. This paper is devoted to development of theoretical model describing the transformation of spontaneous emission from sharp front of electron bunch to stimulated superradiant process.

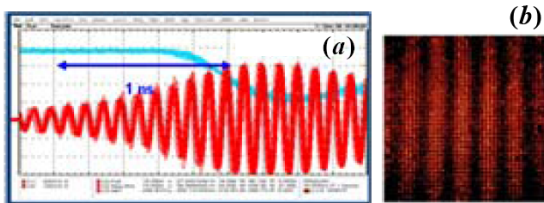


Fig. 1. (a) Oscilloscope traces of 10 X-band SR pulses. (b) Interference pattern of SR pulses formed in two channels

## II. BASIC MODEL AND RESULTS OF SIMULATIONS

We considered the simplest model of SR pulses generation initiated by a radiation of a sharp edge of extended electron bunch moving with the longitudinal velocity  $v_0 = \beta_0 c$  in a planar waveguide with periodically corrugated walls  $b(\xi) = b_1 \sin(\bar{h}\xi)$ , where  $b_1$  is the corrugation amplitude,

$\bar{h} = 2\pi/d$ ,  $d$  is the corrugation period. In the frame of our model in commoving reference frame the electron bunch is described as the gas of macroparticles with length  $\Delta l$  and charge density  $\sigma$  interacting via the average longitudinal force with profile given by following relations:

$$\tilde{F}_z(\xi - \xi_0) = \begin{cases} -\frac{\pi e (\bar{h} b_1)^2 |\sigma| \Delta l}{b(1 + \beta_0)} \cos\left(\frac{\bar{h}(\xi - \xi_0)}{1 + \beta_0}\right), & \xi < \xi_0 \\ -\frac{\pi e (\bar{h} b_1)^2 |\sigma| \Delta l}{b(1 - \beta_0)} \cos\left(\frac{\bar{h}(\xi - \xi_0)}{1 - \beta_0}\right), & \xi > \xi_0 \end{cases}$$

This force has an alternating sign, that leads to development of self-bunching) of electrons (Fig.2a) and formation of SR pulse with power significantly exceeding the power of spontaneous emission from front of electron current. The instantaneous distribution of the radiated field is shown in Fig.2(b).

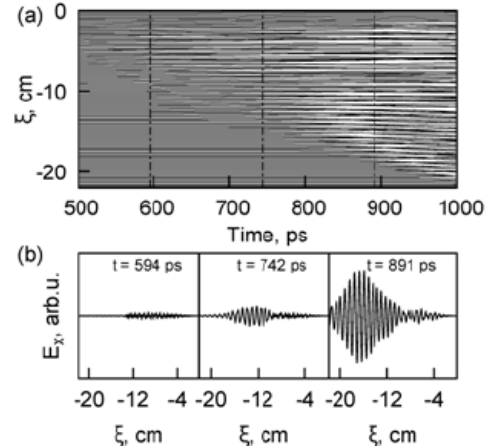


Fig.2 (a) Electrons self-bunching and (b) SR pulse longitudinal profile in different moments of time.

This work was supported by Russian Foundation for Basic Researches (RFBR) (Grant No. 14-08-01180)

## REFERENCES

- [1] S.D.Korovin, A.A.Eltchaninov, V.V.Rostov, V.G.Shpak, M.I.Yalandin, N.S.Ginzburg, A.S.Sergeev, and I.V.Zotova "Generation of Cherenkov superradiance pulses with a peak power exceeding the power of driving short electron beam", *Phys.Rev.E* 74, 016501, 2006
- [2] V.V.Rostov, A.A.El'chaninov, I.V.Romanchenko, M.I.Yalandin, "A coherent two-channel source of Cherenkov superradiance pulses," *Appl. Phys. Lett.*, 100, 224102(4), 2012.
- [3] K.A.Sharypov, A.A.El'chaninov, G.A.Mesyats, M.S.Pedos, I.V.Romancheko, V.V.Rostov, S.N.Rukin, V.G.Shpak, S.A.Shunailov, M.R.Ul'masculov, and M.I.Yalandin, "Coherent summation of Ka-band microwave beams produced by sub-gigawatt superradiance backward wave oscillators," *Appl. Phys. Lett.*, 103, 134103, 2013