MULTIFREQUENCY HIGH POWER MICROWAVE ELECTRIC-VACUUM DEVICES

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Abstract

A new approach for the development of microwave electric-vacuum devices is proposed. It implies extracting output power at two or more frequencies ω, 2ω, …, n·ω simultaneously while applying input power at fundamental frequency ω. The characteristic feature of these devices is that microwave oscillations at different frequencies are phased.

It is possible to obtain output power at frequencies ω and 2ω simultaneously by using double-gap resonator tuned into two multiple frequencies – in-phase one at frequency ω and anti-phase one at frequency 2ω.

It is possible to obtain power on four frequencies ω, 2ω, 3ω, 6ω by using electro-dynamic system of two double-gap resonators placed one inside other.

It is possible to get power at many multiple frequencies by using special coaxial resonator. Has been created a microwave device producing power on nine multiple frequencies simultaneously. The output pulse of the device has ultra-short duration and super-high repetition frequency equal to the input frequency ω.

Multifrequency high power microwave electric vacuum devices can be used in compact accelerators of charged particles.

INTRODUCTION

In microwave devices such as klystron during electron beam grouping are created the bundle of electronic energy with repetition frequency equal to frequency ω of the input RF signal and duration of approximately 0.1 from pulse repetition cycle. In typical klystron such bundles are the inputs for the output resonator which uses only the first harmonic of the electronic current for inducing of high RF voltage amplitude of the first harmonic and tuned to the fundamental frequency ω. Then this amplified signal passes to the load on the same harmonic.

It is possible to take energy off the electronic bundle on two multiple frequencies simultaneously by tuning the output resonator to two multiple frequencies ω and 2ω because the bundle contains wide band of current harmonic ω, 2ω, …, n·ω. It is possible to take energy off the electronic bundle on several multiple frequencies by tuning the output microwave electro-dynamic system into several multiple frequencies. In this case the output pulse of ultra-short duration and super-high repetition frequency will be created instead of a monochromatic signal on the first harmonic as for typical klystron.

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MICROWAVE DEVICE WITH DOUBLE-GAP RESONATOR

The idea of using double-gap resonator tuned into two multiple frequencies in microwave devices were introduced in [1]. This idea was developed in [2-6] where it is suggested to use the double-gap resonator for effective grouping of electronic current [2-4] and for taking off the power on two multiple frequencies simultaneously [5, 6].

There is multi-trace microwave device of klystron type with double-gap output resonator scheme is presented in Fig. 1, [5]. The device consists of electron gun 1, input resonator 2 with RF energy input 3, grouping resonators 4, output double-gap resonator 5 with high frequency interaction gaps 6, 7 and collector 8. The device has two waveguide outputs 9, 10 with different wide of walls. Through the waveguide 9 the power at the frequency ω is taking out and through the waveguide 10 – the power at the frequency 2ω is taking out. In order to prevent energy spreading at the doubled frequency 2ω through the waveguide 9 it is used the rejection filter 11. The electron

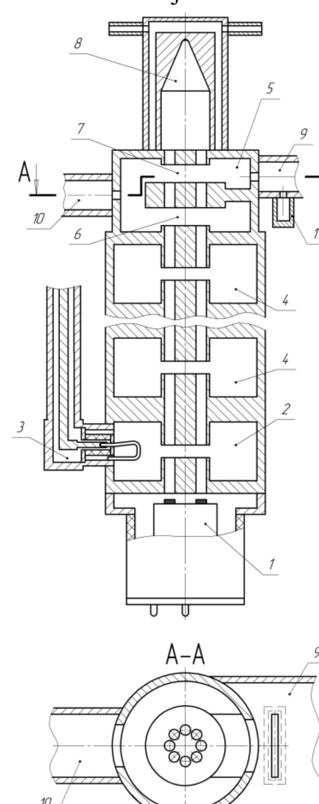

Figure 1: Microwave device with double-gap output resonator.

flow created by the electron gun 1 is exposure by RF fields of the input resonator 2 and the grouping resonator 4. As a result the grouped electron bundles with repetition frequency equal to the input RF signal ω come to the output resonator 5. In the first RF gap 6 of the double-gap resonator each electron bundle enter into the braking RF field, i.e. minus phase of in-phase and anti-phase RF voltage oscillation. The anti-phase oscillation of the double-gap resonator is tuned to the frequency ω and the in-phase one – to the frequency 2ω. The distance between first and second RF gaps is choosing in such a way that every electron bundle in second gap 7 comes to the braking RF anti-phase oscillation electric field. Under such tuning every electron bundle automatically comes to the braking RF in-phase oscillation electric field in the second gap. It leads to the effective taking off energy from electron current by in-phase and anti-phase oscillation RF fields simultaneously.

This device can produce high average and pulse power for each frequencies ω and 2ω. It can be used for acceleration purpose.

If to tune the oscillations reversely then taking off energy on the anti-phase oscillation becomes ineffective because in the first gap the bundle gives its RF energy to the resonator, but in the second gap it takes off the energy.

The output electrodynamics system of the device is presented in the Fig. 2. It consists of two double-gaps resonators 1 and 2 are placed one inside other [6]. Grouped electron flow passes sequentially through first gap 3 of external double-gap resonator 1, then through first 4 and second 5 gaps of internal double-gap resonator 2, and further – through second gap 6 of external double-gap resonator. For effective power taking off anti-phase oscillation of the external double-gap resonator is tuned to the frequency ω and in-phase oscillation – to the frequency 2ω. The anti-phase oscillation of the internal double-gap resonator is tuned to the frequency 3ω and the in-phase oscillation – to the frequency 6ω. This device

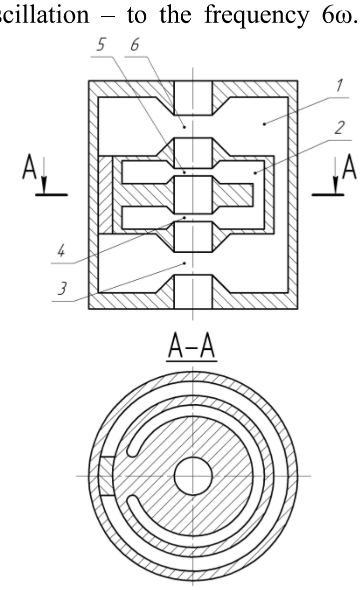

Figure 2: The output electrodynamics system consisting of two double-gap resonators.

with external double-gap resonator can produce the power on four multiple frequencies ω, 2ω, 3ω, 6ω simultaneously at applying to the device the input power on the frequency ω.

MICROWAVE DEVICE WITH MULTIFREQUENCY OUTPUT ELECTRO-DYNAMIC SYSTEM

For some applications it is necessary to have the source of ultra-short electromagnetic pulse with broad emission spectrum. It is important to have high average power and therefore with high pulse repetition frequency. The existing ultra-short pulse generators based on semiconductor devices or on spark gaps can't give high average output power. We propose to produce ultra-short pulses with super-high repetition frequency using electro-vacuum device with wideband output electro-dynamic system [7-9].

The coaxial half-wave multifrequency resonator with oscillation modes tuned to the beam current harmonic frequencies was used as an output electro-dynamic system. The proper oscillations of this resonator have the maximum power on the end of spectrum. It provides effective interaction of the proper oscillations with the electron beam (if output gap is made at the end of resonator) and effective taking off energy into the output section on all harmonics.

Realization of the output half-wave coaxial resonator for the multi-beam microwave device is presented in Fig. 3. It has external 1 and internal 2 conductors separated by

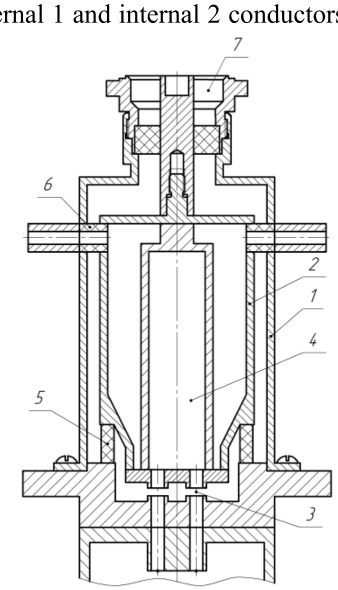

Figure 3: The output electrodynamics system with half-wave coaxial resonator.

the high frequency interaction gap 3. Collector 4 is placed in the cavity of internal conductor. Cylindrical ceramics is used for taking off the output power. It divides coaxial resonator into vacuum and non-vacuum parts. Dielectric tubes 6 are placed into the cavity of coaxial resonator for collector cooling. Coaxial line 7 is used for transmitting RF power to the load.

The electron bundles pass the RF interaction gap 3 and launch in-phase oscillations on the frequencies ω, 2ω, ... nω, in coaxial resonator. It delivers the conditions for producing ultra-short pulses with super-high repetition frequency ω.

The construction presented in the Fig. 3 is convenience because external conductor and a part of internal conductor of the coaxial resonator are removable. It helps to place the tuning system of the resonator outside the vacuum part of the device. It simplifies its tuning after pumping out and during tests. Also it simplifies delivering cooling liquid to the collector.

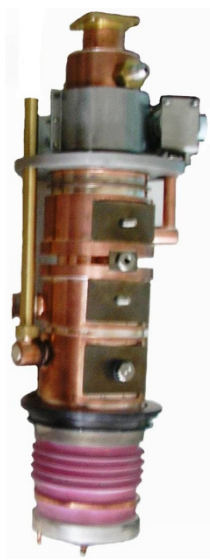

Figure 4: Multifrequency microwave device.

A photo of the first multi-trace super-wideband device is presented in Fig. 4. It produces ultra-short pulses of 140 picoseconds duration with super-high repetition frequency (see Fig. 5), pulse power of 0.5 megawatt and frequency spectrum up to decade. The average power of the device is 1 kilowatt. It is one degree higher in comparison with the existing devices.

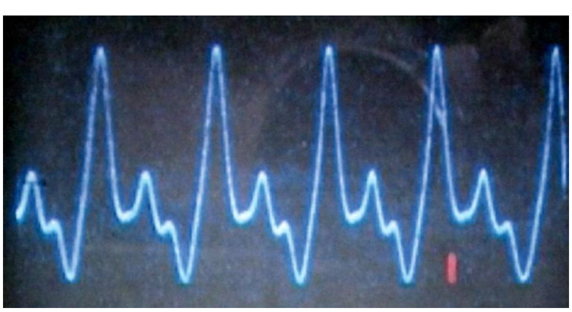

Figure 5: The output ultra-short pulses with super-high repetition frequency.

There are possibilities for enhancing the average power of such devices.

In spite of using coaxial energy output this devices can produce high pulse power due to the ultra-short pulse duration. It is helpful for acceleration devices.

CONCLUSION

It is presented the methods for developing double-frequency and multi-frequency microwave devices with multiple frequencies. It was built a many-frequency microwave device which produces ultra-short pulses with super-high repetition frequency.

We think that such microwave devices can be used for acceleration purposes:

- For reduction of the electron bundle size by grouping its non-monochromatic voltage;
- For producing multi-energetic electron bundles;
- For radical reducing (up to n times) ohmic loss in the acceleration structures [9] and therefore reducing the necessary microwave power.

Two sections accelerator with first section tunes to the frequency 2ω ant the second one – to the frequency ω is an example of the device for getting two-energetic electron bundles. As a result there are two-energetic electron bundles changing at the output.

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