Gyrodevices as Power Sources of Electromagnetic Waves in the Microwave Band

L. V. Kasatkin, G. N. Rapoport, and V. P. Taranenko
Scientific-Research Institute “ORION”, Kiev, Ukraine

Received in final form March 14, 2007

Abstract—The evolution of gyrodevices (generators and amplifiers) where curvilinear electron beams interact with non-slow electromagnetic waves has been reviewed. The material presented covers stages of the development of gyrodevices during the 50 years from the time of their conception till the present time when devices of this class have been qualified as the most powerful VD in the millimeter wave band.

DOI: 10.3103/S0735272708010020

One of the main difficulties in creating conventional classes of vacuum devices (VD) operating in the millimeter wave band involves the need of building slowdown high-frequency systems and cavities having the size of elements of less than wavelength. In this case, in the short-wave part of the millimeter wave band major technological difficulties arise in manufacturing the high-frequency systems due to the need of ensuring a required accuracy of dimensions and quality of the surface processing. In addition, such systems are characterized by enhanced high-frequency losses, reduced electrical strength, and significant drop in thermal heat-resistance. The specified factors in the long run result in an essential degradation of power characteristics of VD of both “O and M types” in the millimeter wave band.

The use of electron flows with oscillating motion of electrons interacting with non-slow electromagnetic waves enabled the researchers to overcome the specified difficulties.

VD featuring the oscillating motion of electrons can be built using different types of motion of electrons: rectilinear with irregularities of motion caused by the periodic acceleration and deceleration in static electric fields [1], wave-like, helical, trochoidal, and other trajectories.

Invention and the initial studies of design principles of VD with curvilinear electron flows interacting with non-slow waves in smooth electrodynamic systems date back to the 1950s. The idea of a possible efficient interaction of curvilinear electron flows with non-slow electromagnetic waves is based on the concept of phase velocity of a sequence of charged particles introduced by S. I. Tetel’baum back in 1954 [2].

This study showed that if aggregated electron bunches of small size with angular frequency $\omega$ travel along the wave-like or helical trajectory in the field of plane wave with a transverse component of the electric field strength, the extended interaction of bunches with the wave will be the most efficient under conditions of their proper phasing and the validity of the following condition

$$v_{ph} = v_z \frac{\omega}{\omega - \Omega}.$$ (1)

Here $\Omega$ is angular frequency of the trajectory of bunches, $v_z$ is the longitudinal velocity of electrons, $v_{ph}$ is the phase velocity of wave, $v_z \frac{\omega}{\omega - \Omega}$ is the phase velocity of a sequence of particles; in this case, the displacement velocity of an envelope of bunches. At $\omega > \Omega$ the phase velocity of a sequence of particles coincides in its direction with that of $v_z$. At $\omega < \Omega$ these velocities are directed into opposite directions and the charged particles will give their energy to the backward wave moving opposite to the linear motion of electrons. In this case, the phase velocity of a sequence of particles can be considered negative. During the interaction of a wave-like electron flow with a plane wave the negative phase velocity of a sequence of particles creates an internal feedback in the high-frequency system representing a basic operation principle of self-excited backward wave generators.