INFLUENCE OF THE LOCAL INHOMOGENEITY OF A MAGNETOSTATIC FIELD ON THE START AND OUTPUT CHARACTERISTICS OF A DIFFRACTION RADIATION GENERATOR

A. I. Tsvyk, G. S. Vorob'yov, A. V. Nesterenko, and V. N. Zheltov

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We study, both theoretically and experimentally, the possibilities of improving the output characteristics of a nonrelativistic diffraction radiation generator (DRG) by creating a local inhomogeneity of the magnetostatic field (LIMF) in the electron-wave interaction region. The LIMF was created in a homogeneous focusing magnetic field using a ferromagnetic rod. We found relationships for calculation of the main characteristics of the LIMF and showed the dependence of the start current on the size of the rod and its location relative to the interaction region. The theoretical results were confirmed by the experimental studies of DRGs in the frequency range 40 to 170 GHz. It is shown that the use of an LIMF improves the start, power, and spectral characteristics of the DRG. We conclude that the proposed technique is useful for designing low-voltage generators with improved output characteristics at short millimeter and submillimeter wavelengths.

1. INTRODUCTION

The possibilities of using spatially inhomogeneous static fields to increase the efficiency of electron-wave interaction and improve the output characteristics of microwave devices have been studied by many authors [1-4]. Clinotrons, magnetrons, and cyclotron resonance devices are best examined along this direction. The output characteristics are improved by using a focusing magnetostatic field which is oblique to the electron beam (EB) in clinotrons [1], and by profiling the magnetostatic field in M-type devices and gyrotrons [2-4]. It is assumed that the same method can be employed to improve the output characteristics of a DRG [5]. However, the studies in this field, and the experimental studies in particular, are not sufficient.

It is well known that a DRG is a source of highly coherent millimeter and submillimeter-wave oscillations. Compared with classical generators, these devices have improved output characteristics, which provides broad possibilities for practical use of DRGs in various fields of science and engineering. At the same time, a decrease in the wavelength in a nonrelativistic (low-voltage) DRG leads to a considerable decrease in the effective thickness of the EB and to higher requirements in the manufacturing technology of diffraction gratings. (In a DRG, the effective thickness $\Delta$ of the EB is estimated from the relation $\Delta \approx \lambda \beta / \pi = \lambda / \pi$, where $\lambda$ is the wavelength of the excited oscillations, $\beta = v/c$ is the ratio of the electron velocity $v$ to the light velocity $c$, and $\lambda$ is the spacing of the grating.) In submillimeter-wave generators, this makes one switch to higher accelerating voltages and solve the problem of generating a thin rectilinear EB [6]. Thus, it is important to study the possibilities of increasing the efficiency of energy exchange in the region of interaction with a thick (compared with the effective thickness $\Delta$) EB by profiling the focusing magnetostatic field. By convention, the EB in a DRG is focused by a homogeneous focusing magnetostatic field [7-9]. The possibility of using a LIMF to improve the output characteristics of a DRG was reported.
for the first time in the experimental paper [10], and the more recent theoretical studies [11, 12] also showed
good prospects for this approach.

In this paper, we study the characteristics of the LIMF created by a ferromagnetic rod in the electron-
wave interaction space of the DRG and examine the influence of this inhomogeneity on the start current and
other characteristics of the generator. The results of experimental investigation of the output characteristics
of such a generator in the frequency range 40 to 170 GHz are presented.

2. THEORETICAL STUDIES

Consider a DRG in which the local inhomogeneity of a magnetostatic field in the interaction region
is produced by a ferromagnetic cylindrical rod located under the grating [10]. A theoretical model of the
interaction space of such a generator (we call it a DRG-MI) is shown in Fig. 1, where $2z_0$ is the equilibrium
thickness of the EB, $a$ is the target parameter, $r_e$ is the amplitude of transverse static displacements (pul-
sations) of the boundary electrons (in a DRG, the relation $a \leq r_e$ usually holds), $a_z = z_0 + a + h_z$ is the
distance from the EB axis to the rod surface, $h_z$ is the distance between the grating and the rod surface,
$r$ is the radius of the rod, $\mu$ is the magnetic permeability of the rod, $y_m$ and $z_m$ are the coordinates of the
rod center, $L$ is the length of the grating, $0 < y_m < L$, and $z_m = -(a_z + r)$. In the chosen coordinate
system, the $y$ axis coincides with the axis of the ribbon electron beam and the induction direction $B_0$ of
the homogeneous focusing magnetostatic field, the $z$ axis is normal to the surface of the reflection grating
located in the plane $z = -(z_0 + a)$, and the $x$ axis is parallel to the rod axis and the grating bars. Hereafter
the vertical dashed lines show the boundaries of the electromagnetic field spot on the grating, which is
usually formed in the open resonator (OR) of the DRG. We now determine the main characteristics of
the LIMF created in the region of interaction with the ferromagnetic rod and analyze the influence of this
inhomogeneity on the excitation of electromagnetic oscillations in the DRG.

2.1. Main characteristics of the LIMF

The existence of a ferromagnetic rod in the homogeneous static field $B_0$ leads to bending of the
field lines toward the rod surface and the formation of a LIMF with longitudinal ($B_y$) and transverse ($B_z$)