EXITATION OF HIGHNUMBER HARMONICS BY NON-RELATIVISTIC OSCILLATORS

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The results of experimental researches of a possibility of an effective of high numbers harmonics radiation by non-relativistic oscillators are represented. The good qualitative consent of experimental and theoretical results are obtained. In experiment the millionth harmonic was excited. It is shown, that the investigated mechanism can be used for excitation optical and ultra-violet radiation.
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INITIAL PREMISES

In our previous researches [1,2] the expression for a radiation power of a charged particle, which is moving in a medium with a dielectric permeability $\varepsilon = \varepsilon_0 + q\cdot\cos(\kappa\cdot r)$ on a trajectory $r = V_0 t + r_0 \sin\Omega t$, was found**.** From obtained results most important was an result about a possibility of effective excitation of high numbers harmonics by non-relativistic oscillators. Therefore far we will interest a radiation only of non-relativistic particles $\beta << 1$.

$$\frac{\partial W}{\partial t} = \left(\frac{e^2\Omega^2\cdot\beta_\perp^2}{3c}\right)\cdot\frac{3q^2}{2}\sum_{n=1}^{\infty}\frac{n^4}{m^2}\cdot J_n^2(m)\int_0^{\pi}(\sin\theta)^3 d\theta\ ,$$

$$\beta_\perp = \frac{r_0\Omega}{c}, \qquad m = \kappa\cdot r_0 \qquad (1)$$

Let's formulate the most important performances of such radiation.

1. The most important feature is the spectrum of a radiation. In fig.1 the dependence of a radiation power of an oscillator on harmonics number n for such parameters $m = 1000$, $\beta = 0.1(\gamma = 1.005), q = 10^{-5}$ is represented.
2. As follows from the formula (1), the radiation diagram of a non-relativistic oscillator for all harmonics coincides with dipole radiation.
3. The polarization of a radiation does not differ from polarization of a radiation of an oscillator in a homogeneous medium.

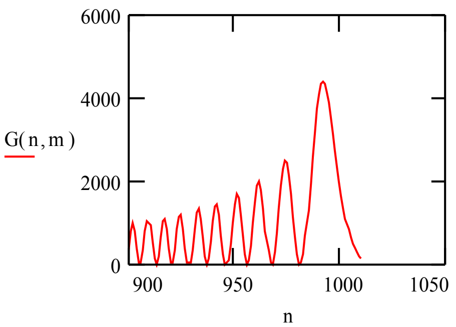

Fig. 1 Efficiency of radiation oscillators on high numbers of harmonics

It is necessary take into account that oscillator energy must exceed energy of radiated quantum ($E = mv^2/2 > \hbar\omega$).

Let charged particle is moving in external electrical field $E(t) = E\cdot\cos(\Omega\cdot t)$ and in a field of a periodic potential $U = U_0 + g\cdot\cos(\kappa\cdot z)$.

The radiation power of such particle on frequency of high number harmonics ($m >> 1$) can be represent as:

$$\frac{\partial W}{\partial t} = \frac{e^2\Omega^2}{3\cdot c}\left(\frac{eg}{mc^2}\right)^2\frac{1}{A^2}\cdot m^2 J_m^2(m)\ .$$

$$A \equiv (eE)/(mc\Omega) = \beta \qquad (2)$$

It is important to mark, that the radiation maximum under this mechanism coincides with the radiation maximum in a periodically inhomogeneous dielectric.

EXPERIMENTAL INSTALLATION

First of all, we investigated the mechanism of harmonics excitation in a microwave - range. In this experimental series plasma electrons were as oscillators. They oscillate in a field of an external electromagnetic wave. The artificially made lattice was as periodic medium. The scheme of experimental installation is represented in fig.2.

The camera (7) is one from main components of experimental installation. In it there was a plasma; the lattice was placed; the high-frequency power from a magnetron was entered into it; in it the recording antennas placed. The lattice represented a row of tungsten filaments with 0.1 mm thickness. The distance between filaments was 0.5 mm. The filaments are oriented in parallel to broad wall of a waveguide. The plasma was created by injection of an electronic beam (1.5 kV, 300 mA) in the camera with residual pressure of gas 10^{-4} - 10^{-5} mm.Hg. The magnetron (1) was source of an electromagnetic wave. It capable to supply a power up to 1 MWt in impulse 2 μ s on frequency 2.7 GHz.

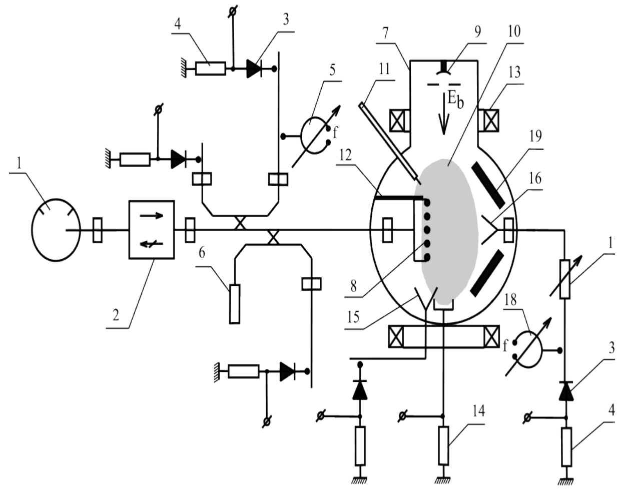

Fig. 2. Scheme of experimental investigation in a microwave-range radiation: 1-magnetron; 2- Faraday isolator;3- the 3-H-F detector; 4- resistor; 5- spectrometer; 6- resistor in directional coupler of a three-centimeter range; 7-vacuum chamber; 8-periodic lattice; 9- electron gun; 10- plasma; 11- mobile Lengmure probe; 12- mobile screens; 13- coils of the solenoid of a magnetic field; 14- resistance in a circuit of a collector for electrons beam; 15 and 16- antennas for reception of signals of a three-centimeter range; 17- attenuator; 18- a spectrometer for three-centimeter range; 19- allocated a high-frequency absorber.

EXPERIMENTS IN A MICROWAVE-RANGE

As a whole, the experimental results are in good qualitative consent with the theory. The excitation of oscillations on the third harmonics (8.1 GHz) was observed only in condition when plasma and lattice, were located on the end of waveguide simultaneously (Fig. 3). If the lattice was taken away, the radiation on harmonics was absent. If the plasma was deleted - radiation was absent too. By rotation of antenna, accepting a radiation (15), (16), was established, that the vector of an electrical component of an emitted field is oriented perpendicularly planes of a lattice, i.e. polarization of the radiation corresponds to a radiation of the dipole. It is in the good consent with the theory. The radiation diagram is also in good consent with the theory: the emission power in a direction of a perpendicular lattice considerably exceeds an emission power in a perpendicular direction (in a direction parallel to a lattice surface).

EXPERIMENTS IN OPTICAL AND ULTRAVIOLET RANGES

Using a crystal as a periodic structure under the same other experimental conditions, one can count on stimulating the radiation emission in the optical and ultraviolet ranges. To check this statement, the same experimental installation has been used. In difference from the previous one the magnetron fed the resonator on half of length of the wave. Semiconductor crystal plates are introduced into the resonator. The radiation emitted from the resonator is registered by the electron multiplier and photoelectric multiplier with scintillation converter of the radiation spectrum (for registering ultraviolet radiation).

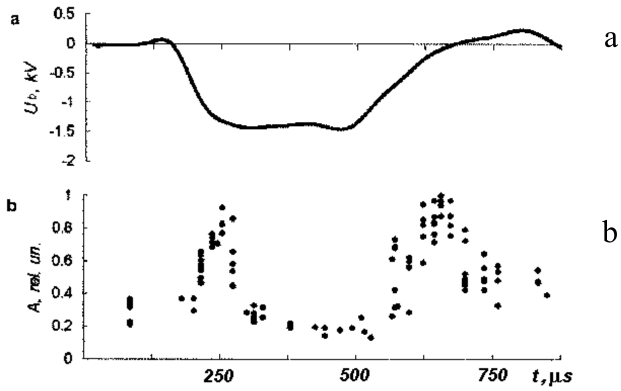

Fig. 3. Pulses of a current of an electron beam for creation of plasma (a) and power of radiation oscillation on frequency 8.1 GHz (b)

As it has experimentally determined, if the field strength of microwaves in the resonator was more then 36 kV/cm there occurs break-down. Therefore, the all experiments have been fulfilled under range of field strength 15—25 kV/cm.

The principal result of these experiments is that in all cases the radiation emission is observed. We present the mechanism, which can be the only one, responsible for this phenomenon.

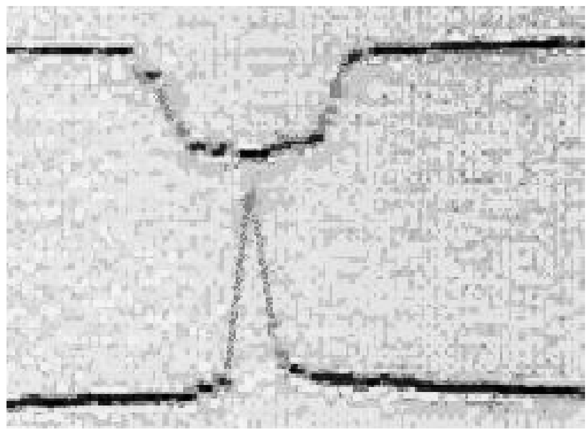

Fig.4. The microwave signal amplitude (the upper ray) and the radiation signal from the crystal (the lower ray)

As an example of radiation, the typical experimental results are presented in Fig.4. Here one can see oscillograms of the microwave pulse in the cavity at the frequency 2.7 GHz and the registered radiation, emitted from a semiconductor crystal ($\lambda \sim 10^{-5}$ cm), under the field strength 20 kV/cm. Thus, the radiation emission at the million--number harmonic has been observed. We have used the silicon crystal of the dimensions 10x4x1 mm. The lattice period $d=4*10^{-8}$ cm. The free electron density $n=10^{19}$ cm^{-3} under the room temperature. If the incident wave frequency is 2.7 GHz, the field penetration depth (the skin layer) makes 4 mm. Consequently, in principle, the electrons, located in vicinity to the semiconductor surface, as well those inside the crystal body can participate in the process of radiation emission.

DISCUSSION OF THE RESULTS AND CONCLUSIONS

Generally speaking, the experimental results convincingly confirm our ideas of the mechanism for radiation emission by non-relativistic oscillators at higher harmonics. In many cases, the experiment rather well corresponds to the theory. It is worth mentioning that the experimental results, obtained for the cm—range, are sufficiently comprehensive for the unique interpretation. In this range, the radiation characteristics are practically clear in all details. As regards the ultraviolet range ($\lambda \sim 10^{-5}$ cm), the pattern is more complicated. For pity, our experimental basis is not sufficient for more detail investigations in this range. At present, the role of electrons, located in vicinity to the semiconductor surface, and those inside the crystal body is still not clear.

Also we cannot distinguish the advantage of periodicity of the potential or the periodicity of dielectric constant for excitation of high number harmonics.

On this time we are unknown other mechanisms (except for investigated by us) which could explain observable radiation. Such radiation could arise as a result of excitation any impurity centers of the semiconductor. However relaxation of impurity centers have absolutely other character of radiation.

The special interest represents collective process of radiation. In a centimeter range of lengths of waves we observed collective radiation definitely. In optical and ultra-violet ranges we can believe on an opportunity of such radiation only. The experimental results do not give us possibility to make any conclusion in this occasion.

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