A NEW GENERATION OF POWER KLYSTRONS ON THE BASE OF MULTIPLE-BEAM DESIGN

E.A.Gelvich, E.V.Zhary, L.M.Borissov,
A.D.Zakurdayev, A.S.Pobedonostsev, V.I.Poognin

Research & Production Corporation "Istok",
Fryazino, Moscow Region, USSR

ABSTRACT

The advantages of multibeam klystrons over single-beam klystrons regarding the reduction of supply voltages, weight and the amplification band expansion, are shown.

Some parameters of industrial samples of multiple-beam klystrons (supply voltages, output powers and amplification band) are given.

A number of unique features of amplifier klystrons, that are typical as a whole of these devices only, made it possible to hold an important position in microwave electronics. Further improvement of the klystron characteristics is of great importance for the development of new and more advanced equipment types.

One of the principal solutions, that allows for achieving higher klystron parameters, is the use of multibeam designs.

The concept of use of several electron beams appeared actually immediately after the klystron invention [1,2] . The multibeam klystrons were intensively examined in the USA in the fifties and , especially, in the sixties: the multibeam klystrons on higher oscillation modes of resonator [3] , the traveling-wave klystrons [4].

However, as the publications show, this work was not completed and was not embodied in industrial samples. Due to this A.Staprans et al. [5] announced in 1973 that the multibeam klystrons were not used anywhere at that time.

During more than two decades (from early sixties) RPC "Istok" has been performing research and industrial development of the multibeam klystrons, mainly on the basis of the fundamental oscillation mode of the resonators. (fig.1). The report includes the brief summary of this work.

Figure 2 is an illustration of the specific example of calculated plots, displaying the variation of the klystron parameters in dependence of the number of electron beams. Not going into profound theoretical statements we can just note, that the main reason for drastic improvement of multibeam klystron parameters compared to single-beam ones in the wide parameter range lies in the fact that low perveance and low current electron beams are focused, grouped and give up energy more efficiently. That's why it is more useful to obtain the output power required by summarizing the powers, that are given up by low current beams to the jointly excited field. Thus it is possible to lower operating voltage significantly, that results in reduction of dimensions and weight of the klystron and leads to the substantial extension of the amplification band.

A typical multiple-beam klystron (MBK) structure operating in the fundamental resonator mode is demonstrated in fig.1 .

As it is obvious from the figure, good passing of electron beams through the channels of the resonant system have in the case of the MBK particularly decisive role in attaining high parameters of the tube. Therefore a more uniform magnetic field distribution in transit channels is required for a multi-beam electron-optical and focusing system in comparison with a single beam one.

The typical magnitude of the magnetic field's cross component in peripheral channels is 1÷1.5 percent of the magnitude of the axial component. A 97÷99% beam current transition ratio through channels in a static mode, and 90-95 percent - in a dynamic mode could be got in this case.

Due to little space between elemental cathodes no collimating optics can be employed in multi-beam klystrons operating in a fundamental oscillating mode of the resonators. That's why high enough current density at the cathodes for short wave length klystrons, especially if broadband amplification is desired, is almost inevitable, and therefore the amplification band is limited by the available high current density cathodes. Dispenser cathodes used in developed multiple-beam klystrons provide above 30 A/cm^2 current density in pulse mode and

QQ

CH2870-4/91/0000-1319$01.00 © 1991 IEEE

up to 10 A/cm^2 in CW-mode.

Multiple-beam klystrons (MBK) feature a two-fold benefit in amplification band in comparison with single-beam ones when employing common single-gap resonators. Multiple-gap and coupled resonators lead to an additional advantage when properly used in the resonant system of the MBK.

Capabilities inherited in mbk design as well as RPC "Istok"-realized research and engineering programs have led to the production of a number of klystrons featuring high enough parameters set for various frequency ranges and for variety of power levels (Table I). These klystrons employ from 6+7 to several tens of electron beams.

Table I

Mode / Parameter	CW		Pulsed			
λ, cm	>10	<10	>10	<10	<10	<10
P_{out}, kW	0.3	0.1	6	500+700	15÷30	150÷300
$\Delta f/f_o$, %	1.5	1.5	18	6	2+6	2+3
U_{cath}, kV	1.7	1.2	2.7	30+32	10+14	20÷27
η, %	40	35	40	40	40	40
G, dB	>30	40	40	40	40	40
Weight, kg	8	1.2	8	20+25	10+15	15+20
Focusing	solenoid	PM	solenoid	solenoid	PM	solenoid

High-power MBKs have pulse power of hundreds of kilowatts, under an average power of about 20 kW. Its amplification bandwidth exceeds 5+6 percent and efficiency achieves 40+50 percent. Voltage and mass of multiple-beam klystrons are two times less than that of similar single-beam klystrons [6].

Medium power klystrons (pulse power - tens of kilowatts, average power - single kilowatts) have about 6 percent of bandwidth in the short-wave region of cm-band being compatible in bandwidth with TWTs based on a chain of coupled resonators, but having considerably more efficiency (30-40 percent) without recuperation and three to four times lower phase to voltage sensitivity.

In dm-band 18 percent bandwidth, with an output power of several kilowatts has been attained in a 61-beam klystron.

Thus, qualitatively new parameters of the developed multiple-beam klystrons operating in a fundamental resonator mode permit to claim a new generation of effective enough high-power amplifying microwave devices.

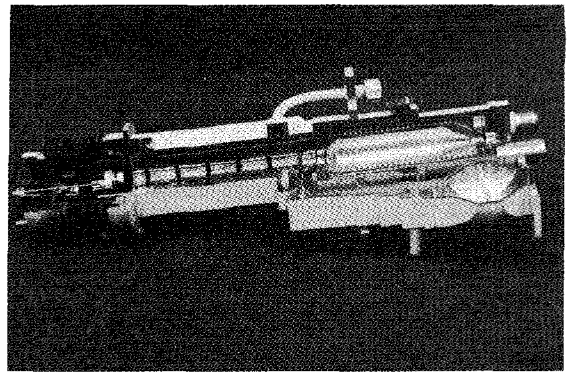

Fig.1. Multiple-beam klystron cross-section.

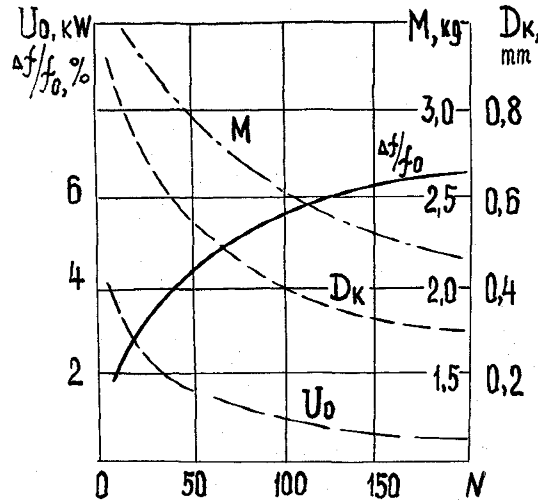

Fig.2. Wide-band klystron: bandwidth $\Delta f/f_o$, operating voltage U_o, magnet weight M and transit channel diameter D_k versus beam number N; λ =3cm, P_{out}=500 W, j_{cath}= 15 A/cm

REFERENCES

1. Bernier J. Pat.No 992 853, Sept. 15, 1944 (France);
2. Kovalenko V.F. "Electron-beam tube", USSR Pat. No 64 257, Dec. 31, 1940;
3. Boyd M.R., Dehn R.A., Hickey J.S.,Mihran T.E. "The multiple-beam klystron", IRE Trans. on ED, May 1962, vol. ED-9, No.3, p.247.
4. Pohl W.J. "The design & demonstration of wide-band multiple-beam travelling-wave klystron",IEEE Trans. on ED,1965, vol.ED-12, No 6, p.351;
5. High-power microwave tubes, ed. by Law L.Clampitt,Proc. of the IEEE, v.61, March 1973, pp. 279-381;
6. Korolyov S.V."On the possibil. to reduce weight of klystrons",Electr.Eng. "Microwave Electronics"1968,Ed.9 p.176