TWO-FREQUENCY KLYSTRON AMPLIFIER

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Abstract

The necessity to create the RF sources operating in two-frequency mode is supported by the proposals concerning the suppression of the emittance growth generated inside the RF gun [1] and the possibility to increase the limited accelerated charge [2] by involving into the interaction with the beam, in addition to the fundamental harmonic, the highest harmonics of a RF field with the power ratio up to 10 : 1 and the absolute synchronism of changing phase and amplitude ratios of signals. In this paper we present the preliminary results on studying the possibilities of multiple-frequency RF power generation by a single klystron through installation of a supplementary high harmonic cavity into the exit one after the main output cavity along the beam direction. The physical motivation of the proposal consists in the effect of lengthy bunch rearrangement due to the interaction with the high-strength RF fields. The computer simulation results and experimental data are given.

The Previous Design

It is obvious that during interaction of the bunches of a large phase length with the field of the output cavity, when the total time of interaction is more than a half of RF oscillation period, one part of particles in the bunch is accelerating. In the further passing of the drift space the possibility exists of ouftlying the main braked part of bunch (“flipping” effect). As a result, the beam may be rearranged so that instead of one bunch formed by the field of a fundamental frequency there will be two flying away bunches in the flow.

It is clear that changing the length of the drift tube one can attain the multiplicity to the wave length in the location of these bunches, i.e. to provide the beam modulation at the multiple frequencies.

Previously, we observed this effect investigating the beam parameters at the bunching system exit of the klystron (“Aurora”-type: 2.797 GHz; 20 MW; 35 % efficiency) [4]. The investigations were performed by a well-known method of reconstruction of the modulated flow structure on a level of spectral components of the output RF power with changing the length of the drift tube. The general view of the installation is shown in Fig.1.

Fig.1. The general view of experimental klystrons with the variable length of the end drift tube (left) and with the additional output cavity (right).

The effect of resonance excitation of the second harmonic signal depending on the space length was discovered (Fig.2).
The pulse output power at the frequency of the second harmonic as a function of the length of the latter drift space for various anode voltage (a); the output power at the frequency of fundamental harmonic as a function of the drift space for the anode voltage 200 kV (b).

Investigation of the characteristics of a RF field excited by the beam in the supplementary output cavity, identical to the main one and installed after it (see Fig.1), has shown besides the other effects, the considerable increase of the second harmonic level signal as compared to the base model of klystron.

The increase of the negative gradient of the focusing field in this space region has resulted in decreasing the amplitude of the excited signal at the second harmonic frequency (Fig.3) and simultaneously the small increasing the power level at the fundamental frequency mode. The effect of the power increase at the fundamental mode was observed for the magnetic field gradient values within the limits of the situation where the low energy component of the beam is removed onto the drift space wall and the main bunch is passed into the output cavity [5].

In our opinion the presented data indicate conclusively on the existence of the effect of an electron bunch rearrangement in the high power amplifiers and confirm the possibility of creating the two-mode operation RF sources.

Computer Simulation

In order to check the second beam current harmonic Laval after the output cavity, the 2D Particle-In-Cell ARSENAL-MSU code [7] has been applied to B-Factory Linac 50-MW pulse klystron PV3050, which has been developed at KEK [8]. Because of the mass production, the tube performances were carefully studied, and detailed information is available on this tube. Therefore this tube is a good example for theoretical study.
of high harmonic energy extraction from spent electron beam in klystron. This tube produces 51 MW at a 310 kV beam voltage with efficiency 47% at saturation. But theoretical investigations had show that significant second harmonic beam current Laval can be reached not for optimal regime. So calculations were made for input power 100W, which is bellow saturation.

The electron beam propagation along the buncher is presented on Fig. 5. On the upper slide the magnetic field (Bz/Bo) distribution is presented. The fundamental and the second harmonic beam current distribution and electronic efficiency (middle slide) and momentary photo of electrons (lower slide) downstream the klystron are shown. Two bunches on the one electron wavelength with different density after the output cavity can be seen on this slide.

The electron beam bunching in normalized (over 2π) phase diagram from the longitudinal coordinate z/Le is presented on Fig.6. Obtained efficiency 33% corresponds to output power 37 MW. Second beam current harmonic Laval 0.7 from fundamental current is quite high for receiving high RF power on the second harmonic. This value allow to extract from spent beam second harmonic power near 5 - 10 MW.

**Conclusion**

The foregoing experimental data and numerical simulation results indicate on the real possibility of creating the high-power klystron amplifier with simultaneous generation of the signal at fundamental and multiple frequency. In turn, the existence of such a RF source can provide the certain progress in the field of accelerators development.

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**References**