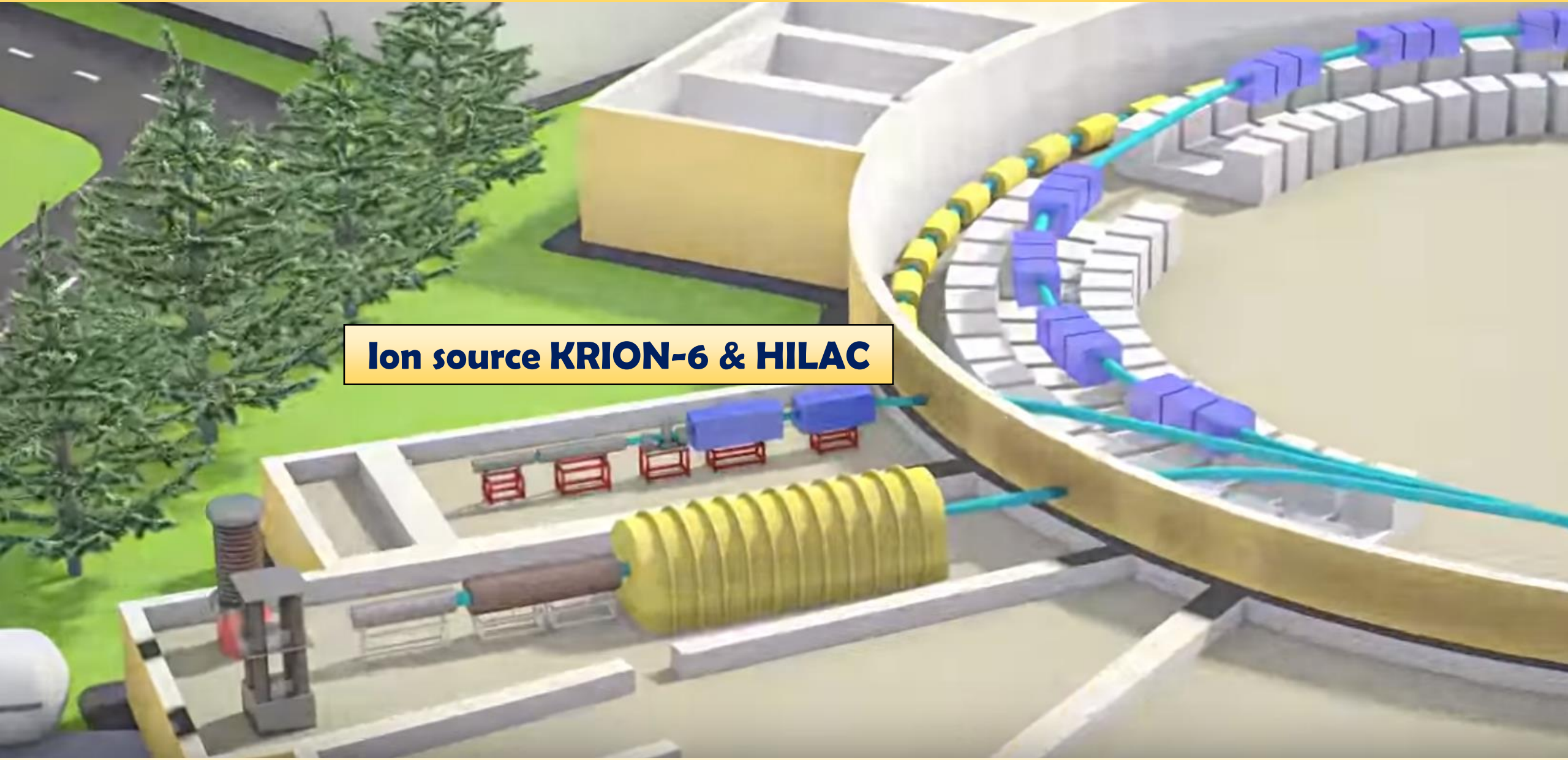
Electron String Ion Source (ESIS) electronics development

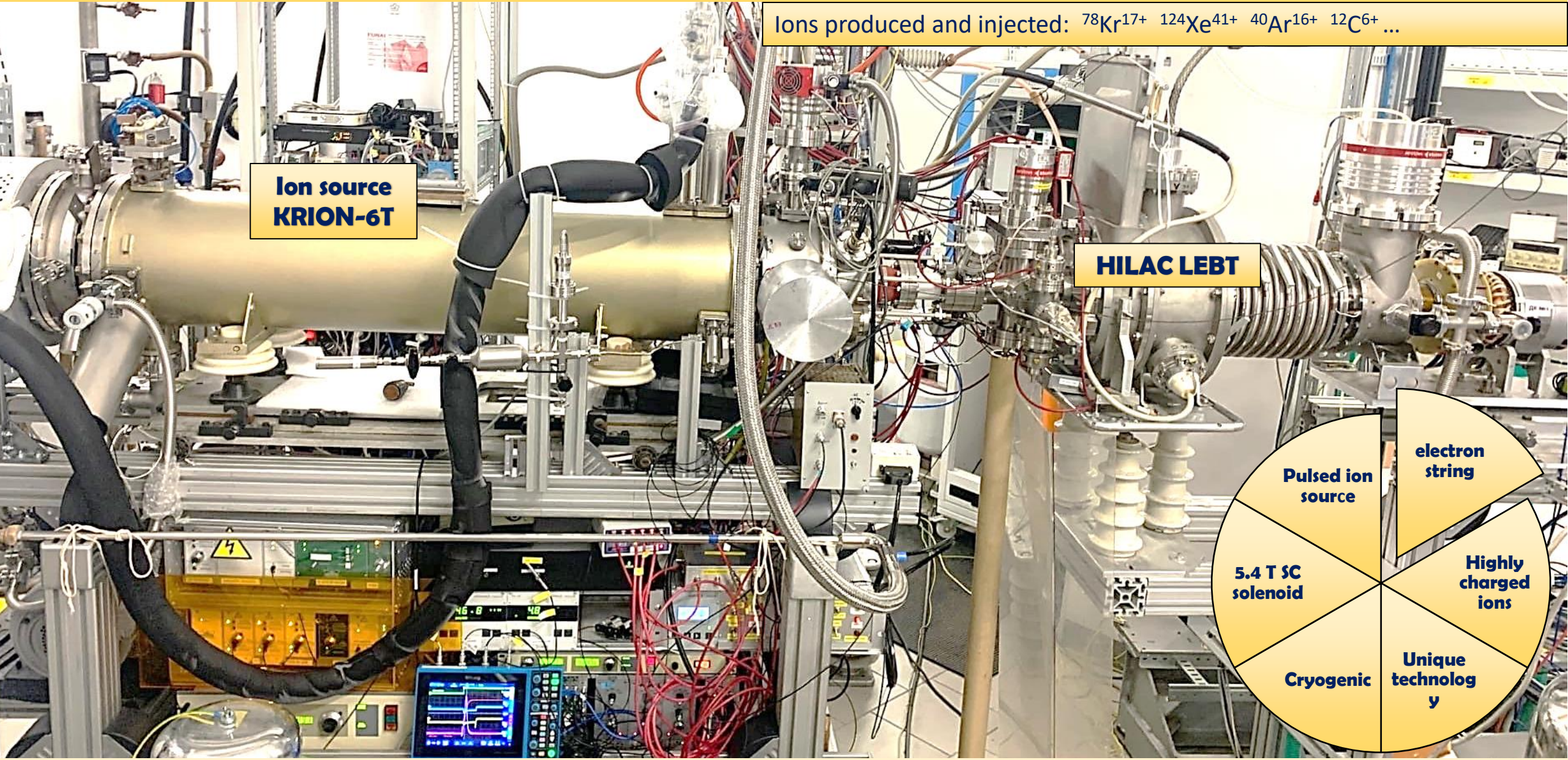
Dzugaev Maxim
Student, LHEP JINR

NICA injection complex



Heavy ion source KRION 6T

Ions produced and injected: $^{78}Kr^{17+}$ $^{124}Xe^{41+}$ $^{40}Ar^{16+}$ $^{12}C^{6+}$ …



ESIS KRION 6T electronics

Slow control

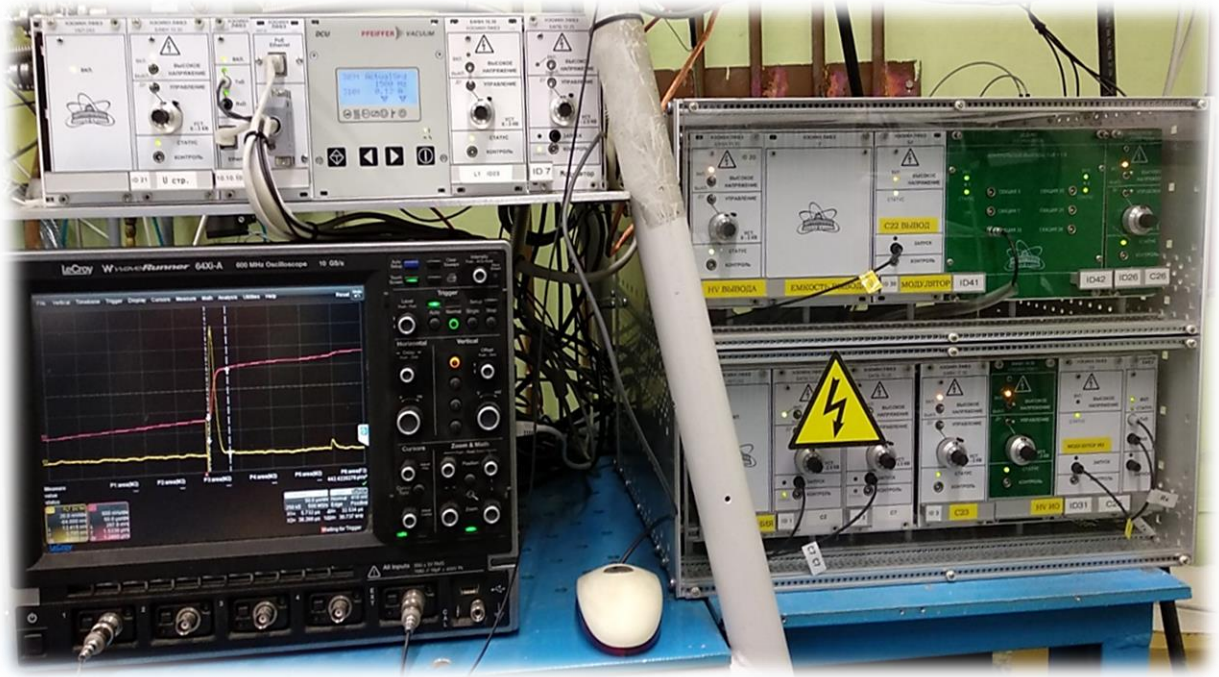
- Thermometry
- Vacuum
- Synchronization

Electron gun supply

- Heating module
- Optical isolation module
- HV modulator

Beam diagnostics

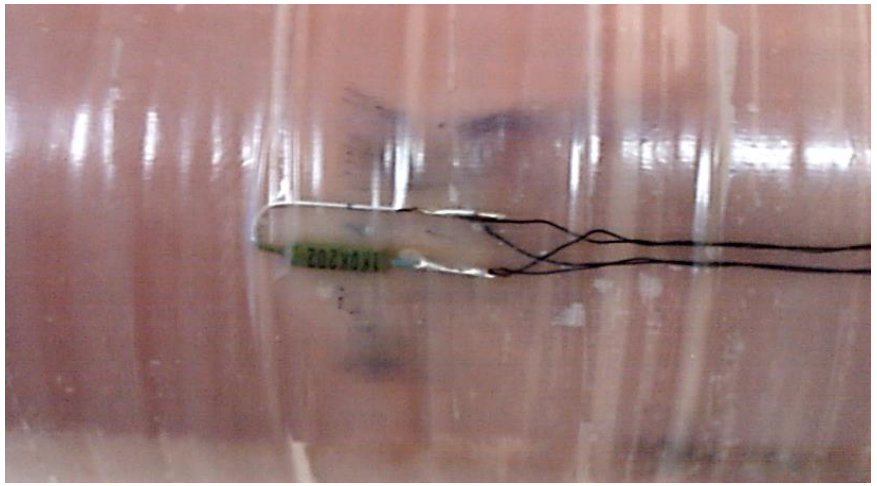
- Beam profile monitor
- Oscilloscopes
- Ion collectors



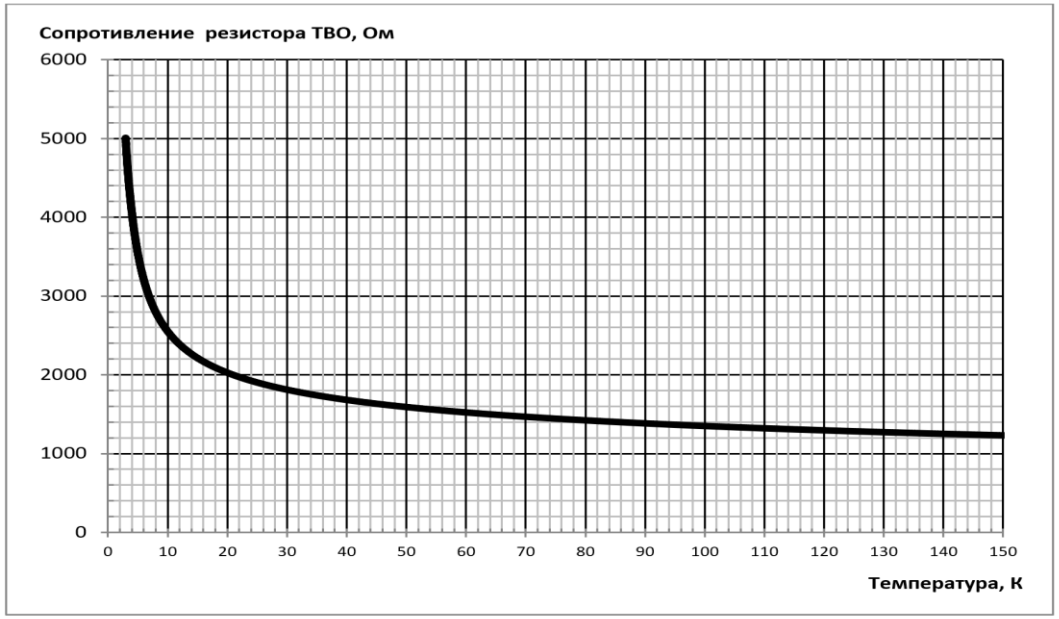
Ion motion control system

- DC barrier modules
- Pulsed barriers modules
- Extraction modules
- Interface modules

Thermometry

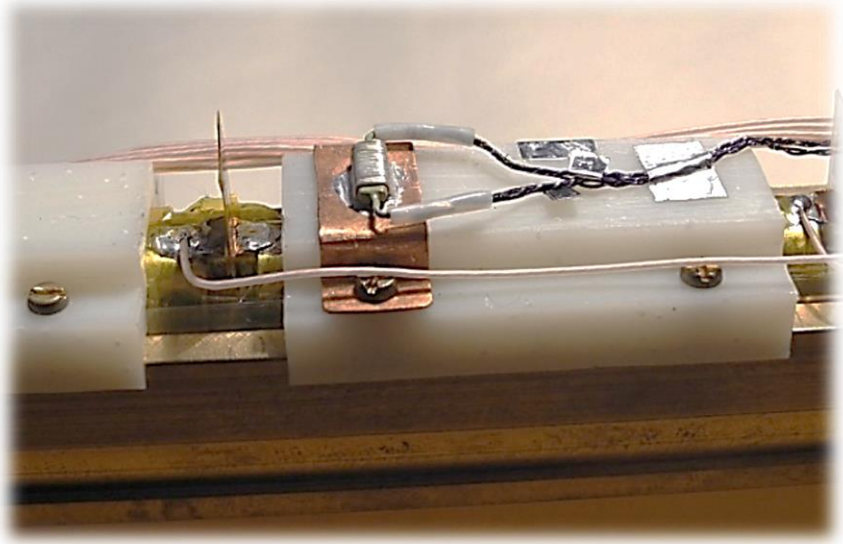


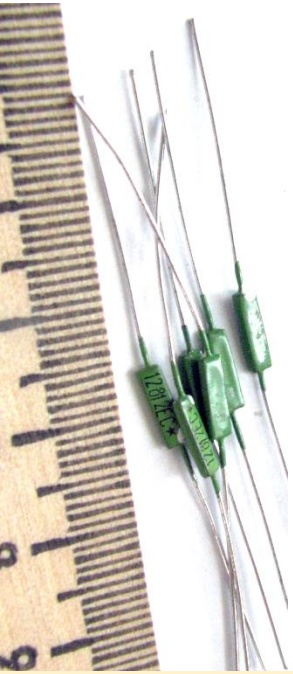
KRION 6T
superconducting solenoid

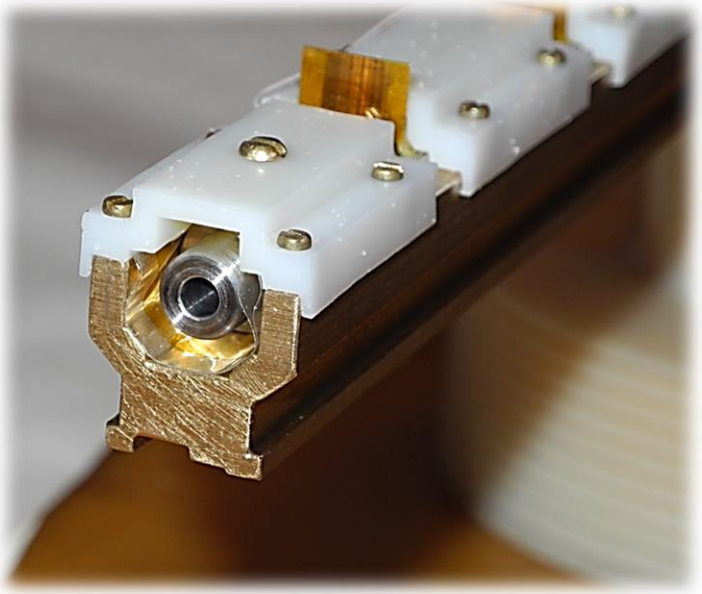


$$T = \sum_{n=1}^{m} K_n \cdot \left(\frac{R_0}{R_t} \right)^{n-1}$$

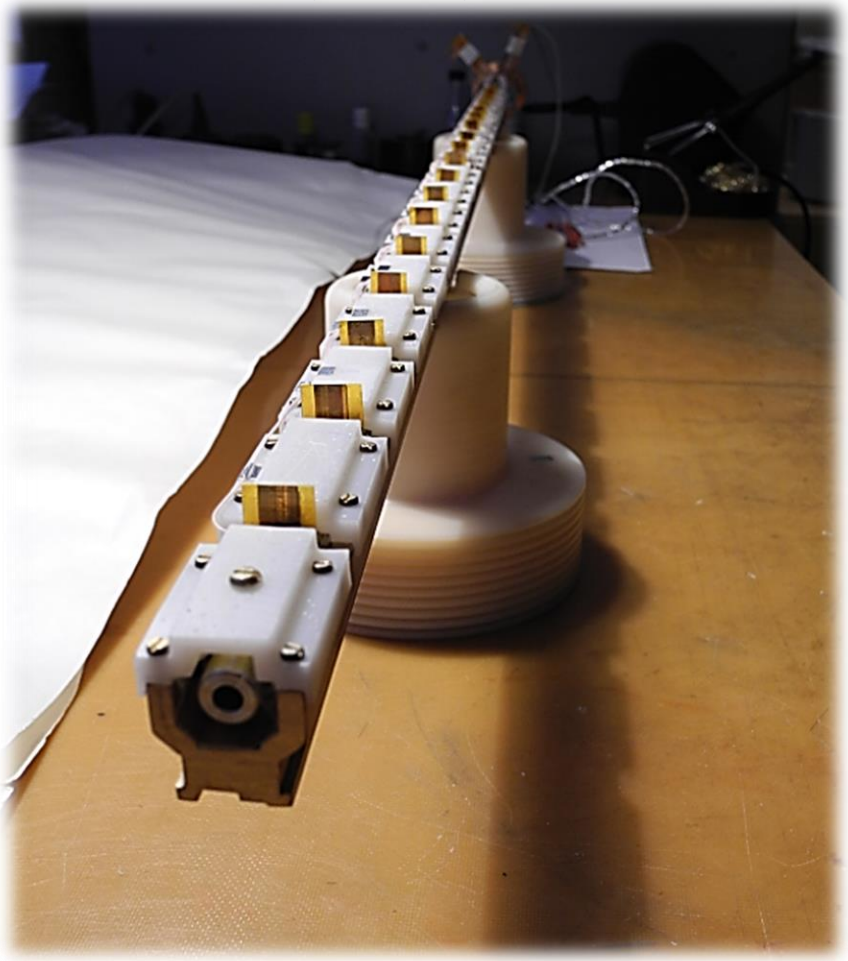
Thermometry



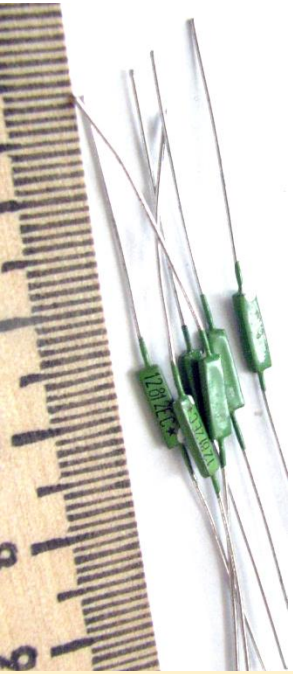




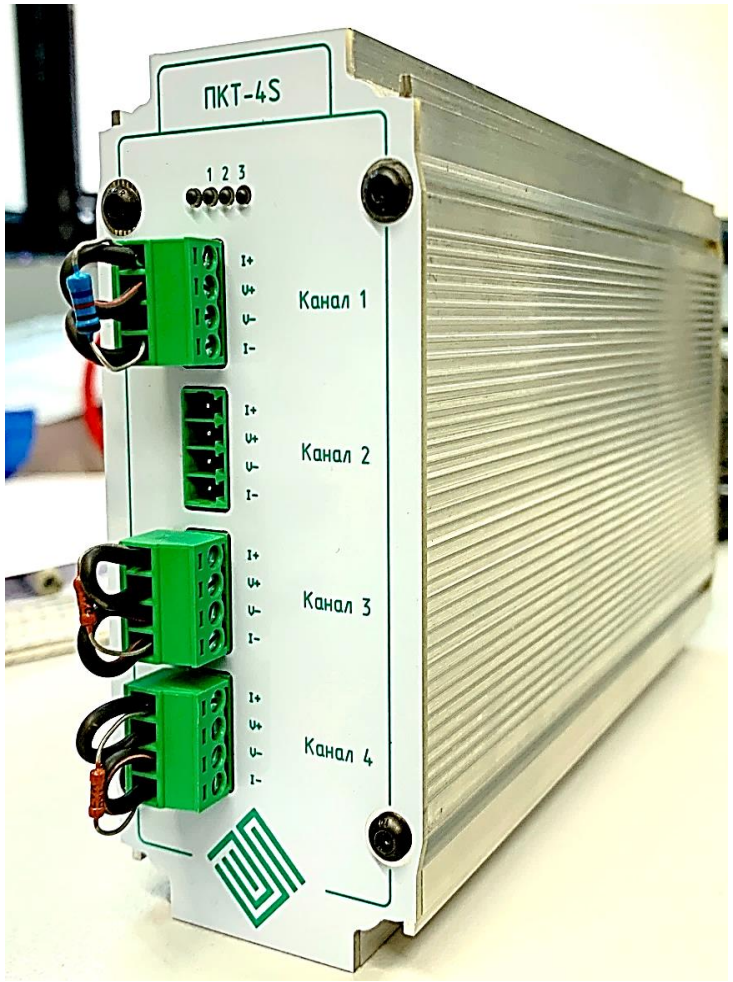
Ions drift structure



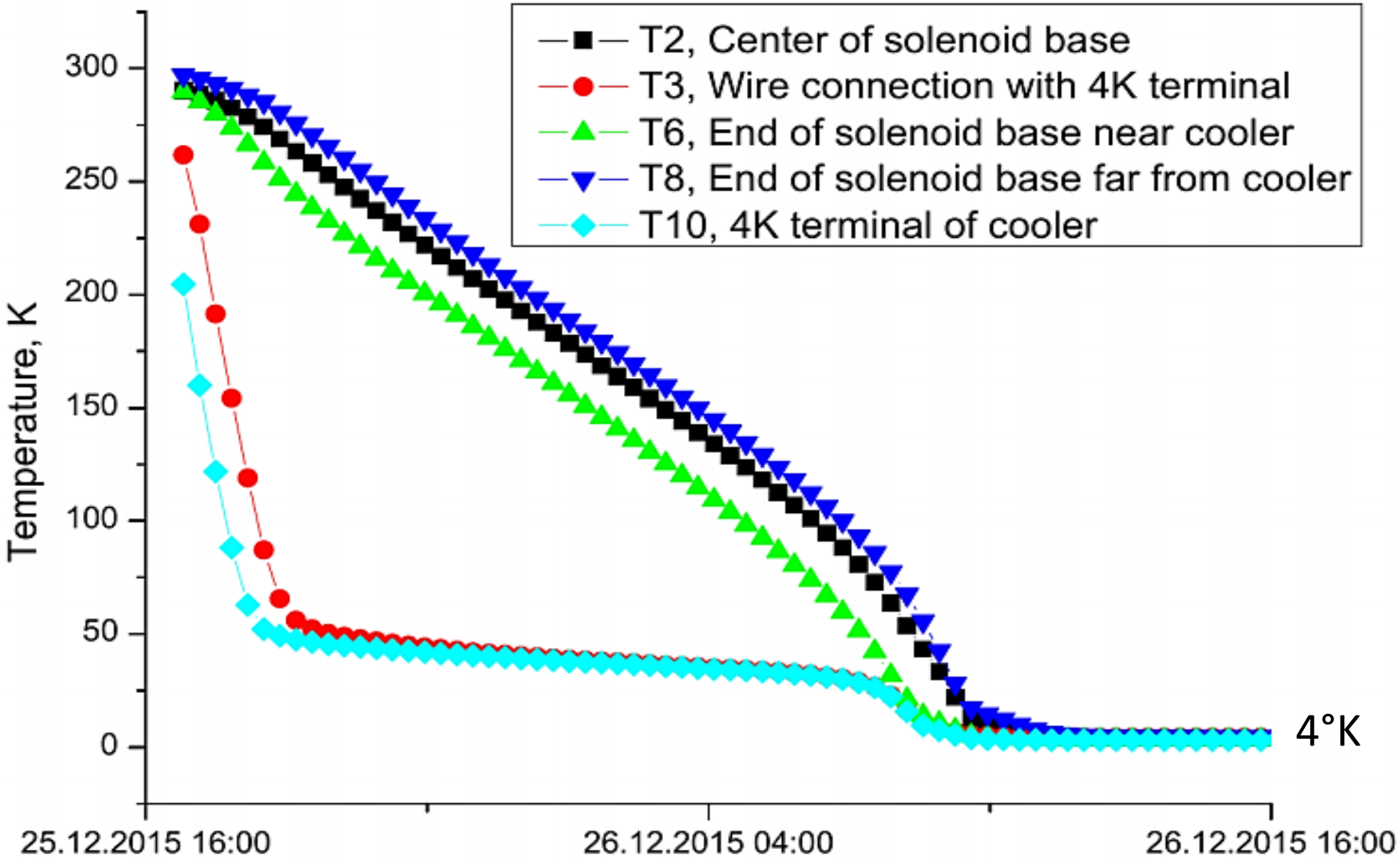
Thermometry



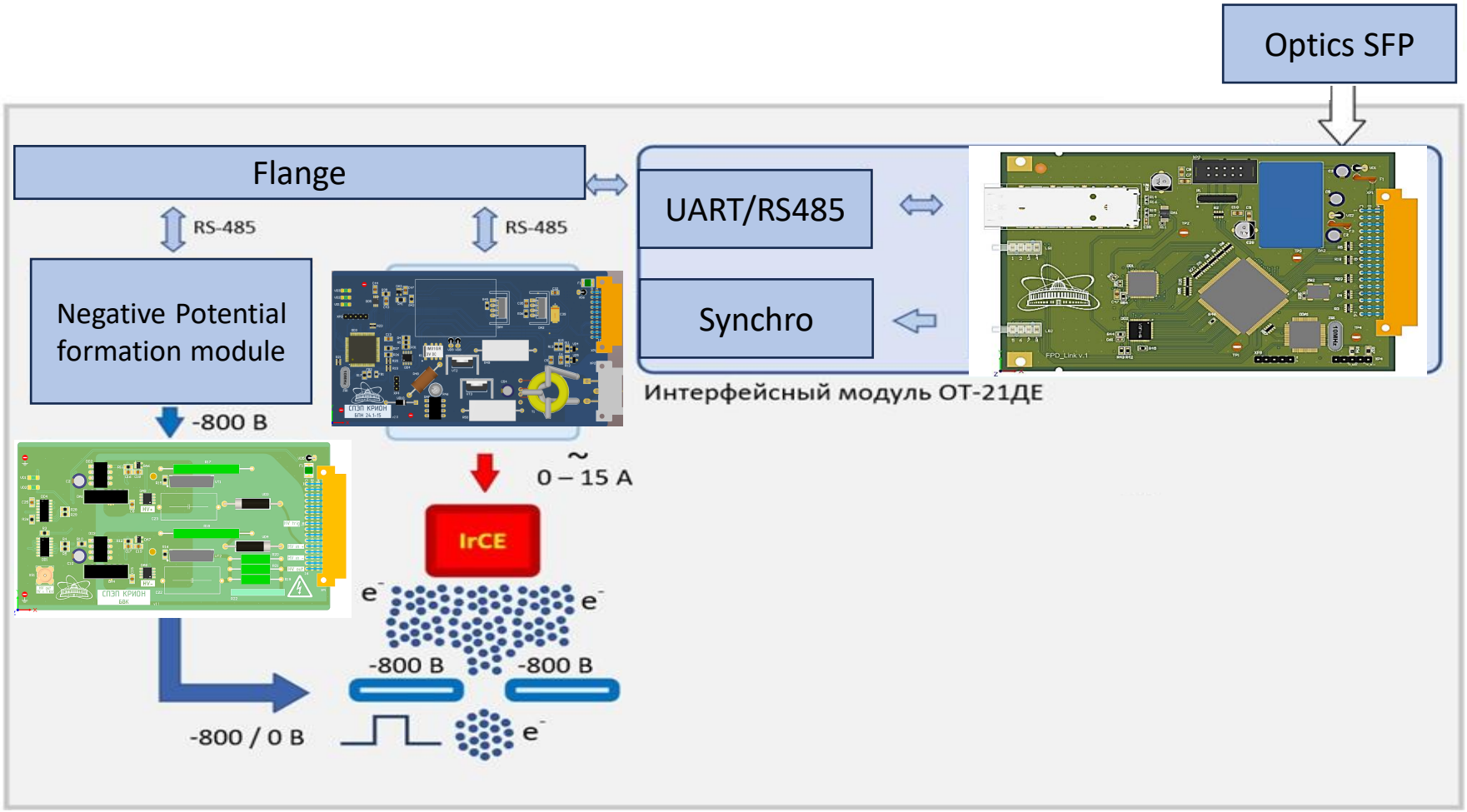
Measurement scale	1,5 - 310 K
Accuracy	± 0,3% in 30 K range
Channels	N * 4
ADC resolution	24 bit
Current source	1-1000 uA

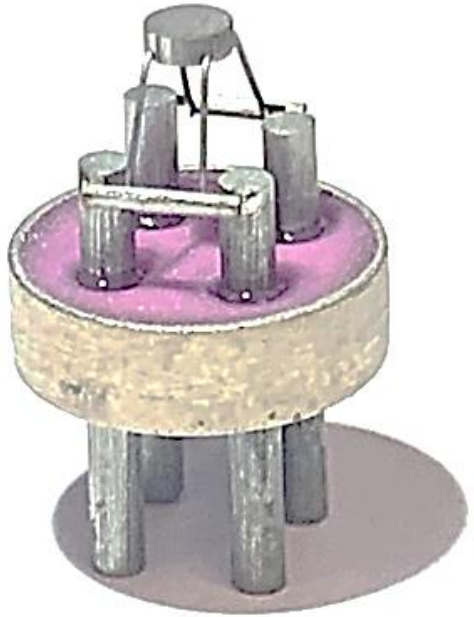


Thermometry

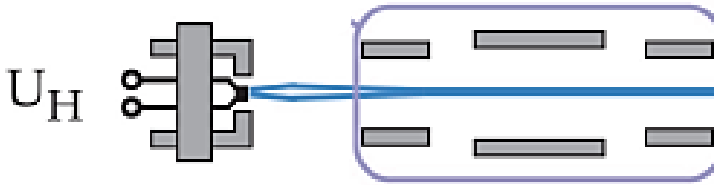


Electron gun supply



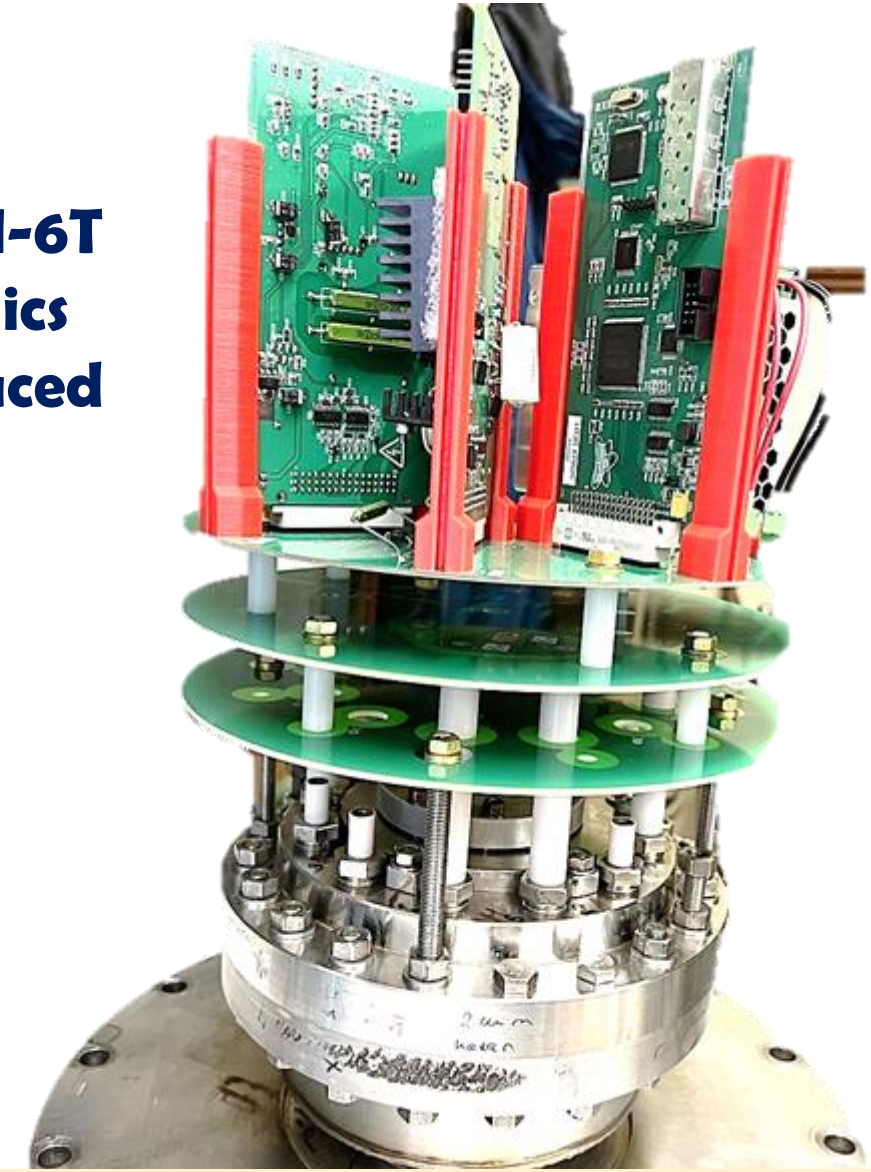


cathode magnet drift tubes

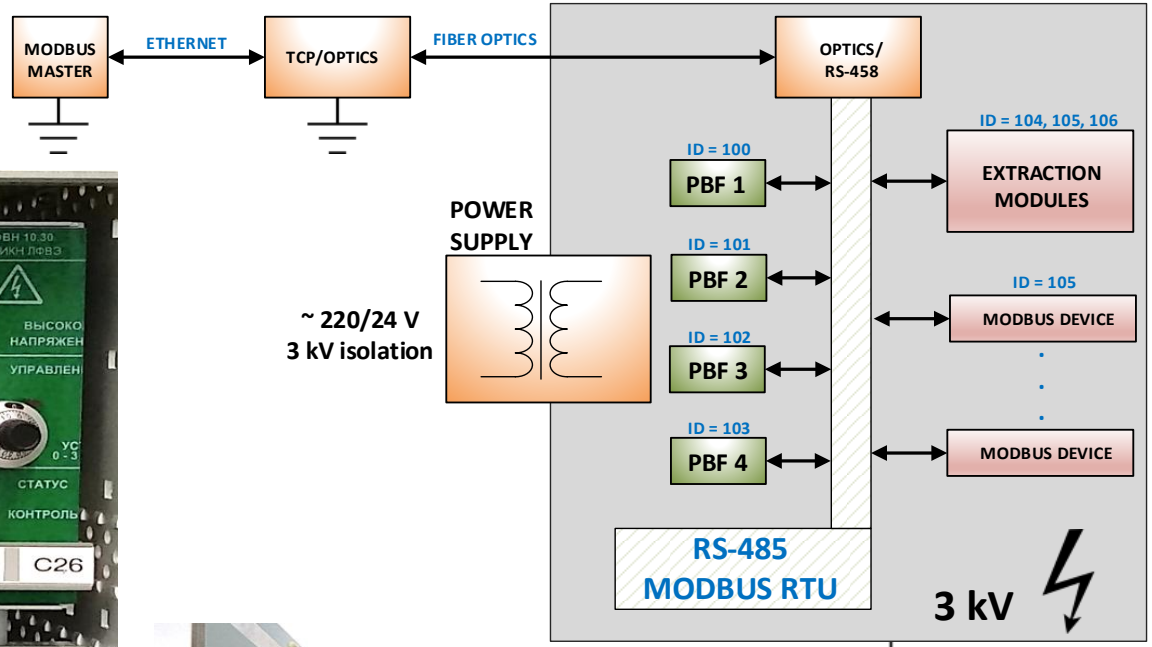


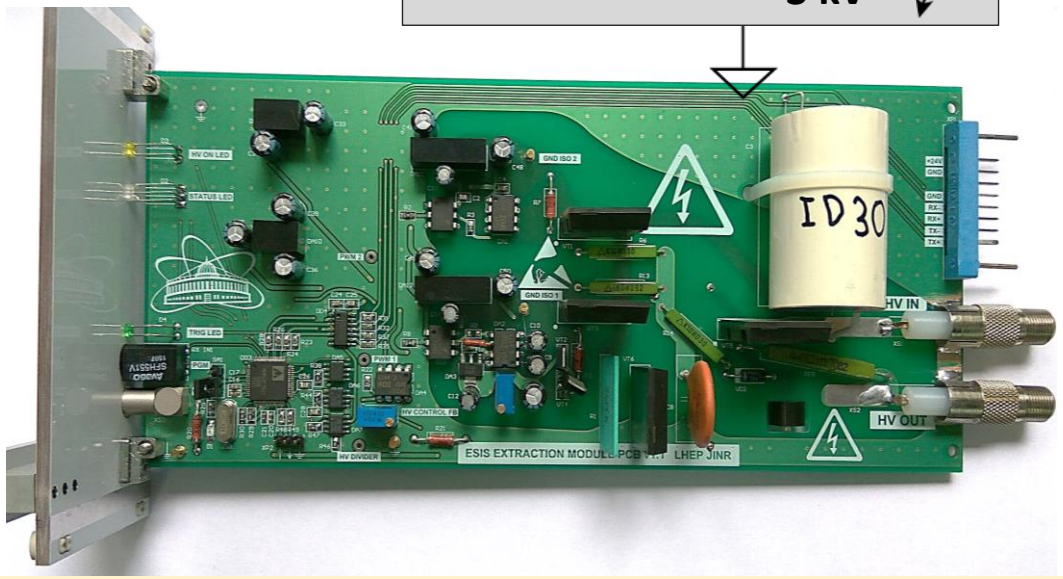
Electron gun supply

The NEW KRION-6T cathode node electronics was designed, produced and tested



Ion motion control system

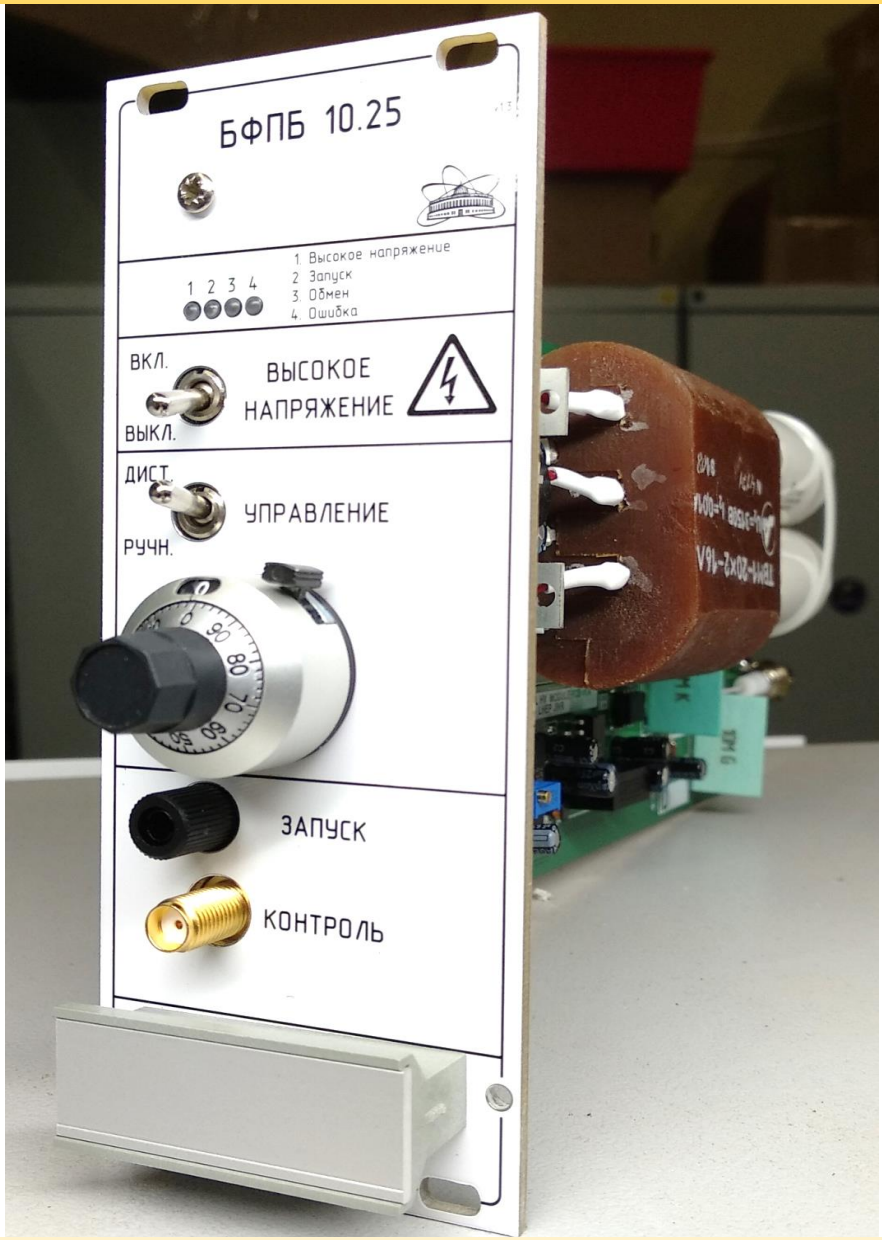




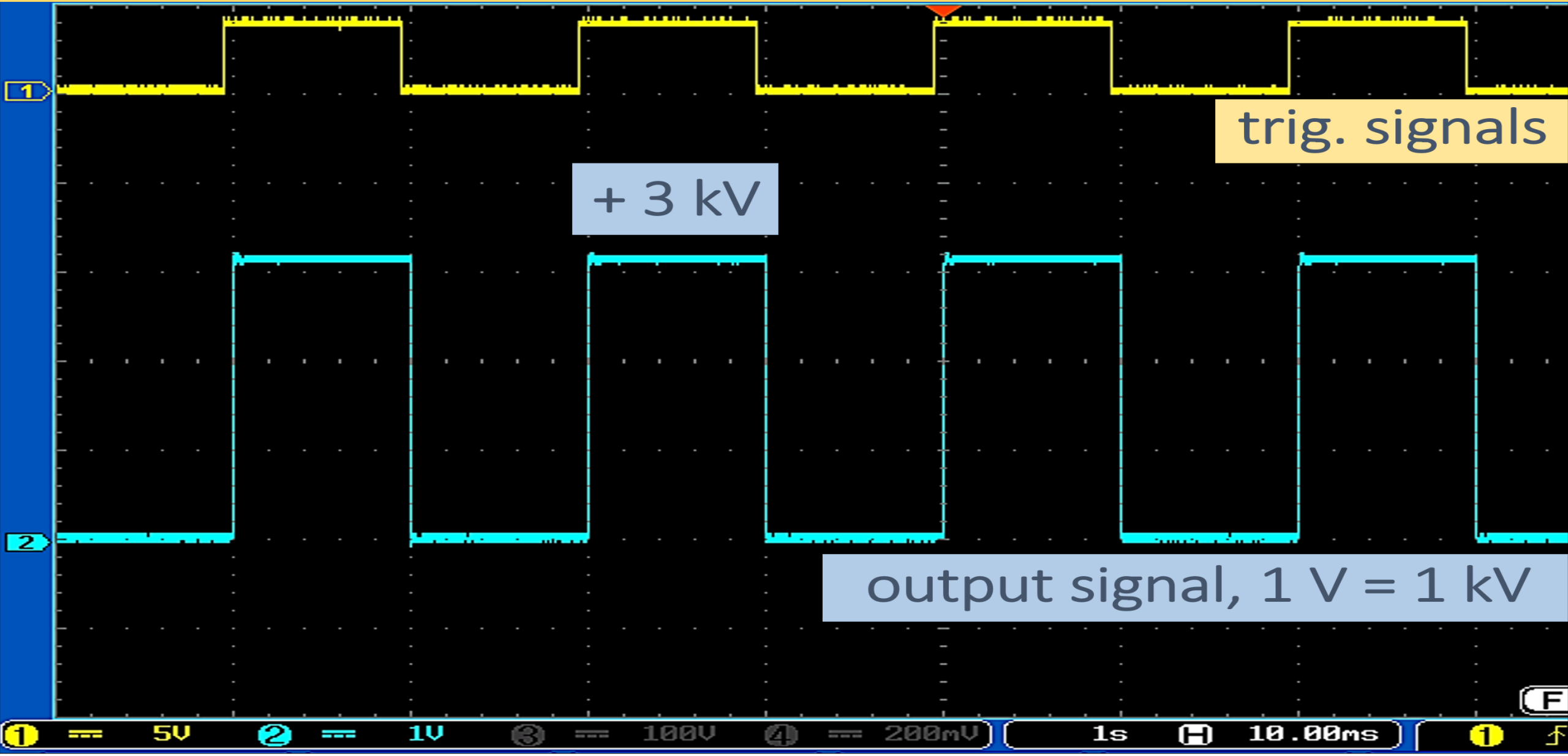
Potential barrier module

Output	0 … +3kV
Edges time	~ 5 us
Pulse with	DC* or 20 us - 10 s
Max load current	10mA
Supply	+24V, 300mA

Overcurrent, short protection
Hand & Remote control (Modbus RTU)



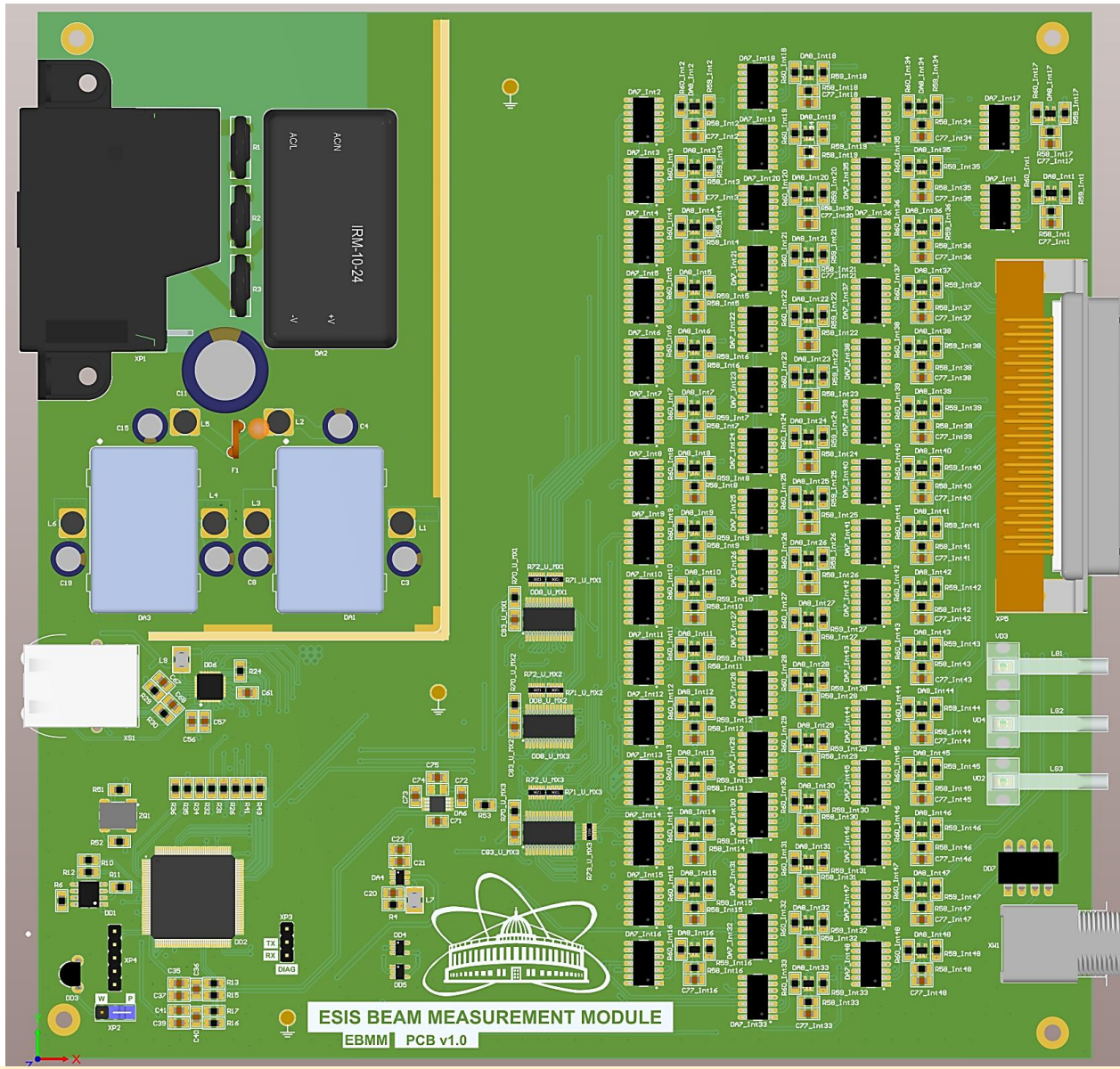
Potential barrier module



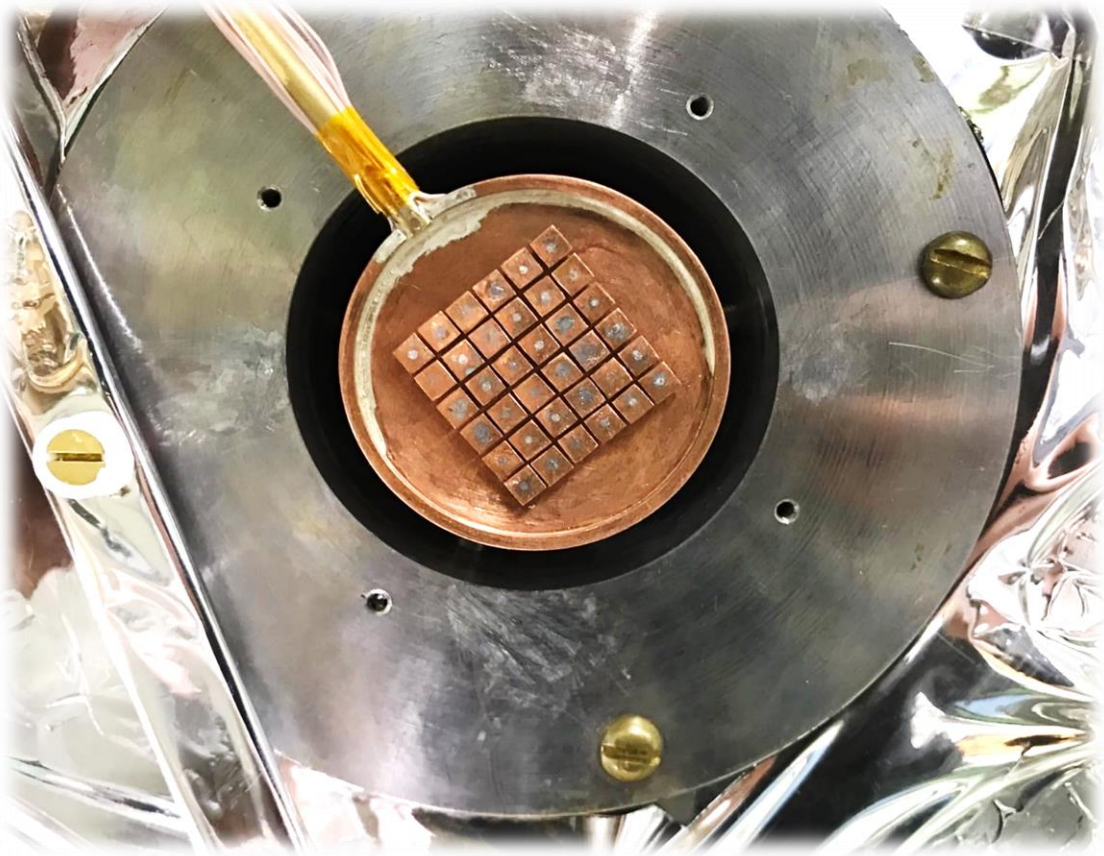
Beam profile monitor

Input	AC 220V
Channels	48
Max load current	100uA

External trigger
Web interface
Light indication of power supply, clocking and data transmission



Beam profile monitor



Beam profile monitor

K6T beam collector

L1 L2 Цикл = 8 13:22:01

ИЗМЕРЕНИЯ | Н 1 | Н 2 | Н 3

Коллектор 6x6 (27 мм, 4 мм)

-0,12	-0,01	-0,03	-0,04	-0,04	-0,03
0,01	-0,06	-0,02	-0,01	-0,04	0,04
-0,01	0,09	0,18	0,09	-0,02	0,07
0,08	-0,04	0,52	0,72	0,04	-0,04
0,04	0,03	0,20	0,17	-0,00	-0,02
-0,03	0,01	0,03	0,03	-0,02	-0,03

Остаток (мишень) [нКл]

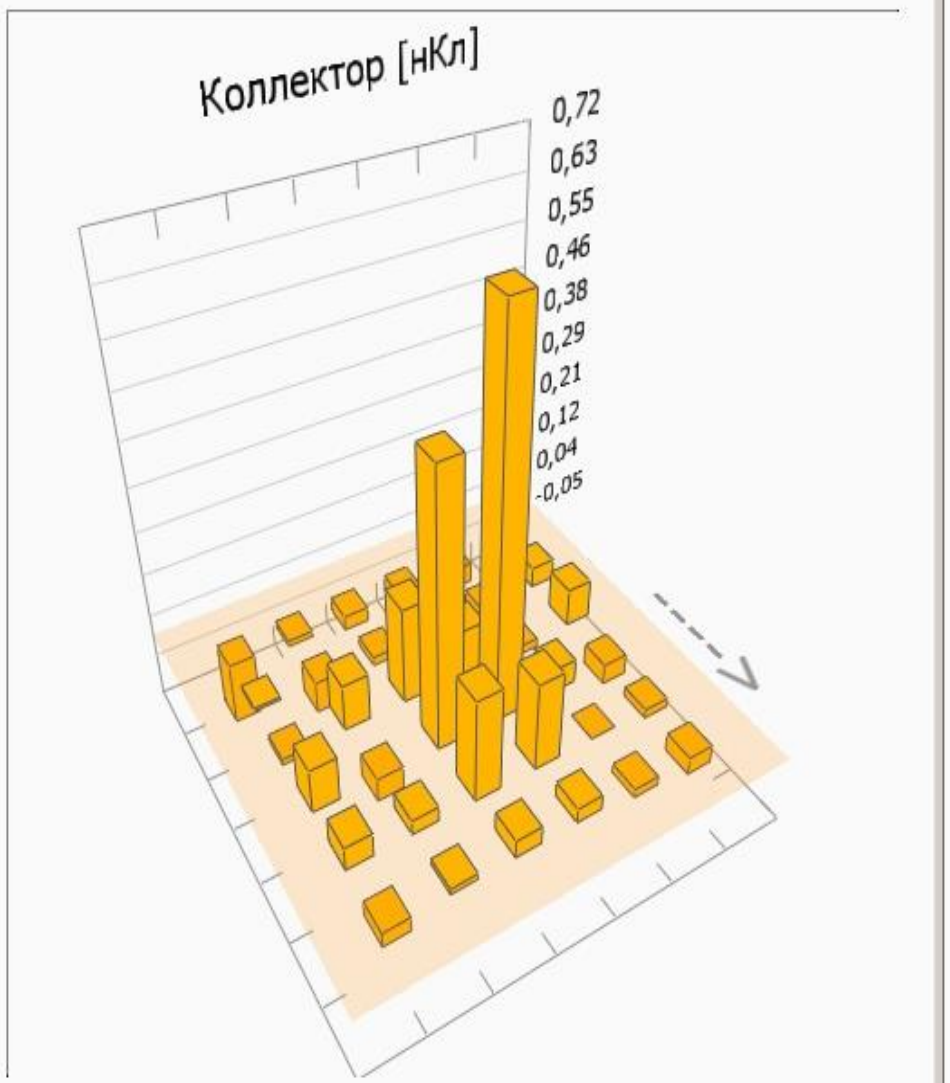
0,27

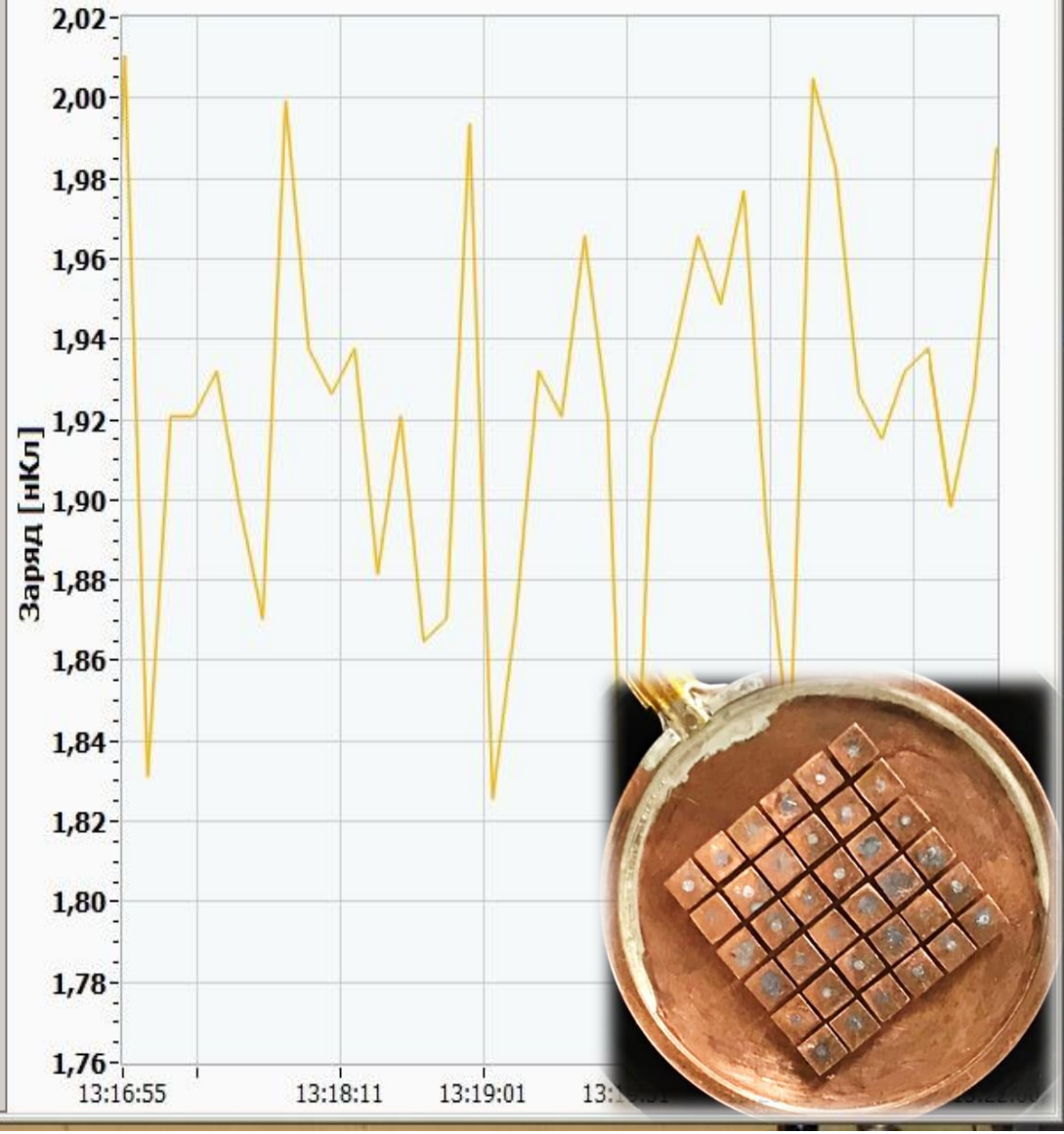
Суммарный заряд [нКл]

1,99

Суммарный ток [мкА]

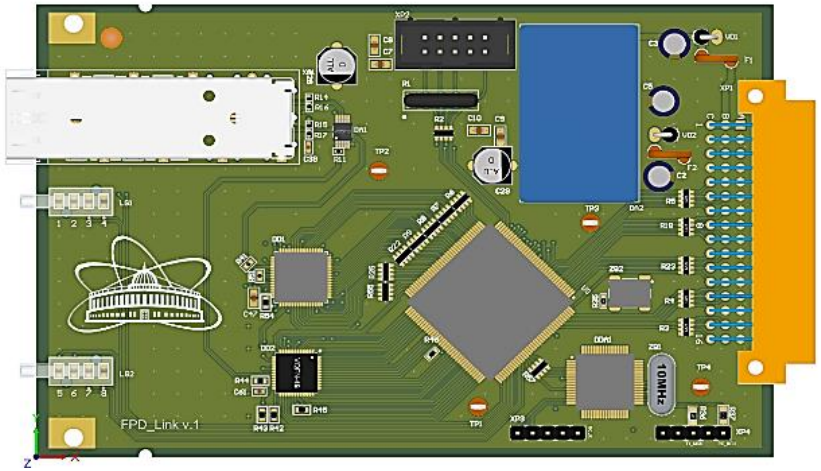
41,6

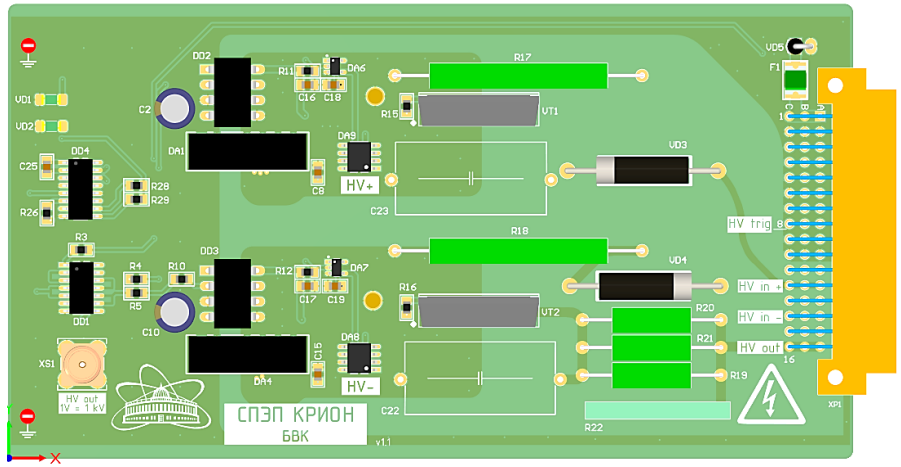


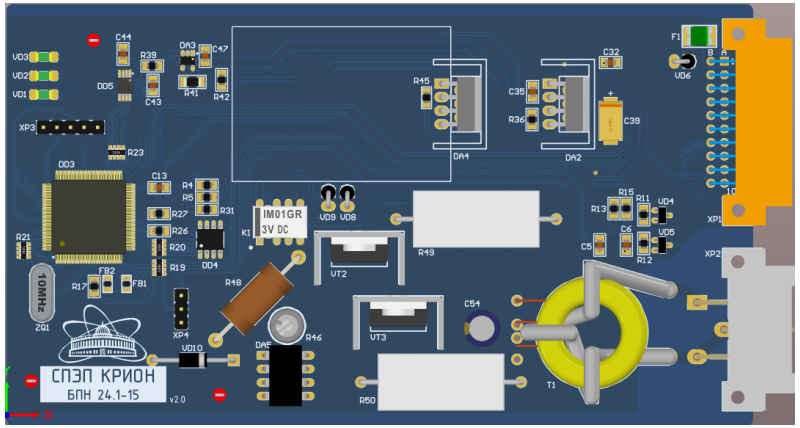


Conclusion

- The developed electronic modules and systems based on them ensured the operation of KRION ion sources at the accelerator sessions of the NICA complex
- They allowed to provide remote control of all the described systems and showed high reliability, which is confirmed by the following publications







Publications

- 1. E.D. Donets, E.E. Donets, D.E. Donets, D.A. Lyuosev, D.O. Ponkin, A.Yu. Ramsdorf, A.Yu. Boytsov, V.V. Salnikov, I.V. Shirikov, ESIS ions injection, holding and extraction control system, EPJ Web of Conferences 177, 08002 (2018)
- 2. E.D. Donets, E.E. Donets, D.E. Donets, N.V. Gorbunov, D.A. Lyuosev, D.O. Ponkin, A.Yu. Ramsdorf, A.Yu. Boytsov, V.V. Salnikov, I.V. Shirikov, ESIS ions injection, holding and extraction control system, CEUR workshop proceedings Vol-2023urn:nbn:de: 0074-2023-0
- 3. M. J. Segal, R. A. Bark, R. Thomae, E. E. Donets, E. D. Donets, A. Boytsov, D. Ponkin and A. Ramsdorf. Liquid metal ion source assembly for external ion injection into an electron string ion source (ESIS). Review of Scientific Instruments, ISSN:0034-6748, Изд: American Institute of Physics 87.2
- 4. A.Yu. Boytsov, D.E. Donets, E.D. Donets, E.E. Donets, K. Katagiri, K. Noda, D.O. Ponkin, A.Yu. Ramsdorf, V.V. Salnikov, V.B. Shutov. Electron string ion sources for carbon ion cancer therapy accelerators. Review of Scientific Instruments, ISSN:0034-6748, Изд: American Institute of Physics 87.8
- 5. Segal M., Bark R., Thoemae R., Boytsov A., Ramsdorf A., Ponkin D., Donets E. Towards Ga+ and Au+ Ion Injection into ESIS: Mock-Setup Experiments and Ion Beam Profiling, Submitted to proceedings of the 17th International Conference on Ion Sources (ICIS 2017)
- 6. D. Egorov, V. Elkin, D. Donets, D. Ponkin, Nuclotron injection beam profiles measurement system, Submitted to proceedings the XXII International Scientific Conference of Young Scientists and Specialists (AYSS-2018)
- 7. D. E. Donets, N. V. Gorbunov, D.O. Ponkin etc. Cryogenic thermometry system for ESIS «KRION-6T», Nuclear Electronics & Computing (NEC’2013): Proceedings of the XXIV International Symposium (Varna, Bulgaria, September 9-16,2013) – Dubna: JINR, 2013 – 291 p., 109 – 113 P.

Thank you for your attention!

7. KRION-6T on the test bench

Specifications of KRION-6T

Length of the superconducting solenoid	1,2 m
Number of layers	24 layers
Induction	~10 H
Current in the solenoid	90 A (105 A planned)
Field on the axis in the middle (Bmax)	5,4 T (6T planned)
Length of the main ion trap	1 m
Maximum energy of the electrons	10 keV (11,5 keV with trap potential lift)
Emitter material	IrCe
Electron current from the gun	up to 30 mA
Capacity of the ion trap	up to 22 nC

8. Results achieved on the test bench

- the **jτ** ionization factor is the most important value giving information about the performance of the ESIS
- impossible to measure directly the electron string current, but possible to measure **effective jτ,** using the extracted ions spectrum.

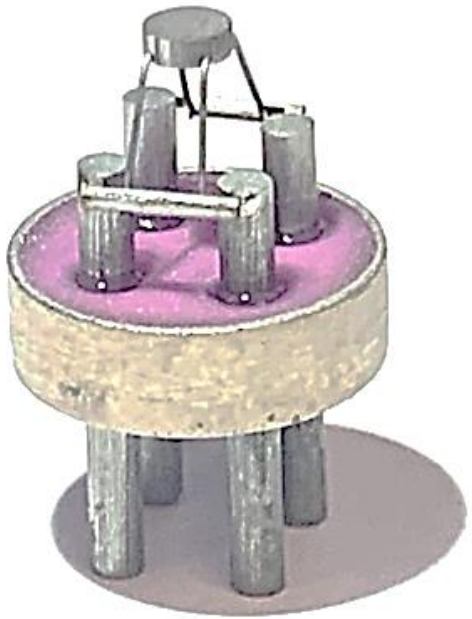
Ion specious	Effective electron string current density **j**, A/cm^2
Kr^{15+}	665
Kr^{18+}	591
$Kr^{24,6+}$	847
$Xe^{23,2+}$	1090
$Xe^{24,9+}$	1579
$Xe^{25,4+}$	1587
$Tm^{40,8+}$	1092

Examples of number of particles per pulse and times of ionization for different ions

C^{4+}	$7x10^9$	-
Xe^{42+}	$5x10^9$	350 ms
Xe^{32+}	-	40 ms
Tm^{50+}	$3x10^7$	-
Au^{33+}	-	30 ms

The new KRION-6T ion source has much higher effective **j** (up to 1600 A/cm^2) in comparison with the KRION-2 which had only 200 A/cm^2. Another typical EBIS devices have only 100 - 300 A/cm^2.

Electron gun supply: Heating module



Material	IrCe
Emission	Thermionic
Small size	1.2 mm
Emission current	6 mA
Heating power	AC 1.5V 10A

The main idea: cathode heating power set and control

Points: 10 kHz sine, 1.5 V, 10 A