RESEARCH OF WAVEGUIDE ACCELERATING STRUCTURES WITH DIELECTRICS

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At a choice of slow-wave structure for application in accelerating technique the main attention is given first of all to its two characteristics: 1) opportunity of use of a partial type of structures in the wider range of energies and 2) the transformation efficiency of high-frequency energy, put to structure, into a kinetic energy of accelerated particles, that eventually leads to comparison of structures on shunt impedance. From this point of view, the waveguides loaded by dielectric disks have doubtless advantages before other traditionally used structures [1]. Really, the acceleration of particles in waveguide dielectric structures can be realized in a wide velocity band from $\beta = 0{,}1$ up to 1,0, that is especially important for acceleration of heavy charged particles. Here $\beta = v/c$ - dimensionless velocity, v - velocity of a particle, c - velocity of light.

Let us note, that the slow-wave structures of accelerators with the use of dielectrics were historically the first offered structures, however, necessity of a realization of particle acceleration through the vacuum channel, at which the redistribution of an energy stream occurs between the channel and dielectric medium, and absence of natural dielectric materials with necessary properties have to provide searching for and development of all-metal slow-wave structures. The use of artificial anisotropic dielectric mediums in the form of waveguides loaded by periodically placed dielectric disks allows more effectively to use energy, put to the waveguide, and a wide spectrum of different dielectrics. Thus, now, waveguide dielectric slow-wave structures are considered as one of perspective directions in accelerating technique.

The earlier theoretical and experimental investigations show a fundamental opportunity of making non-regular waveguide dielectric structures with a varying phase velocity of a wave along an axes of an accelerating channel in the $\pi/2$- mode of the E_{01}-wave. It became possible due to use of a condition of a longitudinal waveguide dielectric resonance (LWDR) [2], which is observed in the below cutoff waveguide with a dielectric load, when the single disk resonant frequency is made equal to the resonant frequency of disk system in the waveguide

$$f = f_c\sqrt{\frac{\varepsilon^2+1}{\varepsilon(\varepsilon+1)}},$$

where f is the frequency, f_c is the critical frequency of the empty waveguide of the radius R, ε is the dielectric permeability of disk material. It is accessible for a special material of the disk at strictly determinated dimensions of the waveguide inner diameter and the disk thickness. The field, exited in every disk, has an asymmetric pattern with the zero value in the central cross-section of the disk.

Experimental investigations of such waveguide dielectric structures were carried out in order to verify their availability and to estimate their main parameters. Experimental models of resonance accelerating structures were made on a basis of comparatively cheap industrial dielectric materials, in particular, of ceramics from the dioxide titanium TiO_2 (rutile) with $\varepsilon \approx 90$ and $tg\delta \approx 0{,}5.10^{-2}$. A model consists of a circular copper waveguide section by the diameter of 81,5 mm, which is loaded along the axes by 32 dielectric disks having central hole as a beam aperture. The radius of hole edge fillets in disks is equal to 1,5 mm. In the present paper we give the results of investigations of two types of waveguide dielectric structures: with regular and biperiodic loading by dielectric disks for two values of the pass channel diameter. In case of regular structure (RS) disks were placed at regular intervals along the waveguide axes with a step proportional to the phase velocity of a wave β_{ph}. In a biperiodic structure (BPS) disks were placed by pairs, at a 1 mm space between disks in the pair.

Before installation in the experimental model each disk of an initial thickness h = 3,0 mm was attuned by change of thickness to the LWDR resonant frequency accurate up to ±0,01 MHz. Under grinding the plane parallel surfaces of a disk were saved within limits ±0,002 mm. After assembly of an experimental model its resonant frequency in $\pi/2$-mode of oscillations was equal 2815,70 MHz and did not differ from the frequency of a single disk more than ±0,025 MHz. In the main, this frequency difference depends on face walls of the waveguide and couplers with a measuring circuit. During adjustment of the disk and measuring the fields the constant temperature of a product was supported equal to 24 ± 1^0C. The measuring of a field distribution was carried out by a small disturbing body method. The nonuniformity of the electric field distribution along the axes of the pass channel of structures did not exceed by 3% the field value of active gaps BPS measured in points of the maximum value.

The measuring of the electric field distribution along the radius in active gaps has shown that the field is concentrated in the neighbouring-to-axis area with a maximum value on the edge of the hole in the disk. With increasing of the hole diameter the density of the electric field in the pass channel area is decreasing and its shunt impedance drops. It is shown in the figure, where dependence of shunt impedance R_{sh} on β_{ph} is given (curve 1 corresponds to the pass channel diameter of 5 mm, and curve 2 - 7 mm).

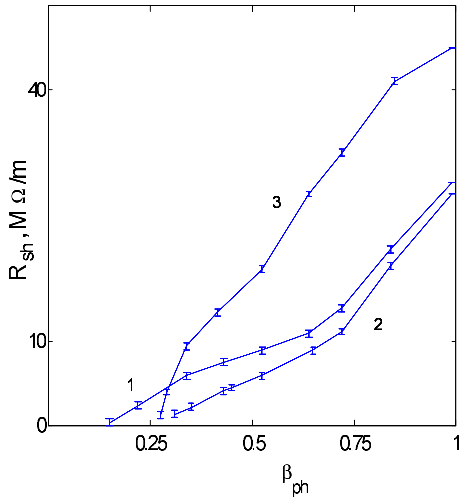

Fig. 1. Shunt impedance of wave dielectric structure vs phase velocity of wave.

For biperiodic structure, when the size of a active gap in comparison with length of a period is extended, we observed increasing density of an electric field within the pass channel and, accordingly, increasing of the shunt impedance (curve 3) in comparison with the regular structure (curve 2) having the same diameter of the pass channel (the given curves correspond to the diameter of the pass channel equal to 7 mm).

The comparison with well-known accelerating structures such as a circular diaphragmatic waveguide (CDW) shows that the waveguide dielectric structures have doubtless advantages in a wide range of values of accelerated particle velocities $0{,}1 < \beta < 1$. So, a shunt impedance of the investigated experimental model of waveguide dielectric structure even with disks from industrial ceramics possessing large losses, calculated at $\beta \sim 0{,}8$, is at a level of 40 MΩ/m, that is comparable to the shunt impedance of CDW, working at $\beta \sim 1$. The application of dielectric materials with large ε, but with smaller losses, will rise considerably the efficiency of such slow-wave structures.

REFERENCES

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