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Radiation hardness of subterahertz radiation source based on heterodyne on Gunn diode generator and superlattice multiplier

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The radiation resistance to gamma irradiation of various dose levels (0.5 kGy, 2 kGy, 10 kGy) of a subterahertz radiation source from a heterodyne on a Gunn diode and a GaAs / AlAs semiconductor superlattice multiplier was estimated. A measuring chamber for studying the radiation resistance of Gunn diodes has been developed and manufactured. The dependence of the output power on the frequency of a sub-terahertz radiation source before and after irradiation was evaluated analytically.

Keywords: radiation hardness, superlattice, Gunn diode, terahertz.

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Introduction

Currently the sources and receivers of electromagnetic waves of subterahertz and terahertz ranges with frequency tuning broad band are widely used to solve the tasks of the spectroscope [1], radioastronomy [2], building of safety systems [3] and telecommunications [4,5], battlefield control systems [6]. However, the application in military and space complexes imposes to receive-transmit equipment the strict requirements on weight and size characteristics, small values of supply voltage and resistance to ionizing radiation. One of such radiation sources is a device, consisting of heterodyne on Gunn diode (GD) oscillator and multiplier on semiconductor superlattice (SCSL) [7]. Currently the resistance of the conventional volumetric [8] and planar GD [9], as well as diodes based on GaAs/AlAs superlattices [10], to ionizing types of radiation is actively studied; radiation resistance of subterahertz range source based on GD and SCSL is examined in this study.

1. Experiment preparation

GD, similar to 3A763LM (developed by JSC „SPE „Salyut", Nizhny Novgorod), was used as an active element for the heterodyne. The basic oscillating frequency of such diodes is in 8-mm range. The diode has a vertical structure, in which the diode contacts are located on the upper and lower edges of crystal. The diode is a semiconducting crystal of gallium arsenide with diameter of about 0.1 mm and thickness of $10-20\,\mu$m, mounted on the heat-removing crystal holder — copper bar with diameter of 1.2 mm and height of 2 mm. Carriers concentration is $n_0 = 8 \cdot 10^{15}\,\text{cm}^{-3}$, active area size is $3\,\mu$m. All three GDs, examined in this study, have the similar parameters within the process accuracy.

The measuring chamber was developed and manufactured to study the operating parameters of GD. The chamber design features allow to install the diode in a cavity of configurable waveguide section without soldering the active element for several minutes and to measure GD characteristics for radiation stability study using non-destructive method. The diode is mounted to the chamber using a collet clamp. Introduction of a band rejection filter in the evanescent for the basic frequency waveguide maximally decouples the circuits at the basic frequency and the second harmonics of the basic frequency for independent settings as per output frequency and power. The specified advantages of the process chamber expand the application scopes of the developed accessory equipment for in-process control and released products sorting at series manufacturing.

2. Experimental procedure

Measurement of the oscillating frequency and power of GD was performed as per scheme, described in detail in study [11]. At bias voltage supply to the diode the electromagnetic oscillations with frequency of about 30 GHz were induced in the chamber. UHF power from the chamber outlet comes through the waveguide with cross section of 3.6×1.8 mm to the primary transducer M5-50, then it is conversed, and the value of the output power level is displayed on the indicator of the power meter M3-22. Measurement of the oscillating frequency is performed using the resonant frequency meter Ch2-26. Extraction of GD oscillating frequency is performed by changing the position of the tuning short circuiters and by output circuit frequency. The value of the measured power appears on the scale of indicator M3-22, reduced by a factor of 2–3.

After obtaining the dependencies of the signal output power on frequency the GDs were exposed to irradiation with gamma rays with the summary dose of: GD № 1 — 0.5, GD № 2 — 2, GD № 3 — 10 kGy. After 6 months the series of measurements was performed for all examined GDs.

3. Results and discussions

Comparing the results of measurements of the operating parameters before and after irradiation: for GD № 1 (Fig. 1) the broadening of the operating frequency band compared to parameters before irradiation was observed, for GD № 2 (Fig. 2) — reduction of the frequency band by 3.8%, for GD № 3 (Fig. 3) — broadening by 6%. After irradiation with gamma rays the reduction of GD output power for the larger part of the observed dependencies is observed.

In study [12] the values of intensity of harmonics of the frequency multiplier on SCSL in the frequency band of

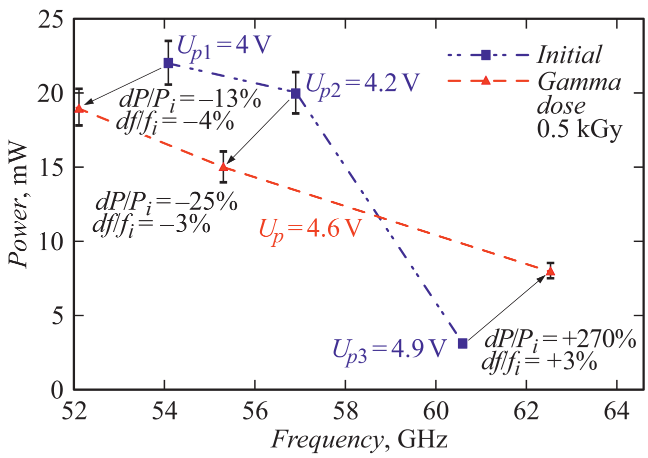

Figure 1. Results of measurement of output power from oscillating frequency for GD № 1.

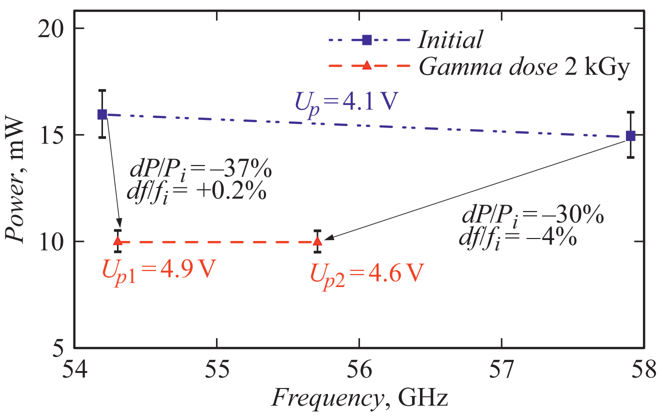

Figure 2. Results of measurement of output power from oscillating frequency for GD № 2.

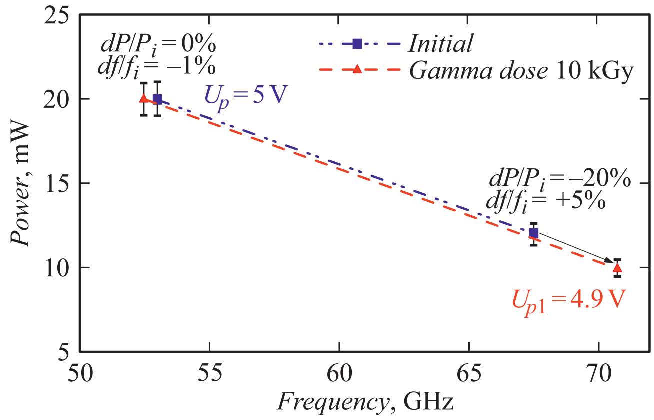

Figure 3. Results of measurement of output power from oscillating frequency for GD № 3.

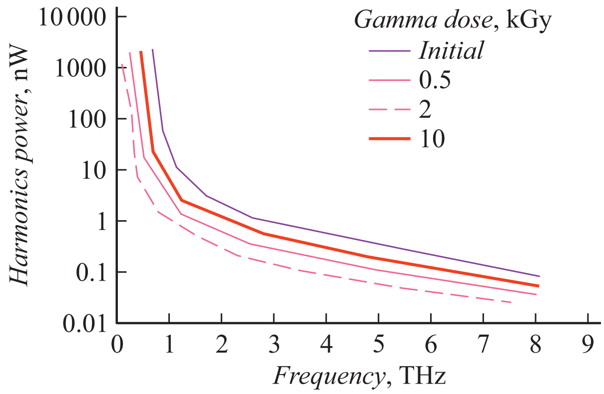

Figure 4. Evaluation of harmonics power dependence on oscillating frequency of subterahertz radiation source.

0.4–6.5 THz are observed; in study [10] the research of the radiation stability of the diodes on GaAs/AlAs SCSL is presented. Based on the early observed power dependencies on GD oscillating frequencies, considering nature of variation of GD (№№ 1, 2, 3) operating characteristics before and after irradiation with gamma rays, it is possible to evaluate the harmonics power dependence on frequency of the subterahertz radiation source as part of the heterodyne on GD and the multiplier on SCSL in general (Fig. 4). The third harmonic of the oscillator ($3 \cdot 54$ GHz) on GD with a value of 162 GHz was selected as a reference frequency of the heterodyne. For dose of 0.5 kGy the oscillator on GD № 1 was selected as the heterodyne, for dose of 2 kGy — GD № 2, 10 kGy — GD № 3. At heterodyne irradiation with gamma rays with doses of 0.5 and 2 kGy the power level of harmonics of the source of THz-radiation is reduced in inverse proportion to the dose value. For dose of 10 kGy the power level of harmonics of the source exceeds the level for 0.5 kGy, but remains less than the level before irradiation.

Novelty of the examined chamber is in possibility of operating parameters measuring for studying the radiation resistance and determination of GD parameters for the further computer simulation (TCAD, ATLAS software packages).

Conclusion

The study presents the dependencies of the output power on the frequency of the heterodyne on GD before and after irradiation with gamma rays of various intensity (0.5, 2, 10 kGy). Based on the measurements of the operating characteristics of the heterodyne on GD and theoretical results of the radiation resistance of SCSL the conclusions were made on radiation resistance to gamma-radiation of the subterahertz radiation source in general.

Conflict of interest

The authors declare that they have no conflict of interest.

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