TERAHERTZ FREE ELECTRON LASER WITH AN ELECTRODYNAMIC SYSTEM BASED ON THE EXCITATION OF TALBOT-TYPE SUPERMODES*

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Currently, there is a growing interest in creating sources operating in the terahertz frequency range with high radiation power. The natural way to implement such a source is to use the radiation of a high-current relativistic electron beam. However, there are a number of problems associated with the generation of powerful coherent THz radiation in free electron masers based on relativistic electron beams. First of all, the application of the traditional approach (i.e., operating on one pre-selected cavity mode) to the THz frequency range faces natural difficulties. Obviously, the cavity in this case must be oversized; this is necessary for a number of reasons, namely, the transportation of a relativistic high-current beam, the problem of breakdown of the field of powerful radiation inside the cavity, ohmic heating of the walls of the resonator by powerful radiation, etc. However, in this situation, the spectrum of transverse modes of the microwave system becomes very dense, which makes it difficult to ensure selective excitation of one operating transverse mode. The second problem is the difficulty of providing selective single-mode feedback in a oversized system.

We describe an alternative concept of selective excitation of a operating oscillation in an electron maser with a oversized electrodynamic system powered by a high-current relativistic electron beam. The main idea is to abandon the excitation of a fixed resonator mode in favor of the excitation of a high-Q supermode formed by a fixed set of transverse modes of a oversized waveguide. Such a supermode can be formed inside a relatively simple cavity, which is a segment of a waveguide ending in two mirrors, as a result of the Talbot effect, namely, periodic reproduction of the transverse structure of a multimode wave field in a oversized waveguide [1].

Despite the complexity of multidimensional spatial structures of Talbot-type supermodes, the ideology that is used in describing the modes of conventional waveguides and resonators, namely decomposition by a set of orthogonal modes, can be applied to them to some extent. Although the formation of supermodes involves a large number of partial transverse modes, the number of supermodes with high Q-factor is limited by the fact that the diffraction Q-factor of a supermode decreases sharply with an increase in the supermode index. Thanks to this, even in very supersized systems, it is possible to ensure that only one lower supermodel remains in the system [2]. Apparently, this gives us a reason to talk about the unique selective properties of Talbot-type caviries.

As an example of the application of this approach, we will present simulations of a free electron laser powered by an electron beam of 10 MeV/2 kA /200 ns and based on the excitation of a Talbot-type supermode at a frequency close to 2 THz. This work is aimed at the experimental implementation of such a laser on a unique high-current accelerator developed at the Budker Institute of Nuclear Physics[3]. The report presents the results of our multi-wave modeling of electron-wave interaction in the space-time process of formation and amplification of a supermode in a oversized microwave system. The calculated electronic efficiency of this laser at the level of 5% corresponds to the gigawatt level of output power. A prototype cavity has been developed and tested in cold experiments.

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