A LOW FREQUENCY RF ELECTRON LINAC FOR AN IR FEL

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Abstract

The status of the specialized RF linac for an infrared free electron laser at P.N.Lebedev Physics Institute is described. The accelerator is designed to produce a high quality electron beam in energy range up to 20 - 25 MeV with a peak current up to 100 A in a 100 mks long train of micropulses. Duration of the micropulses is in the range of 100-200 ps. To achieve the desired energy spread as small as 1% a rather low frequncy of 150 MHz has been chosen for the accelerating structure which is a chain of independently fed cavities. Duration of RF pulses is 300 mks with maximal repetition rate of 1 Hz. A RF photocathode laser driven gun at the main frequncy is used for short pulses production. The initial part of the accelerator for 4 MeV including RF gun and two full scale cavities of the regular structure now is under tests.

Introduction

The choice of construction and parameters of the accelerator was based on the desire to obtain a FEL radiation power of 1 kW in a macropulse of 100-mks duration at a radiation wavelength > 10 mkm [1, 2]. To attain these values, the energy of electrons at the accelerator output should be 20 - 25 MeV for a peak current of 50 - 100 A in micropulses of 100-ps duration and 50-MHz frequency.

The accelerating structure consists of a chain of independently exited resonators. This permits successively increasing the number of accelerating resonators and, correspondingly, the output energy. The calculated increment of electron energy at each of the main resonators is 2 MeV.

The structural scheme of the accelerator is shown in Fig. 1, which differs somewhat from that chosen earlier [1]. In view of the considerable lengthening of microbunches with large peak current at low electron energy in the region between RF-gun and first main resonator, the gun RF-resonaror is located directly in the capacitive insert of the main resonator. The beam is focused by short solenoidal lenses in the intervals between resonators.

Photoinjector and laser-illuminator

The RF-gun consists of a coaxial quarter-wave resonator, the capacitive part of which is the diode gap of the gun. The scheme and construction of the new built-in RF-gun will be similar to the present one in a separate resonator (Fig. 2), except for the photocathode illumination scheme. Owing to very limited access, the most practical appears to be a scheme of cathode illumination along the axis with translation of the electron beam axis at the output of the accelerating structure. Reconstruction of the injector is planned after performing experiments with the present injector.

After investigating various materials for photocathodes [3], the choice fall on Cu + 10% BaO photocathode, capable of functioning in conditions of medium vacuum, stable in atmosphere, and having high quantum yield at the fourth harmonic of a neodimium laser. Such cathodes are easily activated, even after being in air for a long time, by heating the emitting surface to 800C.

To obtain a 50-A photocurrent, the required power of bias lighting is 0.15 MW, or a radiation energy of 15 mJ in a pulse of 100-ps duration. If one takes into account the transformation efficiency in the fourth harmonic, the peak radiation power of a neodymium laser shold be > 1.5 MW and the average power 45 kW.

A hybrid scheme was chosen to achieve the required time structure of the beam. It consists of a pulsed YAG-laser (master ocsillator and amplifiers) with constant pumping spead over entire duration of the pulse. Constancy of pumping spead is provided by feeding the pulsed tube from a storage source in the form of a uniform artificial line. The optical resonator is close to semi-spherical with a 50-MHz frequency of inter-modal beats. Active synchronization of modes is by means of a 150-MHz acoustic-optical modulator. The long (300 cm), close to semi-spherical resonator permits effective use of the volume of the crystal. Tree-fold reduction of the frequency of inter-modal beats with respect to the frequency of Q modulation does not prevent obtaining micropulses with a repetition rate of 150 MHz and when necessary permits going over to a regime of three-fold "thinning". Introduction of weak (about 3%) electro-optical negative feedback permits quite rapidly (10 - 30 mks from the beginning of generation) to achieve a stationary regime. Feedback is introduced by means of a DKDP crystal, which simultaneously serves as a polarizer. The control signal to the crystal comes from a photodetector (photodiode) via an amplifier.

The generator of the illuminator has been assembled and at present is being adjusted in the accelerator hall. The energy in a macropulse (for the first harmonic) is 1 - 2 J.

This generator can operate at a pulse repetition rate of 1 Hz and permits obtaining a photocurrent of up to 10 A, which is quite sufficiently for the entire accelerator without additional amplifier cascades. RF-field in the resonator is synchronized with the repitition rate of micropulses: synchropulses are taken from the photodetector.

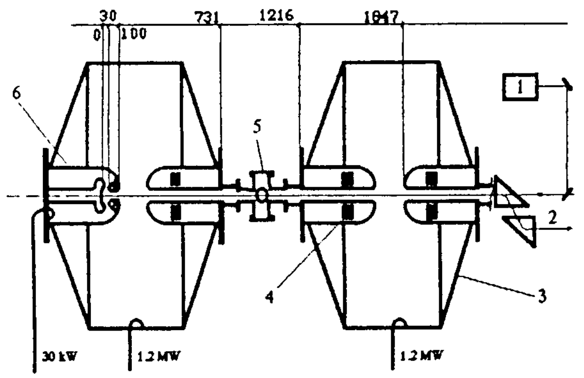

Fig. 1. Scheme of the accelerating structure:
1-laser; 2-electron beam; 3-main resonator; 4-focusing coils; 5-diagnostic port; 6- coaxial built-in resonator.

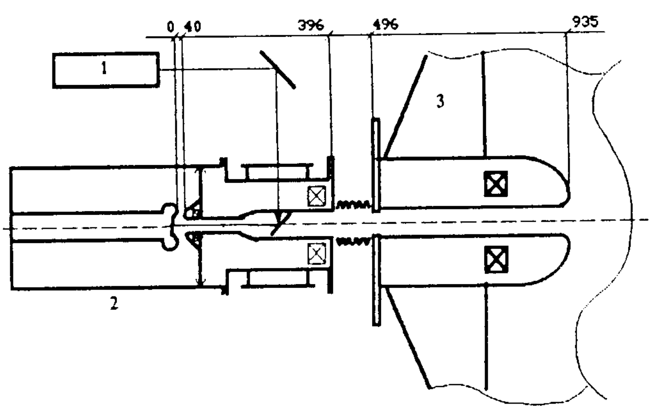

Fig. 2. Geometry of the existing photoinjector:
1-laser; 2-coaxial resonator; 3- main resonator.

The coaxial resonator of the photogun has been assembled, pumped out and supplied with RF-power. Stable operation of the resonator was achieved for RF-power of 30 kW and pulse repetition rate of 1 Hz only after local heating of resonator elements. Results of cold measurements for RF-power of 30 kW indicate that the average electrical field intensity on the resonator axis is 65 kV/cm, which corresponds to 260 kV total voltage.

Accelerating resonators

Two full scale resonators were constructed using as a base cylindrical flat sides cavities designed for 200 MHz. Capacitive isertions were introduced from both sides of the cavities to lowering the resonant frequency up to 150 MHz. The length of the acceleration gap after this modification is 19 cm.

The calculated value for the amplitude of accelerating field on the axis of the resonator is 110 kV/cm when 0,95 MW is introduced into the resonator. This yields an energy increment of 1.8 MeV and amounts to about 80% of the critical field intensity determinated by the Kilpatrik criterion for the given frequency. The measured Q of the resonator is 21430 and the schunt impedance is 3.4 MOhms.

At full level of power >1 MW the each resonator will be exciting by means of two inductive loops connected by two flexible cables to the output loops of the powerful cascade of the RF generator. During the testing the resonators were excited using only one of two loops. Stable operation at intermediate power level 200 kW was achieved after seven hours of training.

RF supply system

The RF supply system of the initial part of the accelerator (Fig. 3) is based on amplifying a stable signal from a quartz generator.

The power amplifiers contain tetrodes 6P23P (a buffer amplifier and preliminary amplifiers in each cascade), triodes GI-7B and GI-39B (supply channel of coaxial resonator) and tetrodes GI-58A and triodes GI-57A, combined in a common generator module (supply channels of resonators with regular structure at intermediate power level). Powerful output cascades based on triodes GI-27AM have been constructed and assembled.

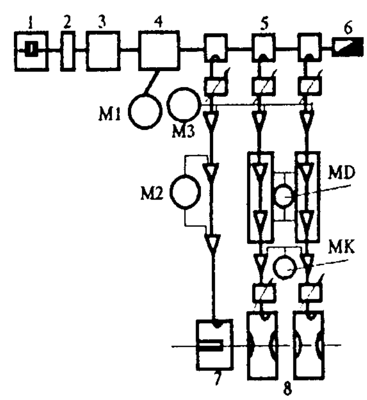

Fig. 3. Scheme of RF-system:
M1-M3, MK, MD - modulators; 1-quartz generator 75 MHz; 2-frequency doubler; 3-preamplifier; 4-buffer amplifier; 5-directional couplers; 6-matched load; 7-coaxial resonator; 8-main resonators.

Five modulators are used to feed the power amplifiers of the initial part of the accelerator. Buffer and preliminary amplifiers are fed from two almost identical modulators, assembled in a scheme with partial discharge of a condenser, a transistor switch is used as the keying element.

The intermediate cascades are fed from a modulator having a pulse power of 100 kW and assembled in a scheme of total discharge of a single forming line. A chain of successively connected thyristors constitutes the switching element. The modulator provides for obtaining anode supply pulses of up to 14 kV.

The modulator for feeding the two intermediate generators is assembled in an analogous scheme with a step-up pulse transformator. The pulse power of the modulator is 1.5 MW. Pulses with an amplitude of 2 and 10 kV for feeding the tetrode and 27 kV for feeding the triode are provided by the multi-winding pulse transformator. A chain of thyristors is used as the keying element.

The 10-MW modulator of the output cascades is designed to obtain pulses with an amplitude of up to 40 kV. It is conctructed analogously to the previous modulator.

Dynamics of particles and structure of installation

Calculation of beam formation in the gun resonator and beam transport and focusing in the initial part of the accelerator was performed by means of electromagnetic code KARAT [4].

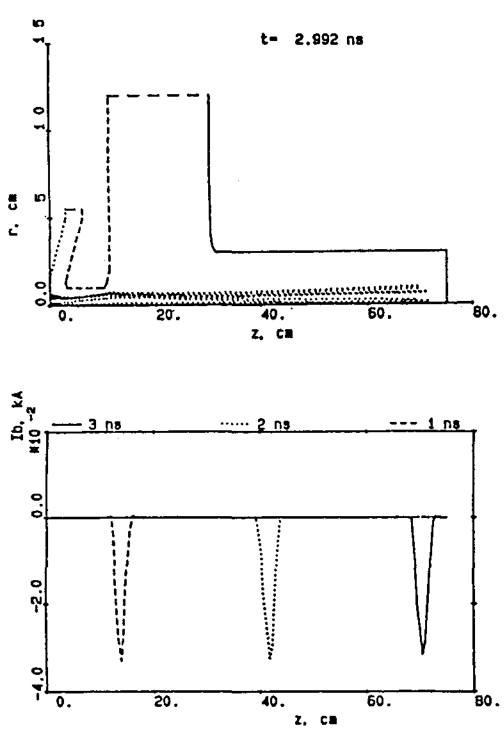

Fig. 4. Modelling results for built-in injector: geometry and beam trajectories (upper) and pulse shape evolution.

Results of calculations for the longitudinal and transverse dynamics of short bunches indicated that because of the low energy of electrons at the output of the gun resonator (200 - 250 keV), for an initial 100-ps bunch length and 50-A peak current (beam profile is Gaussian in both directions), the bunch before entering the main resonator lengthens by at least two times uder the influence of the self space-charge fields, which leads to a fall in peak current. Reluction of the effect of longitudinal repulsion can be achieved by shortening the length of the drift region. Therefore, it was decided to place the quarter-wave resonator within a capacitive cylindrical insert of the main resonator. The variant of placing the photocathode directly in the main resonator does not permit maintaining the gun as an independent element of the accelerator with its own control.

In such a scheme, longitudinal spreading of the bunch practically does not occur. Fig. 4 shows the trajectories of particles and form of bunch current at various positions for a peak current of 30 A, an initial duration of 100 ps, an electron energy of 200 keV at the gun output, and an energy increment of 1 MeV at the first resonator of regular structure.

Acknowledgements

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