HIGH-GRADIENT ACCELERATION OF ELECTRON BEAM BY SUPERRADIATIVE MICROWAVE PULSE*

K.A. SHARYPOV[1], N.S. GINZBURG[2], V.G. SHPAK[1], S.A. SHUNAILOV[1], M.I. YALANDIN[1], I.V. ZOTOVA[2]
[1]Institute of Electrophysics UB RAS, Ekaterinburg, Russia
[2]Institute of Applied Physics RAS, Nizhny Novgorod, Russia

The prospect of high-gradient electron acceleration by microwave superradiance (SR) pulses is related to the fact that in the millimeter-wave band such pulses are shorter than 300 ps, and at low exposures of a strong microwave field, breakdowns of electrodynamic structures are delayed. For example, in a relativistic backward wave oscillator (BWO), it is possible to obtain Ka-band SR pulses with a power of 1–3 GW, although the microwave field strength on the wall of the slow-wave structure (SWS) exceeds 2 MV/cm [1, 2]. Apparently, at the edges of a resonant reflector located at the SWS entrance, many times larger fields arise. The report presents a model of acceleration of a paraxial electron beam in a low-Q “pill-box” cavity [3] pumped by Ka-band SR pulse.

An experimental scheme proposed in [4] is considered, where devices for SR generation and electron acceleration are combined in one block. Coaxial electron beams are used, which are formed from the cathodes powered by the same voltage pulse (-300 kV; 2 ns). The outer tubular beam is used to excite SR BWO, while the inner (paraxial) beam is accelerated. For its emission, a needle cathode is used, the axial position of which determines the beam current. In test experiments this current varied within 15-150 A. In the simulations by particle-in-cell method (KARAT code [5]), it reached ≈250 A. Since the SWS has an average diameter larger than the generation wavelength, it is possible to place a “pill-box” cavity with a central hole for introducing paraxial beam in front of the SWS entrance. The outer tubular beam passes in a narrow annular slot between the anode constriction before the SWS entrance, and the outer wall of the “pill-box” cavity. With that, a resonant reflector at the SWS entrance is not required. After “pill-box” pumping, the used SR pulse is output in the direction of external beam collector. Due to the gap between solenoid windings, magnetic field transporting the beams is profiled to drop external beam onto collector after the SWS. The area of paraxial beam registration by the current probe is located further than this collector.

At a magnetic field induction of ≈7 T in the SWS region, the simulated peak power of SR pulse at the “pill-box” cavity entrance reaches 1 GW. Acceleration effect for a paraxial beam is tracked in numerical simulations using a phase portrait of electron bunches. At the cavity pumping peak, a normalized electron momentum $p_z/mc \approx 4.5$ is reached, which corresponds to their kinetic energy of 1.85 MeV. Thus, a paraxial beam with initial energy of ≈250 keV has accelerated to 1.6 MeV. Since the depth of the “pill-box” cavity is 0.4 cm, the acceleration gradient turns out to be 400 MeV/m. An integral phase portrait of the accelerated beam separated by radius shows $p_z/mc \approx 5$ for paraxial particles at some instants, which corresponds to an energy of ≈ 2.1 MeV. However, this indicator does not refer to the particles at the “pill-box” exit, but to those localized along the SWS closer to the collector. In this additional acceleration, one can assume the influence of the non-synchronous interaction of paraxial bunches with *z*-field of SR wave (TM_{01}), which moves slower than the fast incidental electrons.

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