A 2.45 GHz Photoinjector Gun for a FEL Driven by Laser Wakefield Accelerated Beam

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Abstract

The photoinjector of short electron bunches is a key element of investigations aimed on particle acceleration by pulses of the subpetawatt laser PEARL (10 J, 50-70 fs). Projected parameters of the photoinjector are the following: an electron energy of 5 MeV, charge >0.1 nC, bunch length of about 3 mm, transverse emittance no worse than 1 mm*mrad, and an energy spread no more than ~0.1%. The photoinjector is based on klystron KIU-111 at frequency 2.45 GHz, produced by company Toriy (output power ~5 MW, pulse length ~7 μs, efficiency ~44%, power gain ~50 dB). This klystron will feed a classical 1.5 cell gun resonator with removable photocathode. The gun will be driven by a third harmonic of a Ti:Sa laser with 100uJ energy in a picosecond pulse. The photocathode will be made of CVD diamond film which has high QE, long lifetime and is robust with respect to the vacuum conditions.

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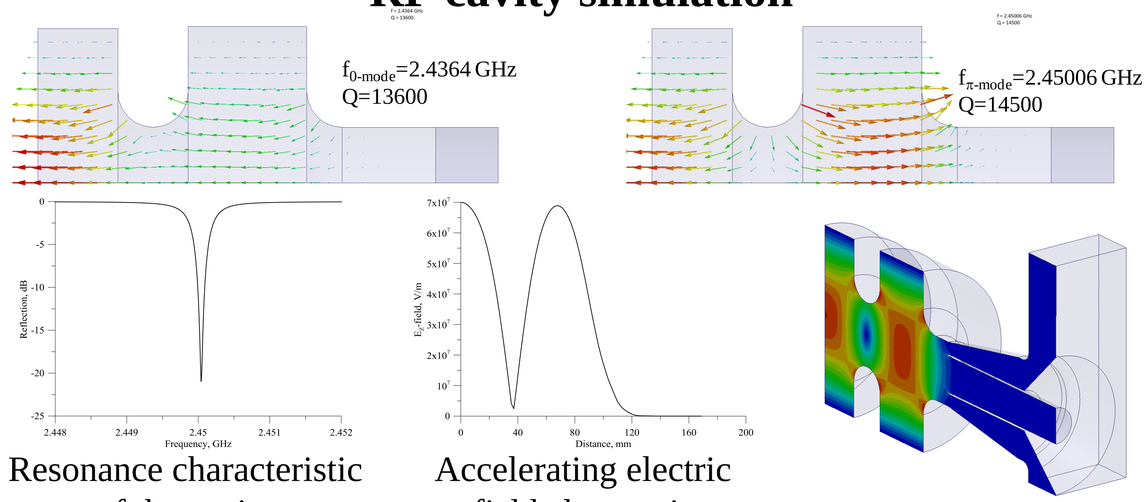
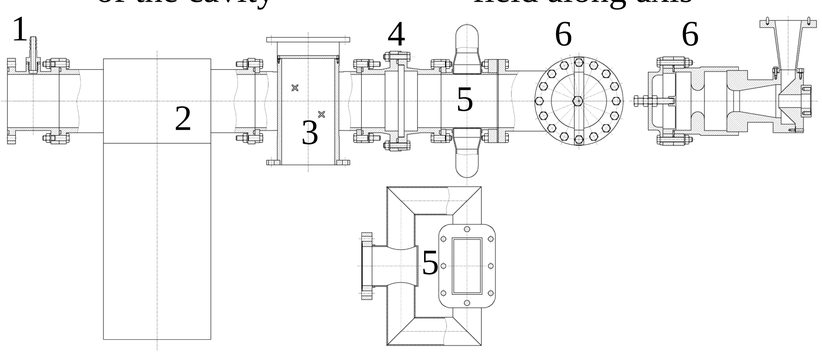
RF cavity simulation



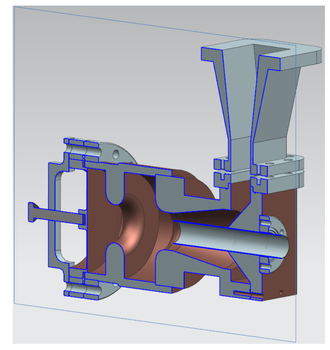
Resonance characteristic of the cavity

Accelerating electric field along axis

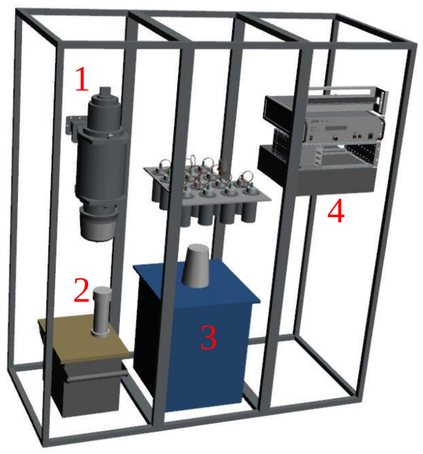
E_{max}=70 MV/m
(P_{in}=5 MW)



1 – gas inlet, 2 – circulator, 3 – directional coupler, 4 – vacuum window, 5 – pumping port, 6 – RF cavity

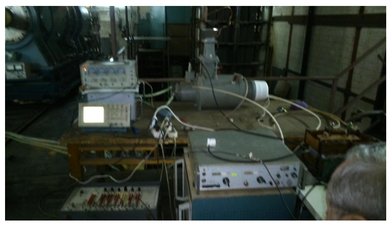


Setup

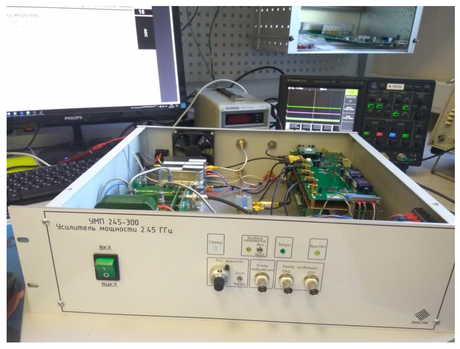


1 – klystron, 2 – voltage transformer, 3 – voltage supply, 4 – RF amplifier

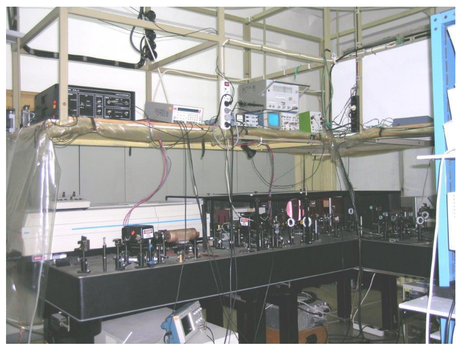
Frequency	2.45 GHz
Peak output power	5 MW
Average power	Up to 5 kW
Cathode voltage	50 kV
Efficiency	<44%
Power Gain	50 dB
Pulse length	7 μs
Mass	85 kg



Klystron KIU-111 “Toriy”

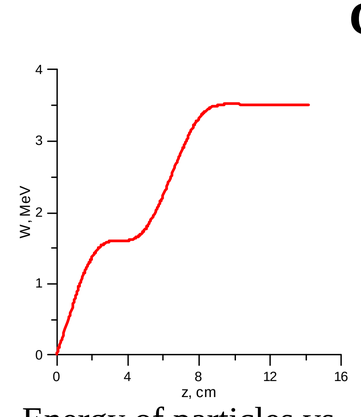


RF amplifier

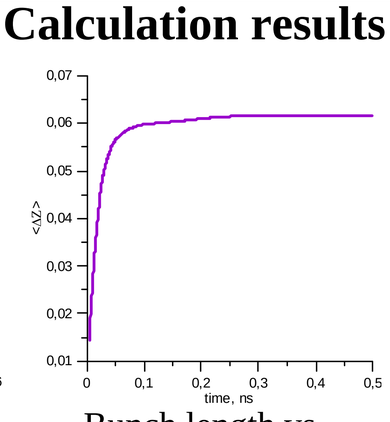


Laser system for 2.45 GHz RF gun

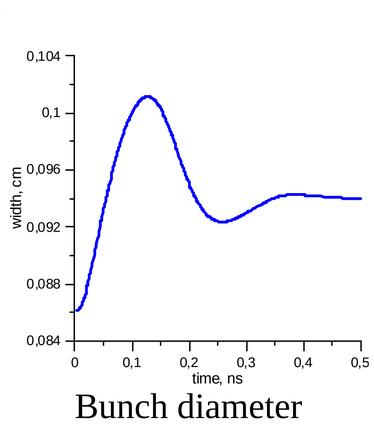
Calculation results



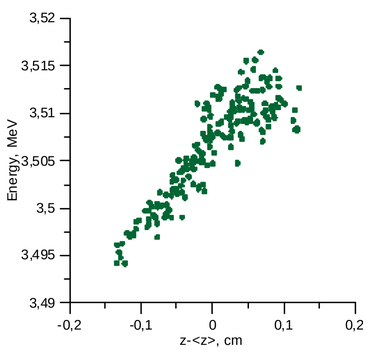
Energy of particles vs. distance from cathode



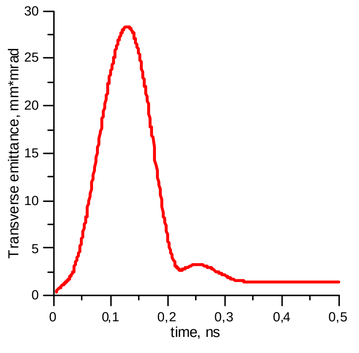
Bunch length vs. distance from cathode



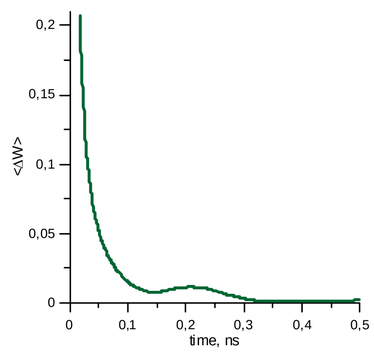
Bunch diameter



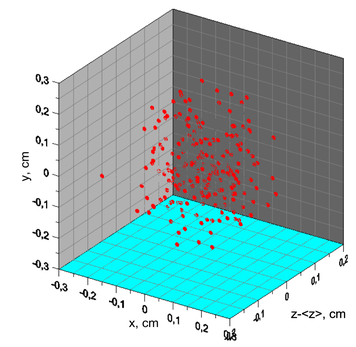
Energies of simulated particles behind cavity



Transversal emittance vs. distance from cathode



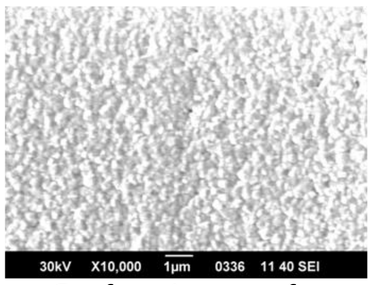
Energy spread vs. distance from cathode



Simulated particles behind cavity

Parameters:	
Frequency	2.45 GHz
Cavity length	11.74 cm
Laser pulse duration	10 ps (Gaussian)
Magnetic field maximum	1.07 T at z=10.1 cm
Bunch charge	0.1 nC
Bunch initial radius	0.45 mm (Gaussian)
Cathode maximum field	70 MV/m
Injection phase	-40°
Injection field	63 MV/m
Average energy	3.5 MeV
Bunch average length	2.4 mm
Transverse emittance	1.4 mm*mrad
Energy spread	0.2%

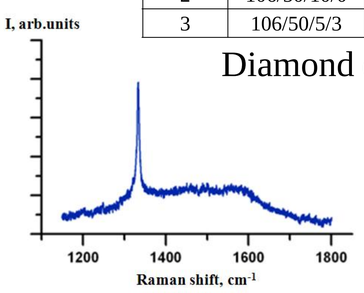
CVD diamond parameters



Surface image of a nanocrystalline diamond film from an electron microscope.

Cathode №	Gas mixture $Ar/H_2/CH_4/N_2$, sccm	Pressure, Torr	Power <P>, kW	Temperature Ts, °C	Time, min
1	106/50/2/0	200	4,5	900	30
2	106/50/10/0	200	4.5	900	10
3	106/50/5/3	200	4.5	850	30

Diamond deposition regimes



Raman spectrum of nanocrystalline diamond film.