

# Diagnostic Equipment of a Generator of High-Current Pulsed Ion Beams “TEMP-4M”

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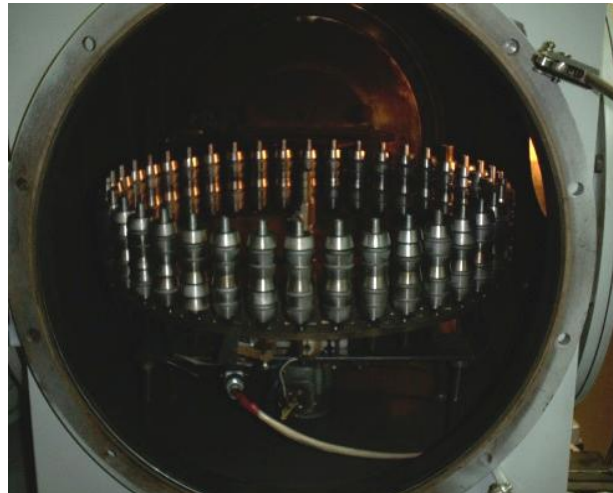
# Outline

1. Introduction;
2. “TEMP-4M” Pulsed Ion Accelerator;
3. Calibration of the accelerator’s diagnostic equipment;
4. Beam composition and ion current density investigations.

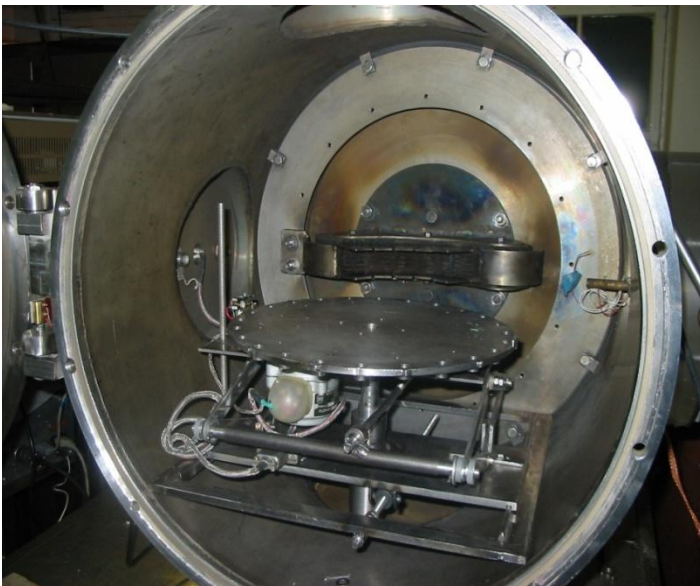
# Introduction

Powerful ion beam irradiation provides heating and cooling of boundary layers of a treated item at a rate of more than  $10^9$  K/s.

As a result, the characteristics of materials improve.



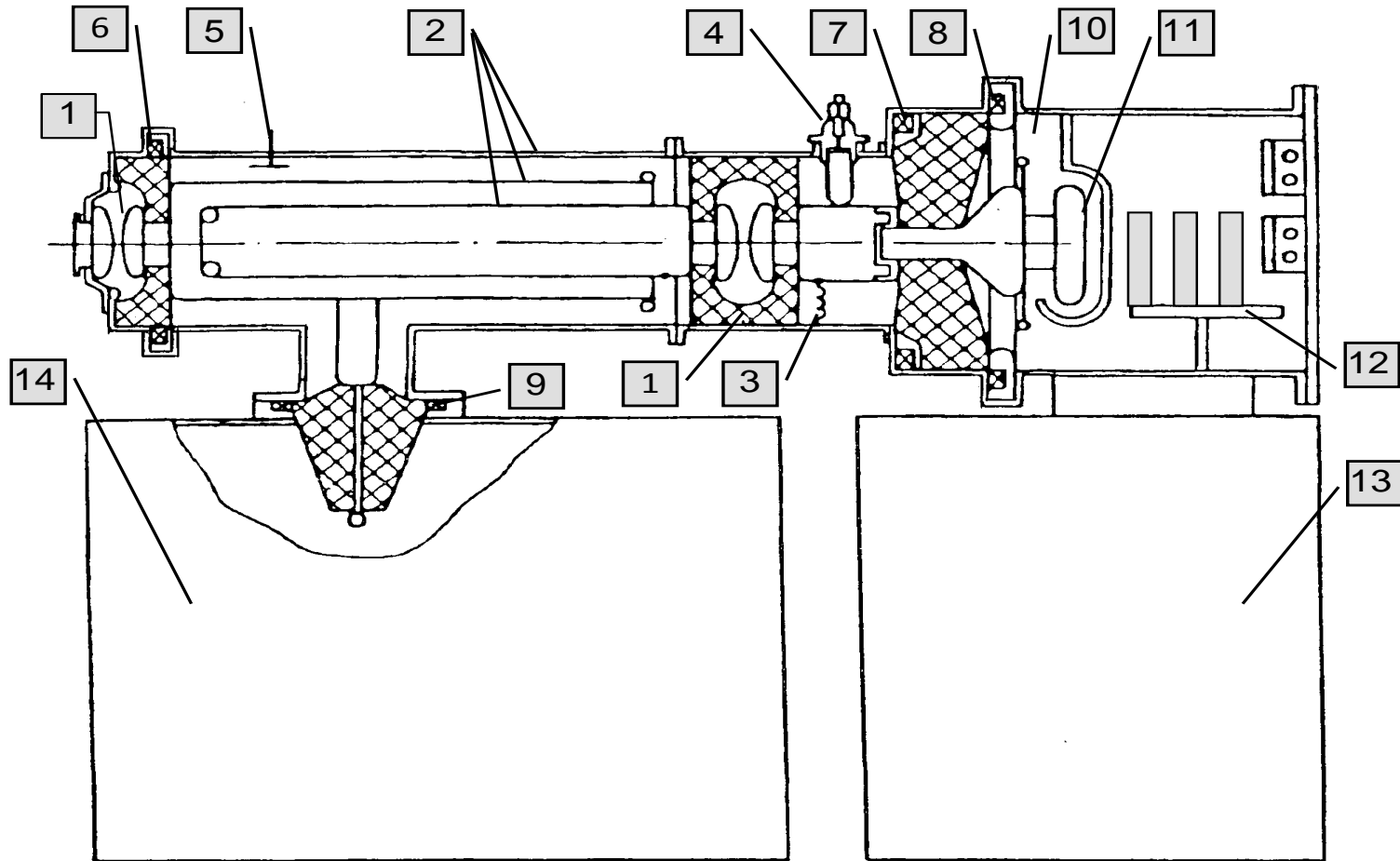
# “TEMP-4M” Pulsed Ion Accelerator



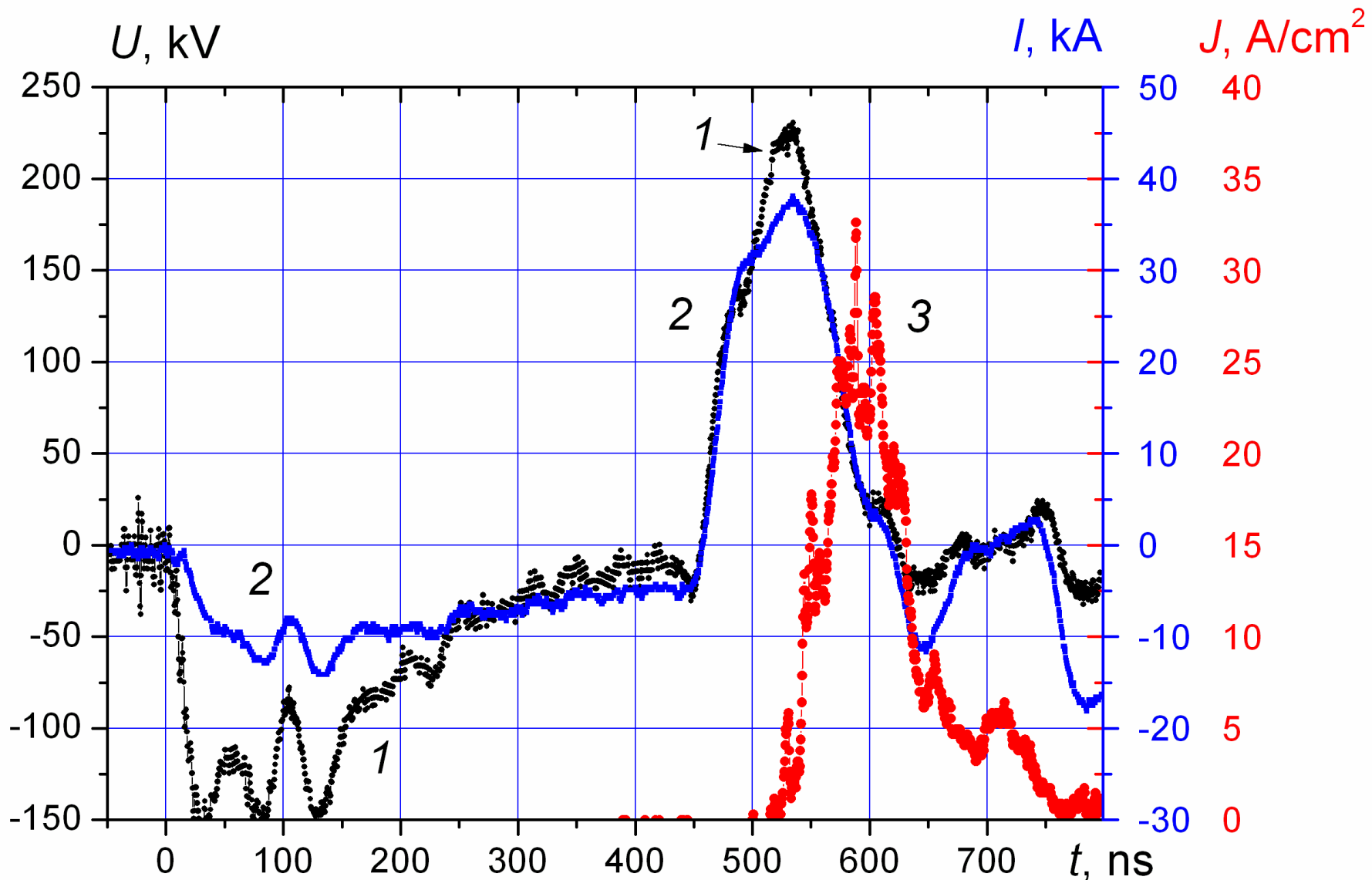
## Main Parameters of the TEMP-4M Accelerator

Accelerating voltage (kV)	250 – 300
Voltage pulse duration (ns)	80
Beam composition (according to the principal elements)	C(70%), H(30%)
Ion beam density at the target (A/cm <sup>2</sup> )	100 – 350
Energy density at the target (J/cm <sup>2</sup> )	1.2 – 5
Pulse repetitive rate (pulses per minute)	15 – 20

# TEMP-4M Ion Accelerator



TEMP-4M Accelerator scheme : 1 – gas-filled spark gaps; 2 – Blumline line; 3 – charging inductance; 4 – Ohmic-capacitive divider; 5 – capacitive voltage divider; 6, 7, 8, 9 – Rogowski coils; 10 – diode chamber; 11 – potential electrode of diode; 12 – target; 13 – vacuum pump; 14 – Marx generator



Oscilloscope traces of accelerating voltage (1), total diode current (2) and ion current density (3) of a flat diode with self-isolation. Distance to the Faraday cup is 15 cm.

# Calibration of the Accelerator's Diagnostic Equipment

- Rogowski coil
- Capacitive divider
- Differential capacitive divider
- Ohmic-capacitive divider

# The Marx generator

Picture of Marx Generator



## Main Parameters:

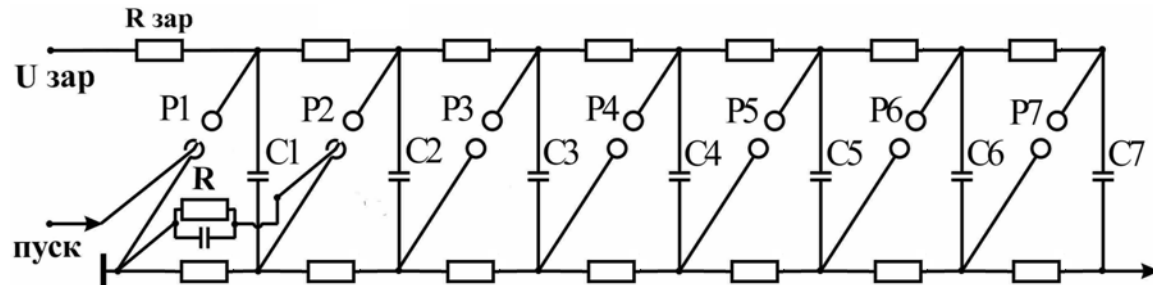
Number of levels– 7;

Shock Capacitance  $C_{sh}$  – 37,5 nF;

Charging voltage  $U_o$  – 25-60 kV (stabilized);

Inductance - 2,5 mH;

Overall dimensions– 1,8x1,8x1,25 m.



Circuit of the microsecond generator

# The Marx generator's diagnostics



Capacitive divider

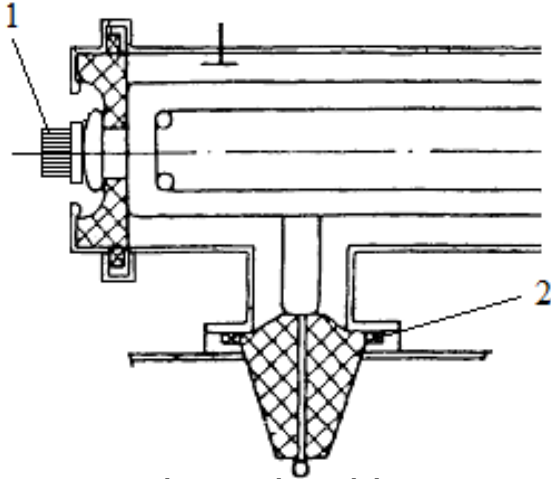


Differential capacitive divider

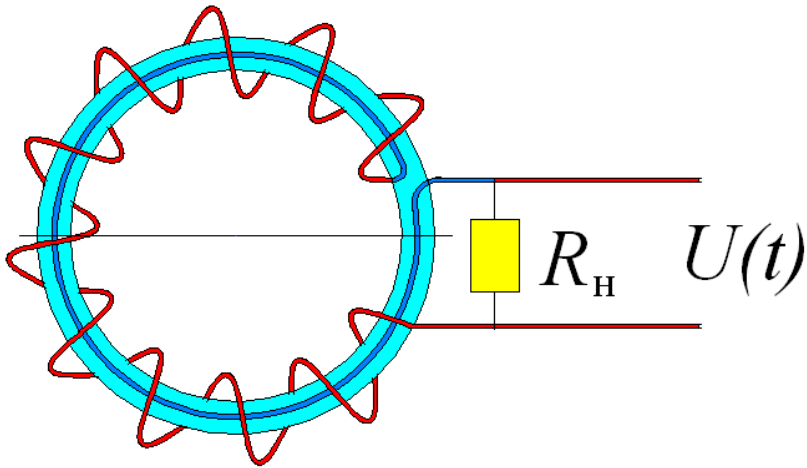


Rogowski coil

# The Rogowski coil



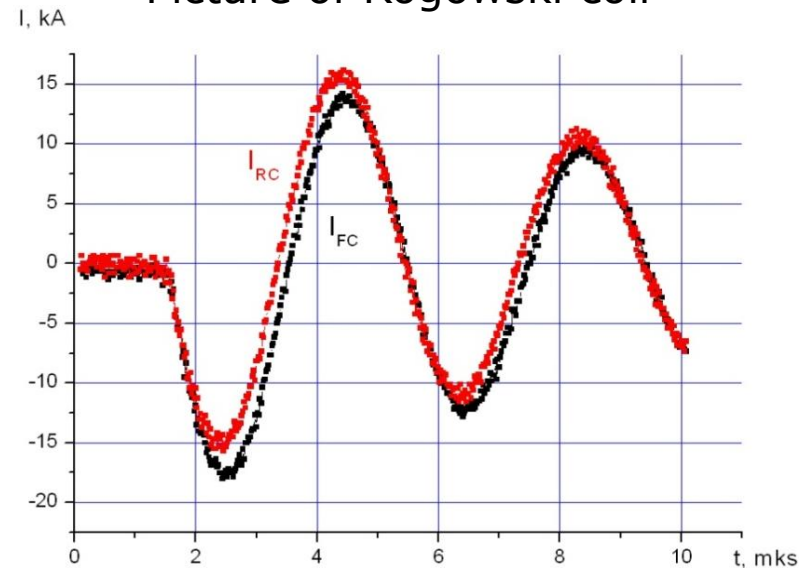
Rogowski coil calibration scheme:  
1 – low-inductive shunt  
2 – Rogowski coil



Rogowski coil with a reverse coil



Picture of Rogowski coil



Current recorded by Rogowski coil (red) and current recorded by a shunt (black)

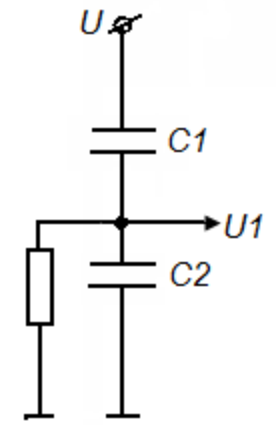
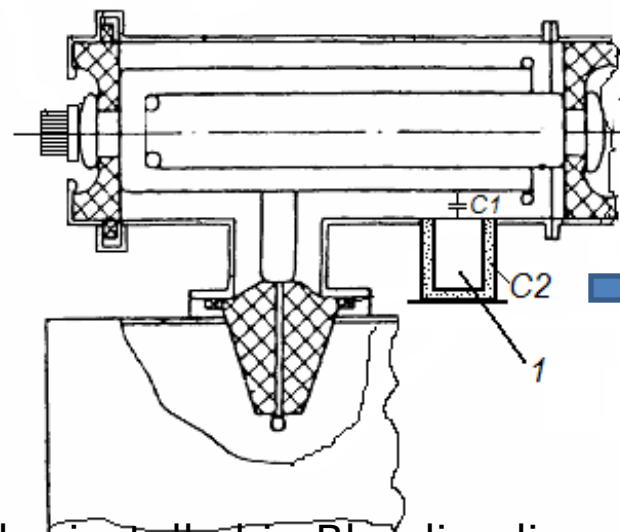
# Capacitive voltage divider



Capacitive divider

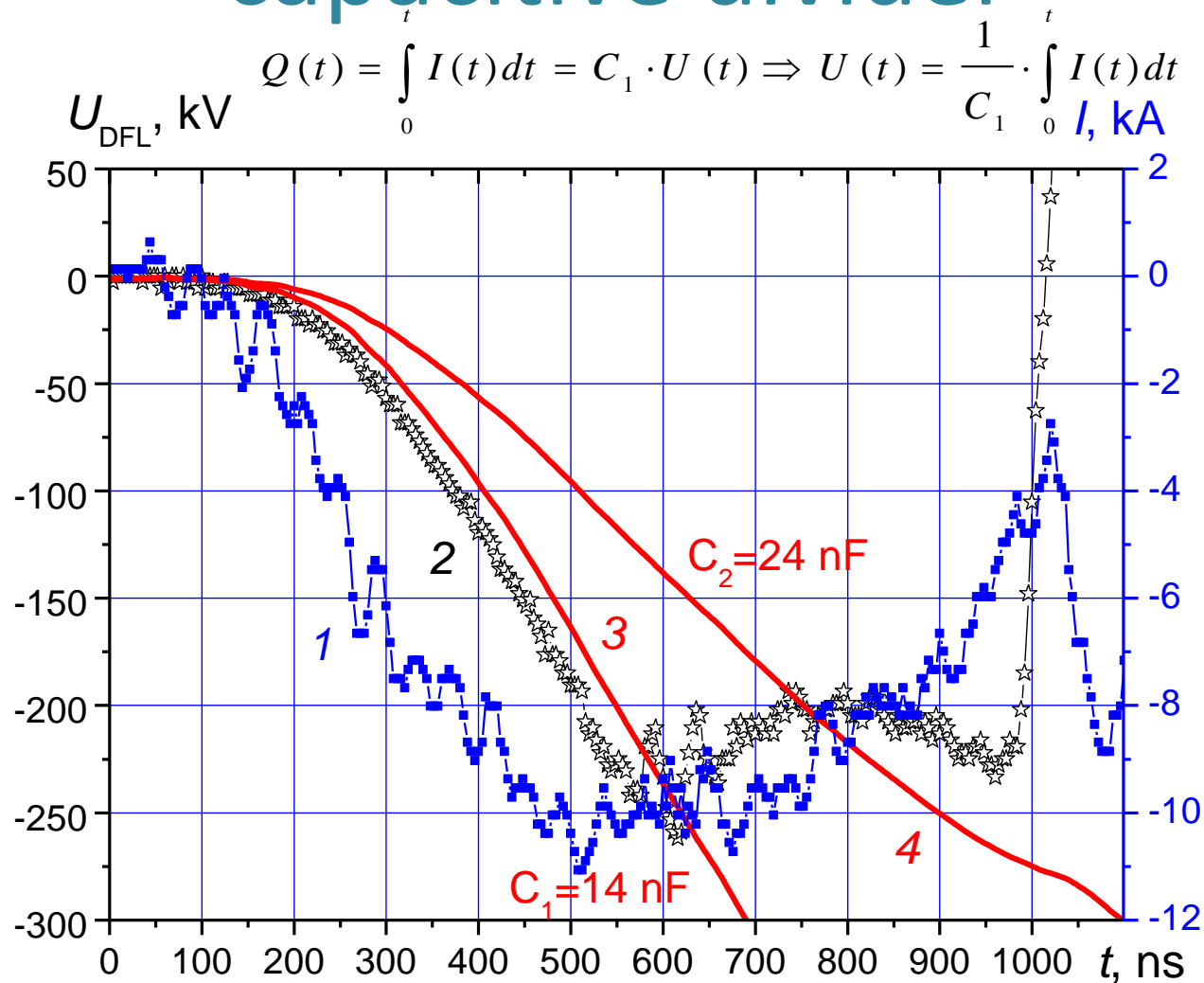


1- Capacitive divider installed in Blumline line



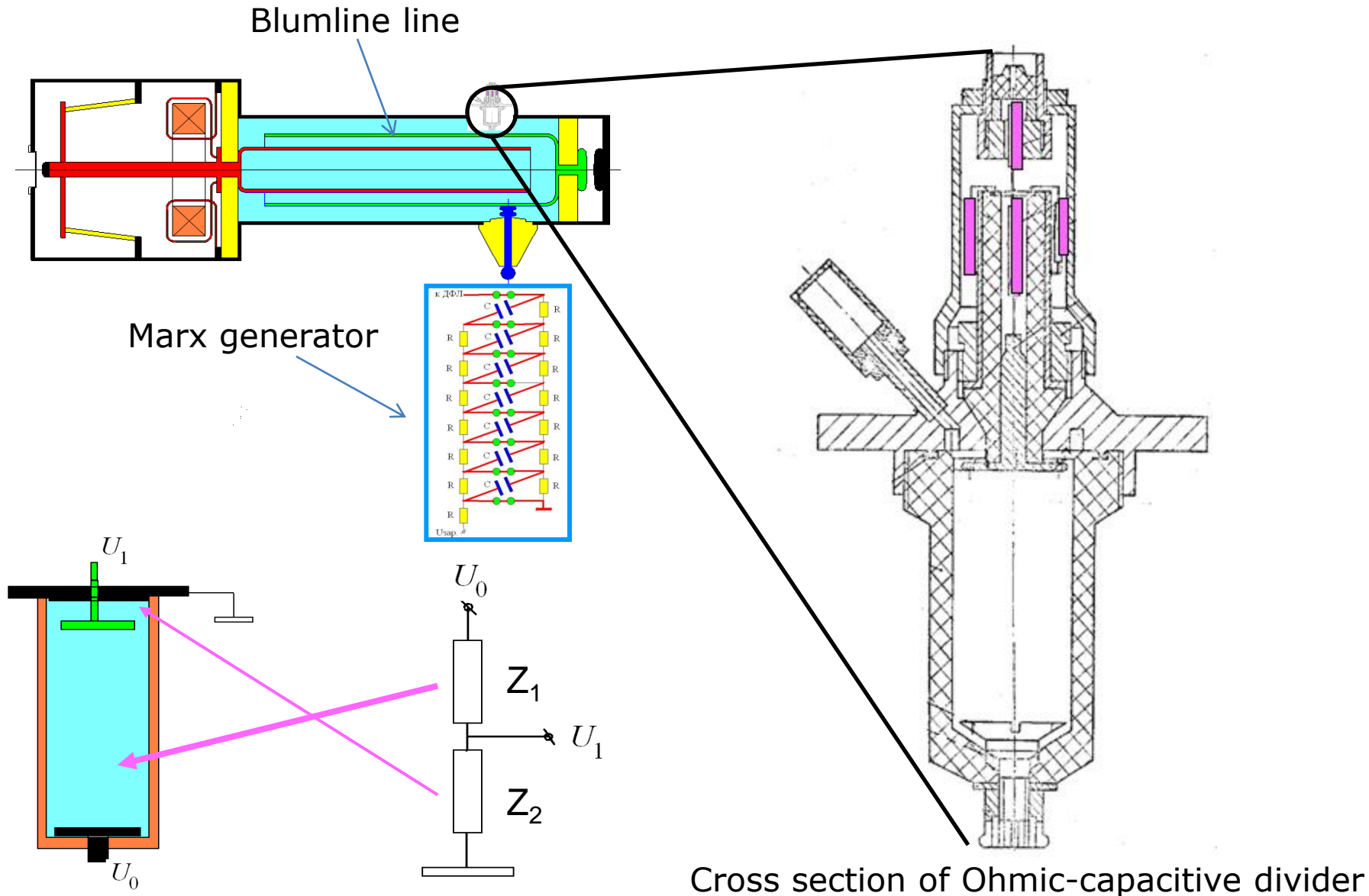
Equivalent circuit

# Calibration of the Rogowski coil and capacitive divider



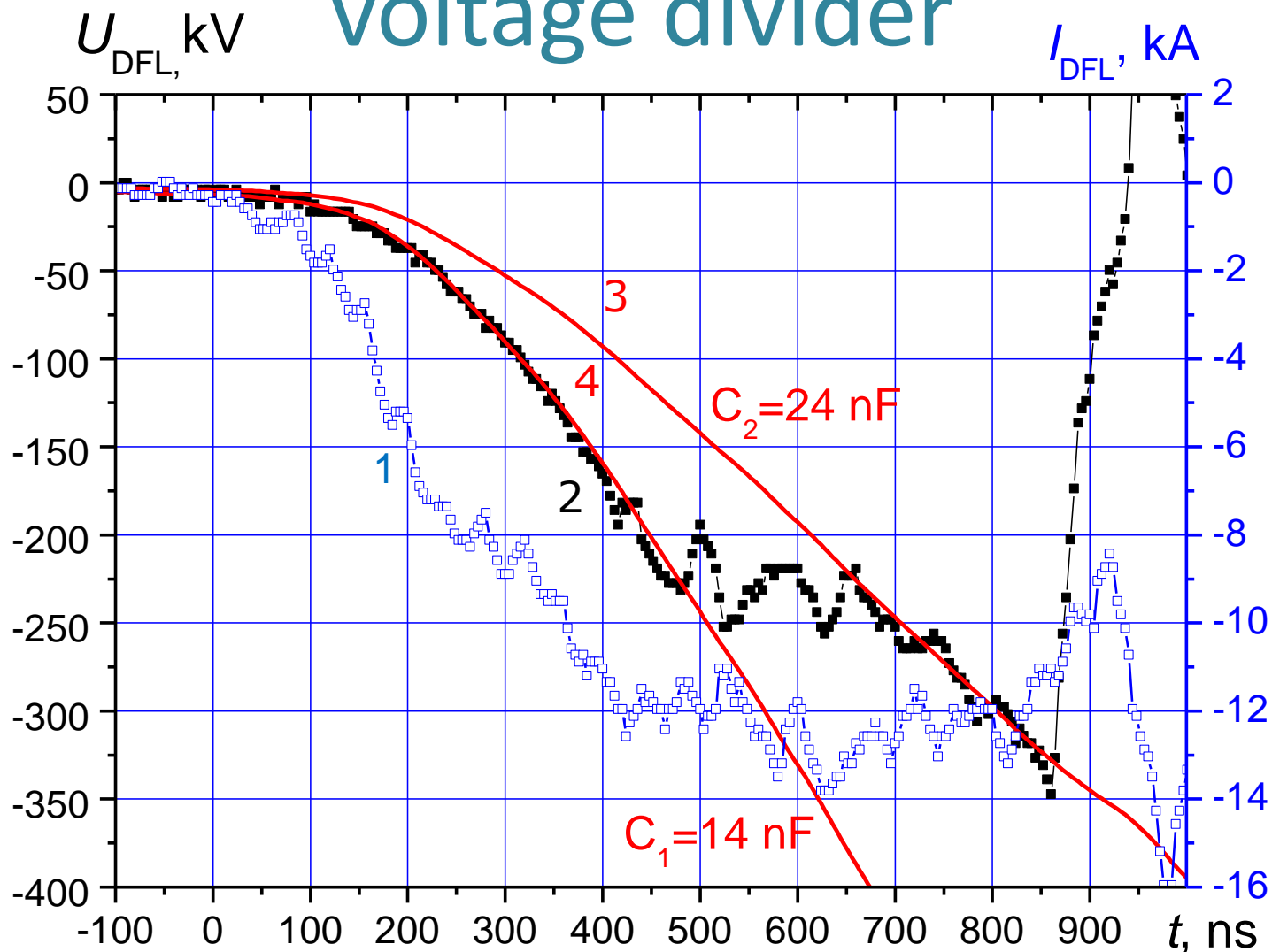
Oscilloscope traces of voltage (1) ,current (2) at the output of the Marx generator. 3,4- calculation

# Ohmic-capacitive voltage divider



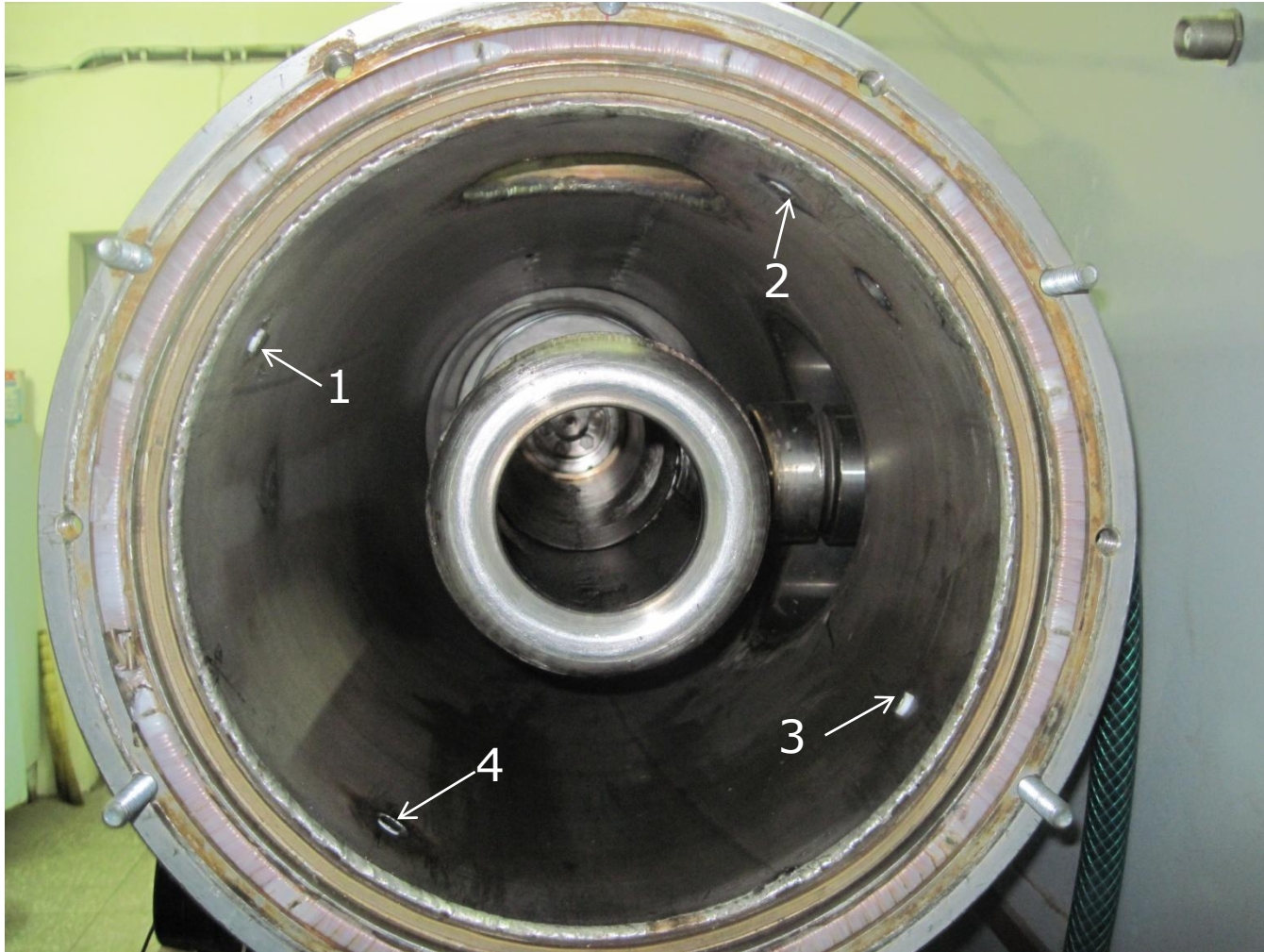
Liquid stage of division and its equivalent circuit

# Calibration of the Ohmic-capacitive voltage divider



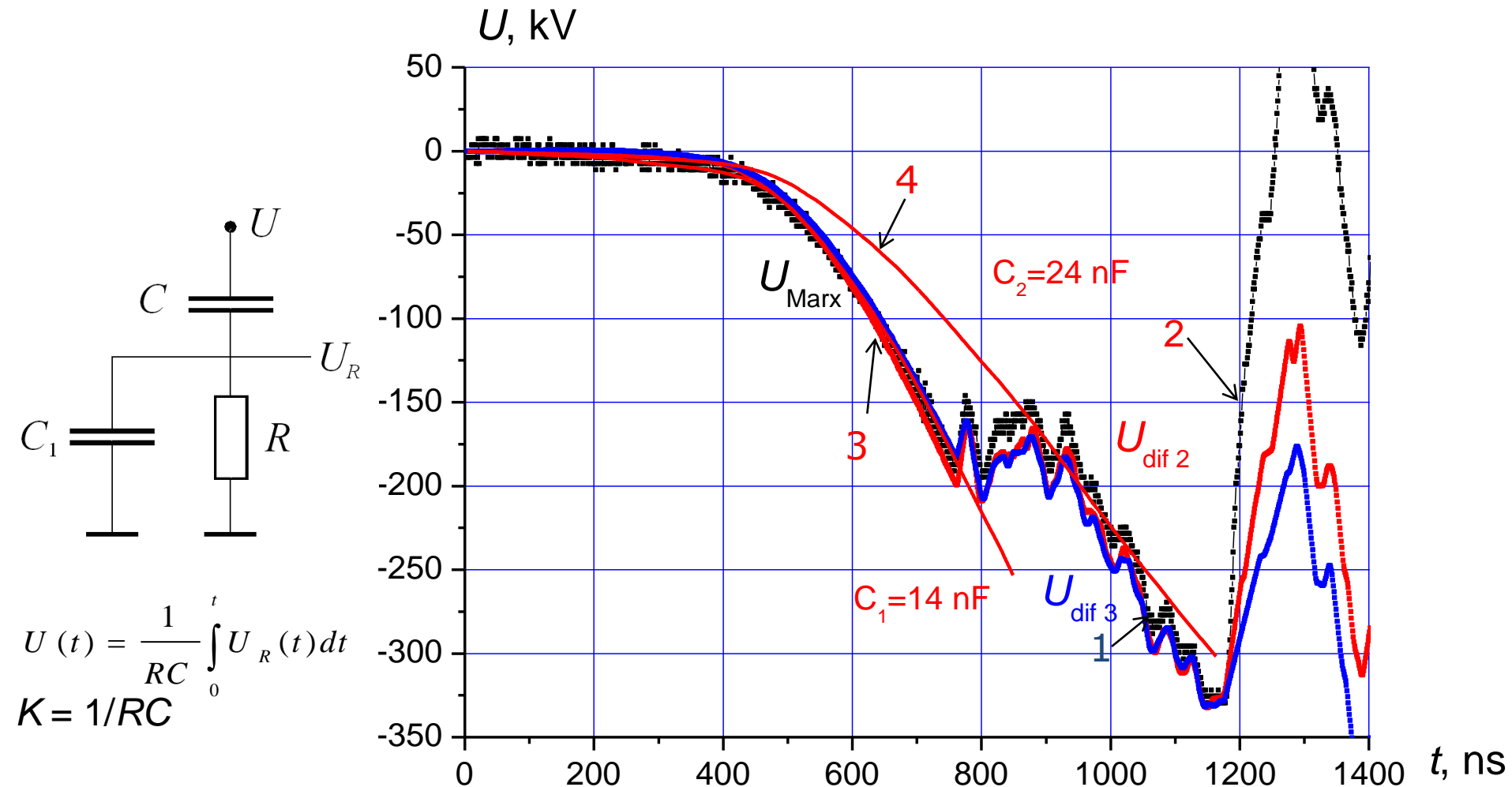
Oscilloscope traces of current (1) and voltage (2 – experiment, 3, 4 – calculation) at the exit of Marx generator.

# Differential Voltage Divider



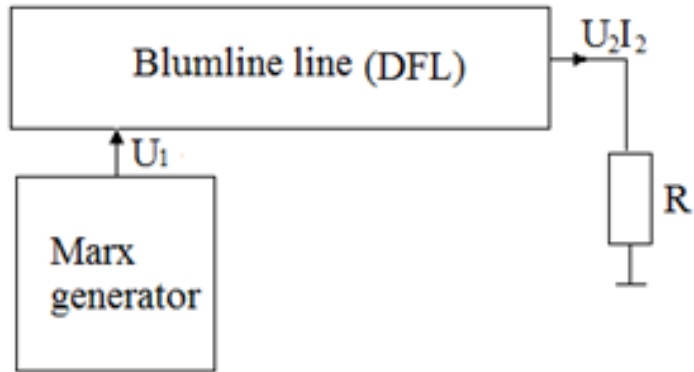
Blumline line (inside view): 1,2,3,4-differential voltage dividers

# Calibration of the differential voltage divider

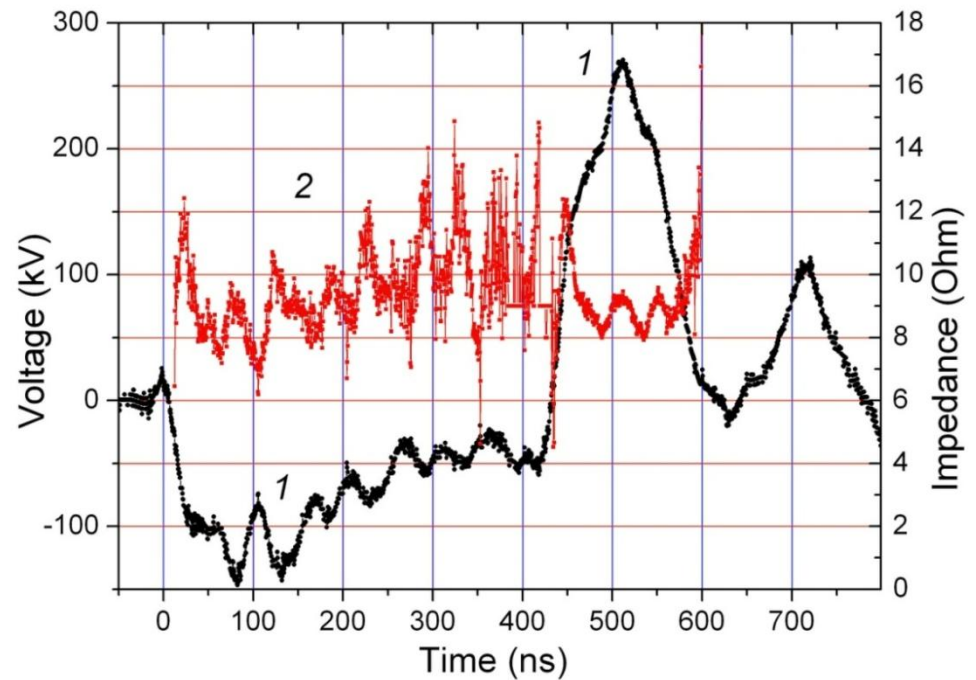


Oscilloscope traces of voltage (1,2- experiment, 3, 4 - calculation) at the output of Marx generator.

# The calibration of the accelerator running on a matched resistive load



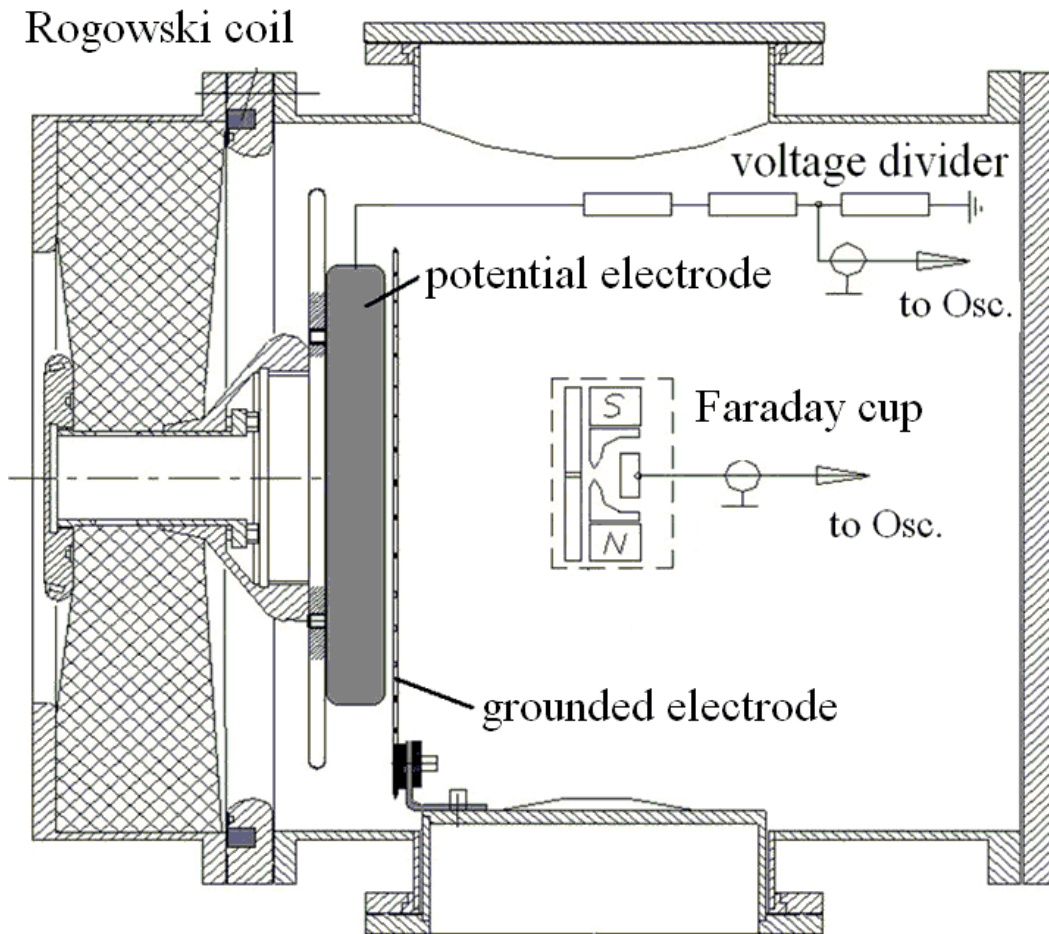
Functional diagram of the accelerator working on a matched load



Oscilloscope trace of voltage (1) and calculated values of impedance (2).

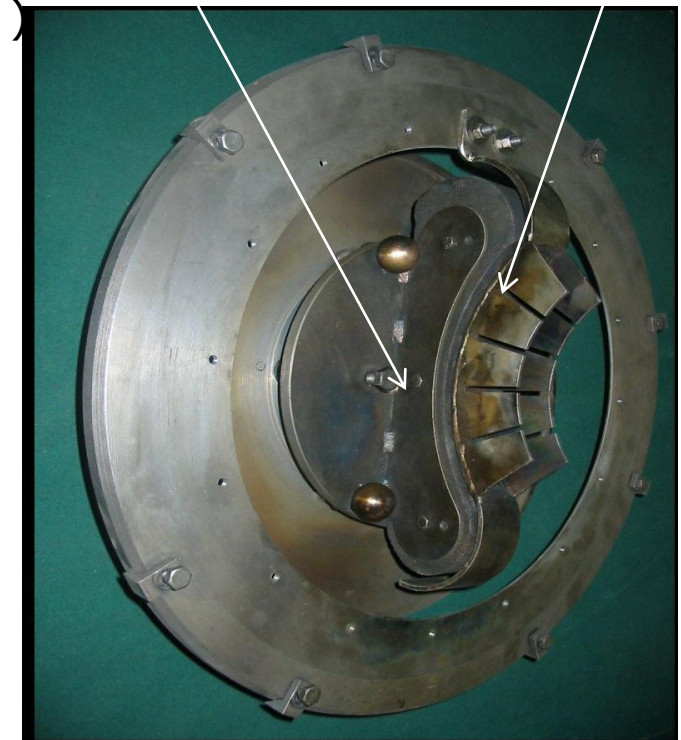


# Diode system



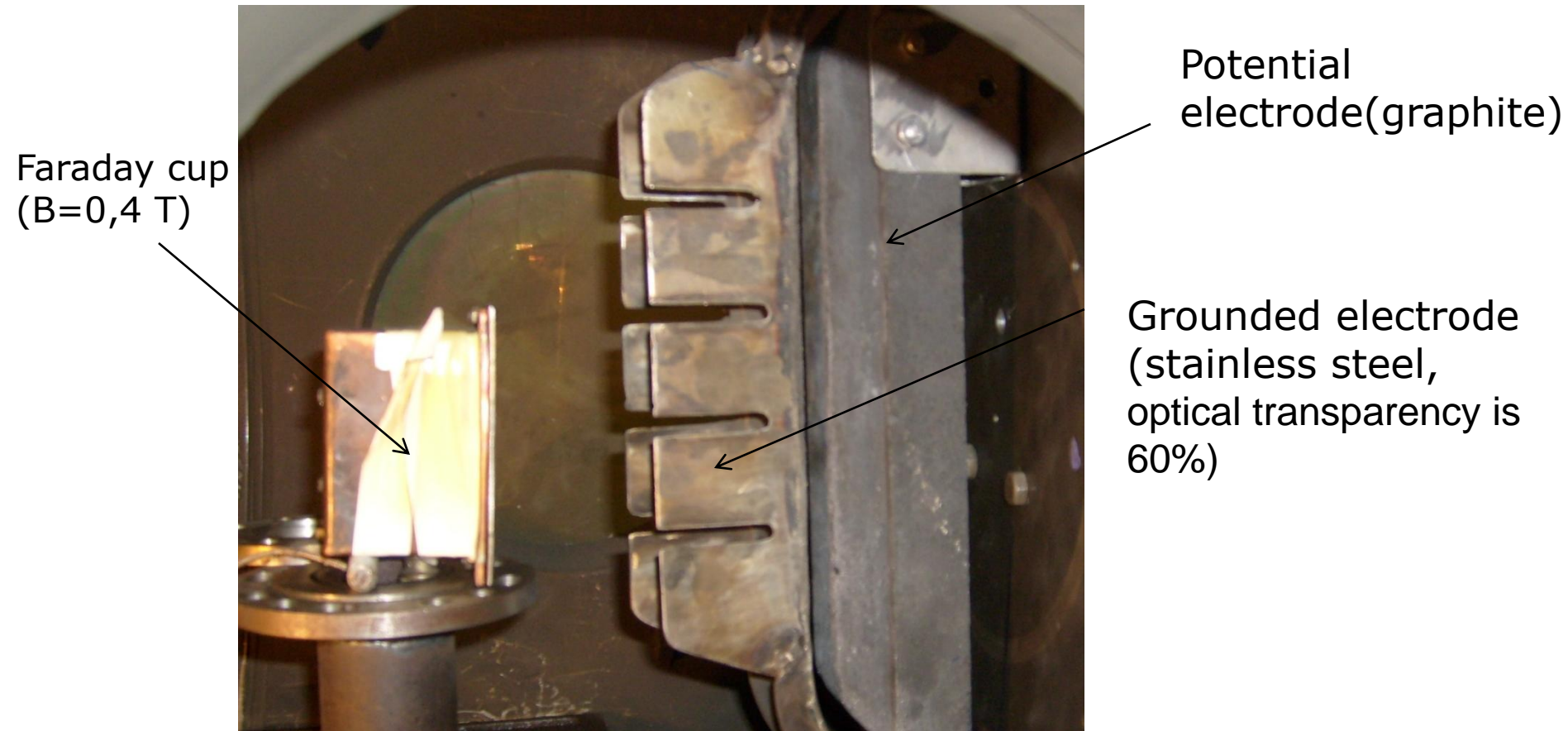
Diode connection in the TEMP-4M accelerator

Potential electrode (graphite)      Grounded electrode (mesh)

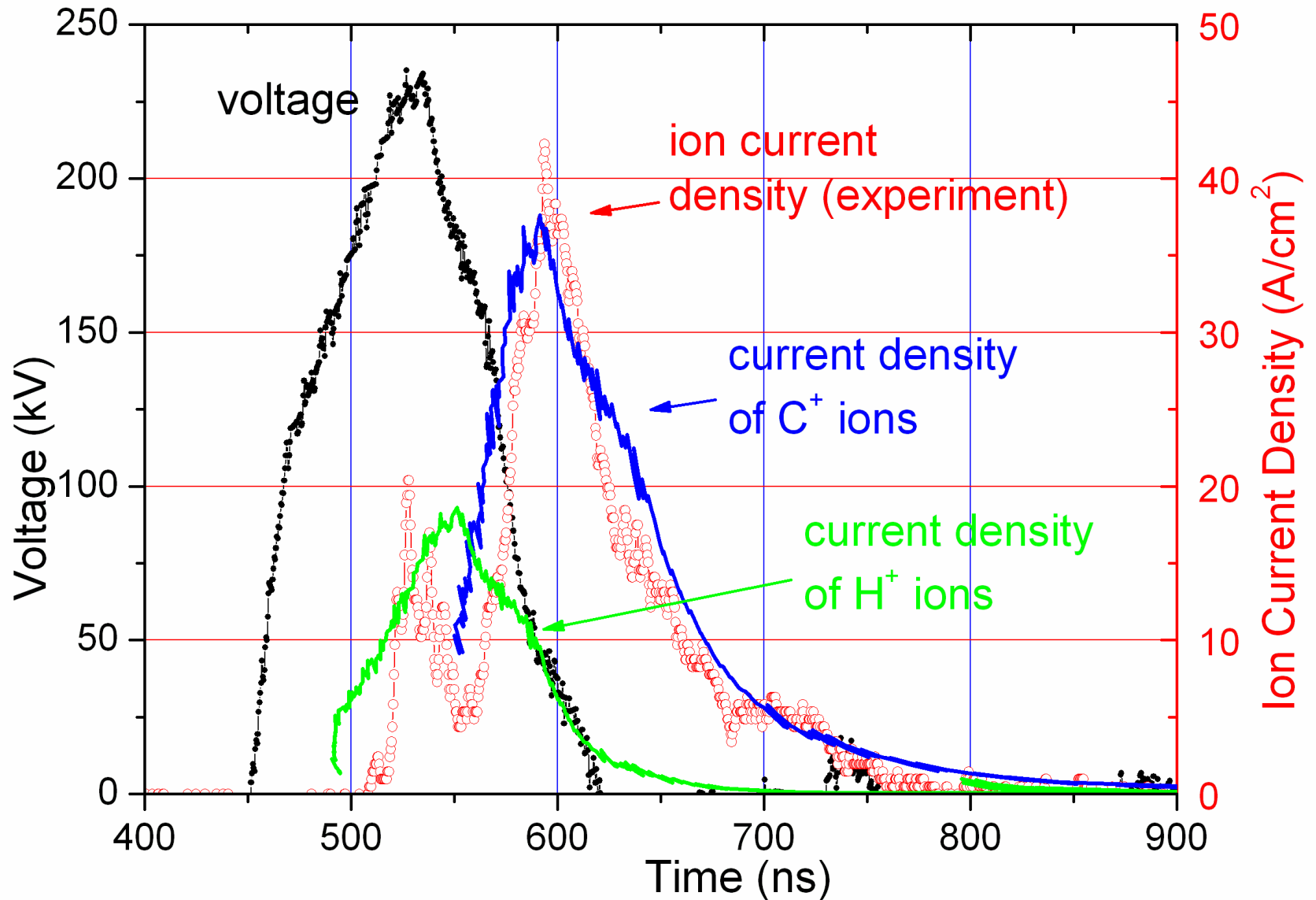


Magnetically self-insulated ion diode

# Beam composition and ion current density investigations



Picture inside of the diode chamber



Oscilloscope traces of voltage and ion current density (dots) in the planar diode.

# Conclusion

Diagnostic equipment correctly reflects the accelerator operation:

- In short circuit mode ( $U = 50\text{--}60$  kV),
- When operating with a resistive load up to 10 Ohm (200–250 kV),
- When operating with the diode.

The results of calibration of the diagnostic equipment were used in preparation of the following reports:

- Alexander I. Pushkarev and Yulia I. Isakova "Plasma compression effect in an ion diode with passive anode" (P\_1014)
- Ivan Yegorov "Three-electrode gas-filled controllable discharger" (P\_1170)

THANK YOU FOR ATTENTION!

QUESTIONS?