

# THE SYSTEM OF POWER SUPPLIES, CONTROL AND MODULATION OF ELECTRON GUN FOR FREE ELECTRON LASER

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## Abstract

The system of power supplies, control and modulation based on triode cathode-grid unit was designed for producing of pulsed electron beam for free electron laser FEL [1]. The main part of the system located inside the tank filled with SF6 gas and has -300kV potential. It's supplied through the isolated transformer and controlled through the fiber optic link with CAN interface. The GaN RF transistor in the output stage of modulator composed of hybrid assembly on the BeO ceramic plate. Pulsed output voltage of modulator can be regulated 0-120V on the load 25Ω. Time duration is <1ns. Repetition rate is 20kHz-20MHz (90MHz). Start of modulator from timer performed through the 1GHz fiber optic link.

The inverter is supplying of isolated transformer and timer for start of modulator with synchronization to RF voltage for grouping and accelerating are located in the control room. The timer ensured the compensation of the slow time shift of the electron beam relatively to RF voltage phase.

The control code was wrote on C++ language under Windows operating system using QT framework, and provide all algorithm of steering in real time with others operating programs for FEL with remote control Channel Access server from EPICS.

## INTRODUCTION

For effective work of electron accelerator for Free Electron Laser (FEL) the system of power, control and modulation of triode cathode-grid unit was designed. It

was designed with the high end components: GaN JFET transistors, 1GHz fiber optic link and RF micro strip transformers. The pulses on the output of modulator have very high parameters.

- Time width of pulses 1ns
- Pulse amplitude 0-120V
- Repetition rate 20kHz-90MHz
- Load 25Ω
- Part 2 of the system works at -300kV potential

## SYSTEM DESCRIPTION

The system can be divided on two parts as depicted in Figure 1. The part 1 is under ground potential and provide power, control and start pulses (St) for part 2. It consists of power inverter, timer and two fiber optic converters. Power inverter has 220V input line with 50 or 60Hz. The output of power inverter is connected to input coil of isolated power transformer (300kV). Timer generates start pulses (St) with phase attached to RF voltage on the grouping resonator. The first fiber optic converter works as galvanic isolation for start pulses (St) and has 1GHz bandwidth. The second fiber optic converter works as galvanic isolation for CAN interface and has 1MHz bandwidth. The part 2 works under -300kV accelerating potential in the tank filled pressed SF6 gas (1.5 excessive bars). Figure 2 shows the total view of part 2. It consists of a cathode-grid unit, modulator, power supplies, isolated transformer, control unit CEAC124 and fiber optic converters.

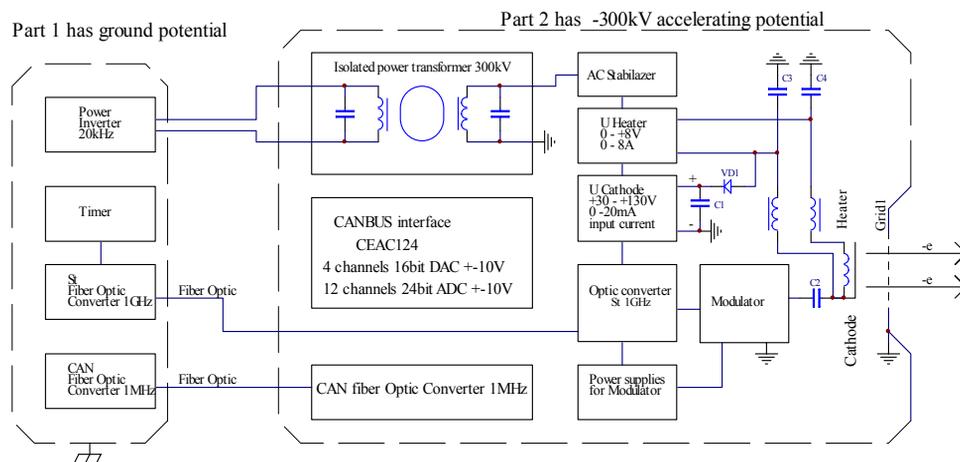


Figure 1: Block diagram of the system.

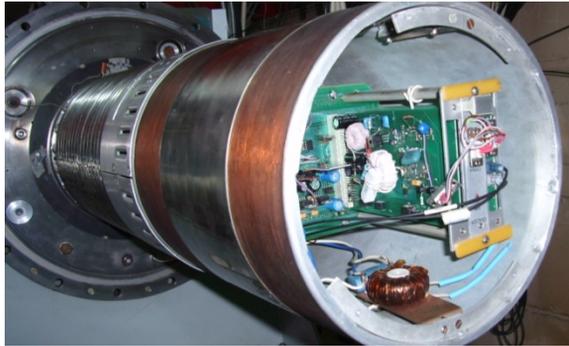


Figure 2: The part 2 works at -300kV potential.

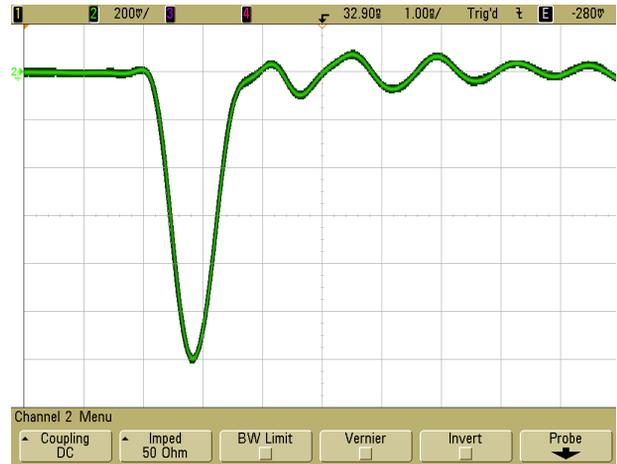


Figure 4: Modulator output pulse on 25 Ω load

Electric power for part 2 goes from power inverter through isolated power transformer (isolation voltage 300kV) to AC stabilizer and to set of power supplies. Power supplies consist of supplies for heater, cathode bias and four power supplies for modulator, control unit and fiber optic converters. For control signals isolations (300kV) we used plastic fiber optic lines with 1MHz bandwidth. For start signal isolation we used silica fiber optic line with 1GHz bandwidth. Fiber optic cables goes through vacuum tight connectors directly in the electron gun tank, filled with pressed SF6 gas. Inside tank there is sectioned isolation of these fiber optic cables along 40cm of sectioned isolators of electron gun.

### MODULATOR

Figure 3 shows modulator block diagram.

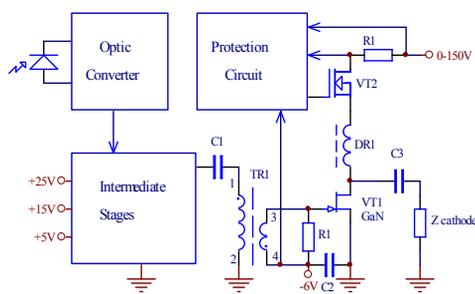


Figure 3: Modulator block diagram.

The main feature of modulator is GaN JFET RF transistor [2] in the output stage. The picture of 100 times attenuated signal from modulator output on the load 25 Ω is depicted in Figure 4. Time scale is 1ns per division. Real vertical scale of output signal is 20V per division. So we can see 1ns pulse with amplitude 120V on 25 Ω load. Repetition rate of modulator can be from 0 up to 90MHz. This modulator has very high

efficiency. Only 30V from 150V of power supply dissipate in GaN transistor. GaN JFET transistors have great RF and power parameters but they have also one disadvantage. They are open when input gate voltage near 0V. It must be -6V of input gate voltage for total close these transistors. During switch on or switch off power supplies there may be uncontrolled situations when we have drain voltage but gate voltage near 0V, therefore transistor can be open and high drain current can destroy transistor. So, for reliable work of GaN JFET transistors, special protection circuit was designed. It watches for gate voltage and if this voltage to low then, this protection circuit switches on, and removes voltage from transistor drain. Also this protection circuit watches the average current of transistor drain and switches on during 1us if current more then threshold value. After 10ms protection circuit automatically switches off and restores transistor drain voltage. So, this circuit removes disadvantage of GaN JFET transistors. Pulse transformer TR1 which connected to input GaN transistor VT1 has very low output impedance 6Ω. Its construction based on strip lines and two holes RF ferrites. Optic converter accepts start signal St from timer and transmit it to intermediate stages of modulator. They are consisting of two stages with RF NPN transistors and two stages with RF MOSFET power transistors. Figure 5 shows cathode grid unit and output stages of modulator. Figure 5 shows thermogram of modulator at 50MHz repetition rate. Alternative stile of modulator reported in [3]

### SUMMARY

For output stage transistor we try many types of Si RF transistors, few SiC RF transistors and only GaN RF transistors have suitable parameters and reliability in real installation.



Figure 5: Cathode-grid unit and modulator.

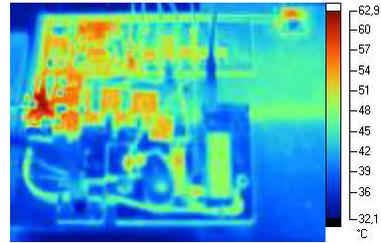


Figure 6: Thermogram of modulator.

### REFERENCES

- [1] [ssrc.inp.nsk.su/CKP/biblio/2012/a11.doc](http://ssrc.inp.nsk.su/CKP/biblio/2012/a11.doc)
- [2] <http://www.rfmd.com/CS/Documents/RF3932DS.pdf>
- [3] N.A. Vinokurov. et. al. Source of High Electron Current for Injection into Accelerator. RuPAC 2006, Novosibirsk, Russia