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GYROTRON COLLECTOR SYSTEMS: TYPES AND CAPABILITIES

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A classification and a comparative analysis of the collector systems of gyrotrons of different frequency ranges and power levels are presented. Both the classical schemes of gyrotron collectors with an adiabatic magnetic field and new ones, including the systems with dynamic scanning of the electron beam, collectors with a highly nonuniform field, as well as multistage recovery schemes, are considered. Recommendations on the use of this or that type of collectors, depending on the output power of the device and the pulse width, are given.

Keywords: gyrotron; electron beam; collector; energy recovery

1. Introduction

Gyrotrons, which are a variety of cyclotron resonance masers [1], are now undoubted leaders among the sources of electromagnetic radiation in the millimeter and submillimeter wavelength ranges both in terms of the output power level and the achieved generation frequencies, differing at the same time in relative compactness and moderate (in comparison with free-electron lasers) cost (the characteristic overall size of continuous-wave gyrotrons of the megawatt power level does not exceed 3 m, while the cost of the device is several hundred thousand dollars). The operating frequencies of gyrotrons lie in a range of 20 GHz [2,17] to 1.3 THz [2,4,5], and the power varies from tens of watts to a few megawatts [2,3], reaching 10-15 MW for relativistic tubes [2].

As is known, the electron efficiency of gyrotrons is relatively small, about 30-40% in the millimeter wavelength range [2]. For a number of reasons, in particular due to an increase in ohmic losses, this figure is several times smaller for the submillimeter range [4]. Therefore, most of the residual power of the electron beam after interaction with the microwaves must be scattered at a copper collector cooled by water. In modern high-power gyrotrons, the collector experiences large thermal loads and the main problem in the construction of a collector system is to provide a sufficiently small specific power density dissipated on the collector wall and, as a consequence, ensure its durability. Recently, attention has increasingly been paid to circuits with electron energy recovery, which along with the reduction in the thermal load provide a significant increase in the total efficiency of the device. Many papers have been devoted to the development of collector systems (see a list of references below), but most of these examples are aimed at realizing a specific device with a given fairly narrow range of parameters. At the same time, the requirements for the gyrotron power are constantly increasing. In particular, for the project of a fusion power plant of the future, such as DEMO, the possibility of increasing the gyrotron power by two times (up to 1.5-2 MW) is discussed, which will sharply complicate the heat sink from the collector. A wide variety of currently existing types of gyro devices leads to a large specificity of the corresponding collector systems. Therefore, for the proper design of the collector, it seems relevant to classify and assess the potential capabilities of each type of