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Viktor Kulish, Dr. Sci. (Physies & Math.), Prof.
Olexandr Lysenko, PhD
Igor Gubanov, PhD
Georgy Valdenmayer, stud.

THE PROJECT OF THE COMPACT MLIA-ACCELERATOR FOR THE TWO-STREAM SUPERHETERODYNE FREE ELECTRON LASER

The results concerning the project of compact two-stream superheterodyne free electron lasers, which can be constructed on the basis of MLIA-accelerator, are represented. In the work is described the nonlinear theory of the multi-harmonic TSFELs and accomplished corresponding physical and project analysis. A specific characteristic of the considered system is the source of intensive relativistic electron beam is constructed on the basis of a two-beam MLIA-accelerator. The design-scheme of the compact MLIA-accelerator is proposed and analyzed. It is shown that main merit of studied devices is their potential compactness.

Наведено результати проектування компактного двопотокового супергетеродинного лазера на вільних електронах, який може бути побудований на базі MLIA-прискорювача. Описано нелінійну теорію мультигармонічного двопотокового лазера на вільних електронах і виконано відповідний фізичний і проектний аналіз. Особлива характеристика розглянутої системи − джерело релятивістського електронного пучка побудовано на основі двопотокового MLIA-прискорювача. Запропоновано і проаналізовано функціональну схему компактного MLIA-прискорювача.

Introduction

It is well known that one of characteristic features of the Two-stream Superheterodyne Free Electron Lasers (TSFELs) is inclination to generation of many higher harmonics of output electromagnetic signals. This, in turn, is caused by specific multi-harmonic properties of the two-stream instability, which serves as a basic physical mechanism.

It should be mentioned that traditionally the multi-harmonic TSFEL properties are regarded as one of important drawbacks of this class of devices. In contrast to the tradition we offer in this article an opposite approach to the problem. Namely, we propose the models (and corresponding systems) whose work is based just on the use of multi-harmonic feature mentioned. As it is shown below the systems of such a type have quite rich physical picture and they could be very interesting for practice. Moreover, it is cleared up that such systems can be realized successfully in an experiment. Including, in the form of relatively compact and, at the same time, power actual TSFEL designs or in the form of the laser cutting and welding machine for sheet material etc.

Thus the main goal of the work is the constructing the nonlinear theory of the multi-harmonic TSFELs and accomplishing corresponding physical and project analysis.

General design-scheme

The general design-scheme of a TSFEL-device, as a whole, that is destined for amplification of electromagnetic waves in millimeter-submillimeter range is represented in fig. 1.

Section of the TSFEL, in itself, is the main components of the proposed device [1]. The device works in the following manner. Two relativistic electron beams *2* (partial beams) with some different (but, close) velocities $\vec{\upsilon}_1$, $\vec{\upsilon}_2$ are generated by the MLIA-accelerator 1. These beams *2* are directed into the merging system *3*, where single two-velocity electron beam *4* is formed. The two-velocity beam *4* further follows to the compression system *5*, where it is exposed the compressing. As a result, the density of the beam *6* attains some optimum magnitude, which is required for further effective work of the TSFEL-section *7* (TSFEL, in itself). The project analysis of each of the mentioned structural element of the device shown in fig. 1 has been accomplished. Optimal design variants and parameters are determined during this analysis.

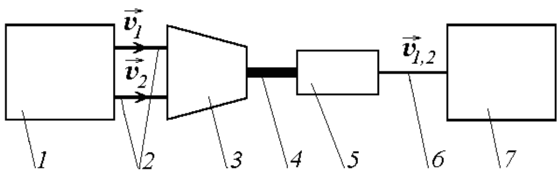

Fig. 1. General design-scheme of the device for amplification of electromagnetic waves in millimeter-submillimeter range:
1 is the MLIA-accelerator;
2 are the partial electron beams with different velocities $\vec{\upsilon}_1$, $\vec{\upsilon}_2$;
3 is the merging system;
4 is the merged two-velocity electron beam;
5 is the compression system;
6 is the compressed two-velocity electron beam;
7 is the section of TSFEL (TSFEL, in itself)

We have analyzed the system at 2 mm frequency range electron beam energy 1,5 MeV. It was shown that such system could be compact and it possesses unique set of work parameters. This makes they rather promising for various commercial applications such as the space communication, technological systems for different use, etc. However, taking into consideration of limited volume of this work, the system of two-velocity beam forming is discussed below only.

MLIA-accelerator as an source of intensive relativistic two-velocity electron beam

Key point of the proposed in the project multi-channel design of the MLIA-accelerator is utilization of a special "honeycomb" design of accelerative block. The undulative version of the proposed two-velocity MLIA-accelerator is proposed and analyzed.

Design elements of the MLIA-accelerator

In distinct from the earlier discussed multi-level one-beam designs [2; 3], in this work we accept that the considered design is two-beam one. This means that two electron beams are accelerated simultaneously in differ two design levels of the two-level design.

The scheme of one of the partial channel in the first design level of such MLIA-accelerator is shown in fig. 2. Correspondingly, the scheme of the other partial channel is the same.

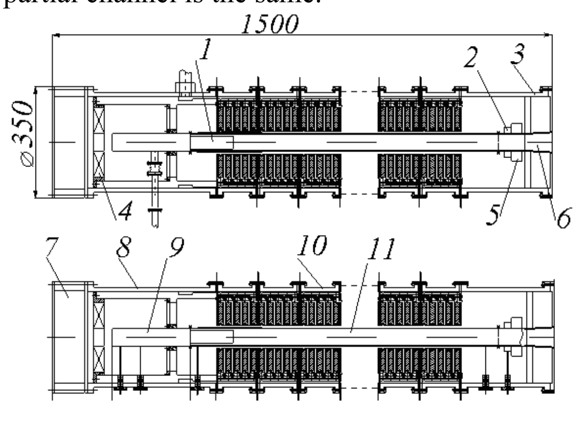

Fig. 2. Scheme of one induction block of the MLIA-accelerator:
1 is the electron beam corrector;
2 is the sensors;
3 is the attachment system;
4 are the induction modules;
5 is the corrector system;
6 is the merging system;
7 is the air filter;
8 is the casing;
9 is the electron gun;
10 is the fan;
11 is the resistive vacuum tube

Thus, the two-level design of stationary honeycomb MLIA-accelerator (see design of the induction block in fig. 3) is chosen as the basic one.

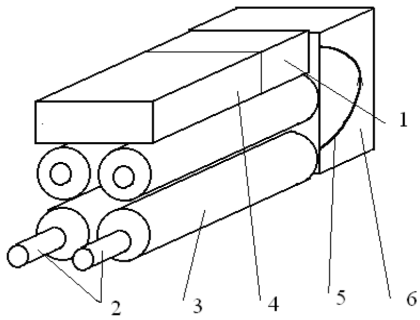

Fig. 3. Design of the construction block-scheme of the superheterodyne free electron laser with the acceleration block on the base of the stationary MLIA-accelerator:
1 is compressing system;
2 is injector;
3 is accelerators block;
4 is FEL;
5 is electron beam;
6 is turning magnet

Therein, the first and the second levels are destined for acceleration of two separate (partial) electron beams. It is proposed to construct each design level on the basis of inductors of Linear Inductional Accelerators (LINACs). All such LINAC-inductors are placed parallel one to other within the design level.

High stability of the beam velocity difference (that is very important for the TSFELs - see below for more details) is provided in this case. This is attained because the electromagnetic field, which is generated by the MLIA-accelerator induction block, is common for all design levels.

The calculated project parameters of the considered MLIA-accelerator are given in table. Different voltage for the upper and lower channel design level of the MLIA-accelerator are put for forming of the two output electron beams with different energy.

Parameters of the two-level honeycomb two-beam MLIA-accelerator

Parameters	Values
Pulse current of one channel, A	100
Pulse duration τ, nc	200
Energy difference between both electron beam $\delta\mathbf{E}_s$, MeV	0,15
Averaged energy of electron beam $\langle\mathbf{E}\rangle$, MeV	1,5
Output electron beam diameter, mm	1,5
Plasma frequency for the output electron beam, s^{-1}	$\sim 10^{11}$

Transportation of the electron beam through the MLIA-accelerator

Let us to study the beam motion through the MLIA-accelerator. The large particle model will be used for this purpose. Therein, the Coulomb repulsion will be accounted. Results of beam parameter calculation are given in table.

Merging and compression systems

The margin system, constructed on the basis of the special construction turning magnet. As analysis shown, this system is suitable for accomplishing the function of merging two relativistic electron beams with different energies. The system works in the following manner. The two electron beams with different energies (velocities) formed by the MLIA-accelerator are directed (though the thin magnetic lenses) into the channels of the turning magnet. Further both beams merge into one two-velocity electron beam within of this turning magnet. The formed two-velocity electron beam further directed (through the thin magnetic lenses) into the compression system.

System for the two-velocity beam compression

This system is accomplished in the form of a solenoid with longitudinally inhomogeneous winding. Their action leads to the beam transverse compression. Due to the beam compression its spatial density increases without the current increasing. The compressed two-velocity electron beam further is directed in the section of the klystron-FEL.

Conclusions

Thus the design-scheme of the compact TSFEL, which can be constructed on the basis of MLIA-accelerator is proposed. Apart from that the result of project analysis of the block for the two-velocity electron beam forming are given. Taking into consideration that this block determines roughly characteristic sizes of the TSFEL-device, as a whole, this means that especially compact sources (oscillators and amplifiers) could be constructed on the discussed way.

References

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