VDBT BAC MBK klystrons family. Status report

Igor Guzilov
JSC "Vacuum device's basic technologies",
Moscow, Russian Federation,
email: iag@bk.ru

BAC S-band MBK family

Parameters	BT258B	BT262	BT267	BT268
Peak RF power, MW	6	8	16	3,1
Average RF power, kW	30	10	30	12
RF gain, dB	45	45	45	45
Efficiency, %	>60			
RF pulse length, µs	16	5	16	12
Pulse repetition rate, Hz	300	200	300	200
Duty cycle, %	0,5	0,1	0,25	0,2
Peak voltage, kV	54	60	75	50
Peak current, A	220	280	420	120
Weight together with PPM, kg	95	90	90	75
Lifetime, ours	8 000	6 000	2 000	15 000

The development of BAC MBK BT258 was supported by CERN, Switzerland

Why do we use BAC method? (comparison with COM)

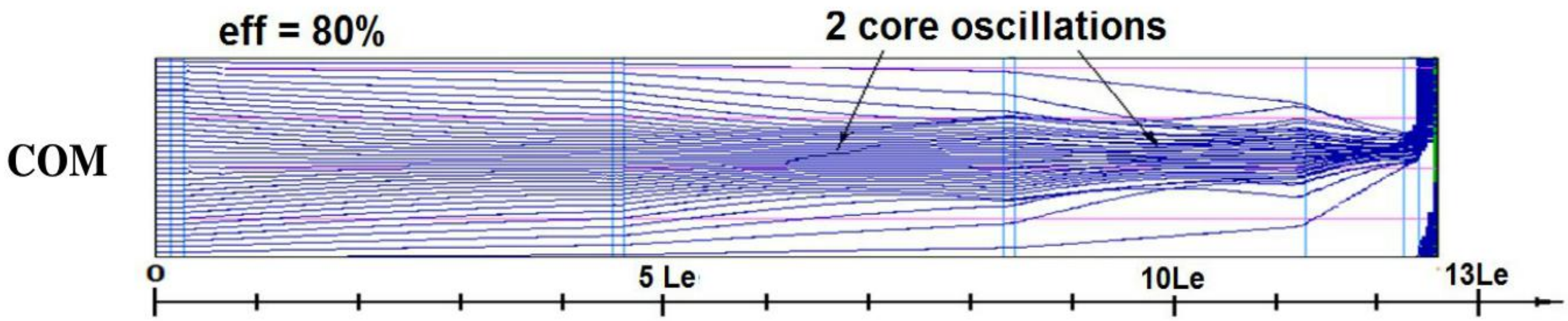
Core oscillation method, COM

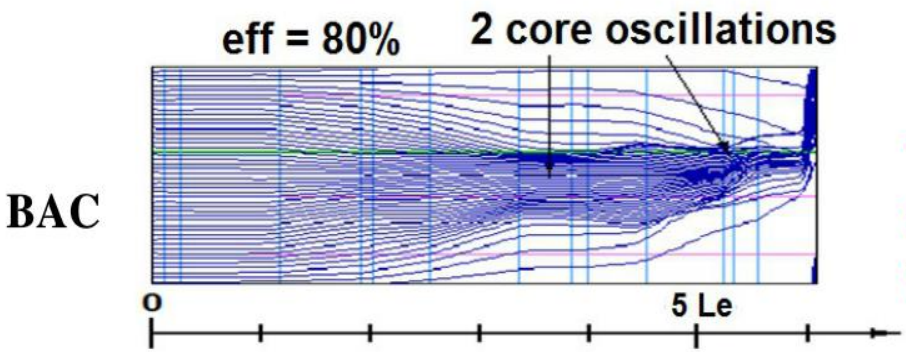
A. Baikov, C. Marrelli and I. Syratchev, "Toward high power klystrons with RF power conversion efficiency on the order of 90%", IEEE Trans. Electron Devices, vol. 62, no. 10, pp. 1-1, 2015.

Difference with the BAC method

Core oscillation occurs due to space charge forces of the bunch, which are much less then external forces inside the BAC triplet. As the result very long, very efficient tubes.

Using of BAC method allows to reduce the length of the interaction space more then twice in comparison with COM method, while maintaining high efficiency.





The main drawback of COM method is a very long tube which makes it difficult to use it in practice

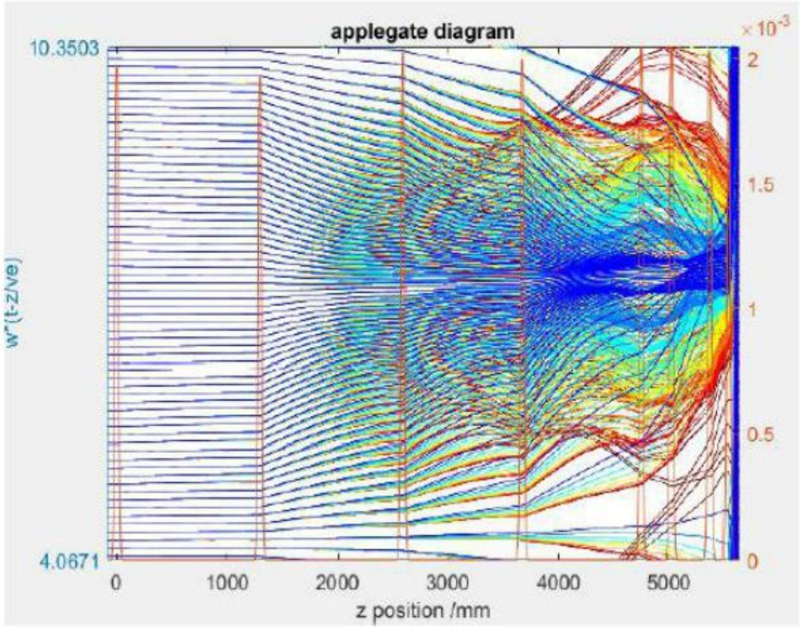
Why do we use BAC method? (comparison with CSM)

Core Stabilization Method, CSM

A. Baikov, C. Marrelli and I. Syratchev, "Toward highpower klystrons with RF power conversion efficiency on the order of 90%", IEEE Trans. Electron Devices, vol. 62,no. 10, pp. 1-1, 2015.

Difference with the BAC method

Core oscillations in CSM occur due to the influence of second and third harmonics cavities doublet. Third harmonics cavity strengthens the movement of peripheral electrons toward the core of the bunch, which allows to get 10% decrease of the RF circuit length for the same efficiency. RF circuit includes 2-3 cavities less than that one in BAC method



The main drawbacks of CSM method are:

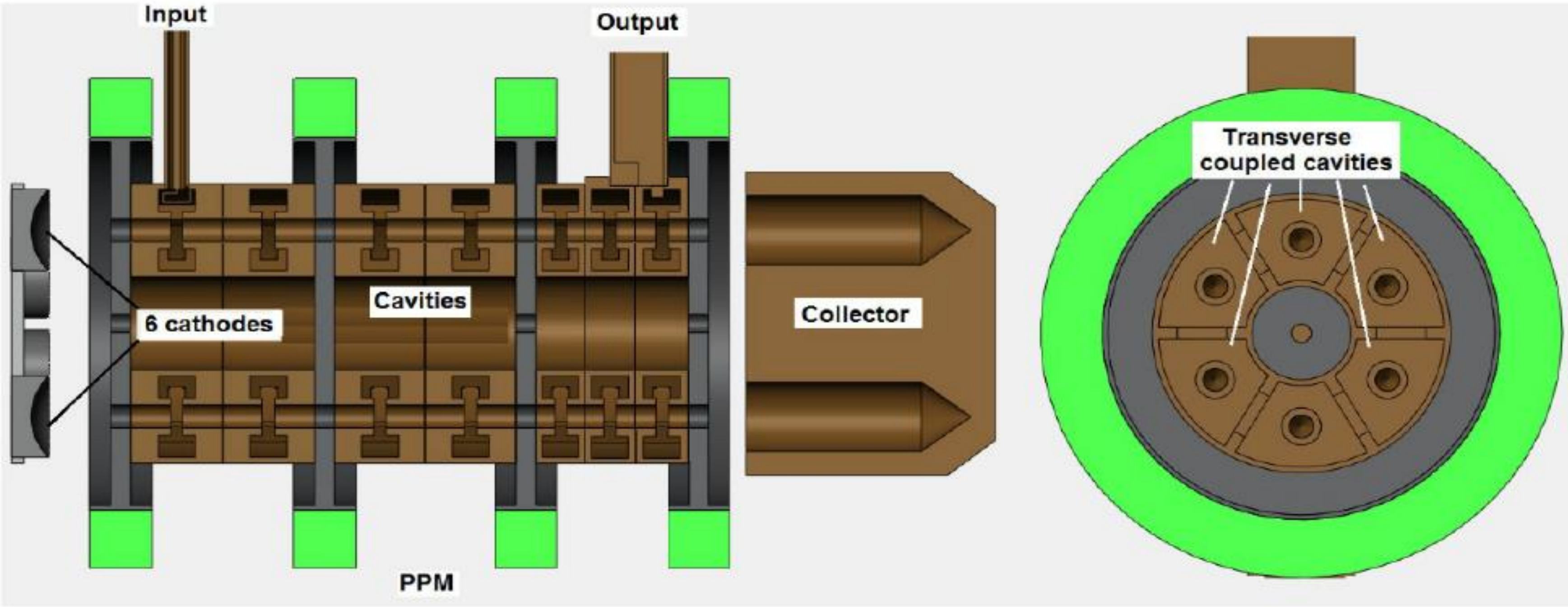
1. Relation around 1:3 between third harmonics cavity gap and channel diameter which leads to big radial stratification of electric field in the gap and as a result strong radial stratification of the bunching.

2. Difficulties of implementation in MBKs, especially for HOM (high order mode) cavities

Advantages of VDBT BAC MBKs

- Low Working voltage (less than half) when compared to similar RF power single beam klystrons.
- Reduction of harmful X-rays during operation.
- High efficiency performance due to the state-of-art Bunching Alignment Collecting (BAC) beam technology.
- Ability to work in air, without an oil tank, which reduces the installation weight.
- It can operate in spatial position and on mobile installations.
- Total cost of ownership (TCO) is much better since you need less power and the overall systems becomes smaller.
- Permanent magnet focusing that significantly reduces the MBK weight and additionally increases overall system efficiency due to absence of solenoid power losses.
- Application for the MBKs is Medical, Industry, Science and Defense.

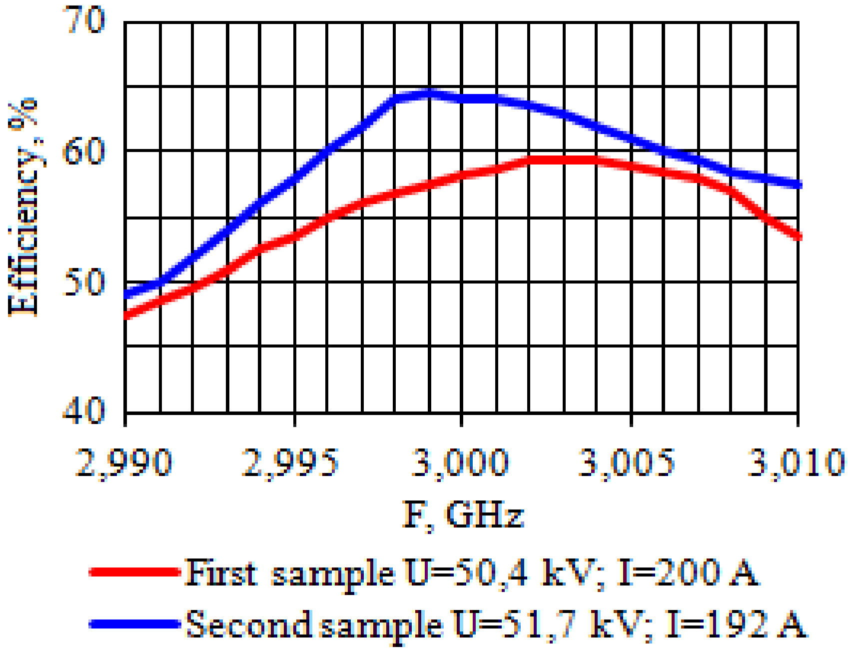
TCC – technology for CSM and BAC methods, which allows to increase efficiency, power and lifetime in C/X/Ku band MBKs



Advantages in comparison with traditional technologies:

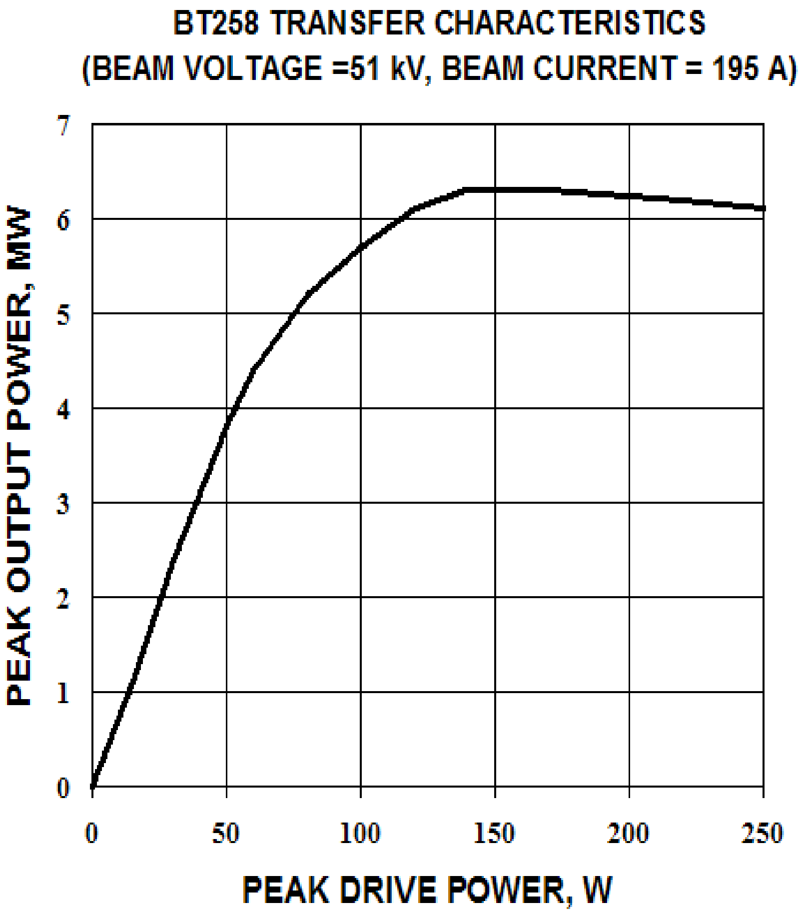
1. Increasing of useful cathode area more than 10 times and, as a result, to increase lifetime more than 3 times for the same output power.
2. Allow to increase output power for high frequencies - up to 100 MW in C-band and up to 50 MW in X-band with long lifetime.
3. Low voltages for high powers - no more then 150 kV for 50 MW klystrons and 55 kV for 3,5 MW klystrons

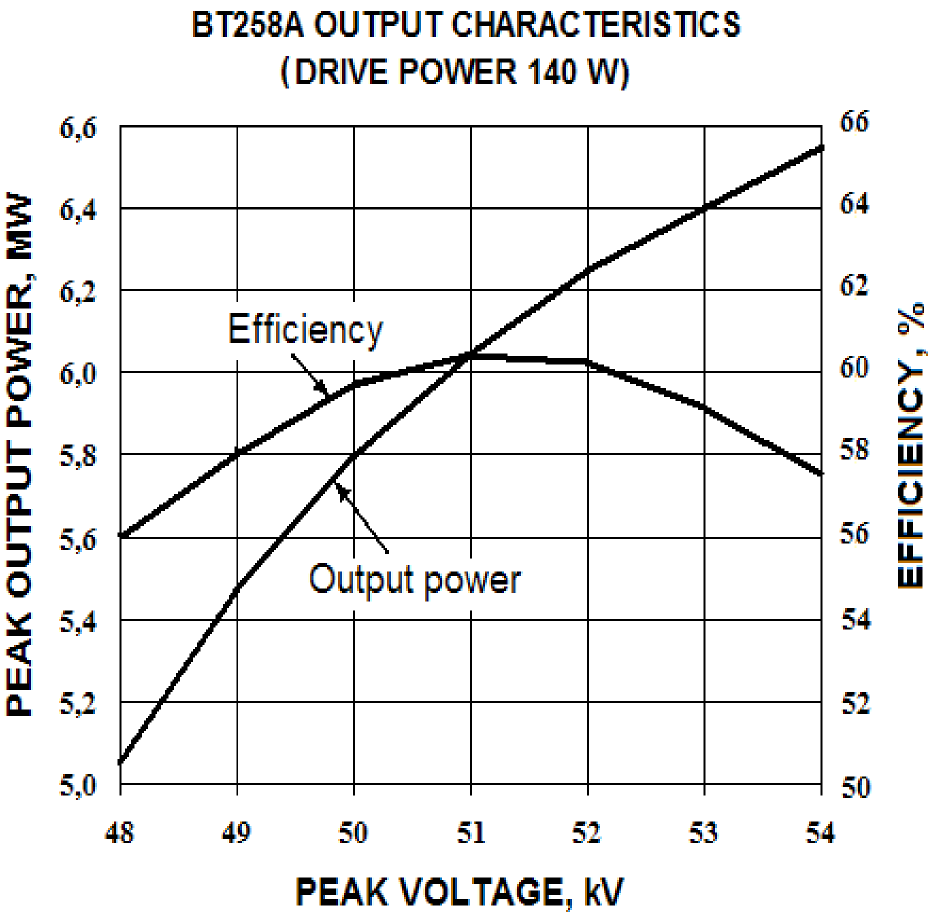
Test results of BT258 at CERN and JINR



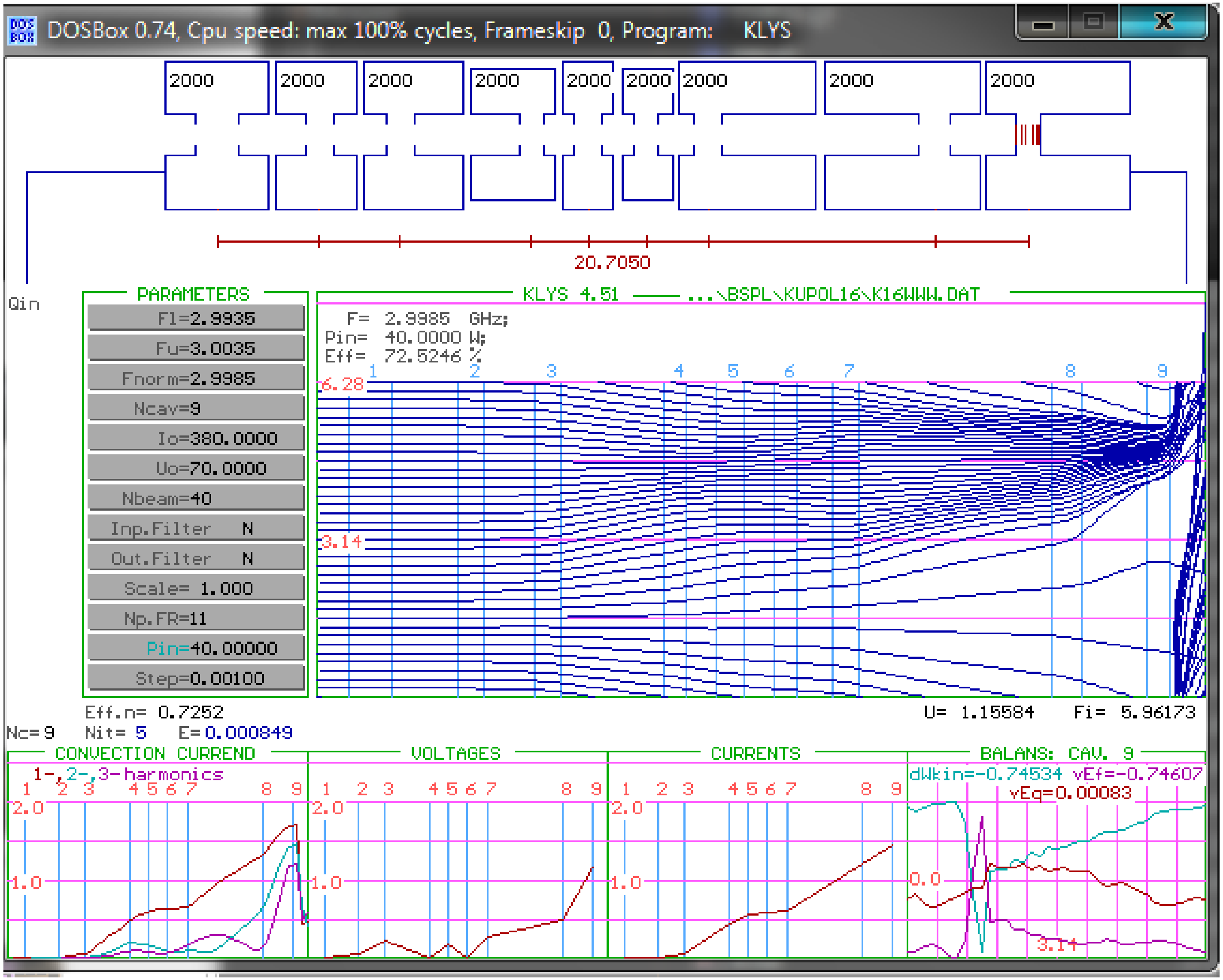
Pulsed output power of 6,4 MW was observed in second sample for the frequency 2,9985 GHz, cathode voltage of 51,7 kV. Gain changed in the range from 45 db (for the left side of the frequency band) to 53 db (for the right side).

Typical transfer characteristics of BT258



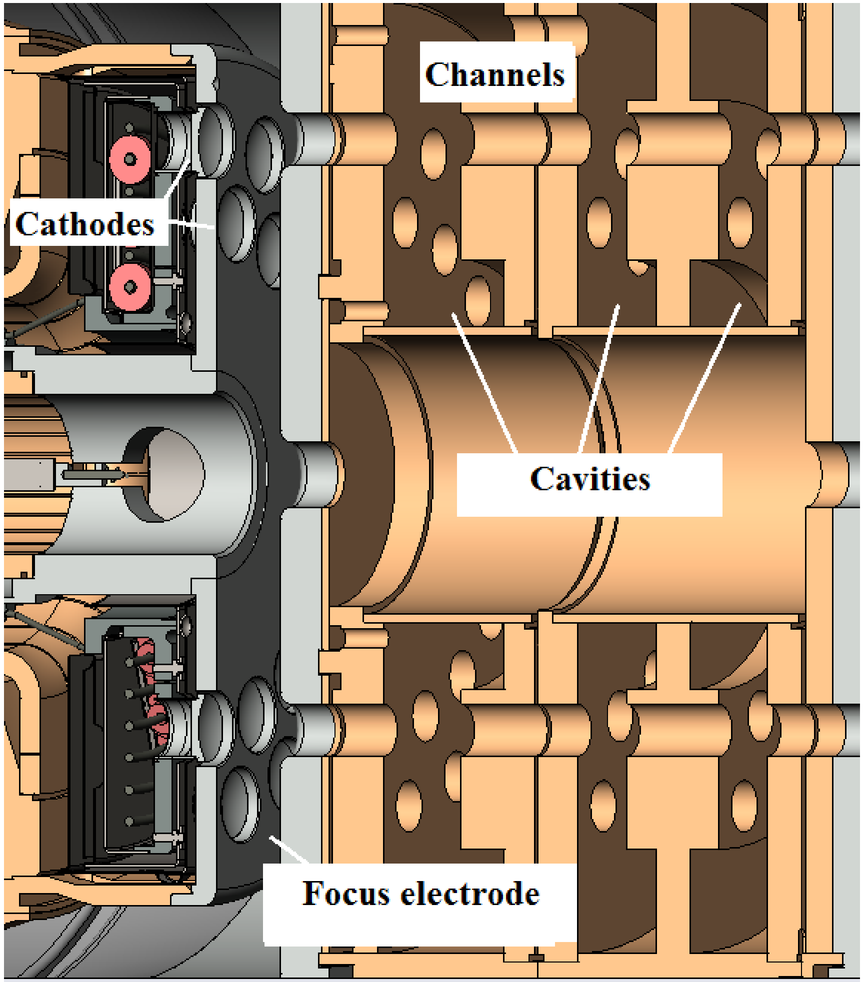


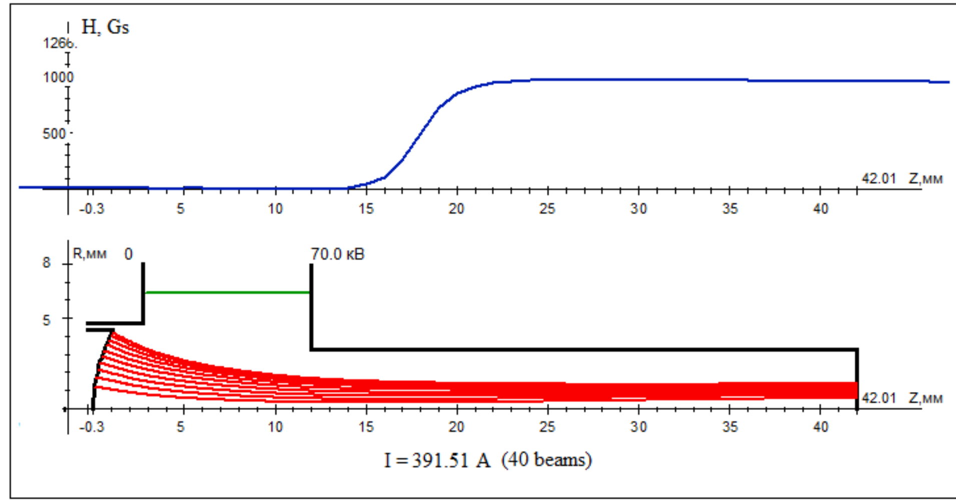
BAC MBK BT267 – klystron for high output power of 16 MW



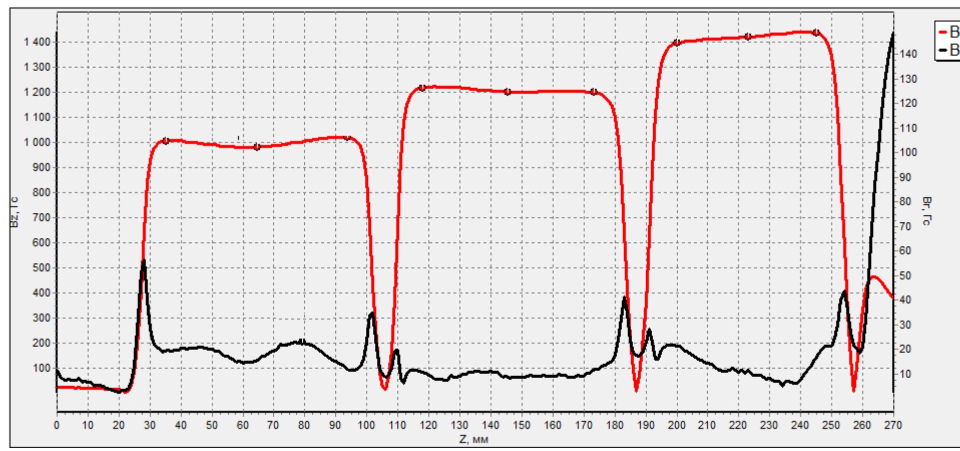
Simulated by 1D in-house code Klys4.5 efficiency is 72,5%

BT267 (16 MW) – electron optics





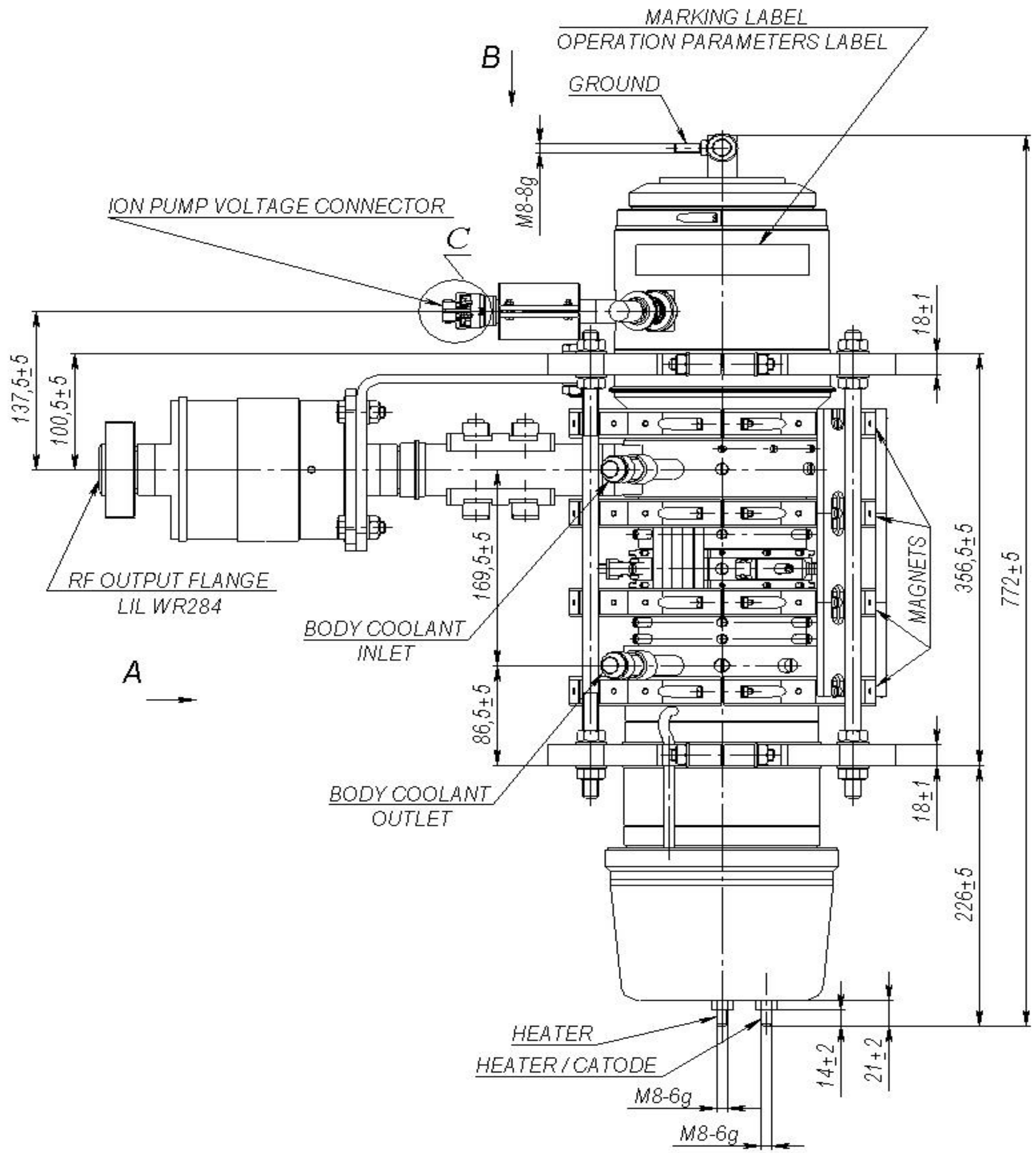
Electron gun



Magnetic field in the channels

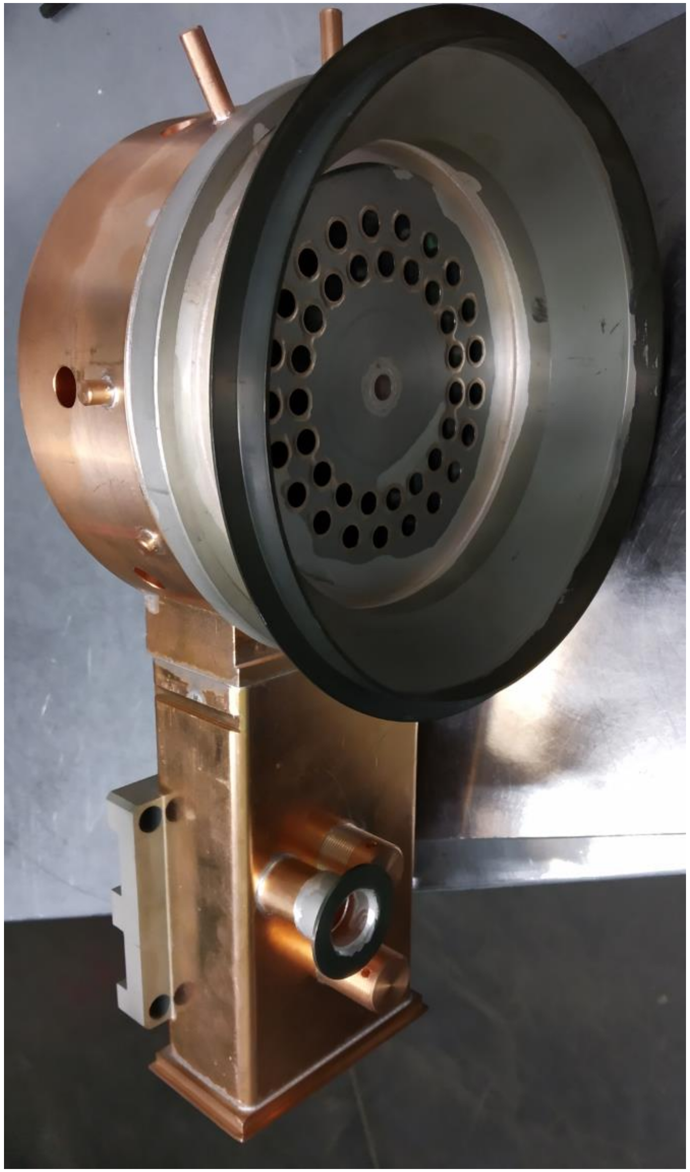
Cavities include 40 channels for beam propagation

Design of 16 MW BAC MBK BT267 – dimensional drawing



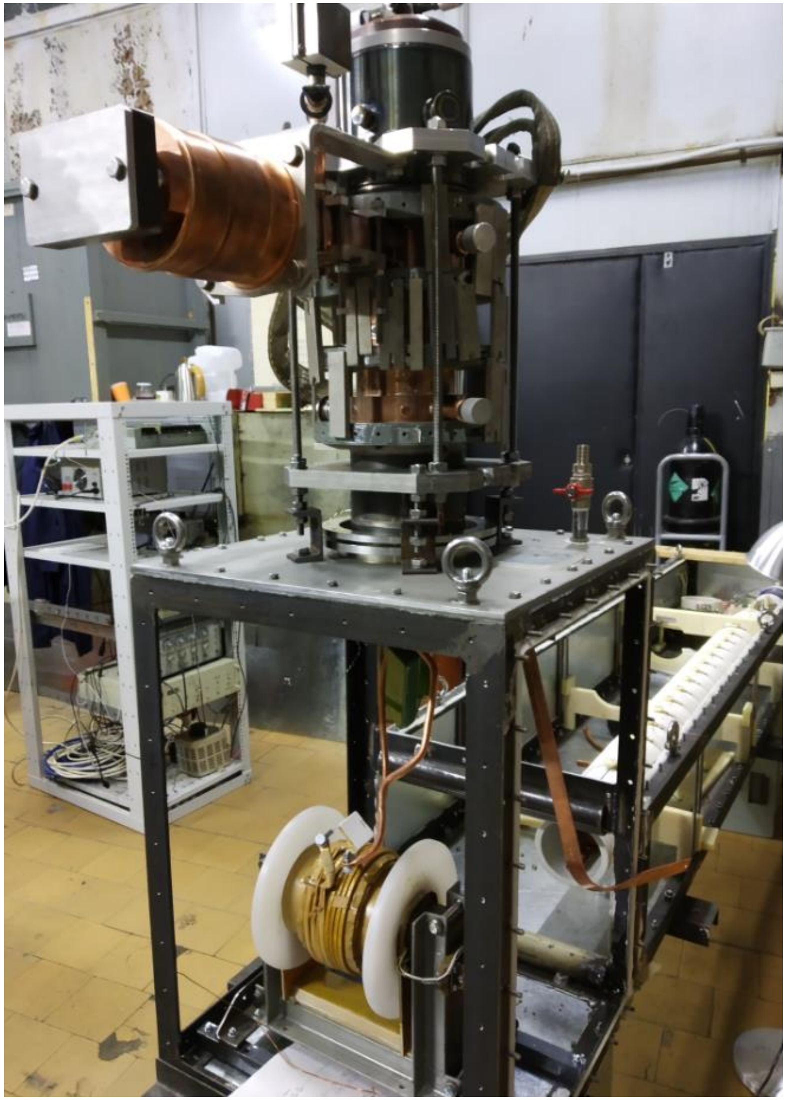
Cavities

Input and intermediate cavities

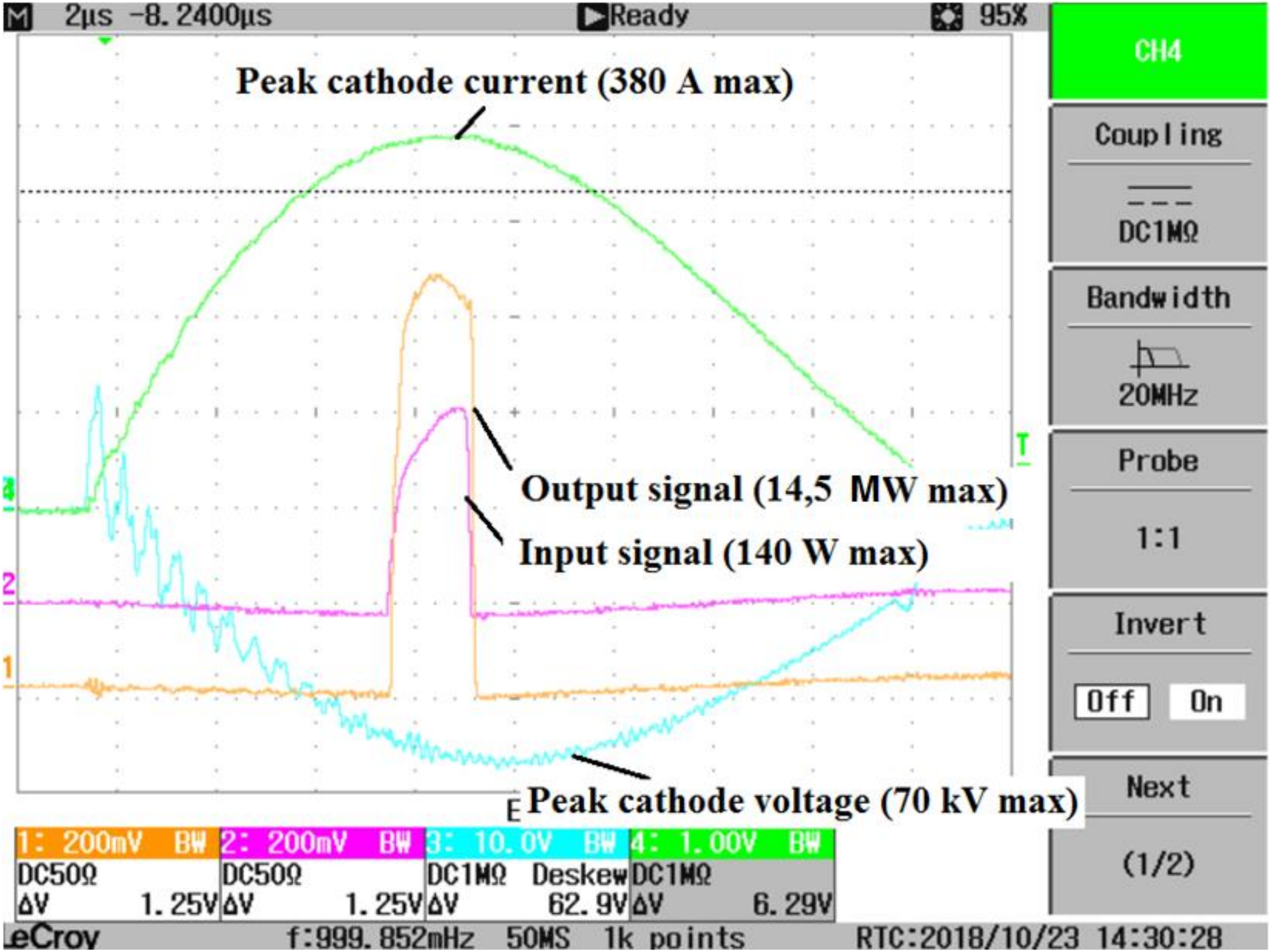


Output cavity

BT267 test installation



BT267 test results



MBK instead of magnetron for medical application

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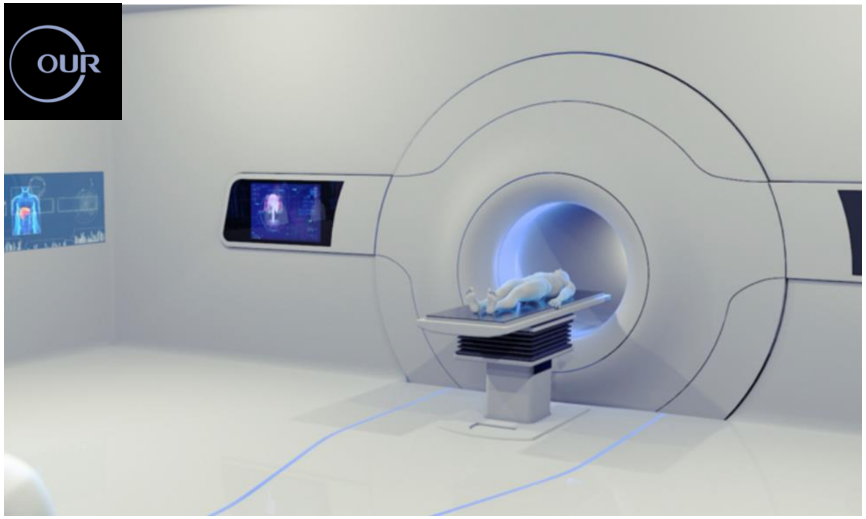
Comparison on a 3.1MW S-band Magnetron and 3.1MW S-Band MBK BT258 with focus on medical application



Courtecy:
OUR UNITED GROUP
Model: iMasteRay
ournewmed.com

Now

- Integrated modulator into gentry
- Rotating gentry
- Limitation of 10MeV
- No need for very high peak power
- Overall compactness
- Magnetron system well established

Future demands

•Better pulse stability/reliability
•Better uptime on RT machine
•Higher pulse repetition rate
•Klystron know-how
•Artificial Intelligence(AI)

Comparison on a 3.1MW S-band Magnetron and 3.1MW S-Band MBK BT258 with focus on medical application

Conclusion: By using MBK in a future medical system it is enable to have higher uptime, higher precision on beam delivery while using compact modulator, the same to magnetron system.

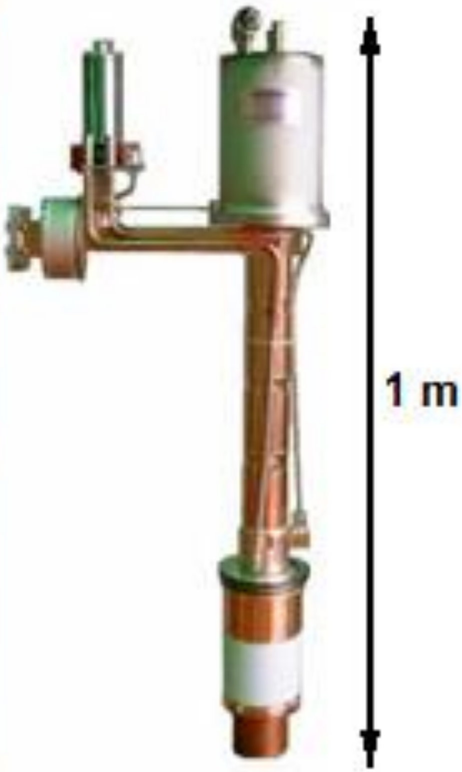
	Magnetrons	MBK
Peak Power (MW):	1- 3.1	0-3.1
Avg. Power(kW):	4	10
Warranty:	500h/12months	15000h/24months
Stability/Flatness:	Low	High
Pulse Length(Max. μs):	5	16
Focusing Magnet:	Electro magnet	Permanent magnet
Weight ,kg	+	70

Comparison with existing SBKs

Currently 3 vendors deliver 6 MW, 2.9985 GHz SB klystrons. All the klystrons are equipped with normal conducting focusing solenoids and were specially designed for industrial particle accelerators.

TH2173

E3779



VKS8262

BT258

Comparison with existing SBKs

Klystron	TH2173	E3779	VKS8262	BT258
Producer	Thales	Toshiba	CPI	VDBT
Average power, kW	36	6	36	30
Peak voltage, kV	130	145	135	<52
Peak current, A	90	105	109	190
Number of beams	1	1	1	40
Pulse length, us	17	2,5	17	17
Efficiency, %	50	42	45	64
Length, mm	975	1000	1000	800
Diameter, mm	410	500	400	265
Weight	160	240	200	95

Sizes are given together with magnetic systems

Conclusion

It was experimentally proved that new bunching technology (BAC) can significantly increase the efficiency of klystron amplifiers till 64%. New family of BAC MBKs combines such features as (four L):

1. Low voltage
2. Low weight
3. Low power consumption
4. Low X-ray radiation

Thank you for attention!