ABOUT FE ELECTRON LOADING OF THE CAVITY WITH HIGH LEVEL RF POWER

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Abstract

The degradation of the radio-technical parameters of the cavities in the proton linear accelerator with RFQ focusing at a high level RF power has been investigated. The Faraday cup is used to show that this is caused by the FE electron loading of the cavities without discharge development. The dependencies obtained are in agreement with the results on measuring the intensity of the x-ray radiation at different levels of the RF power, fed to the cavity. The data characterising emission properties depending on the treatment of the electrode surfaces, are given. Possible ways to suppress the FE electron loading are discussed.

When operating the injector for the proton synchrotron booster [1] we have revealed the dependence of the tuning system with RF feedback on reflectional wave on the RF signal value, steepening of the pulse from the cavity and shortage of the generator power. The phenomena mentioned above deteriorate the beam parameters at the accelerator output and require to be studied and eliminated.

A possible reason for this may be the increase of the RF losses in the accelerator cavities. The measurements carried out at a low power level showed no Q decrease, therefore the conclusion was made that the aforementioned effects are characteristic to high RF power levels. Figure 1 shows the accelerator section connected with a powerful RF generator through a decoupling ferrite Y-circulator, which was done with the view to investigate the dependence of the cavity performances versus power level. The field level U_n in the cavity was recorded with the aid of the coupling loop and a block of pulse-height detector. The value for the power from the cavity corresponded to the U_{fall} readings from the reflectometer. Figure 2 presents the experimentally obtained dependences of the relational Q value (curve 1) and field level in the cavity (curve 2) versus the root of the relative power value in the cavity. The experimental results revealed the instability of the Q factor and nonlinear changes of the field level, it is worth mentioning that the deterioration rate of the Q factor increases more than three time within the range of curve 2 nonlinearity. FE electron loading without further development of the multipactor electron loading may be the reason for what was said above. By a capturing a fraction of the electron beam with the Faraday cup we tries to find confirmation of our assumptions. The construction of the cylinder installed on the accelerator section at a minimal distance from the accelerating beam line electrodes is schematically shown in figs.3a,b.

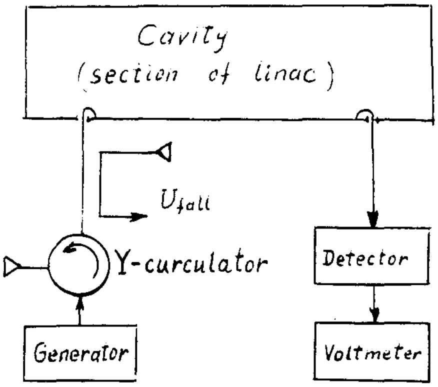


Fig.1. Block diagram of measurement system.

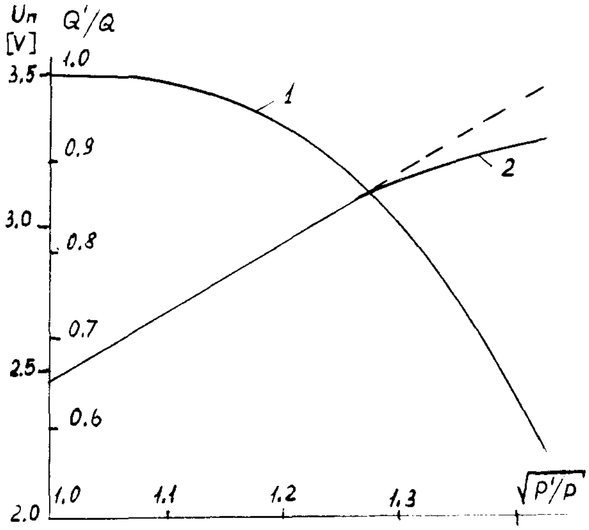
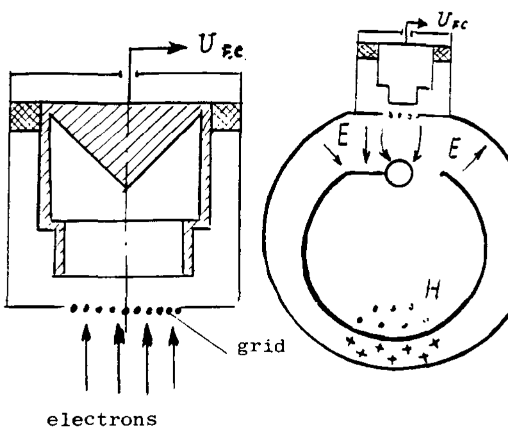


Fig.2. Dependences of the relational Q value (C-1) and field level in the cavity versus the root relational power.

Figure 4 presents the FE electron loading dedendence on the field in the accelerator section working without the beam. Curve 1 corresponds to the accelerator commissioning after a long shut down, when air leakages occurred. Curve 2 was obtained after the linac conditioning, curve 3 - commissioning the machine after one week shut down



a) b)

Figs.3a,b). a) Faraday cup; b) Faraday cup and H-cavity.

without air leakage. Curves 4 and 5 correspond to the measurements after 5 and 40 days after continuous operation of the machine. The x-ray intensity is described with curve 6. The correspondence in the forms of the FE electron loading dependence and Roentgen radiation points to the existence of the electron fluxes.

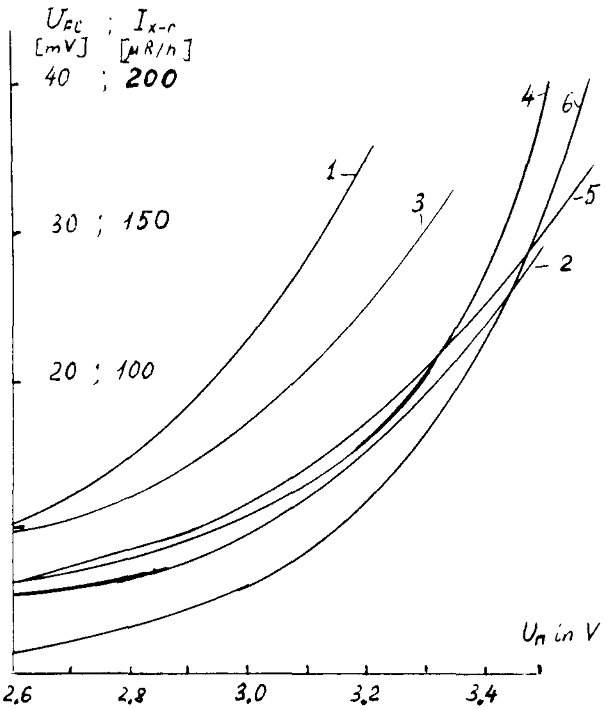


Fig.4. Dependences of the U_{FC} (curves 1÷5) and x-ray intensity - 6 on the field in the accelerator section.

From the data quoted it follows that in the course of the machine conditioning the FE electron loading decreases 1.5-2 times and becomes stable at a constant field value U_n. With the growth of U_n the FE electron loading increases nonlinearly, in this case the nominal level of the RF field in the cavity U_n=(3.4-3.6) V corresponds to a sharp growth of the FE electron loading current. The current density of the loading is approximately equal to 60 μA/cm^2. Since the electrical field distribution in the cavity is rather inhomogeneous one can carry out only averaged calculations of the current growth over the surfaces of the cavity units because of the loading. Under constant energy stored in the cavity we obtain that $J'_{\tau i}/J_{\tau i} = \sqrt{Q/Q'}$ where $J'_{\tau i}$ and $J_{\tau i}$ is the current over the surface of the i-th element with and without loading, respectively.

From the data of fig.2 we have the current ratio of 1.3, which causes larger losses in the elements, and consequently their thermal deformation increases 1.7 times.

To eliminate these phenomena one should reduce electron emission. According to the data from [2] the values for the pre-breakdown currents at a constant voltage depend on the material and physical-mechanical properties of the electrode surface. In connection with this we studied the emission properties and limit electrical strength of the electrode samples made of OFHC copper depending on the their surface treatment. This particular material was chosen for the tests because the electrodes of the injector for the booster are made from OFHC copper. The electrodes work at the voltages very close to the breakdown ones [5]. In our investigations we used electrode-samples Ø 15 mm of the Rogovski profile installed in the flat-parallel gap of 0.3 mm. The electrodes were treated without any cooling lubricant and polished with tungsten wire until the surface clearance was 0.2 Ra and then electropolished at the current of 10 A/cm^2 at a depth of 10, 50, 100 μm . The vacuum in the facility was 10^{-7} Tor. The technique applied allowed one to take constant current-voltage characteristics after breakdown conditioning. Some of the samples were fired right in the test vacuum chamber at 600° C according to the well-known technique. The field amplification factor and emission area are calculated in agreement with the standard FE technique [2]. As it follows from the results of Table vacuum firing deteriorates practical voltage limits and leads to a considerable growth of electron currents. It seems that this phenomenon may be explained by the appearance of a solid oxide film produced during e.p.*), which hinders the emission (which makes the emission difficult). Under vacuum firing this layer is deteriorated. It has been shown that the samples with the electropolishing depth of 10 μm posses best characteristics. It seems that a large depth of polishing smears the lattice and isolates the grains in the structure, as it was observed in [6] , which in its turn increases the number of emission centers.

It should be noted that the results obtained at a constant voltage should be confirmed in the work with the RF power supply. According to the data from refs. [3,4], the suppression of the electron multipactoring in the cavity may achieved by covering the surface with a thin layer (10^{-6} m) of dielectric (TiN or carbon). Under certain assumptions about the influence of such a layer on the secondary emission coefficient as well as on the emission properties of electrodes, one make a conclusion about a necessity to study possibly suppression of electron RF loading by using different layers on the cavity surface.

Table

Parameters Variants of the treatment			E_{max} $\frac{kV}{mm}$	I mA	μ —	$A\cdot 10^{-14}$ cm^2	I, when $U=20kV$ mA
without Vacuum-firing	w.e.p.**)		67	0,II	II9	I40	-
	electropol. in μm	I0	95	0,20	I22	I0	0,008
		50	9I	0,35	202	0,8	0,025
		I00	74	0,40	I82	5	0,200
Vacuum-firing cathods	w.e.p.**)		86	0,25	I28	I2	-
	electropol. in μm	I0	88	0,40	93	500	0,032
		50	65	2,00	I2I	I000	4,0
		I00	62	I,2	II4	5000	5,0
Vaccuum-firing anods	w.e.p.**)		85	0,25	I28	I2	-
	electropol. in μm	I0	73	0,3	360	0,I6	0,I8
		50	59	I,0	293	3,0	8,0
		I00	46	2,5	243	6,0	>I00

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*) Electropolishing.

**) Without electropolishing.