POWERFUL LONG-PULSE FEL OSCILLATOR IN THE SUB-THZ/THZ RANGE: DEVELOPMENT AND TESTING OF AN ELECTRODYNAMIC SYSTEM *

N.YU. PESKOV[1,2], A.V. ARZHANNIKOV[2], V.I. BELOUSOV[1], N.S. GINZBURG[1,2], D.A. NIKIFOROV[2], YU.S. OPARINA[1,2], M.D. PROYAVIN[1], A.V. SAVILOV[1], E.S. SANDALOV[2], S.L. SINITSKY[2], V.YU. ZASLAVSKY[1]

[1]Federal Research Center Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Russian Federation
[2]Budker Institute of Nuclear Physics of Siberian Branch Russian Academy of Sciences, Novosibirsk, Russian Federation

Development of a high-power long-pulse FEL operating from the sub-terahertz to the terahertz range was initiated in collaboration between the INP SB RAS (Novosibirsk) and the IAP RAS (Nizhny Novgorod) based on a new generation of linear induction accelerators "LIA 5" - 20 MeV / 2 kA / 200 ns. The goal of the project is to achieve a record sub-gigawatt power level and energy content in radiation pulses up to 10 – 100 J in the specified ranges. One of the key problems in the implementation of this FEL is the development of an electrodynamic system capable of providing stable narrow-band generation under conditions of significant oversized factor.

To ensure the current passage of an intense electron beam formed by the LIA through the FEL interaction space, the diameter of the system should be $Ø \geq 20$ mm, which is orders of magnitude greater than the radiation wavelength in the discussed ranges. To solve the problem of mode selection under these conditions, two main types of electrodynamic systems have been studied: (1) modified Bragg resonators and (2) quasi-optical Talbot resonators.

A distinctive feature of the modified Bragg resonators is the inclusion of quasi-cutoff waves in the feedback loop, which makes it possible to significantly improve their selective properties compared to conventional analogs. To operate in the range of 0.7 THz, structures of this type were developed with a diameter of $Ø \approx 20$ mm ($Ø/\lambda \sim 45$) and a length of about 5 cm, an axisymmetric corrugation with a period of 0.43 mm and a depth of 0.15 mm provided a feedback cycle $TE_{1,1} \leftrightarrow TE_{1,45} \leftrightarrow TE_{1,1}$. Three-dimensional modeling using the CST Microwave Studio software shows that even with such large transverse dimensions, the modified Bragg structures allow selective reflection of the operating wave with an efficiency of ~ 80 – 90 % in power. The performed “cold” electrodynamic tests confirm the simulation results and demonstrate the presence of effective narrow-band reflection in the calculated frequency range.

To carry out “cold” tests of an electrodynamic system of the second type, a model of a Talbot resonator was made with a diameter of 36 mm ($Ø/\lambda \sim 40$) and a length of about 80 cm for operation in a frequency range of about 0.3 THz. The mirrors located at the edges had a width of 4 mm; a coupling hole with diameter 2 mm was made on the output mirror (the position of the hole corresponded to the position of the calculated field maximum). The resonator was excited from the input side of the resonator by a $TE_{1,1}$ wave. According to the simulation, this wave is effectively transformed into the $TE_{1,7}$ wave, which is maximally represented in the supermode at the operating frequency. The detection of the output signal was carried out through the specified coupling hole. The simulation shows that at the frequency corresponding to the desired supermode, there should be a power peak at the coupling hole. In accordance with the simulation results, in the carried out "cold" tests, a well-defined peak of the detected output power at the calculated frequencies was observed, which thus confirmed the operability of this type of resonator.

* This work was supported by Russian Scientific Foundation (RSF), project 19-12-00212.