High efficiency IOT with 3 cavities

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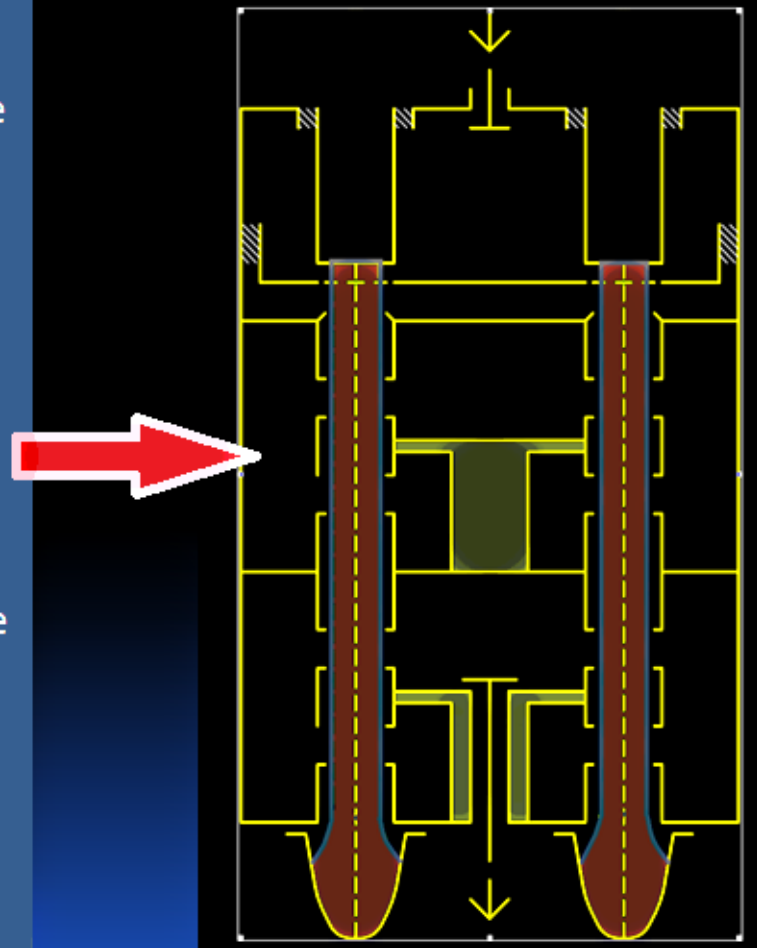
CERN

The first 90% efficiency 4-beam klystrode was built in 1997 at Scientific-production enterprise "Kontakt", Saratov

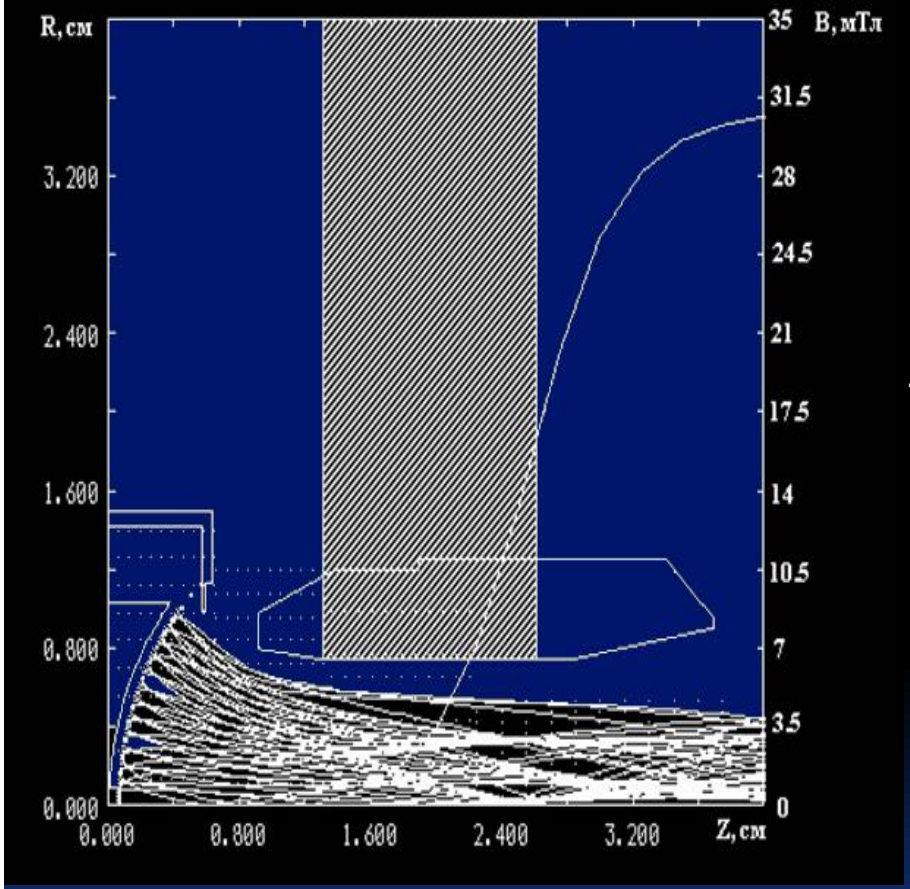
1) Pat. RF № 2073283 , H01J25/02, H01J25/04. Klystrode/ V. A. Tsarev, A. Yu. Miroshnichenko.- No. 94024403/07; Appl. 29.06.1994; Publ. 07.10.1997.

2) Tsarev, V. A. Multibeam klystrode with dimensional-spaced electron beams : prospects for development and possible applications / Materials of scientific. Conf. devoting to research and development. 275 anniversary of the Russian. Acad. of Sciences (Saratov, 23-25 March 1999). - Saratov, 1999. - P. 108-110

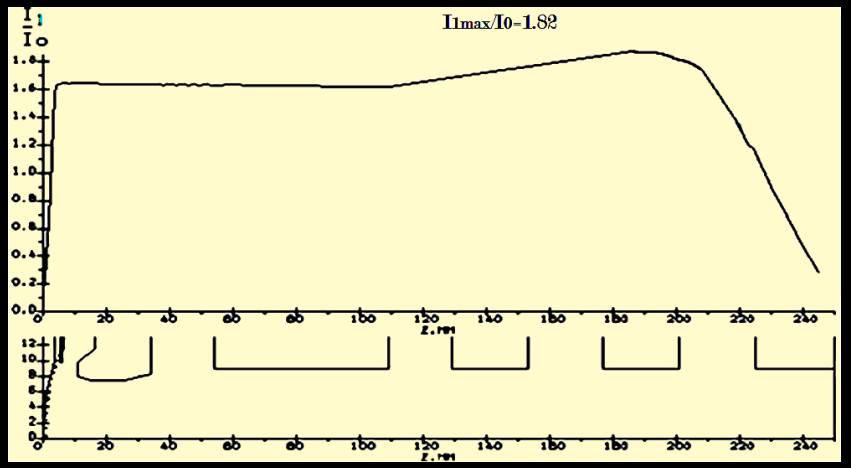
- 4 Electron guns placed in a circle
- Separate grids and cathodes
- 4 beams:
- The penultimate "rotation" tree integral double gap cavity
- Double-gap tree integral output cavity
- 4- individual collectors
- Coaxial output



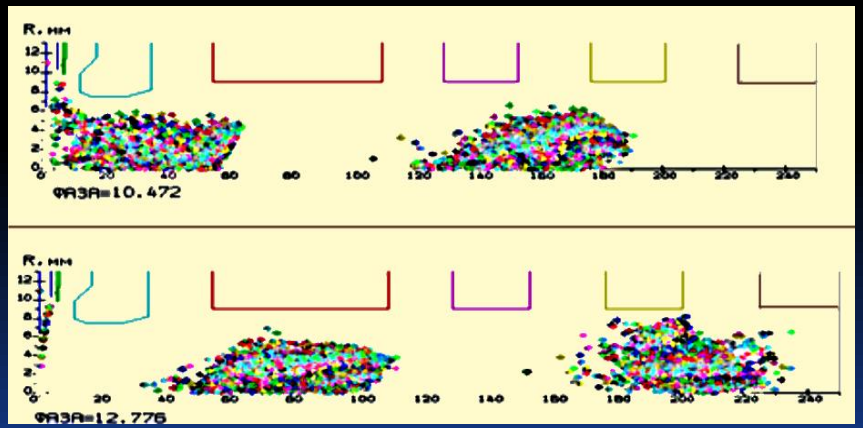
Results of computer simulation



The trajectories of electrons in the gun

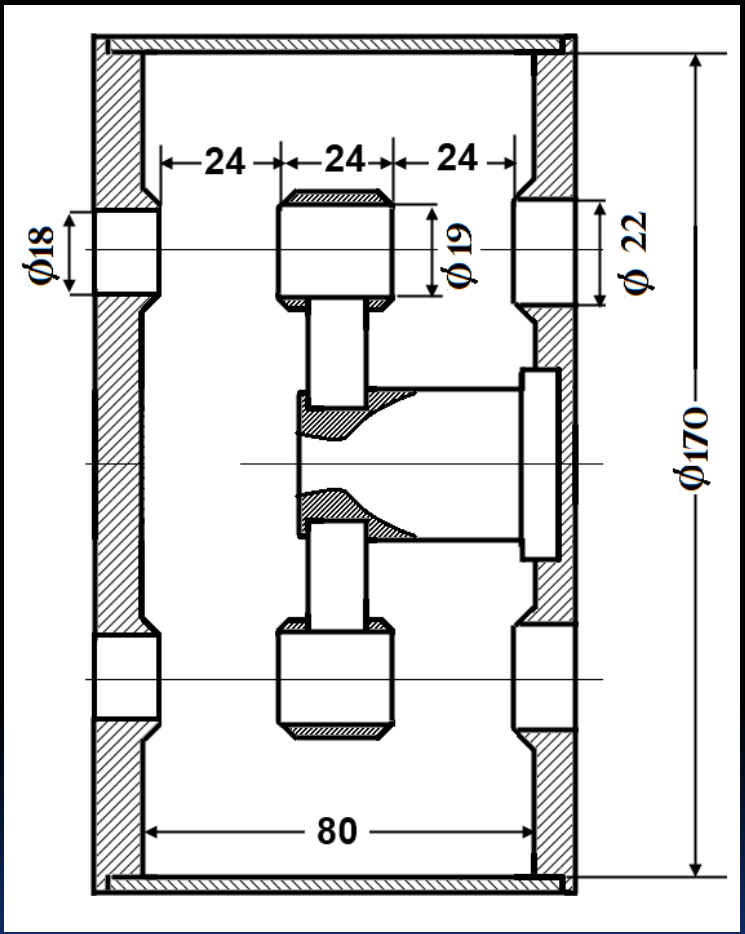


The behavior of the first harmonic of the convection current along the interaction space



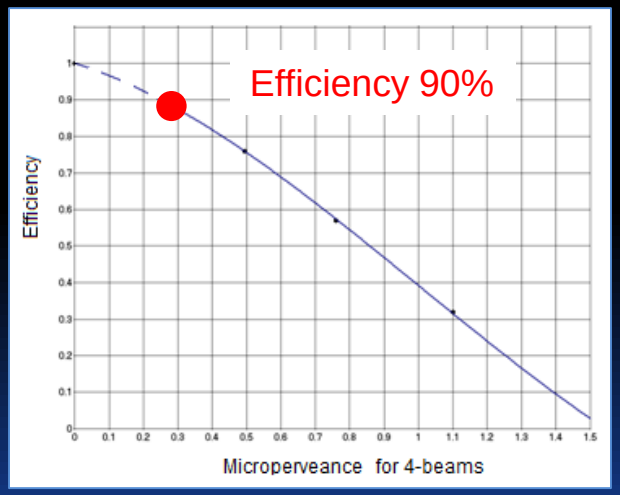
The process of electron bunches formation at different phases

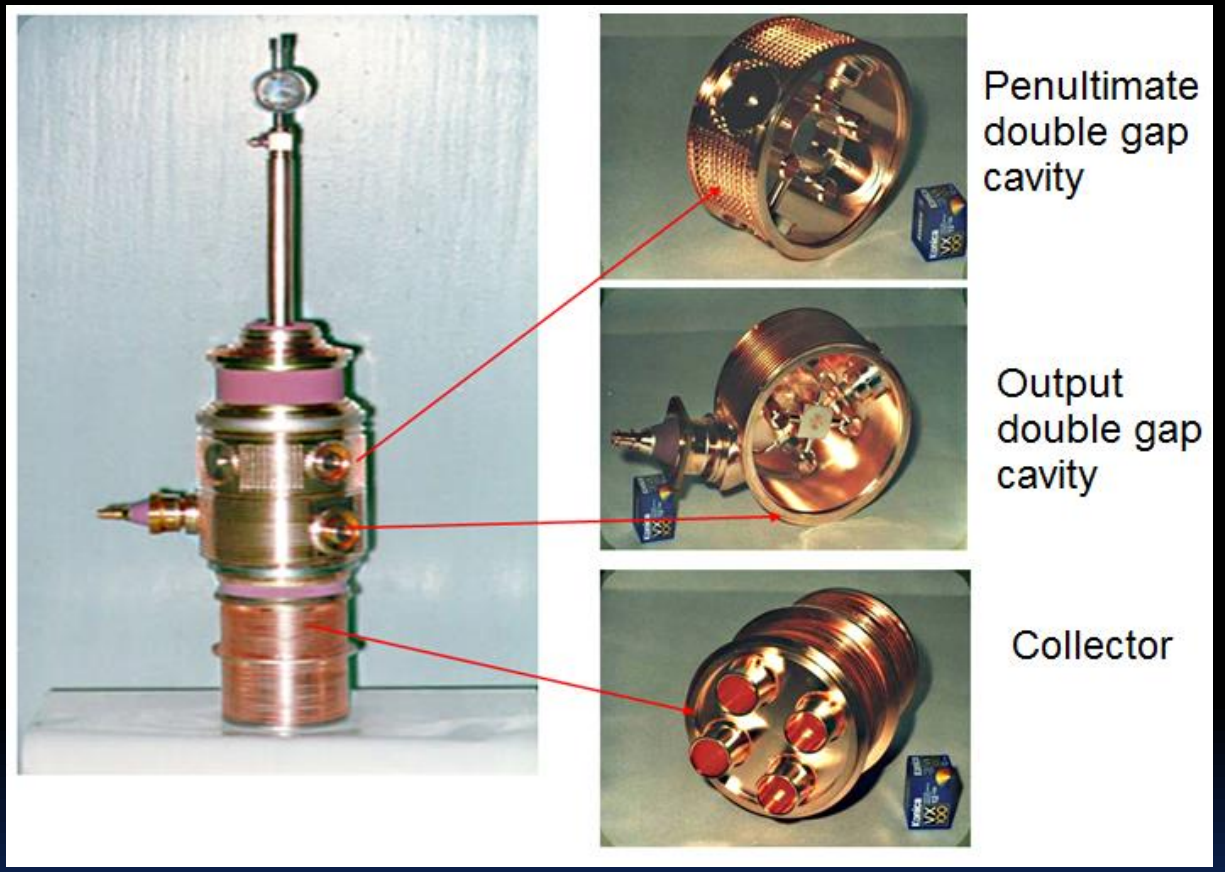
Special double gap output cavity of tristrode has high impedance.



The Experimental results

Mode of operation	Class C	Class D
Output CW power, kW	14	10.6
Beam power, kW	18.4	11.73
Beam voltage, κV	16	17
Bias voltage, V	-4	-39
Beam current, A	1.15	0.69
Efficiency* load, %	76	90
Total micro perveance, $P_{\mu\Sigma}$, $мкА / В^{3/2}$	0.494	0.27





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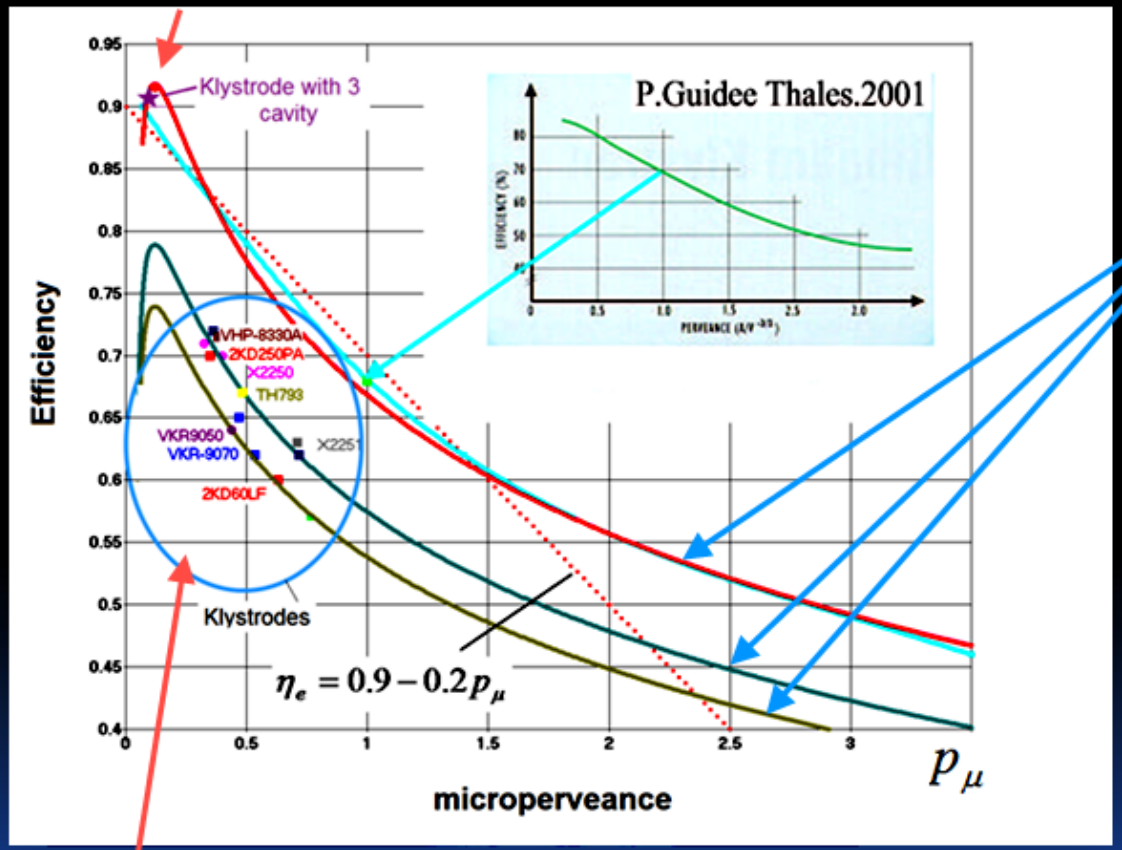
The dependence of efficiency on microperveance/beam

To obtain high efficiency we have worked in class D at microperveance/ beam less than 0,1



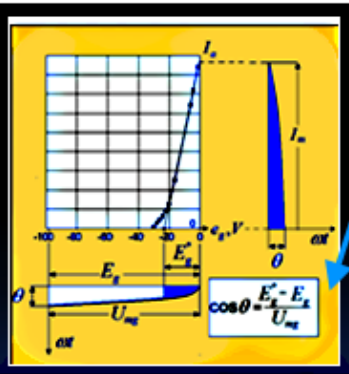
Maximum efficiency IOT at class B usually does not exceed 0,785

The dependence of efficiency on microperveance well described by the following equation

$$\eta_e = \eta_{e,\max}(0.08 + (0.85 - (q^* - 1)^2)^{1/2})$$

$$q^* = 0.345 / p_\mu^{1/2}$$

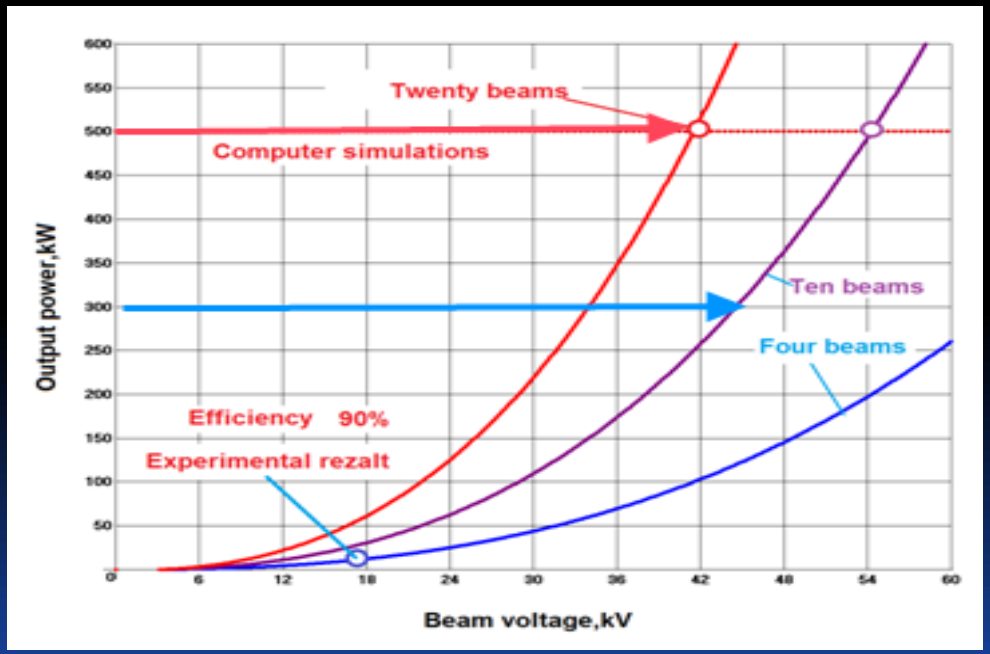
$$\eta_{e,max} = 0.5\,(U_{mg}/U_0) M_n \frac{\Theta - \cos\Theta \sin\Theta}{\sin\Theta - \Theta\cos\Theta}$$



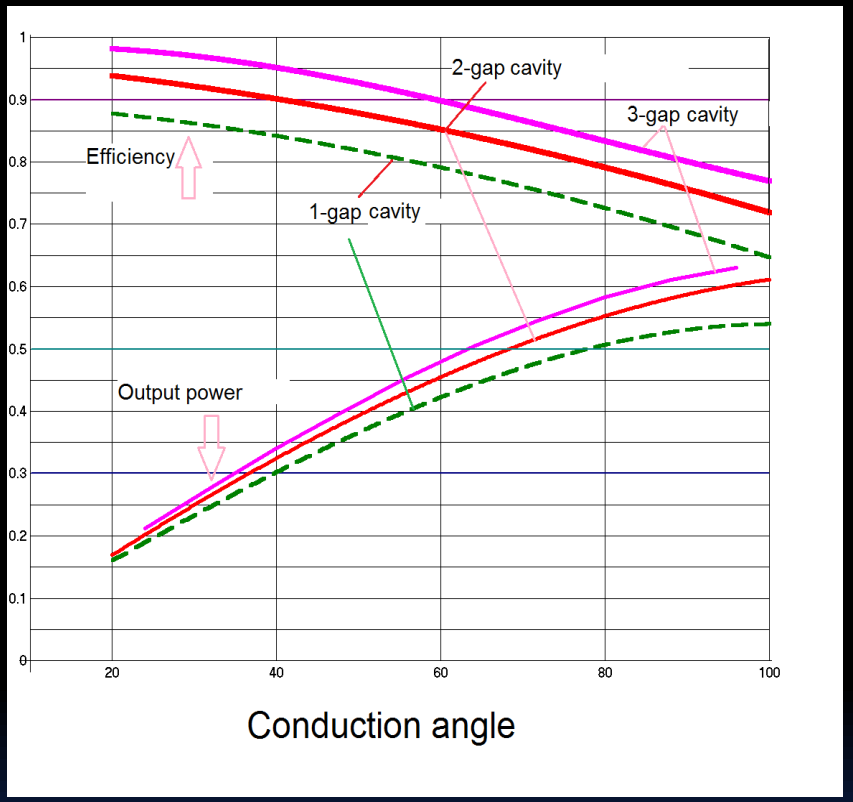
Tsarev, V. A.
A general regularity of behaviour for the klystron electronic efficiency depending on space charge parameter of electron] beam // IEEE International vacuum electronics conf., Monterey, 22-24 april 2008. - Monterey, USA, 2008. - P. 144-145

Efficient (90%),0.4 GHz tristrode key features

- Number of beams should be more than 10
- The conduction angle between 40 and 60 degrees
- Microperveance per beam <0.1 μA /$V^{3/2}$
- Multi-gap (2-3 gaps) output cavity



The RF power vs. beam voltage for the different of beams.



RF output power efficiency of the MB tristrode vs the conduction angle for the different number of the gaps in output cavity.

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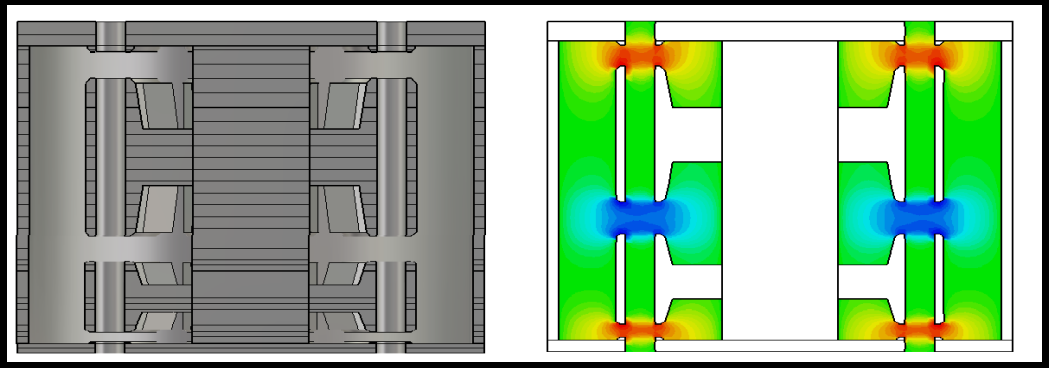
Comparison between LHC klystron and multi-beam tristrode

RF POWER GENERATION
IN LHC
O. Brunner, H. Frischholz, D. Valuch

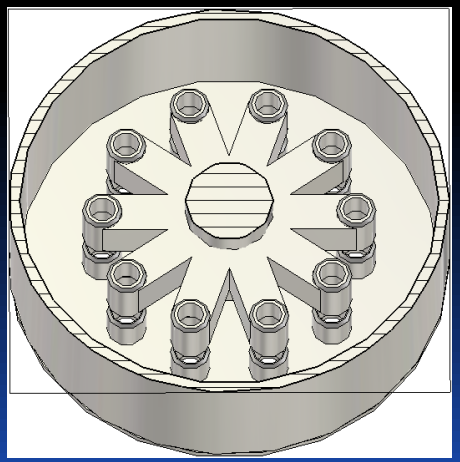
Parameters	Klystron	Klystrode
Rated Output Power	300 kW cw	300 kW cw
Operating Frequency (f_0)	400.8 MHz	400.8 MHz
DC-to-RF Conversion Efficiency	≥ 62 %	90%
-1dB Bandwidth (@1dB below rated output power)	≥ ±1 MHz	≥ ±1 MHz
Beam Voltage (U_B)	54 kV	45 kV
Beam Current (I_B)	≤ 9 A	≤ 8 A
Relativistic Gun Perveance, $mA/V^{3/2}$	0.66	0.08

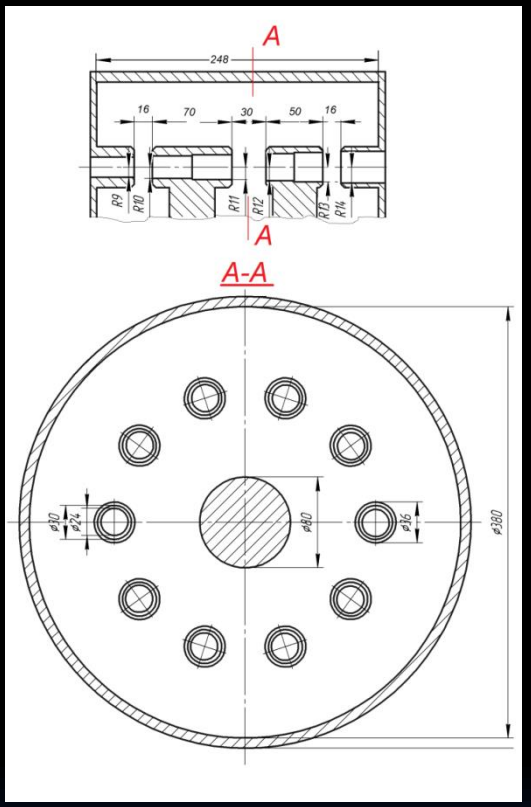
Three gap output cavity design

In further studies we will consider a three - gap output cavity with decreasing amplitude of the field intensity in the gaps



General view of the resonator and the electric field distribution in the gaps





Another new feature is an enlarged drift tube diameter downstream.

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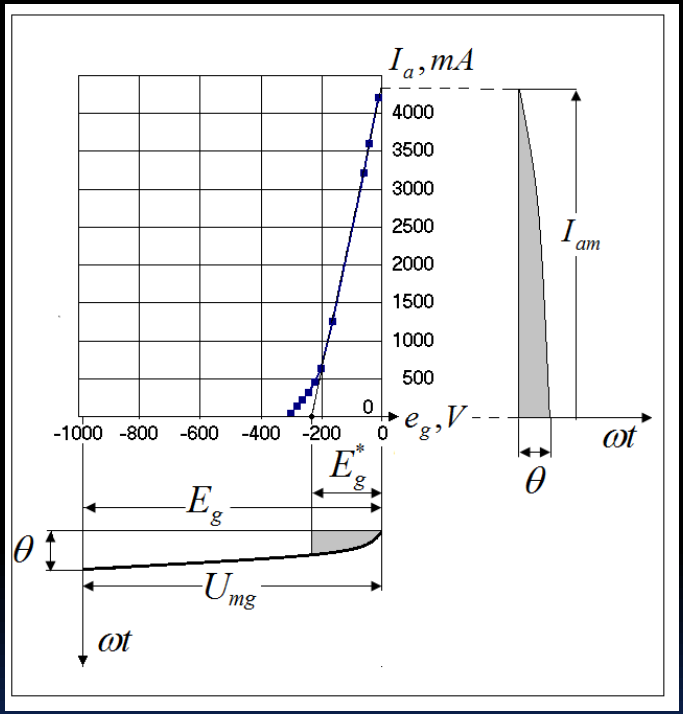
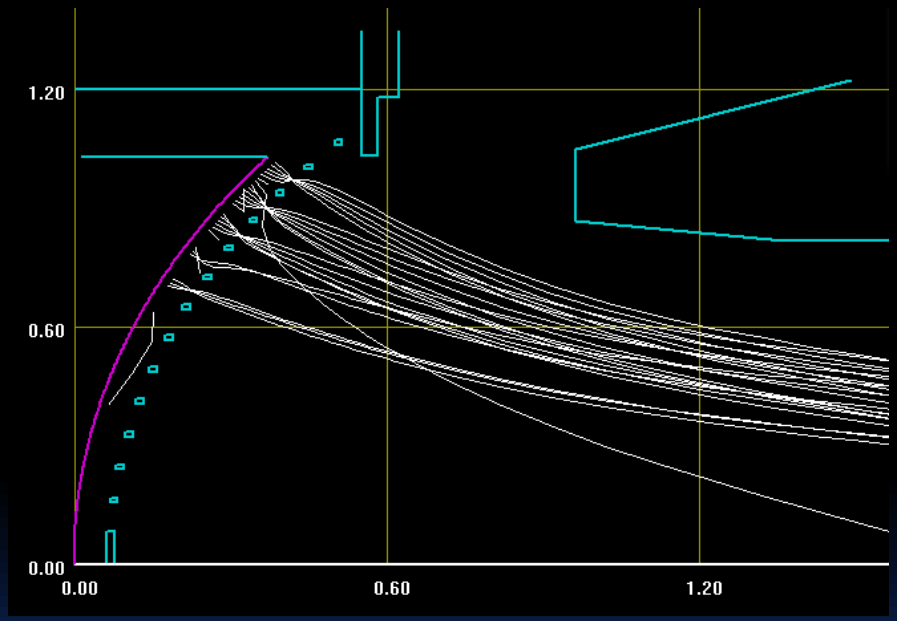
For the Class D devices, the gun with spherical cathode is not efficient. We should either choose a different shape of the cathode curvature or to use a hollow beam



Anode -grid transition at anode voltage 40kV



The trajectories of electrons in the gun (class D)

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