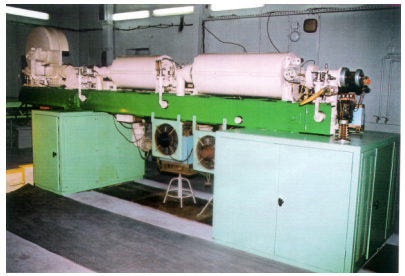
ELECTRON ACCELERATOR FOR RADIATION STERILIZATION AND R&D STUDY

Zbigniew ZIMEK, Zygmunt DZWIGALSKI, Stanisław WARCHOL, Sylwester BULKA, Karol ROMAN

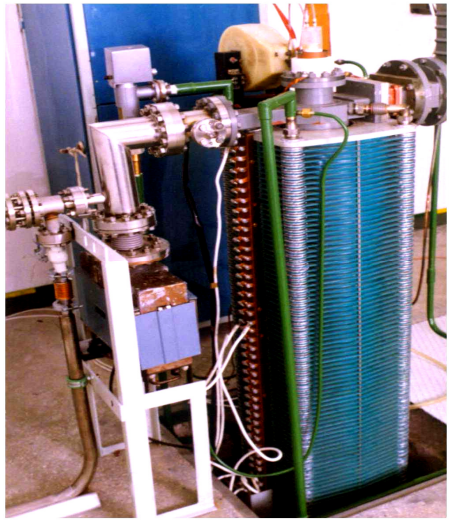
Centre for Radiation Research and Technology,
Institute of Nuclear Chemistry and Technology, Warsaw, Poland
zimek@orange.ichtj.waw.pl

ELECTRON ACCELERATORS IN
Centre for Radiation Research and Technology
of Institute of Nuclear Chemistry and Technology

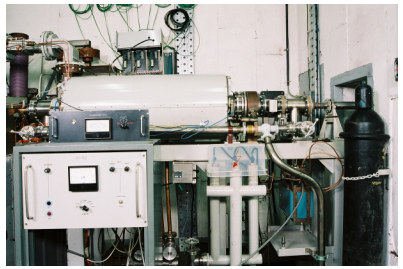
LAE 13/9
Linear, energy 10–13 MeV,
beam power up to 9 kW
Manufacturer: NIIEFA,
St. Petersburg, Russia
R&D, Installation: 1971



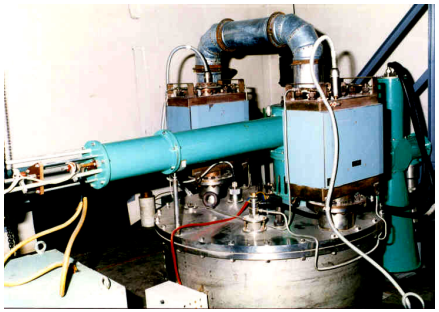
2 x Elektronika 10/10
Linear, energy 10 MeV,
beam power up to 10 kW
Manufacturer: TORIJ,
Moscow, Russia
Radiation sterilization and
Food products treatment,
Installation: 1993



LAE 10
Linear, 10 nanosecond single
pulse mode, energy 10 MeV,
Manufacturer: INCT, Poland
Pulse Radiolysis Research
Installation: 2001

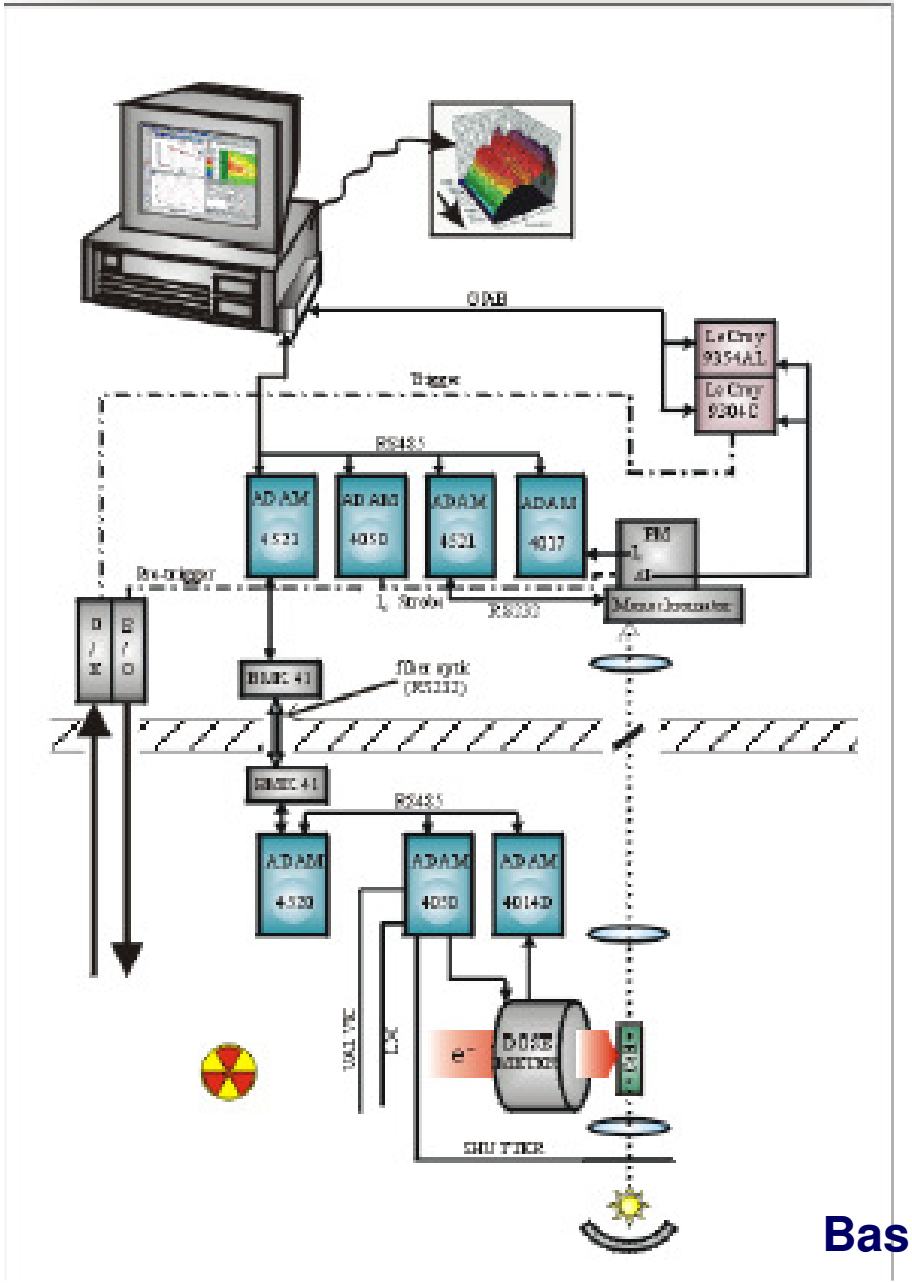


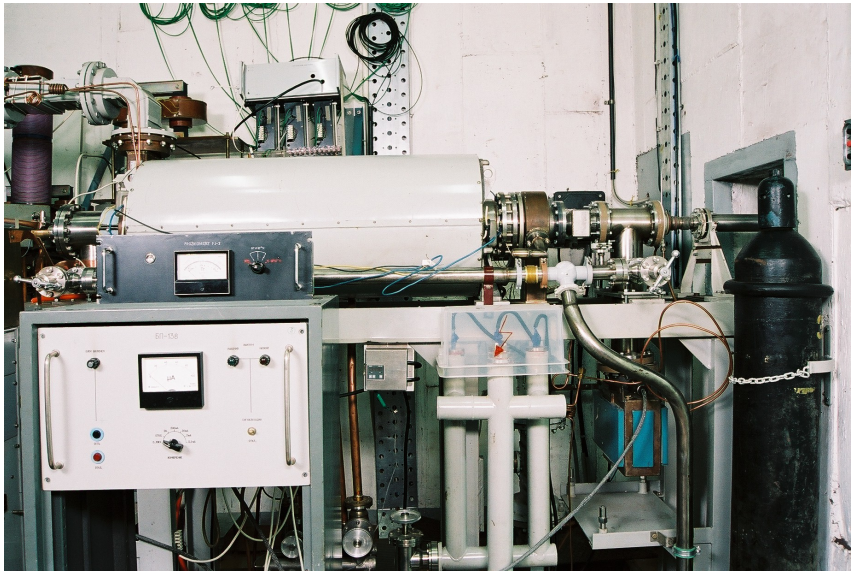
ILU – 6
Resonance Cavity,
energy range 0.5–2 MeV,
beam power up to 20 kW,
Manufacturer: INP
Novosibirsk, Russia
Polymer cross-linking,
flue gas treatment
Installation:1988



AS – 2000
Van de Graaff type,
electron beam 0-100 μA,
energy range 1-1.5 MeV,
Manufacturer:
HV Engineering,
Netherlands.
Research on radiation
modification of
semiconductors
Installation at INCT: 1987

ACCELERATOR LAE 10





Energy 10 MeV, Pulse duration 10 ns

Basic research: pulse radiolysis experiments

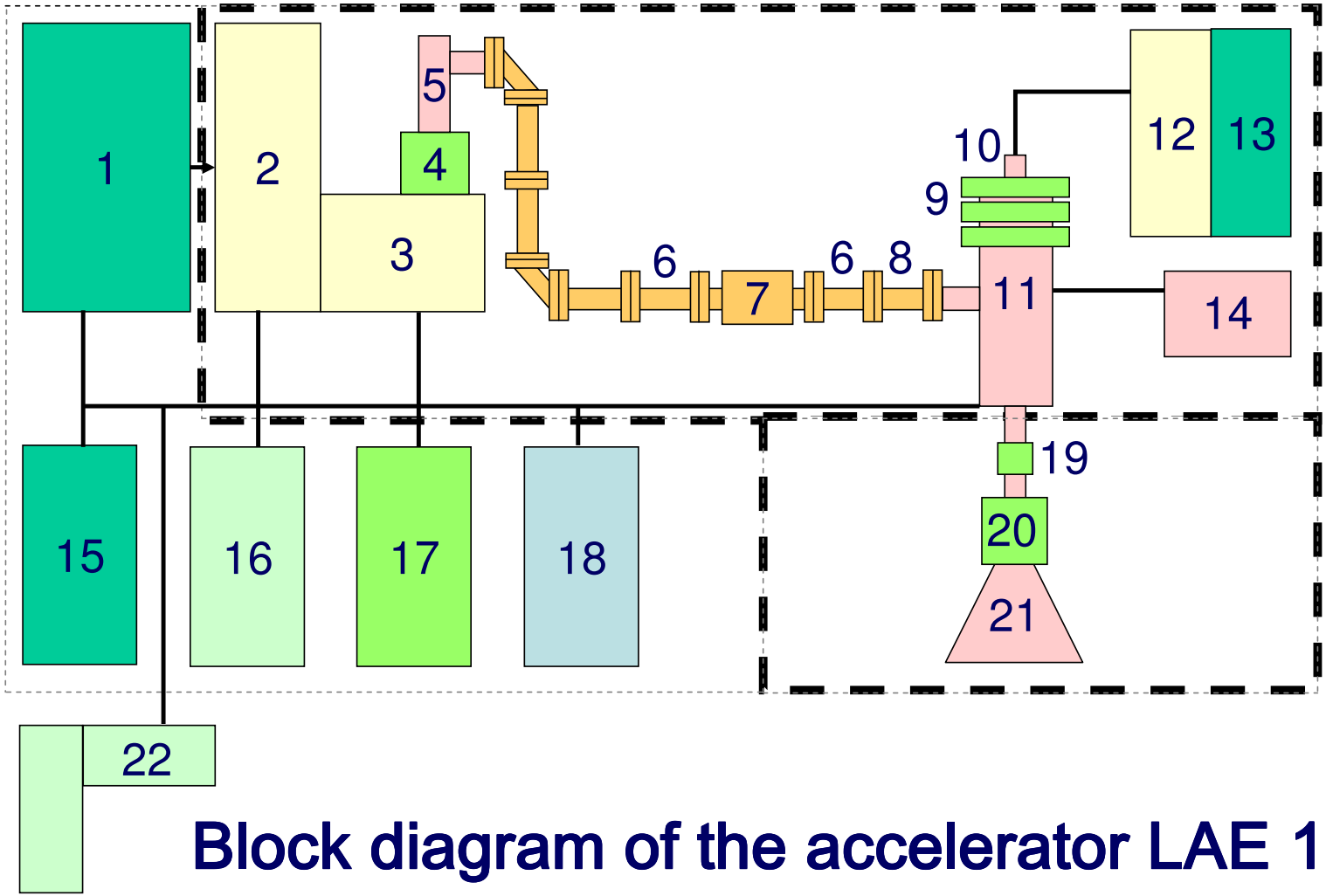
Upgrading of radiation facility located at Centre for Radiation Research and Technology of INCT in Warsaw has been initiated towards:

- higher technical and economical effectiveness,
- better operational characteristics (better accelerator availability, more stable beam parameters, better spare parts availability),
- radiation sterilization of medical devices and tissue grafts,
- radiation processing and research program.

The objective of the project is 10 MeV of electron energy and 15 kW beam power linear electron accelerator equipped with standing wave accelerating section and microwave source based on modern klystron type TH2158 operated at frequency 2856 MHz.

The following stages of the project have been completed:

- electron gun construction and testing,
- electron gun modulator stand,
- microwave system of accelerator (driving generator, pulse amplifier, high power klystron TH 2158 and waveguide components),
- pulse power modulator stand based on semiconductor HV high current transistor switch,
- control system based on microprocessor system (Siemens modules S7-300),
- vacuum system,
- water cooling system.

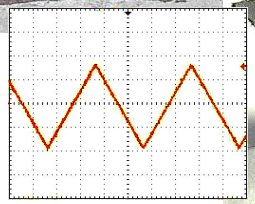


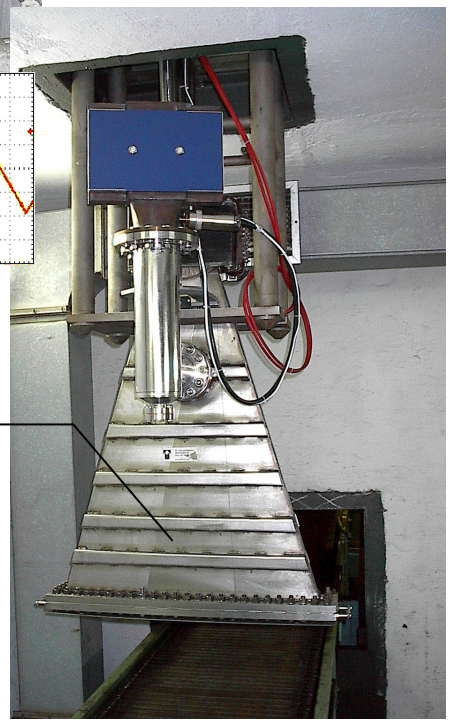
Block diagram of the accelerator LAE 10/15

1 – HV power supply 13 kV, 50 kW; 2 – modulator; 3 – pulse transformer 135 kV; 4 – focusing coils; 5 – klystron; 6 – directional coupler; 7 – circulator; 8 – RF window; 9 – focusing coil; 10 – electron gun; 11– accelerating section; 12 – gun modulator; 5 kV; 13 – gun modulator 50 kV; 14 – vacuum pumps; 15 – AC panel; 16 – PLC microprocessor; 17 – auxiliary equipment; 18 - water cooling system; 19 – beam current monitor; 20 – scanning electromagnet; 21 – scanner; 22 – control desk

Gun

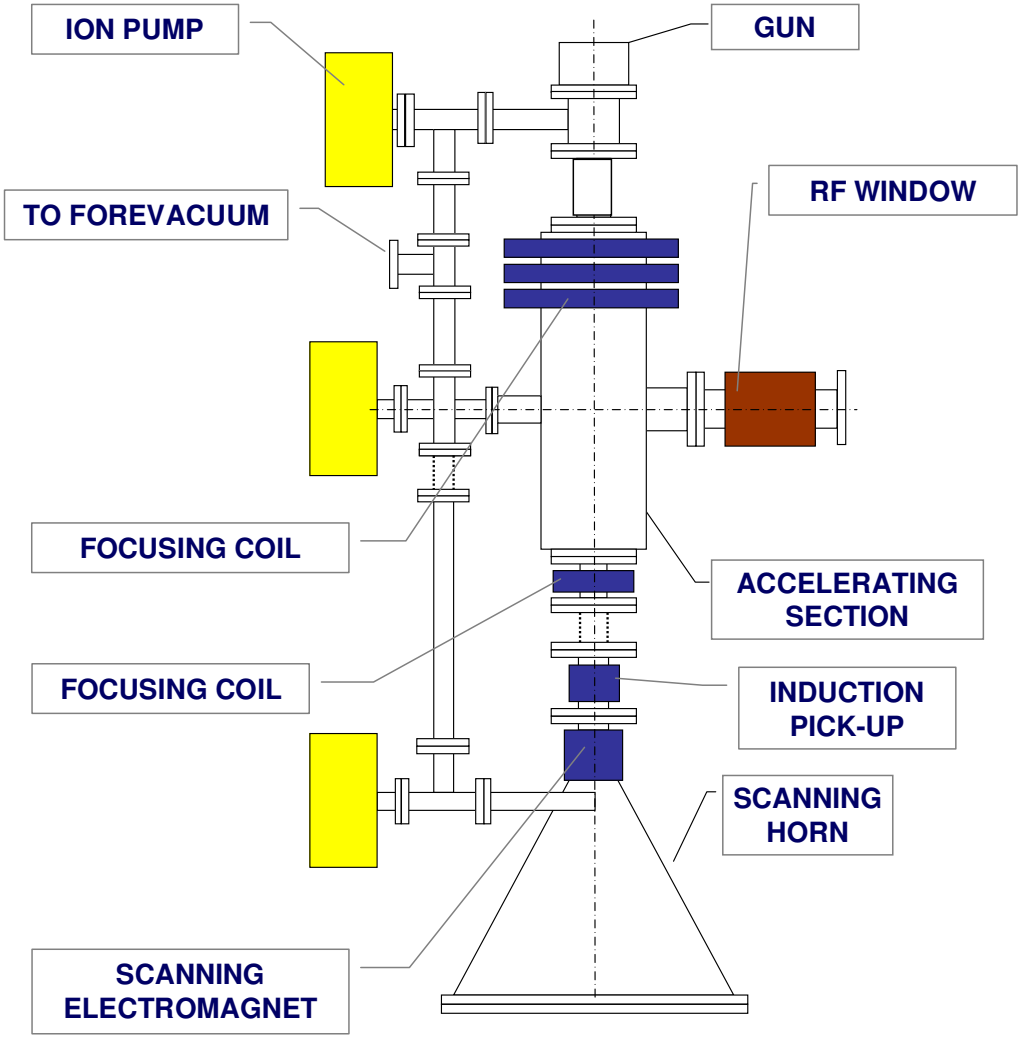
Focusing coils

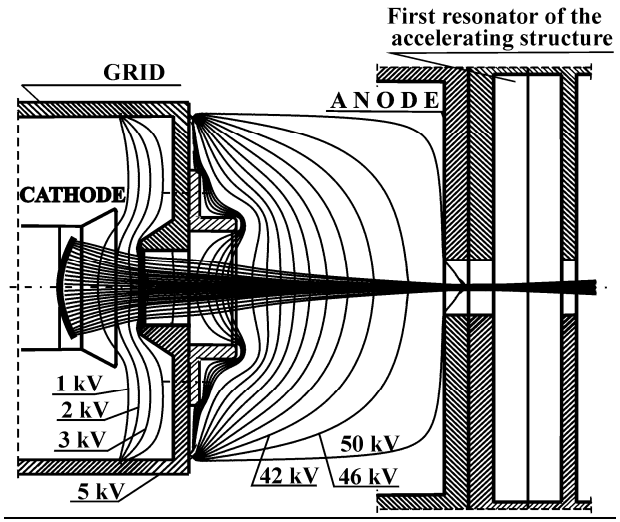


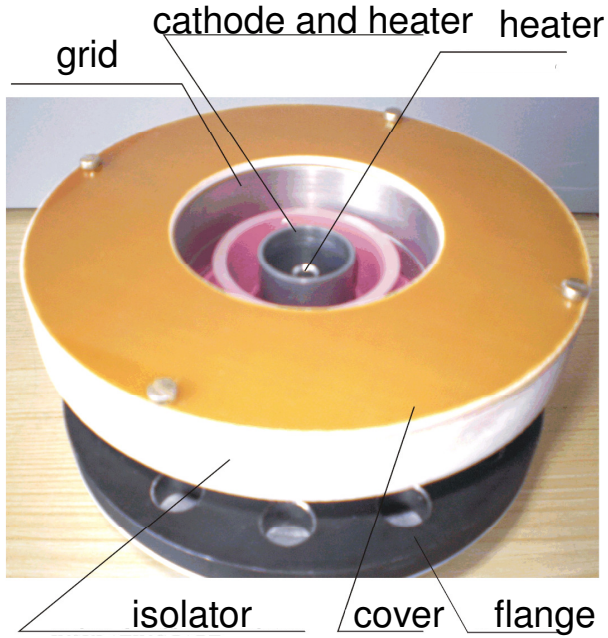


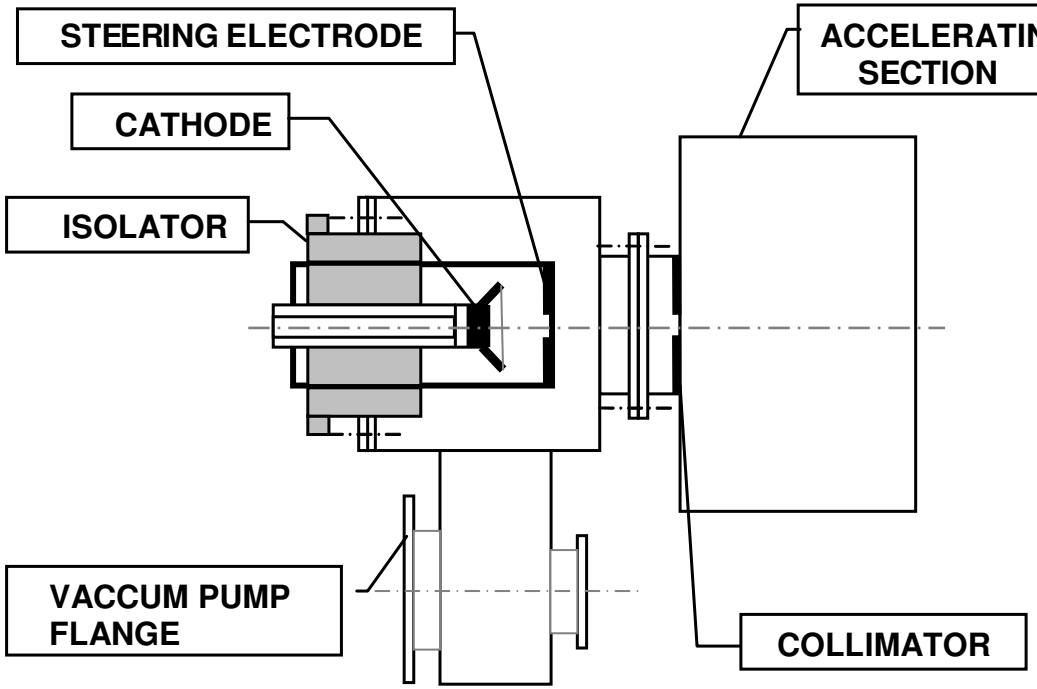
Scanner

Linear electron accelerator
10 MeV; 15 kW



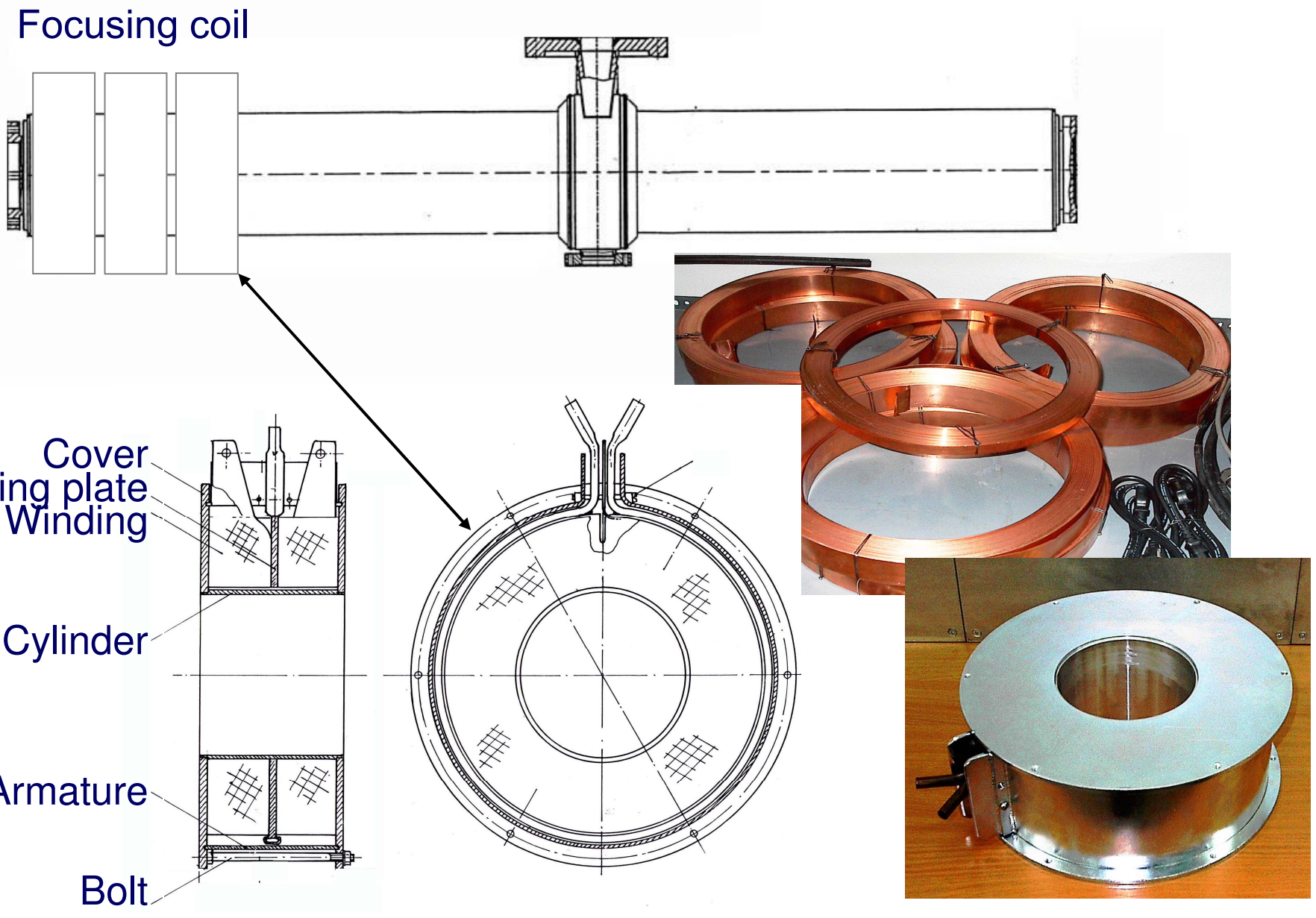




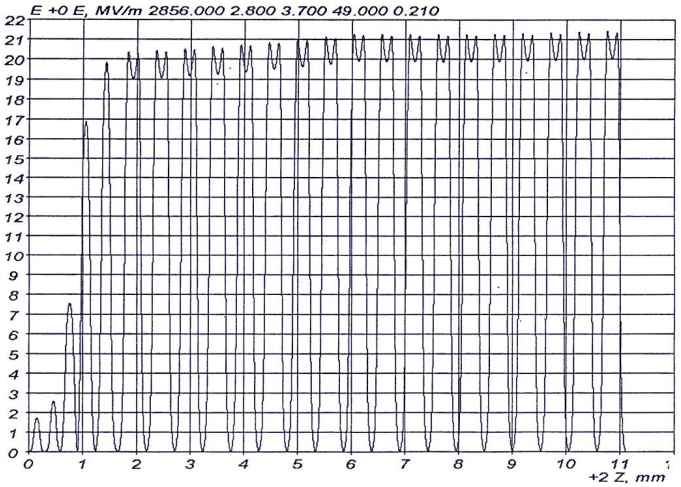


Electron gun alignment

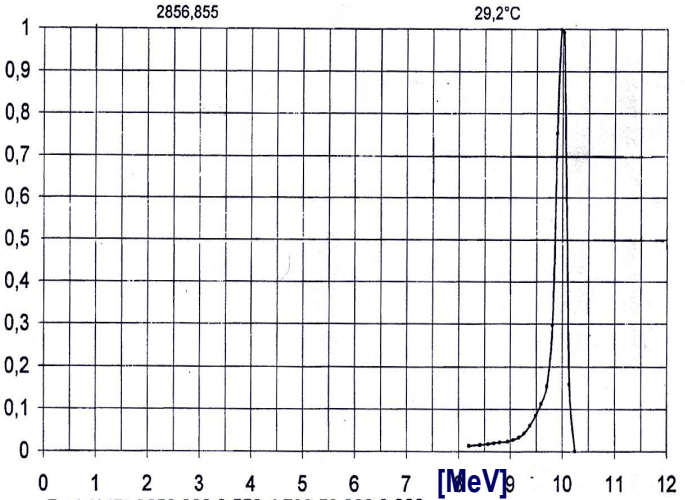
Accelerating section



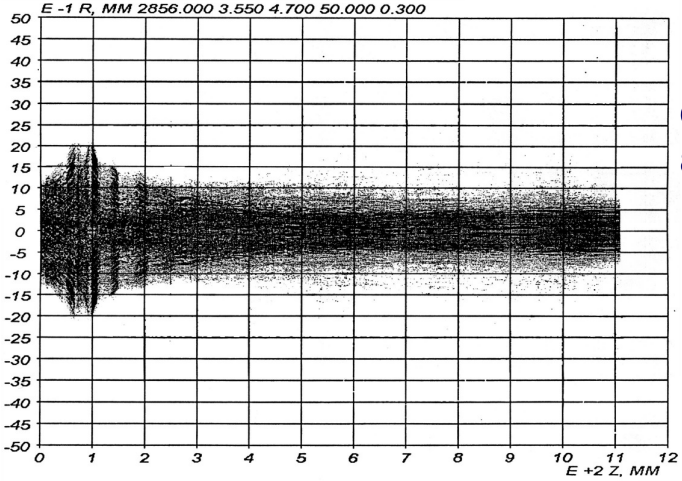
Performances of accelerating section



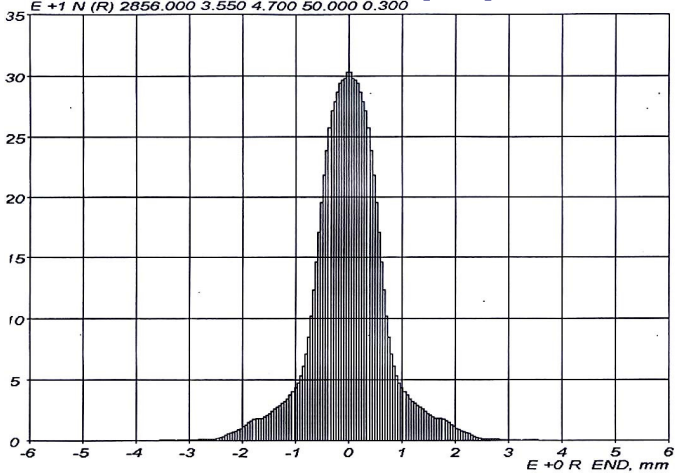
Electrical field distribution along accelerating section



Electron energy spectrum: ± 1,5 %



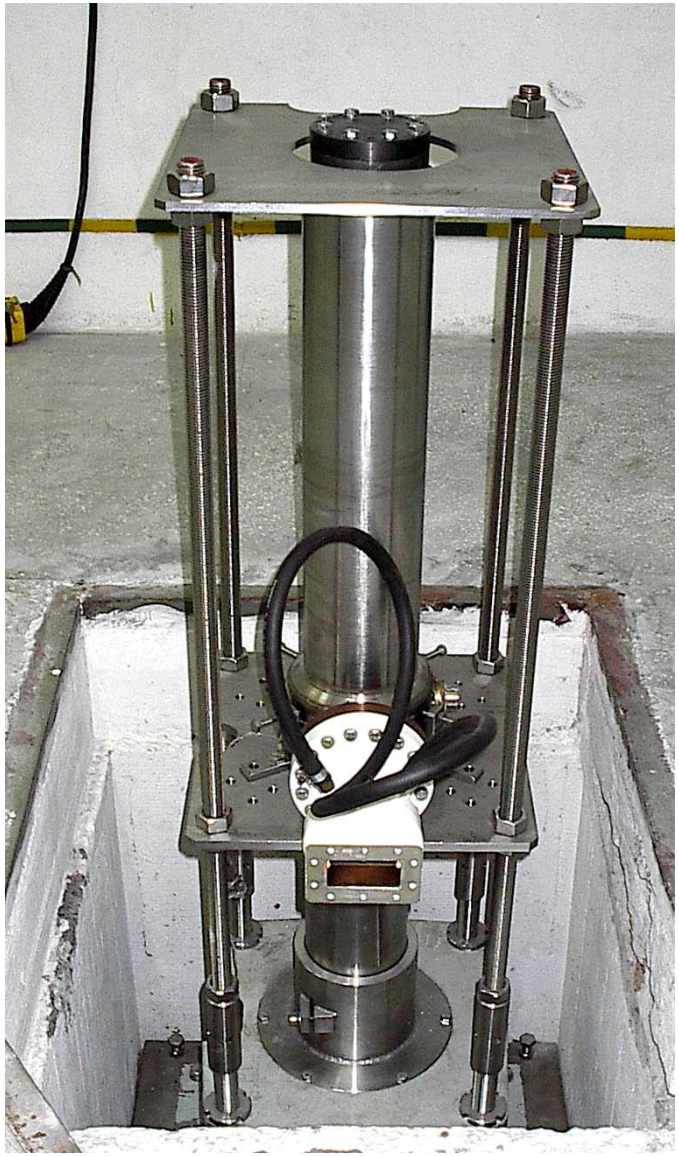
Electron beam diameter along accelerating section



Beam diameter: 5 mm
Beam diameter in a half height: 1,2 mm

Accelerating section was designed and built by NIIEFA, St Petersburg, Russia and provided under TC project supported by IAEA

Accelerating section in assembling holder



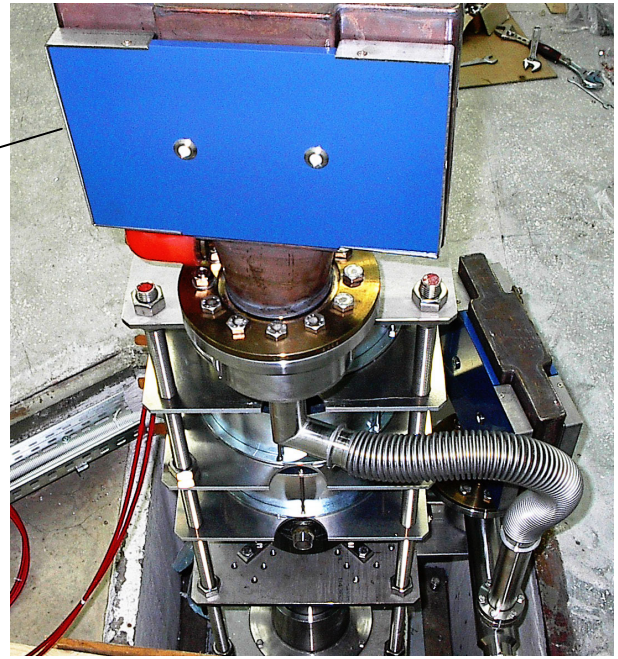
Parameter	Value
Electron energy	10 MeV
Beam power	15 kW
Frequency	2856 MHz
Type of sw oscillation	π/2
RF pulse power	3.7 MW
RF average power	28 kW
Section efficiency	up to 58 %
Q factor	14800
Impedance	2.9 MΩ
RF pulse duration	25 μs
Repetition rate	300 Hz
Beam pulse duration	23 μs
Injection electron energy	50 kV
Beam pulse current	210 mA
Electron gun pulse current	300 mA
Electron capture coefficient	up to 85 %

VACUUM SYSTEM

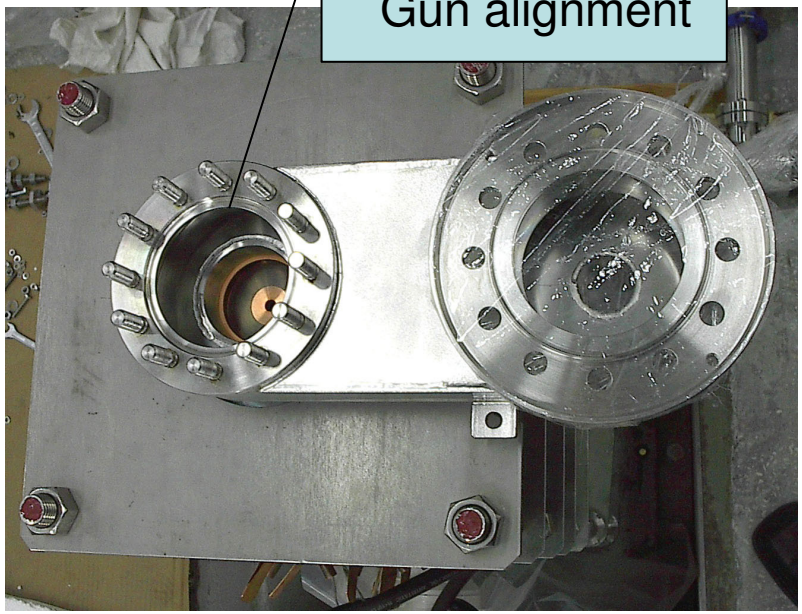
Fore-vacuum pump

Ion pump

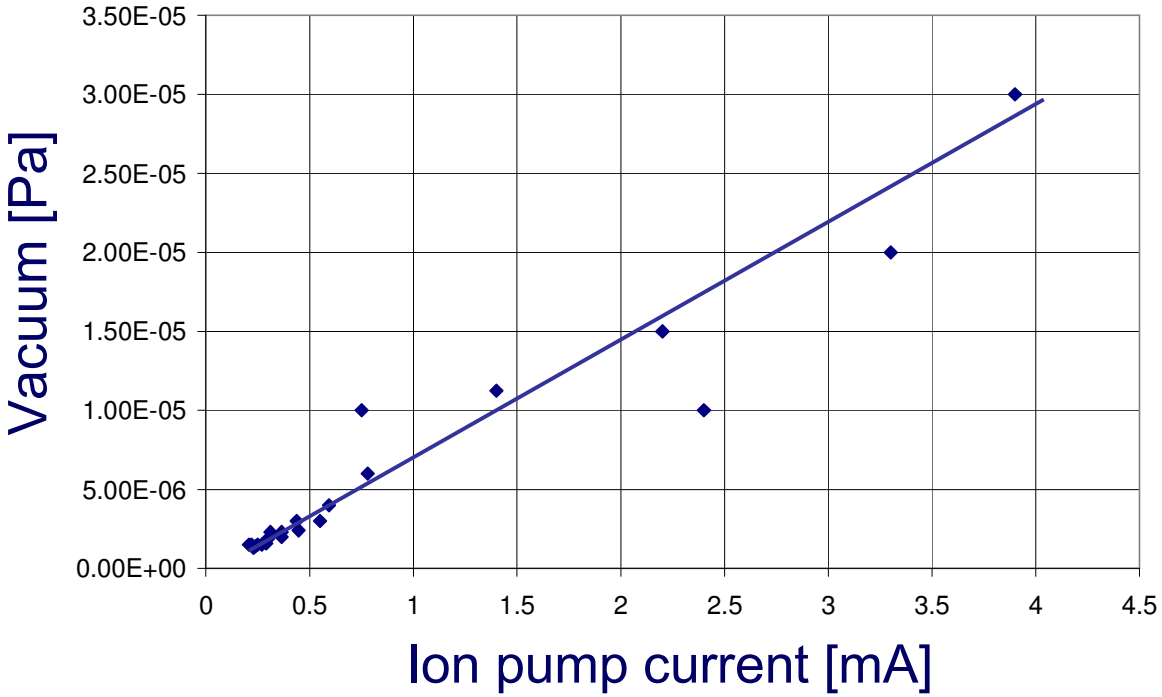
Ion pump

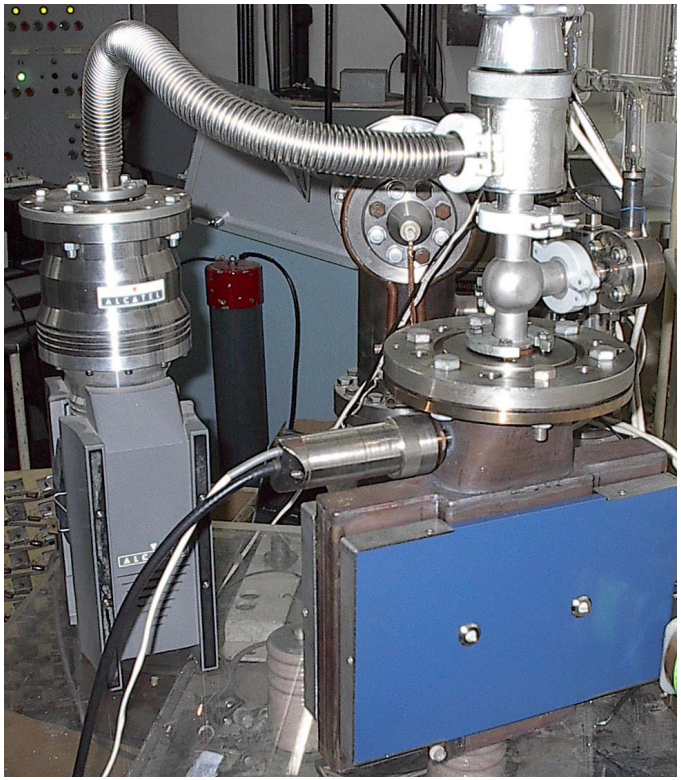


Gun alignment

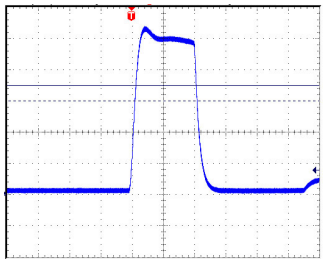


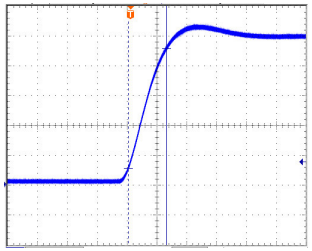
Vacuum system: calibration curve

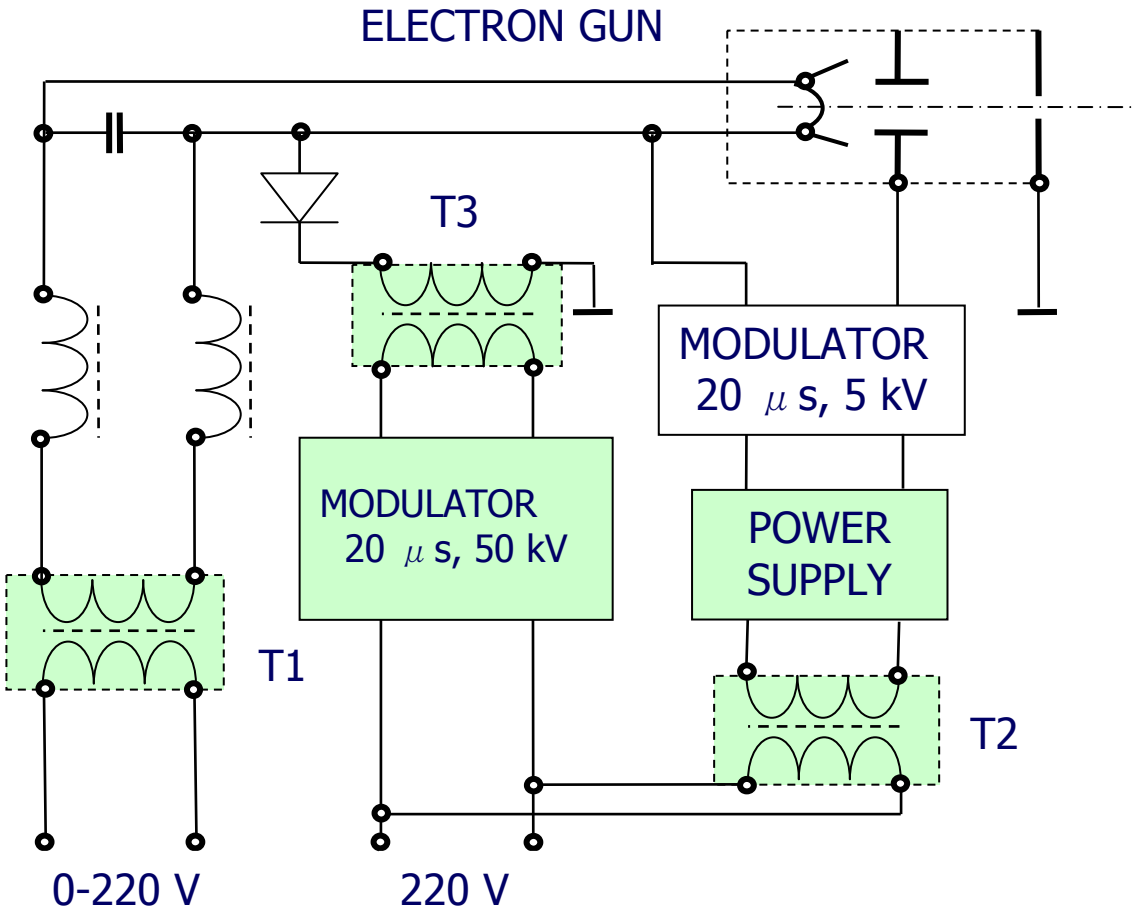




Electron gun supply system







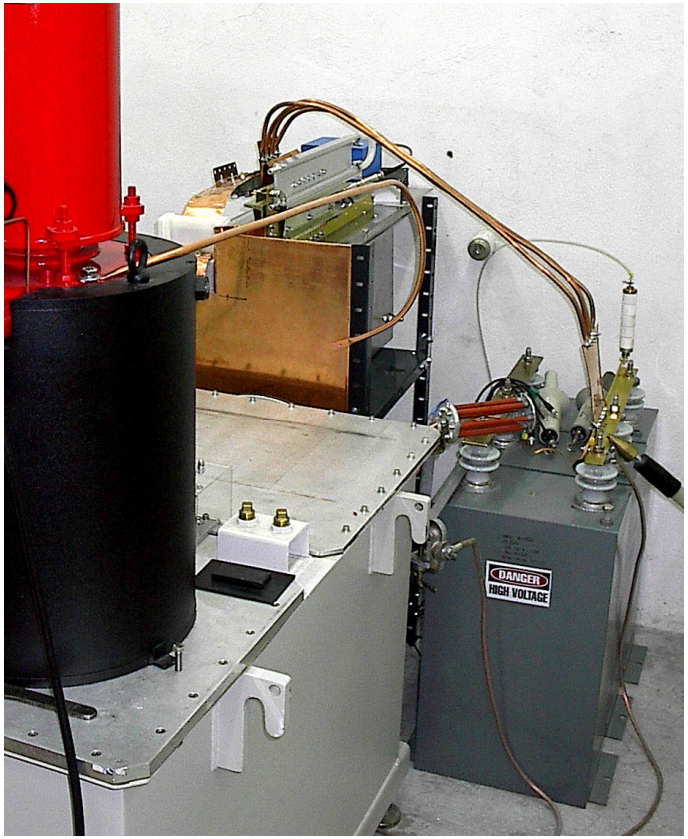
Modulator 20 μs, 50 kV

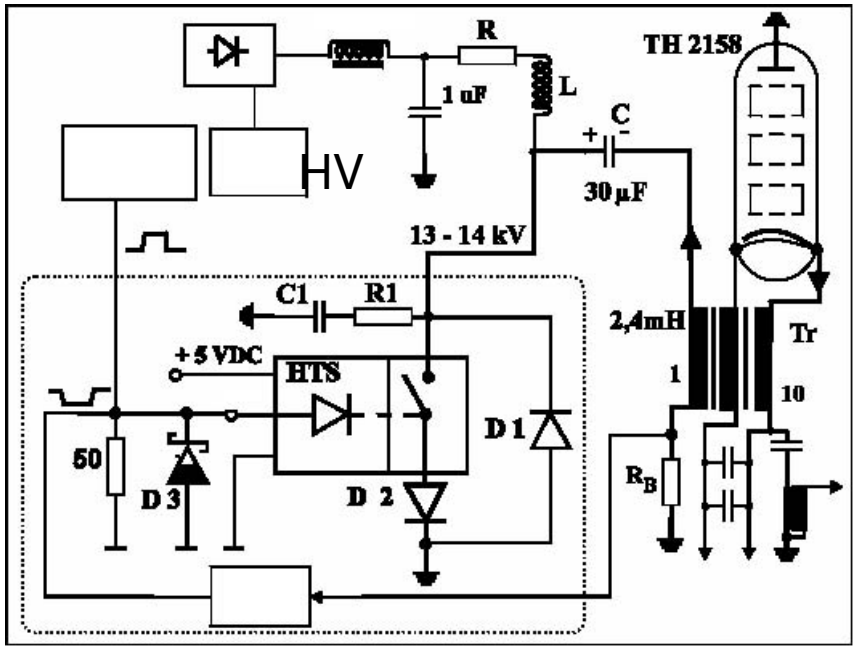
North Star Power Engineering

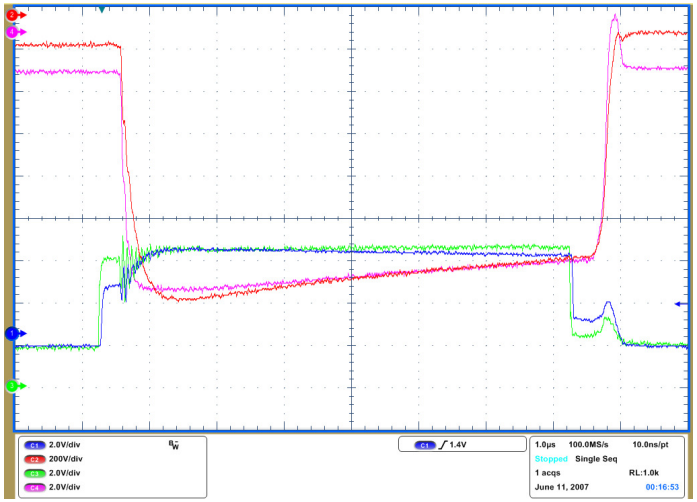
Electron gun power supply parameters

Parameter	Value
- Anode pulse amplitude	50 kV
- Grid pulse amplitude	5 kV
- Pulse current (max)	0,3 A
- Pulse duration	20 μs
- Repetition frequency	330 Hz
- Average current	2 mA
- Pulse peak power	100 kW
- Average power	300 W
- Heater voltage	10,5 V
- Heater current	5,5 A

TH 2158 KLYSTRON PULS MODULATOR



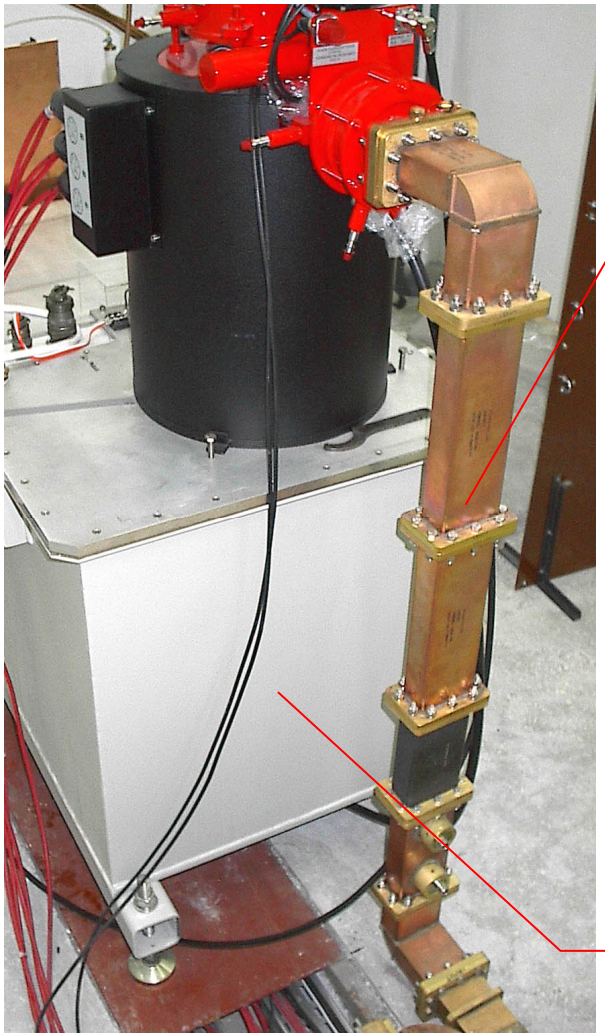




Semiconductor switch HTS 181-160-FI

Parameters	Ratings
Voltage (max)	18 kV
Voltage in oposite direction (max)	540 V
Saturation voltage	82 (0,1* I_{ampl}) V 250 (1* I_{ampl}) V
Pulse current (max)	1600 A t_{imp} < 100 µs
Pulse repetition rate (max)	500 Hz
Delay	130 ns
Rise time	80 (0,1 I_{ampl}) ns 180 (1 I_{ampl}) ns
Fall time	1µs

TH 2158 klystron stand



Klystron
TH 2158

Waveguide

Focusing
coils

Accelerating
section

Pulse
transformer

MICROWAVE ENERGY SUPPLY SYSTEM

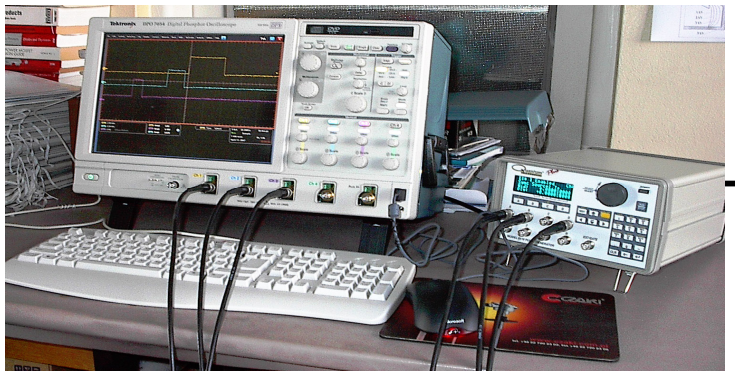
GENERATOR

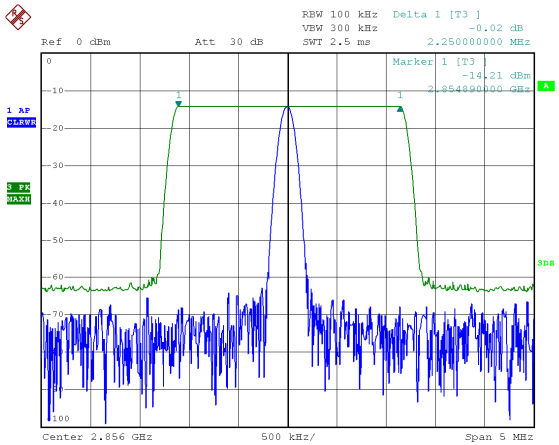
AFC

C

C

AMPLIFIER





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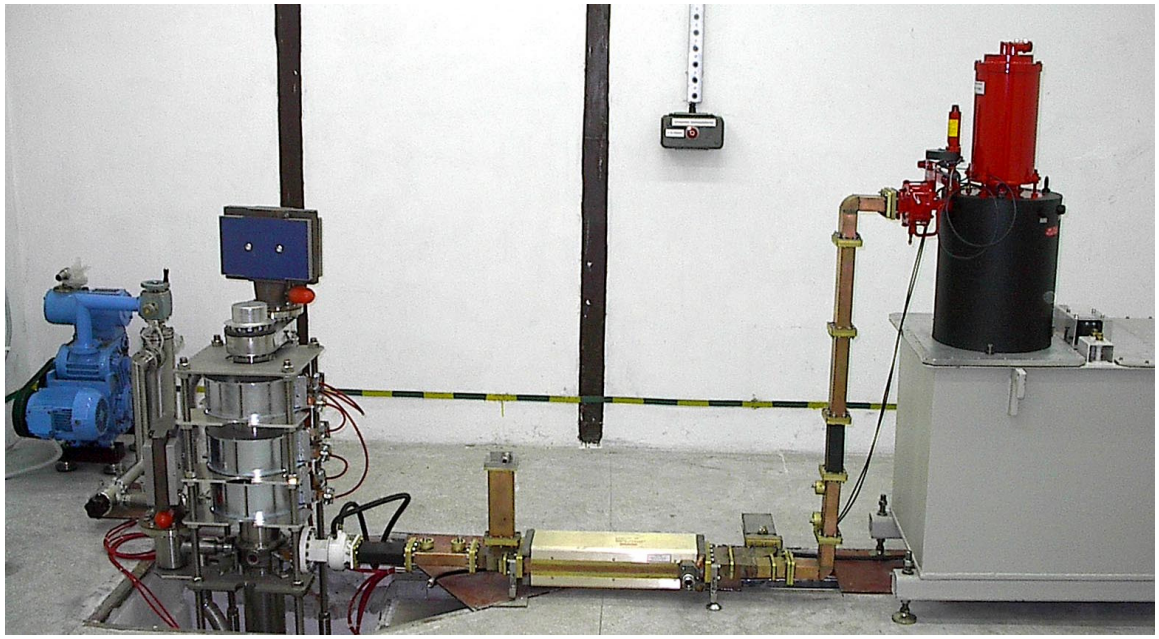
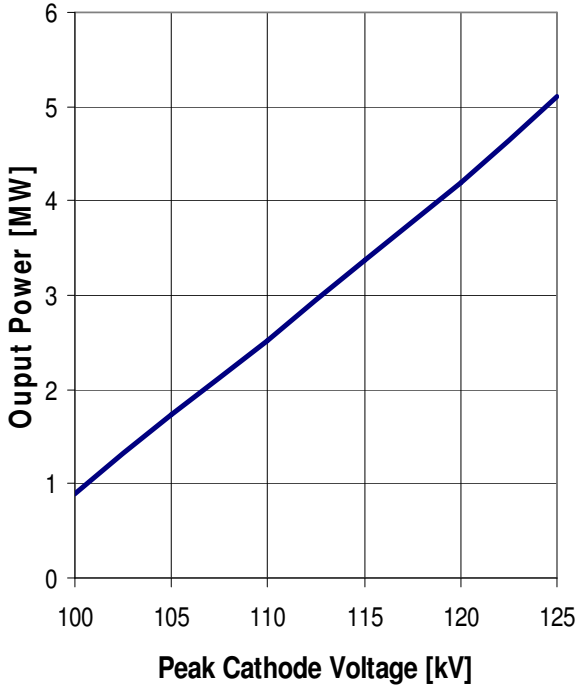
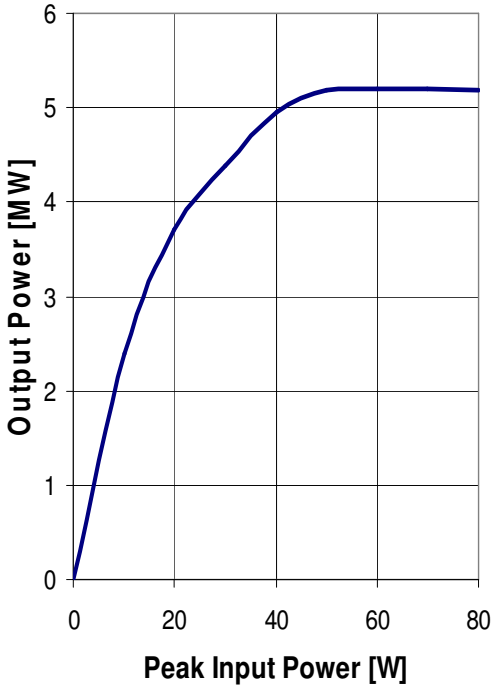
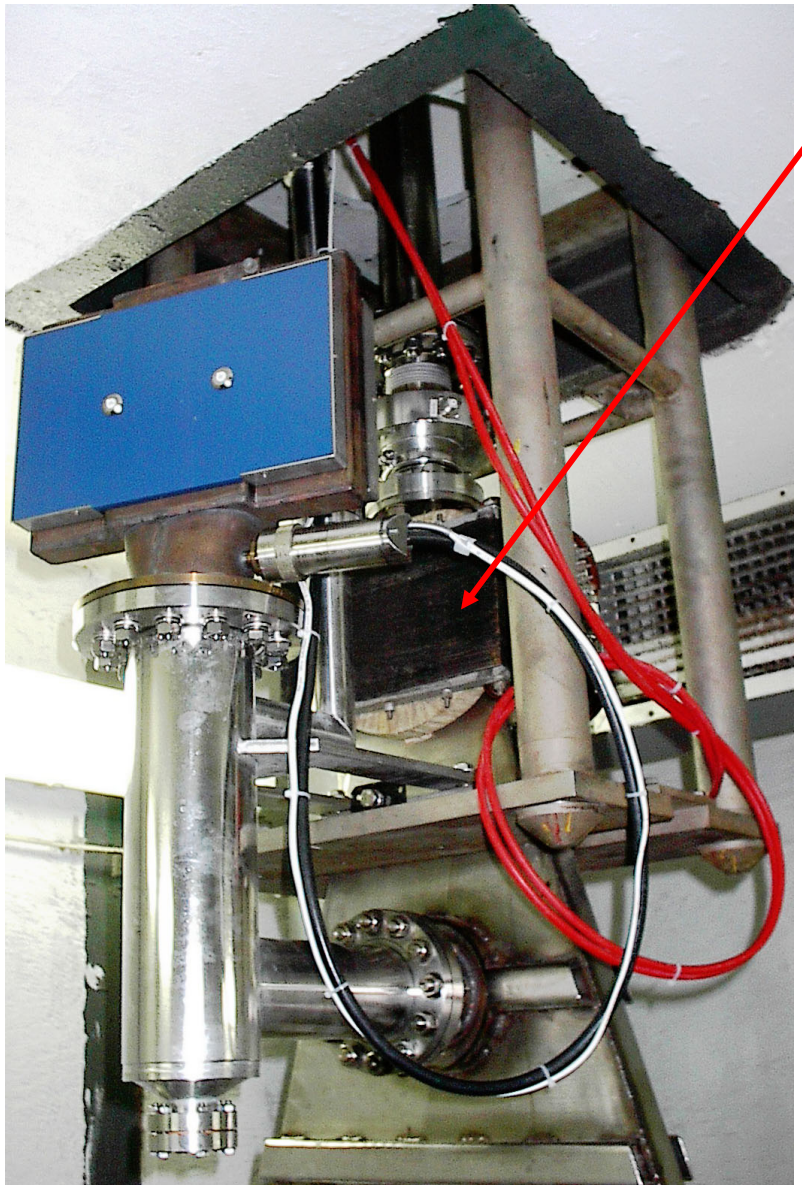


SOURCE OF MICROWAVE ENERGY KLYSTRON TH 2158 #158011

Parameter	Measured
Pulse power (output)	5.2 MW
Average power (output)	45 kW
Pulse power (input)	64 W
Gain	49 dB
HV pulse duration	26 µs
HV pulse amplitude	126 kV
Peak cathode current	87 A
Heater	9/31 V/A
RF Frequency	2856 MHz
RF pulse duration	27 µs
Cooling water temperature	40 °C
pressure	8 bar
flow rate	120 l/min

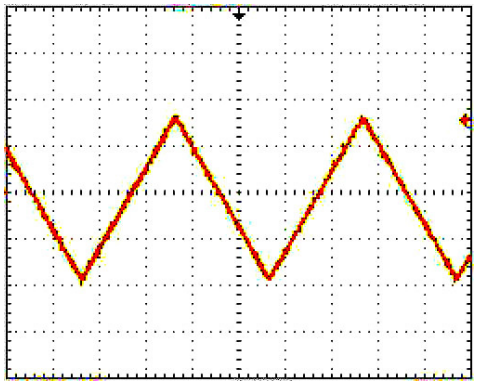




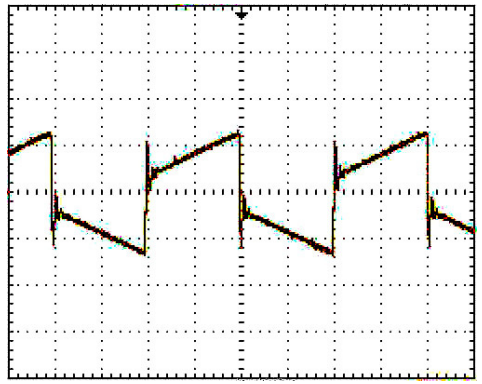


BOP 50-20MG, KEPCO Inc.
- Output power: 1 kW,
- Voltage: ±70 V,
- Current: ±20 A,
- Interfejs: RS232.

Electron beam scanning arrangement



Current



Voltage

WATER COOLING SYSTEM

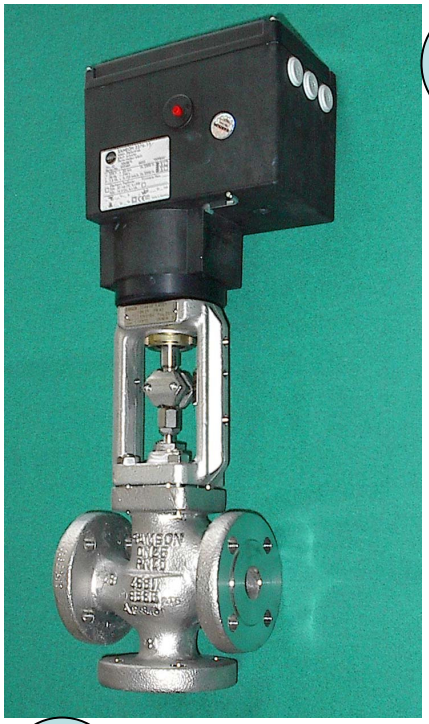
Secondary loop

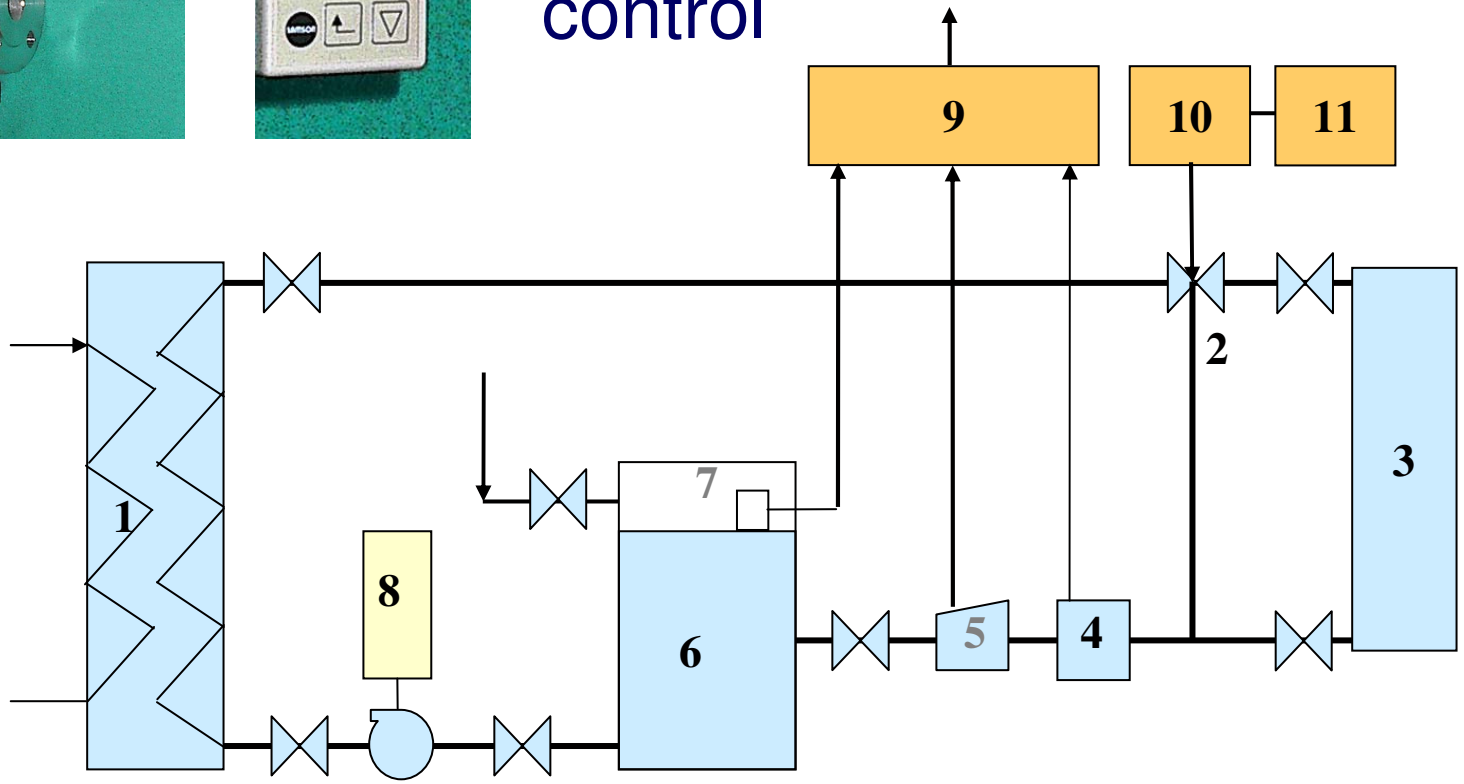
Primary loop

WATER COOLING SYSTEM

Secondary loop with temperature control

1 – Heat exchanger;
2 – Valve;
3 – Accelerating section;
4 – Temperature sensor;
5 – Flow rate sensor;
6 – Water container;
7 – Water level sensor;
8 – Water pump;
9 – Sensors controller;
10 – Power unit;
11 – Flow rate controller.

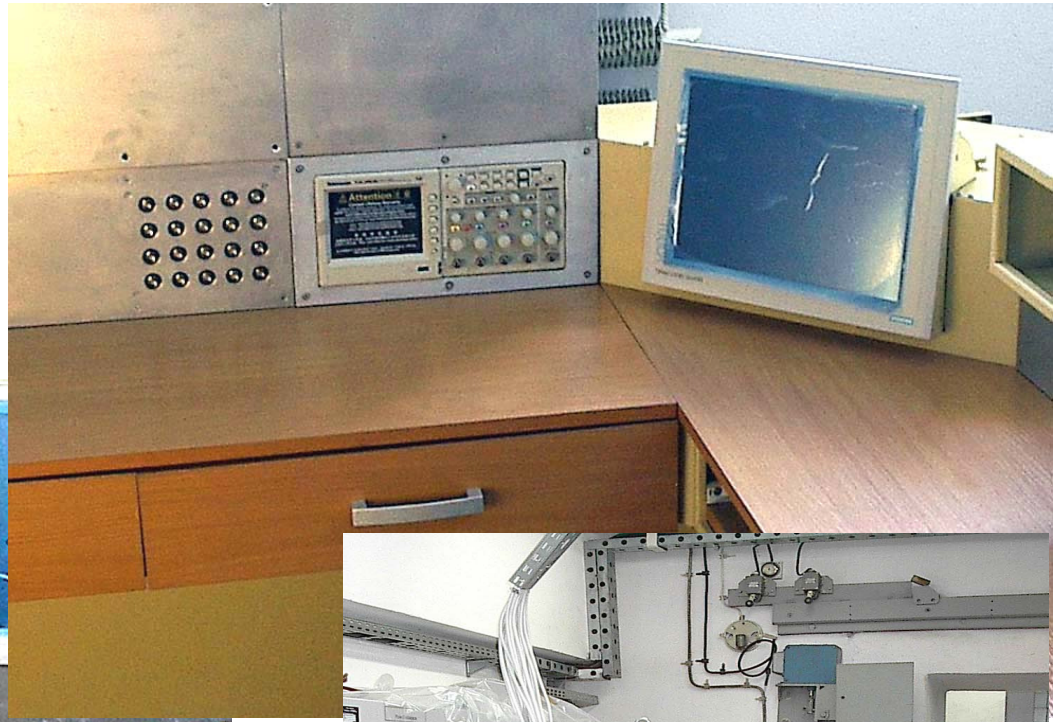




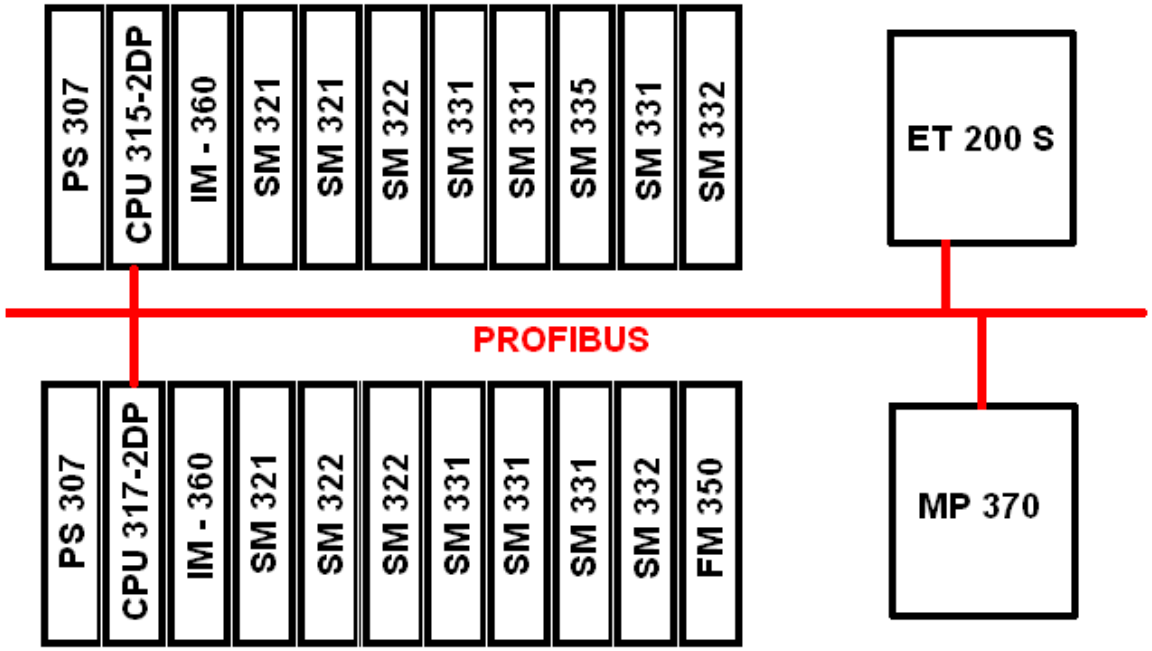
Control room

LAE 10/15

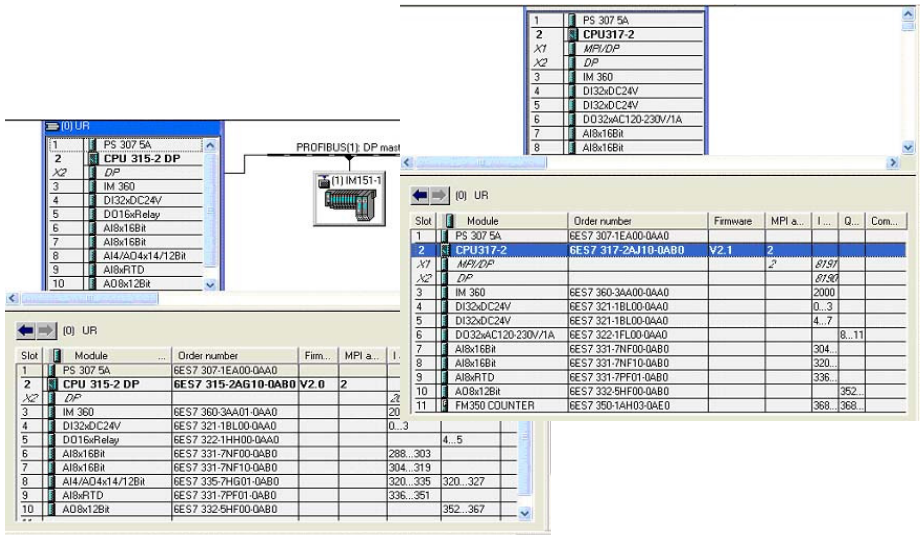
Power supplies and control panels



Control system block diagram
(based on Siemens modules S7-300)

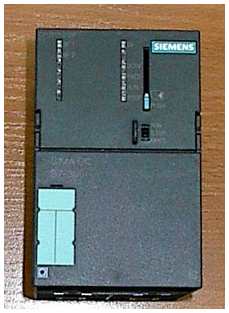


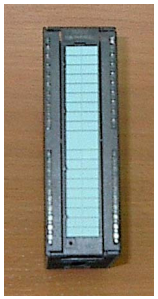
PS-307 – power supply;
IM-360 – interface;
SM-321 – digital input;
SM-322 – digital output;
SM-331 – analog input;
SM-332 – analog input;
SM-335 - analog output;
FM-350 – counter;
ET-200S – extension;
MP-370 – touch panel.



PS-307

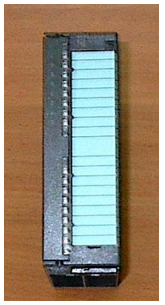
CPU-317



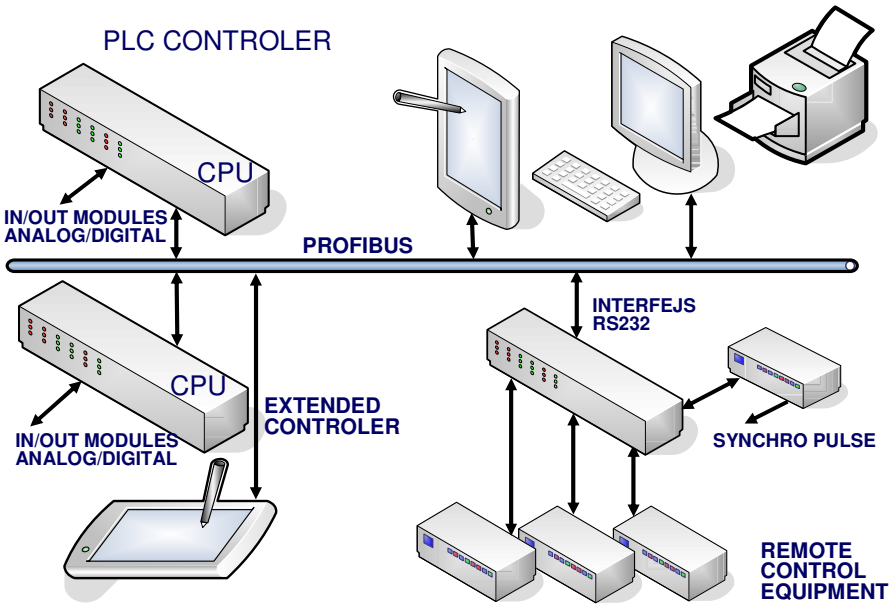


SM-321

SM-331



Control system based on Siemens modules S7-300)



REMARKS

Electron beam alignment, beam parameters evaluation and accelerator commissioning are foreseen in the final stage of the project during last quarter of 2009.

Project realization provides opportunity to:

- international cooperation (personal, technical and financial),
- improve accelerator operational characteristics (availability, exploitation cost reduction, spare parts availability),
- introduce novel technical solutions in accelerator technology (power semiconductors technology, new generation of microprocessor control system),
- develop skills and knowledge of the personnel engaged,
- transfer the knowledge to other facilities located in Poland and central European countries.