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CHARACTERISTICS OF PICOSECOND ELECTRON BEAM TO EXCITE OF HIGH NON-EQILIBRIUM STATES IN METAL SOLID-STATE-DENSITY PLASMA

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Electron Beam interaction with various targets

Pulsed Charged Particles Beams

Applications
- Industrial
- Material
- Medical
- *Scientific*

Imitation experiments
- short and ultra-short thermal impact
- EM radiation (λ = 10 nm ÷ 10^{-2} m)
- *shock and acoustic waves in solids*

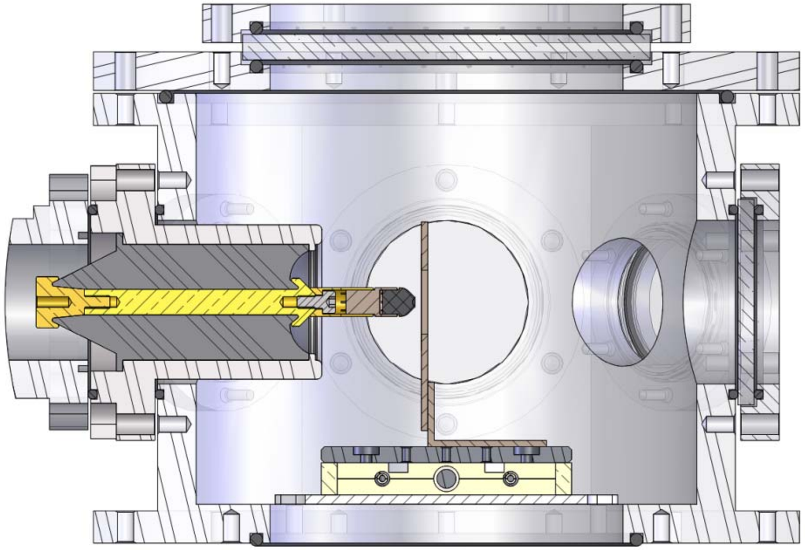
electronic components & construction materials for nuclear fusion reactors & spacecraft applications

High-Energy Densities and Fundamental Physics
- particles beams generation
- intense radiation initiation
- beam-matter interactions

The generators, allowing to acquire high-voltage pulses with voltage amplitude $U_{max} \approx 200$ kV, duration $\tau_p \leq 1$ ns and voltage rise rate $dU/dt \geq 1$ MV/ns are of great interest for *fast non-linear electrodynamic process in quantum plasma investigation*.

At that one can limit to the value of the stored in the source energy at the level of about $W = 1\text{-}10$ J

Experimental Setup



«RADAN-300» series HVPG

voltage pulse refined and shortened to amplitude of about 150 kV and duration < 600 ps (front < 300 ps fall < 200 ps)

Target (anode):

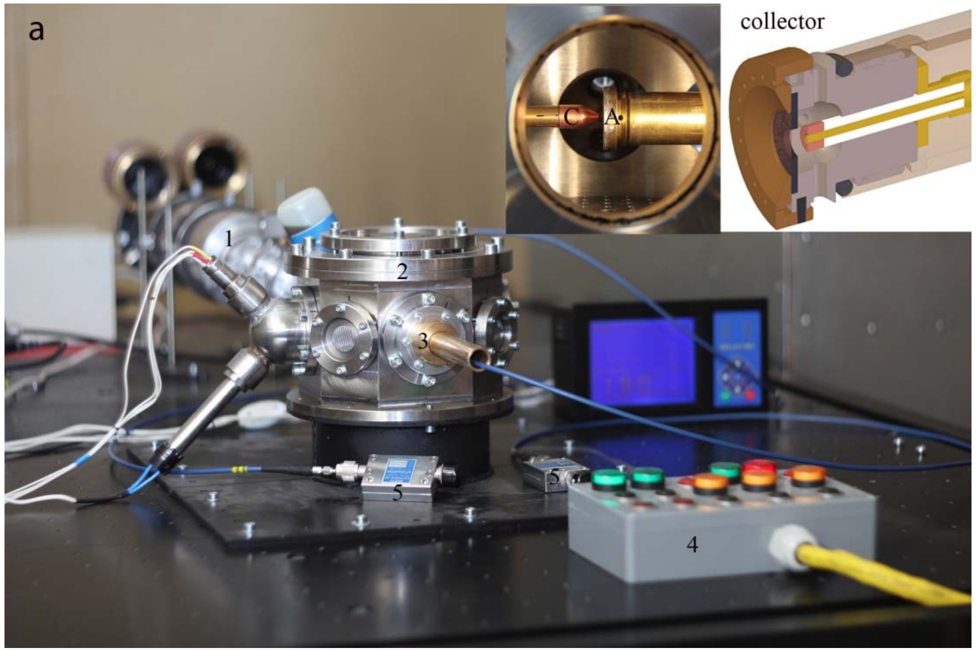
Two Cu foils 18μm thickness

Cathode:

Sm, Cu, W and Graphite rods with cone in 2 mm diameter

Remote controlled Vacuum Pumping System

EMP-shielded measurements chamber



Measuring Equipment

Oscilloscope

Tektronix

mod. DPO70404C

4-channel, 4 GHz bandwidth
analog sample rate 25GS/s

HUBER+SUHNER
Excellence in Connectivity Solutions

Sucoflex 18 GHz coaxial cable assembies

Attenuators

Barth Electronics, Inc.

mod. 142-NMFP-20B

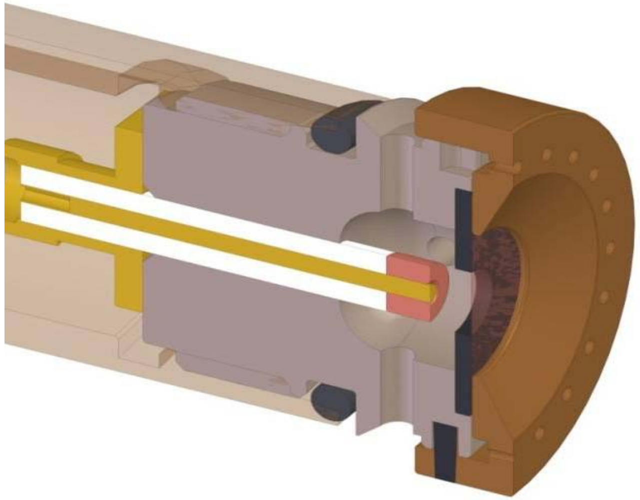
high-voltage pulse rated for 2.5 kV / 400 ns
50 Ω impedance *20 dB attenuation*
unique precise voltage ratio factory measured
up to 30 GHz bandwidth

AEROFLEX WEINSCHEL

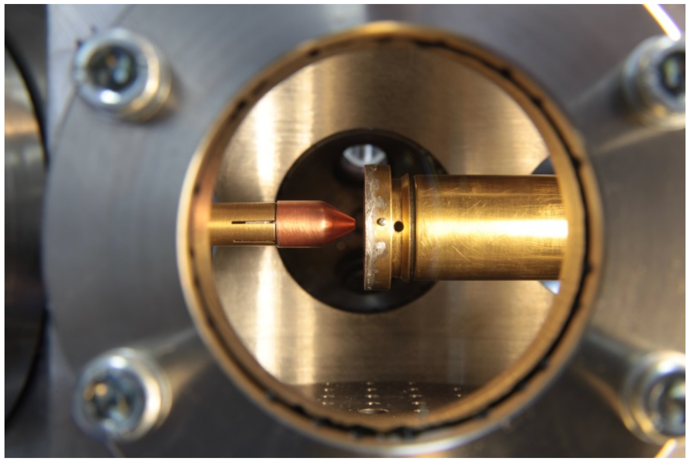
mod. 23-6-34 and *mod. 23-20-34*

6 dB attenuation 20 dB
50 Ω impedance
peak power rated for 1 kW / 1μs
up to 18 GHz bandwidth

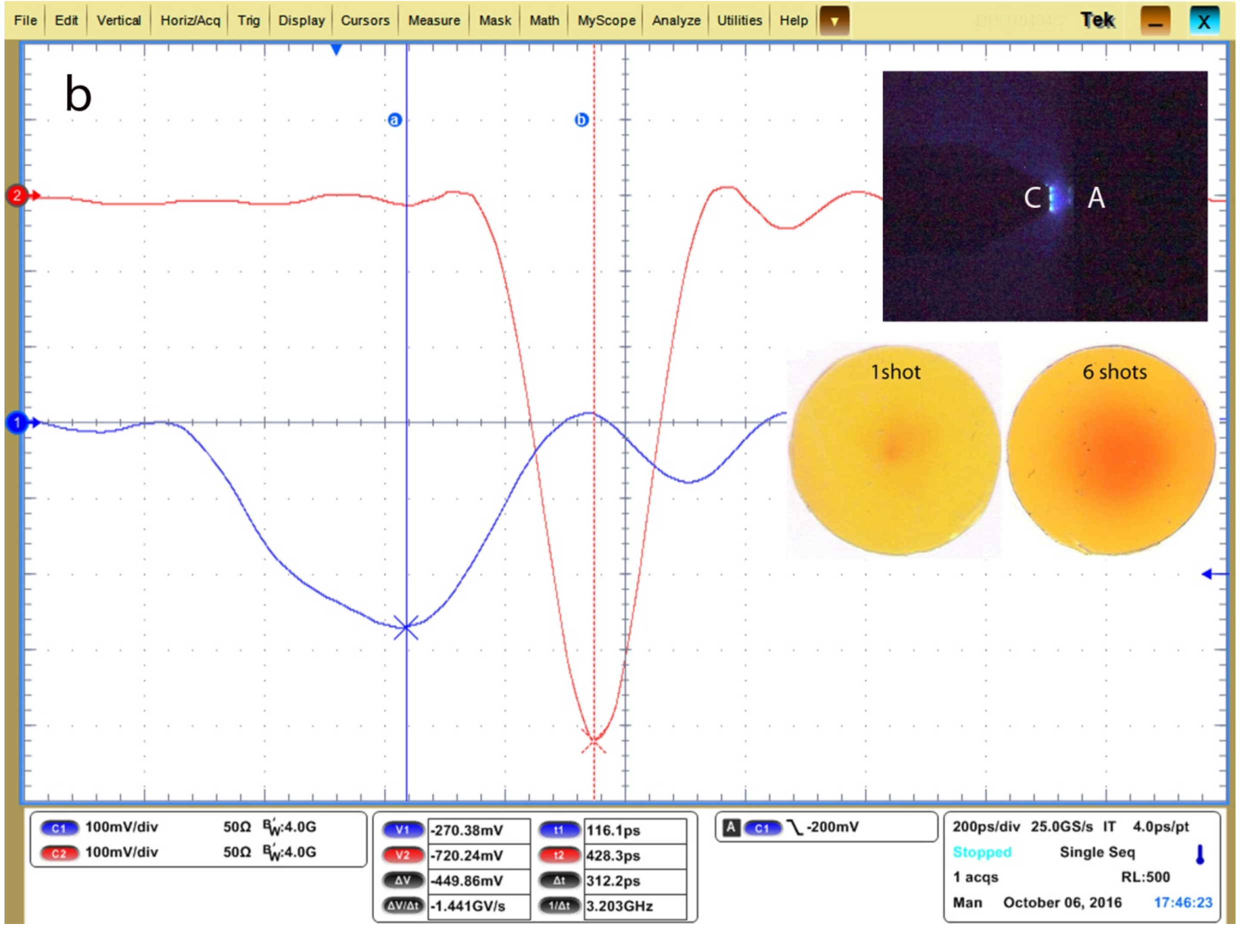
Beveled-head current collector cross-section



2mm inter-electrode gap, Cu cathode

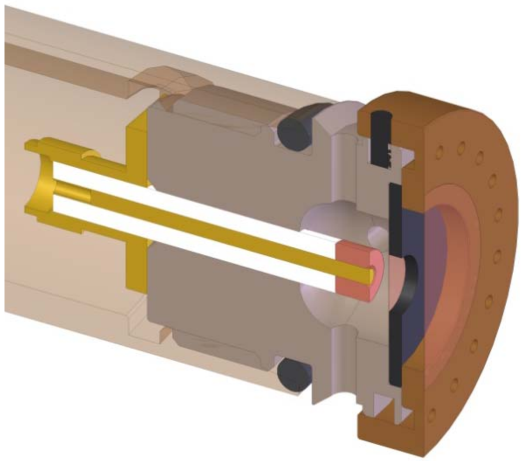


Typical oscillograms of voltage (Ch1) on an entrance of the coordinating oil line 30 cm long and a beam current (Ch2) on the collector after passing two copper foils 18 microns thickness.



Voltage and current measurements

Flat-head current collector cross-section

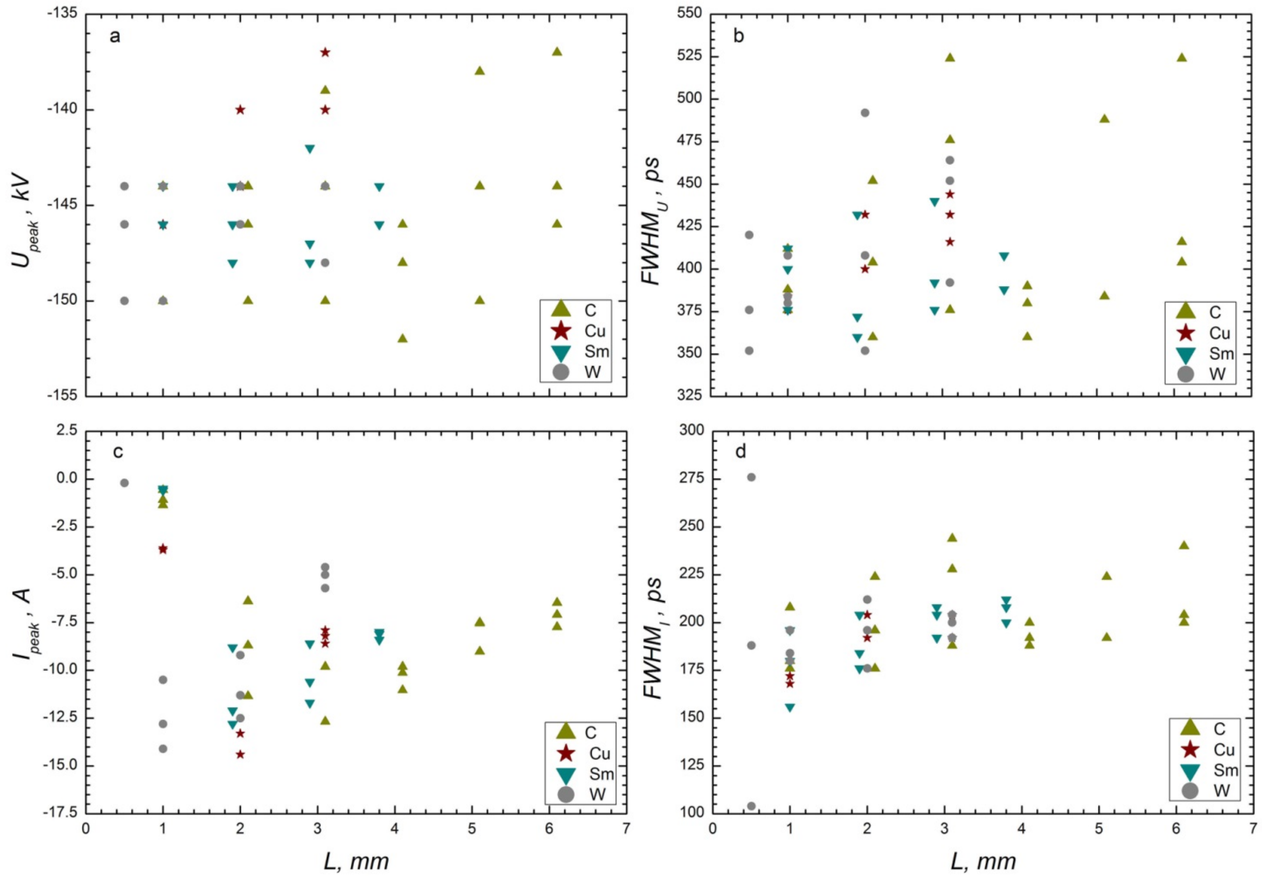


<u>Cathode</u>: Cu, Sm, W and C rods ø 2mm

Disassembled current collector head

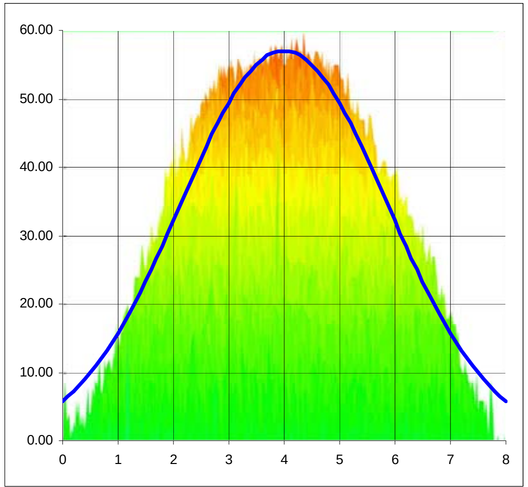
50 Ω impedance designed Faraday cup

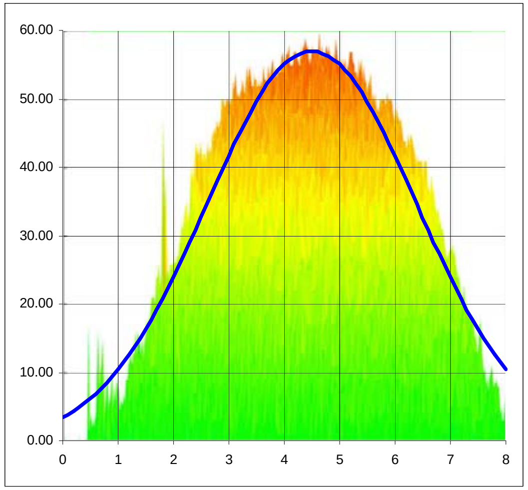
2 spaced Cu foils (18 μm each)

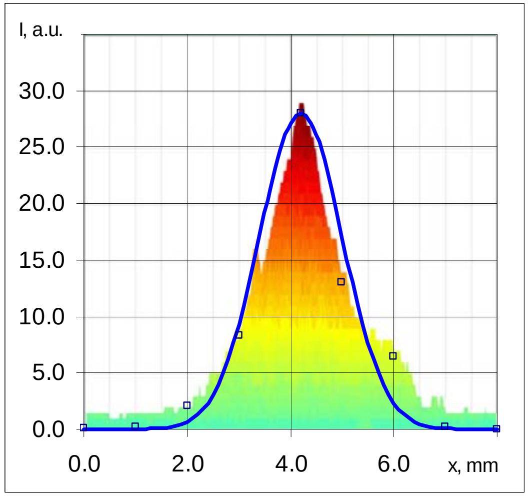


Intensity of the electron beam image on dosimetric film has view:

For 6 shots – XZ (left) and YZ (right) cross-sections; for one shot.







It is described by the Gauss formula

$$I(x) = \frac{A}{\sqrt{2\pi}} \exp\left(-\frac{(x - x_0)^2}{2\sigma^2} \right),$$

where:

Cross-section	A	x_0 , mm	σ, mm	FWHM*, mm
XZ	22.74	4.0	1.87	4.41
YZ	22.74	4.5	1.89	4.43

A	x_0, mm	σ , mm	FWHM, mm
11.17	4.2	0.81	1.90

* FWHM is the full width on a half amplitude level.

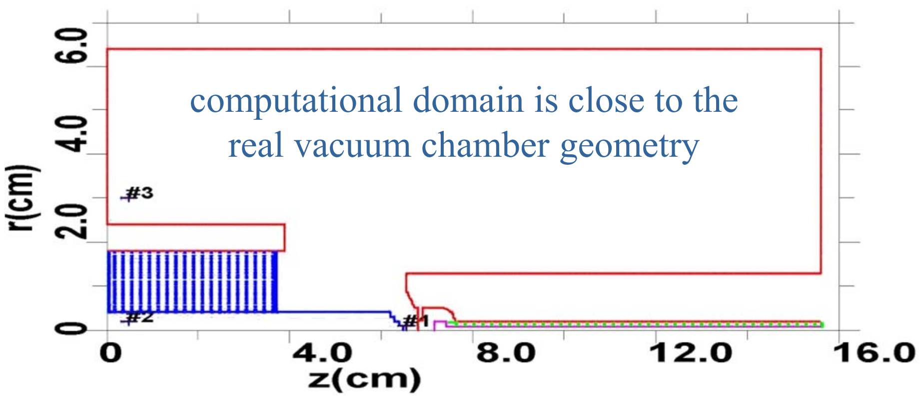
KARAT simulations

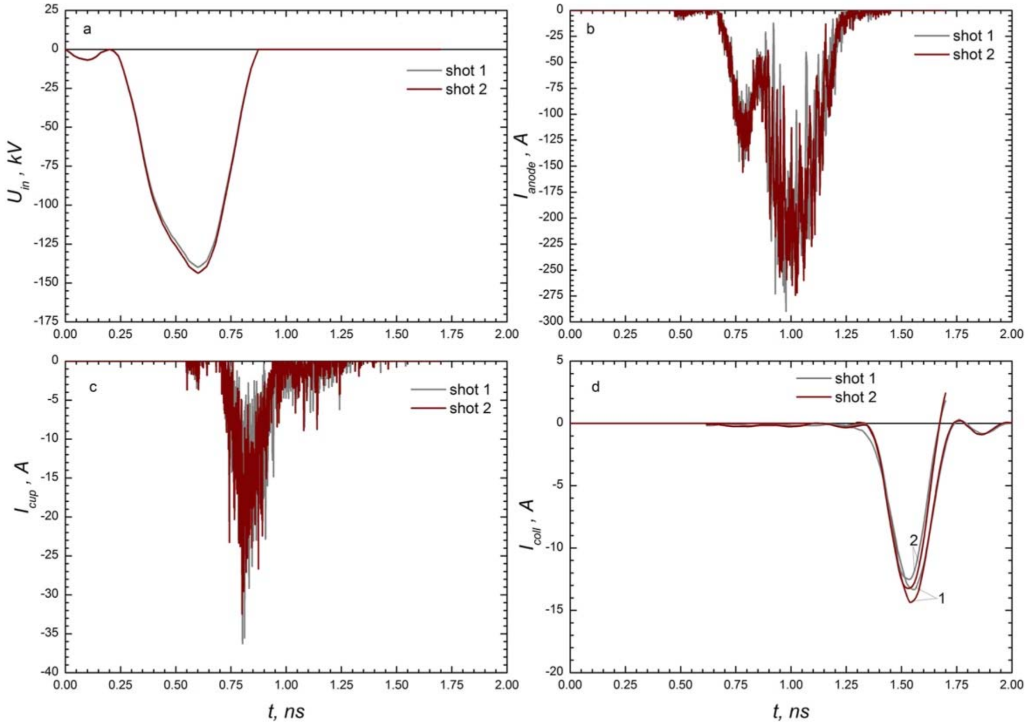
KARAT is a fully electromagnetic code based on the particle-in-cell (PIC) method. *

* *Tarakanov V.P.*, User's Manual for code KARAT, Springfield, VA: Berkley Research Associates, Inc., 1992.

Cu cathode, 2mm inter-electrode gap

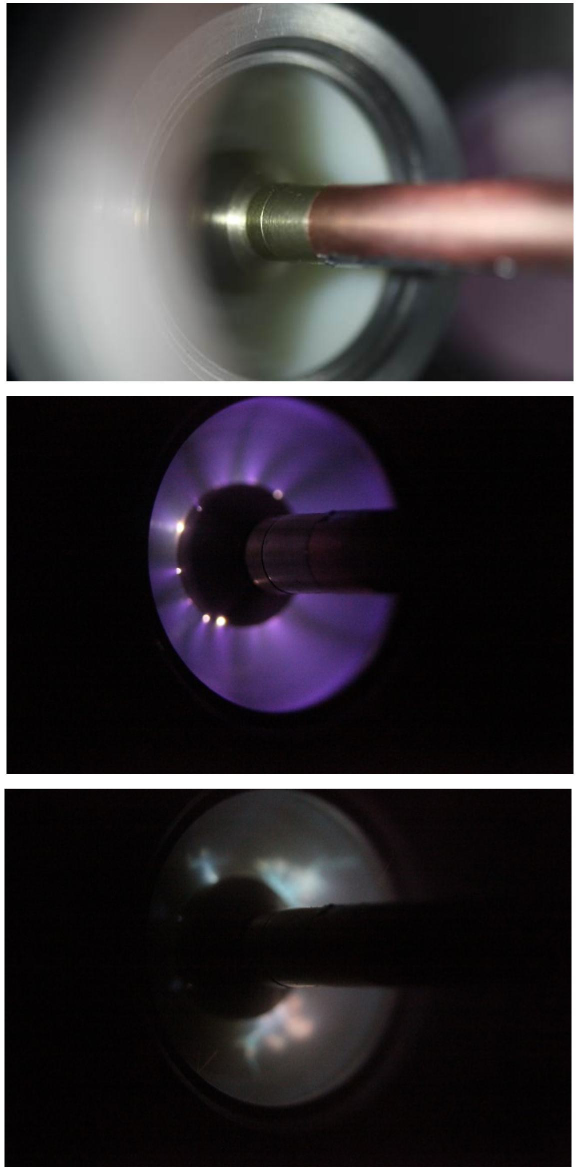
Initial geometry



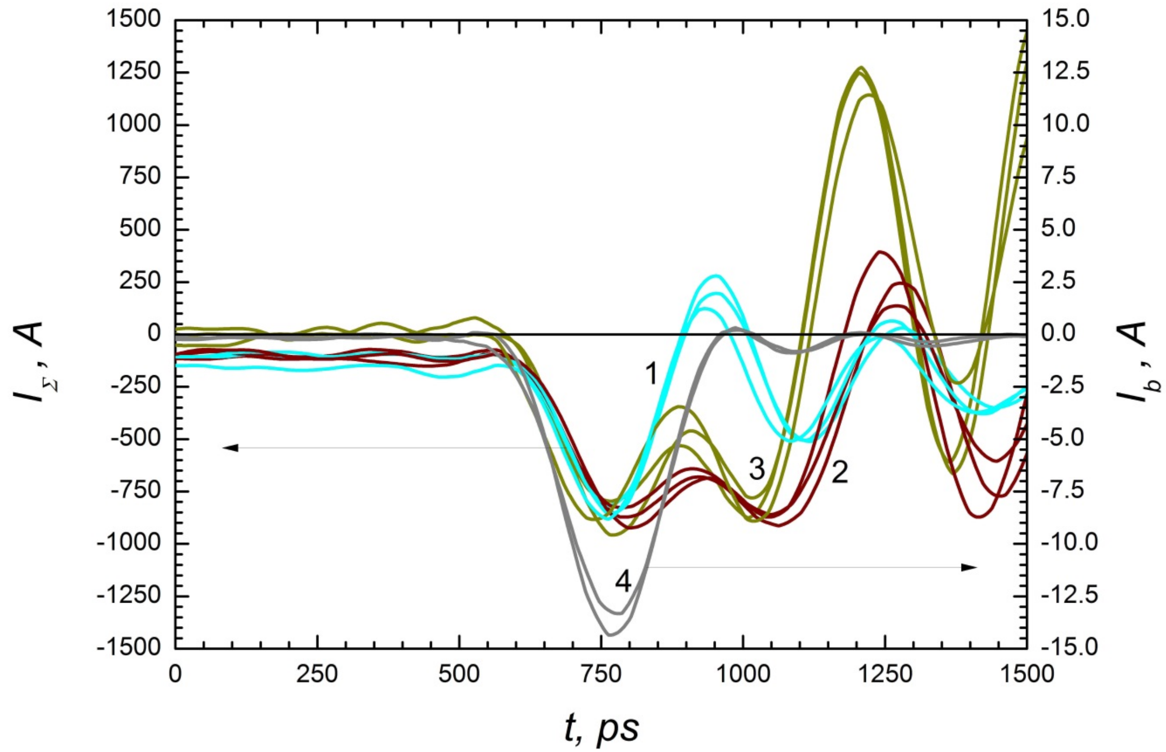


foil thickness was
absorption probability defined

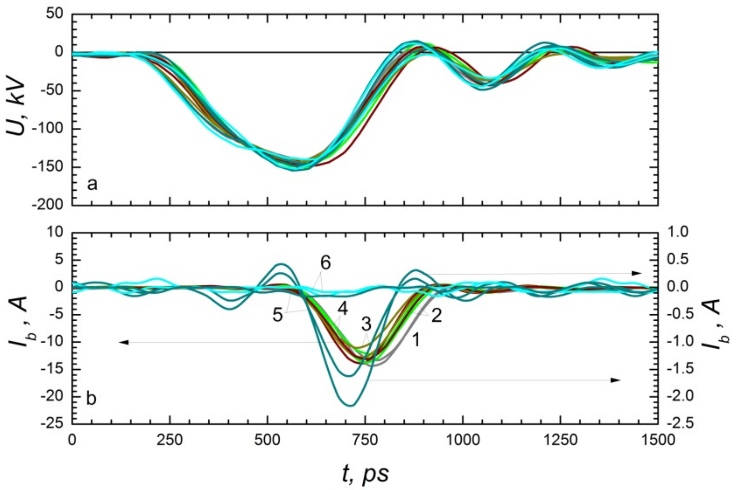
experimental voltage pulse
from the vacuum diode input
was taken to be
the boundary conditions

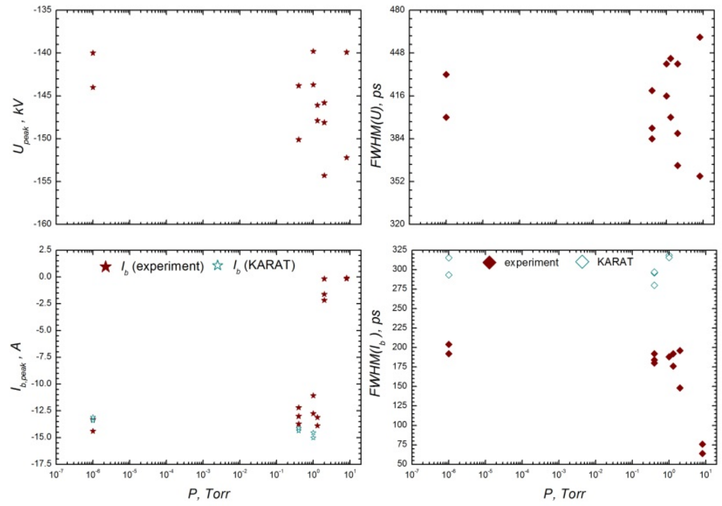


Photos of the inter-electrode gap closed by a copper rod with 8 mm in diameter from high-voltage input to the discharge (the top picture), during the discharge on air (a middle picture) and in vacuum (the lower picture).

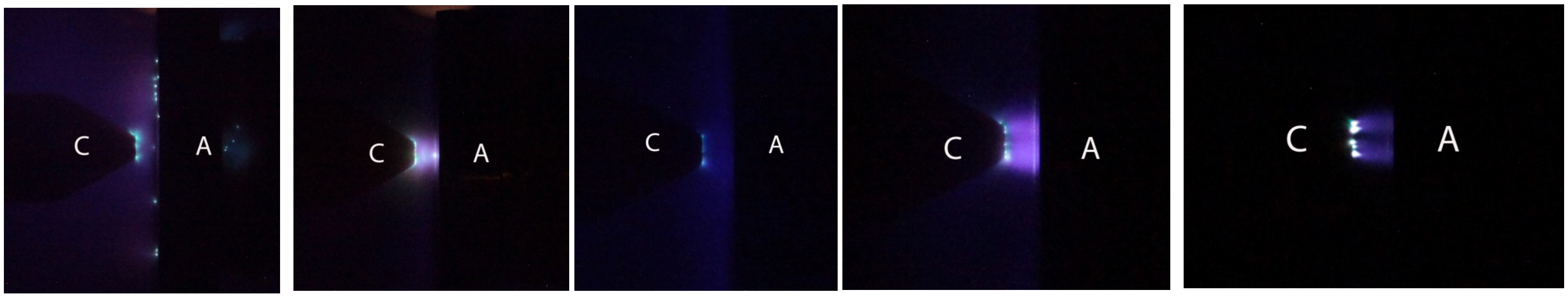


Total current of electric discharge on closed by a copper rod on air (1), in vacuum (2) and on the opened vacuum gap (3). Curves 4 show the current of an electron beam measured by means of the collector.





Input voltage and beam current via pressure: $P = 10^{-6}$ *(1), 0.4 (2), 1.0 (3), 1.3 (4), 2.0 (5), 8.1 Torr (6).*



P=0.4; 1.0; 1.3; 2.0; 8.1 Torr.

All photos are received at the same value of a diaphragm: D=18.

Conclusions

- The experimental setup for picosecond pulse interaction with metal targets investigation had been designed and assembled. Also the EMP-shielded measurements chamber had been built.
- The beam current was acquired via the Faraday cup current collector.
- The obtained experimental data match qualitatively and quantitatively the electron beam formation numerical simulations using KARAT electromagnetic code, where the computational domain was close to the real vacuum chamber geometry, and the experimental voltage pulse from the vacuum and gas diode input was taken to be the boundary conditions.
- With help of the current shunt the total current of a discharge on the closed and opened gap is measured. Experimentally and by means of modeling in the KARAT code dependence of the beam current on pressure is investigated.
- Further work is aimed at mechanisms of excitation and relaxation of highly non-equilibrium states of metals investigations, using interferometric measurement system for acquiring both modulus and phase of laser beam absorption ratio.

Acknowledgements

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Many thanks for Your kind attention!!!