REMOTE CONTROL SYSTEM FOR H-MINUS IONS SOURCE OF INR LINAC

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A system of remote control of negative ions source for LINAC INR RAS designed, constructed and put into operation. Galvanic isolation and spatial separation of elements that are at potential 400 kV in the power rack of the ion source and the host computer are carried out by means of fiber-optic extender USB-interface from firms Icron. A set of multifunctional units from National Instruments allows to monitor the oscilloscope signal with up to 50 Ms/s and to control the ions source power settings.

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INTRODUCTION

Negative ions injector for INR LINAC is based on the accelerating tube at energy of 400 keV [1]. In this scheme, an ions source with its power supply system is located under pulsed potential of 400 kV. Ions source is a surface-plasma source developed at INP SB RAS (Novosibirsk) [2]. In this source the increase of the negative ions yield achieved by reducing the work function of the electrodes by deposition on its surface the layer of alkali metal (cesium).

A characteristic feature of the source is the presence of several modes, which have different discharge voltage, discharge current and the output of negative ions. "Pure hydrogen" mode of operation is characterized by high discharge voltage 400…600 V and low discharge currents 1…10 A. The appearance in the discharge of cesium vapor causes decrease in discharge voltage (to 100 V – "low-voltage operation") and increase in the discharge current up to ~ 100 A. Furthermore, in the discharge gap may develop arcs with very low discharge voltage ~ 20…40 V and high current. Arcs can lead to significant erosion of the electrodes and are characterized by the absence of negative ions current at the output of the source.

Extraction of the negative ions from the plasma of a gas discharge occurs through the emission hole in the anode by apposition of extracting voltage with amplitude of 16…20 kV to the extracting gap with size of about 1.5 mm. Breakdowns in this gap can cause increased erosion of the electrodes and are also characterized by lack of output current of negative ions. Such breakdowns occur with the source electrodes training and during normal operation of the source.

The transition from "high-voltage" discharge mode in the "low-voltage" mode can occur quite quickly. The change in the discharge voltage is an indication of the emergence of cesium in discharge and is usually accompanied by a change in the intensity of H-minus beam.

This rather complex behavior of the discharge and the dependence of the negative ions yield from the history of the source, cause the urgent need for a reliable detailed control of key parameters of the source, which works with a pulse repetition rate up to 50 Hz. To do this, the operator is required to monitor the pulse waveforms of discharge current and discharge voltage, extracting voltage, extracted current of the H-minus ions and others, as well as to control a variety of continuous signals.

The use of the ions source in the injector of LINAC requires some additional conditions on the control system. In particular, it should be possible to integrate it into the control system of the linear accelerator and to choose the different places for the entrance to the source control system, including from the main control room of the LINAC.

1. STRUCTURE OF THE CONTROL SYSTEM

The control system is based on the connection of multi-function ADC / DAC units to the host computer via the USB-interface. The control system includes multi-function ADC / DAC units, digital oscilloscope unit, the control computer and fiber-optic isolator of the USB-interface. Block – diagram of the control system is shown at Fig. 1.

To register "fast" analog signals used multi-function ADC / DAC unit NI USB 6363. It has ADC resolution – 16 bits, data transfer rate – 1 Ms /s in multi channel mode or 2 Ms/s in single channel mode. The maximum error at the full input voltage of 10 V is 1.6 mV. Number of analog outputs – 4, DAC resolution – 16 bits. The maximum output update rate is 1.25 Ms/s. The maximum error at full output voltage of 10 V is 2 mV [3].

To register a "slow" analog signals, we used multi-function ADC / DAC unit NI USB 6009. It has data transfer rate 48 Ks /s and 14-bits resolution ADC [3].

As a digital oscilloscope we used a unit NI USB 5132 with data transfer rate 50 Ms/s and a number of channels – 2 [3].

2. FIBER OPTIC ISOLATION

For communication between the host computer, which is located on the control panel of the ion source, with multi-functional units and a digital oscilloscope, which are under the pulse potential of 400 kV, optical fiber system – extension of the USB-interface Ranger 2224, produced by Icron has been chosen.

This system allowed galvanically isolate and spatially spread at considerable distance (about 80 m) equipment of control system and host computer of the ion source operator. In this case, retains all the advantages of working with devices via USB-interface. The system provides a connection in the USB 2.0 standard at 480 MB/s, which allows you to connect a digital 2-channel oscilloscope with a bandwidth of up to 50 Ms/s, and the required set of ADCs and DACs.

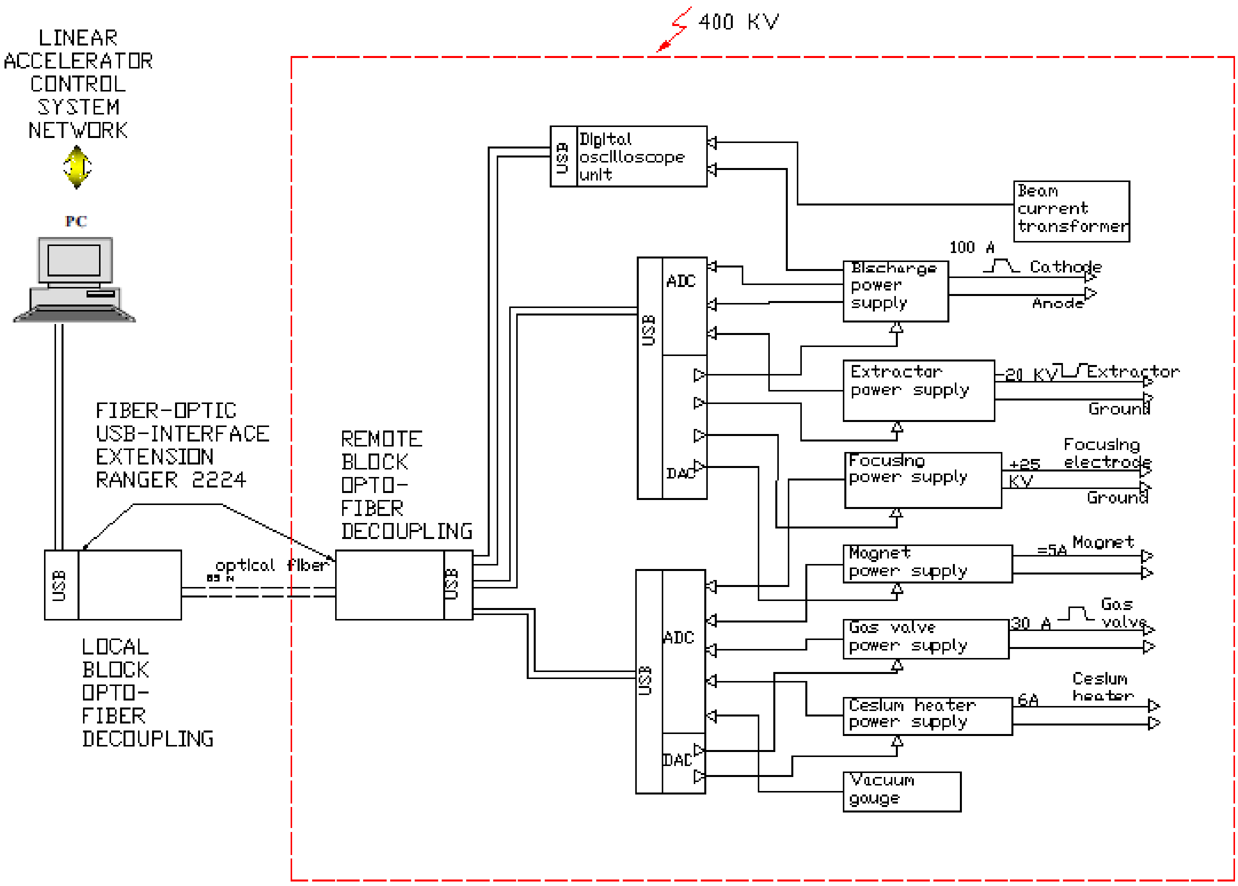

Fig. 1. The block diagram of the remote control system of negative ions source

3. PROGRAMMING

The data acquisition devices programming performed in a graphical environment LabView (2010 version).

Digital oscilloscope NI USB 5132 and "fast" ADC /DAC NI USB 6363 are synchronized by external triggering at 50 Hz from power system of the ion source, the "slow" ADC / DAC NI USB 6009 is synchronized by the internal clock frequency of 2 Hz. The front panel of digital oscilloscope is a standard from the device software NI USB 5132. The front panel of "fast" ADC / DAC NI USB 6363 is formed by a graphical display that simulates an oscilloscope (WaveformGraph), a graphical output that simulates recorder (WaveformChart), digital controllers and indicators. The front panel of the "slow" ADC / DAC NI USB 6009 is formed from a graphical output that simulates recorder (WaveformChart), digital controllers and indicators.

The screen of the control computer with front panels of the NI USB 6363, NI USB 6009, NI USB 5132 is shown at Fig. 2.

The graphical display of NI USB 6363 front panel (the screen of a "fast" ADC) shows the signals of extracting voltage (green trace of 2 kV/div), the discharge current (purple trace, 10 A/div), the voltage of forming line (white trace, 200 V/division), discharge voltage (blue trace, 200 V/div). For all traces horizontal scale - 200 μs/division, the ADC measurement period - 2 microseconds. At the graphical display that simulates recorder (logging parameters Up, Ip, Ufl) are displayed averaged in each pulse signals of the discharge voltage (upper trace), the discharge current (low trace), the charging voltage of forming line (lower trace) in a 2-time minutes per division, which corresponds to 6000 source pulses per division.

The front panel of multi-function unit NI USB 6009 (the screen of the "slow" ADC) shows the voltage signals on the cesium heater (blue trace), the voltage on the power supply of the gas valve (green trace), the signal from the linear output of the vacuum gauge (white trace) and the current signal of the source electromagnet (red trace). The scale along the horizontal axis is 1 hour per division.

The front panel of the NI USB 5132 shows the signals from beam current transformer (upper trace), and the discharge voltage (low trace). Horizontal scale has 100 μs per division. A more detailed picture of the beam current pulse amplitude of 25 mA and discharge voltage amplitude of about 150 V on the front panel of a digital oscilloscope NI USB 5132 are shown at Fig. 3. Standard software LabView (2010 version) allows for on-line processing of the data and graphically display the results on the screen. Fig. 4 shows an example of the current processing of averaged values of the beam current in the form of a histogram of distribution of the intensity values of the beam current for the recent 100 pulses of ion source.

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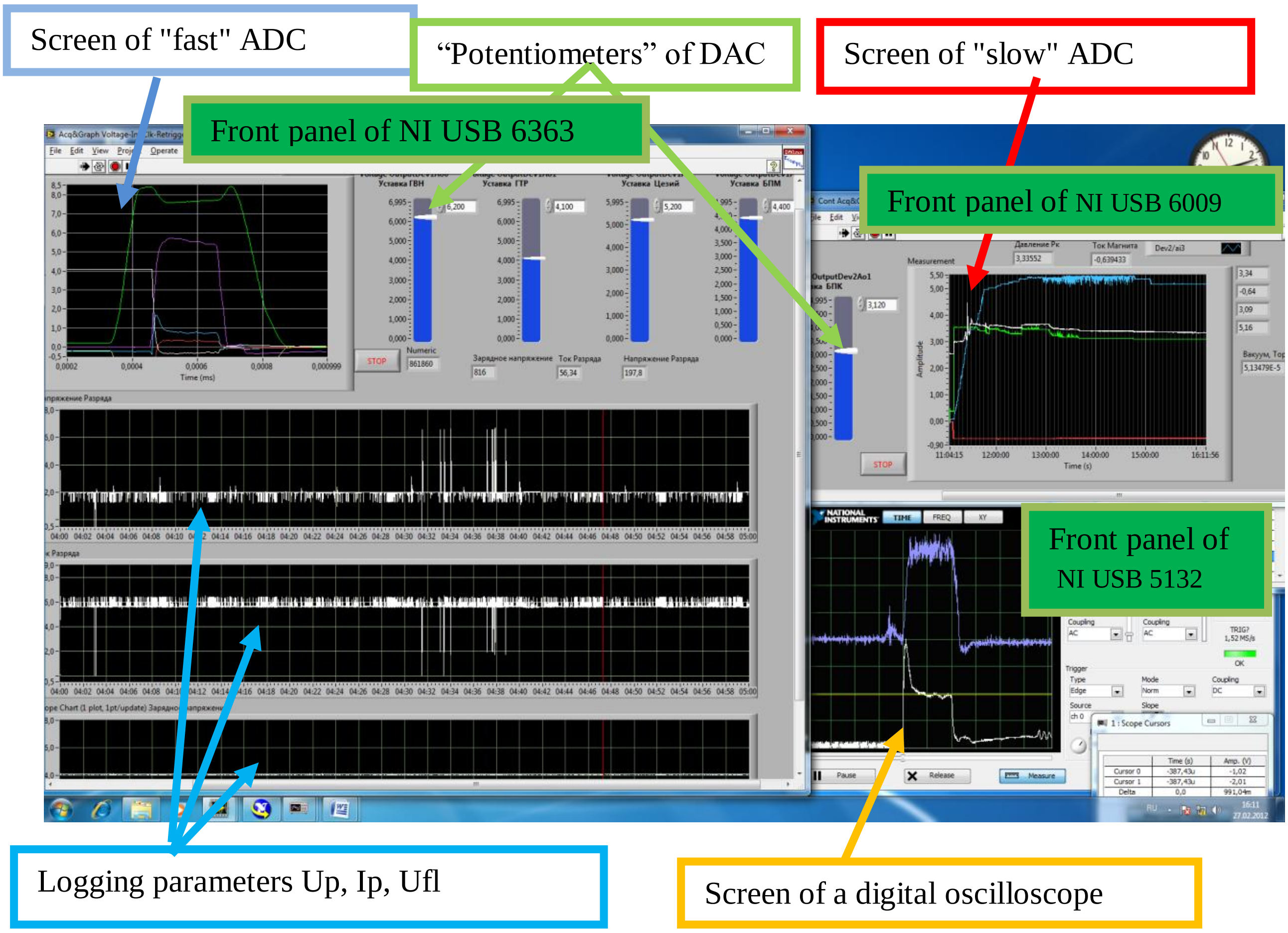

Fig. 2. View of the control computer screen with front panels of the devices NI USB 6363, NI USB 6009, NI USB 5132

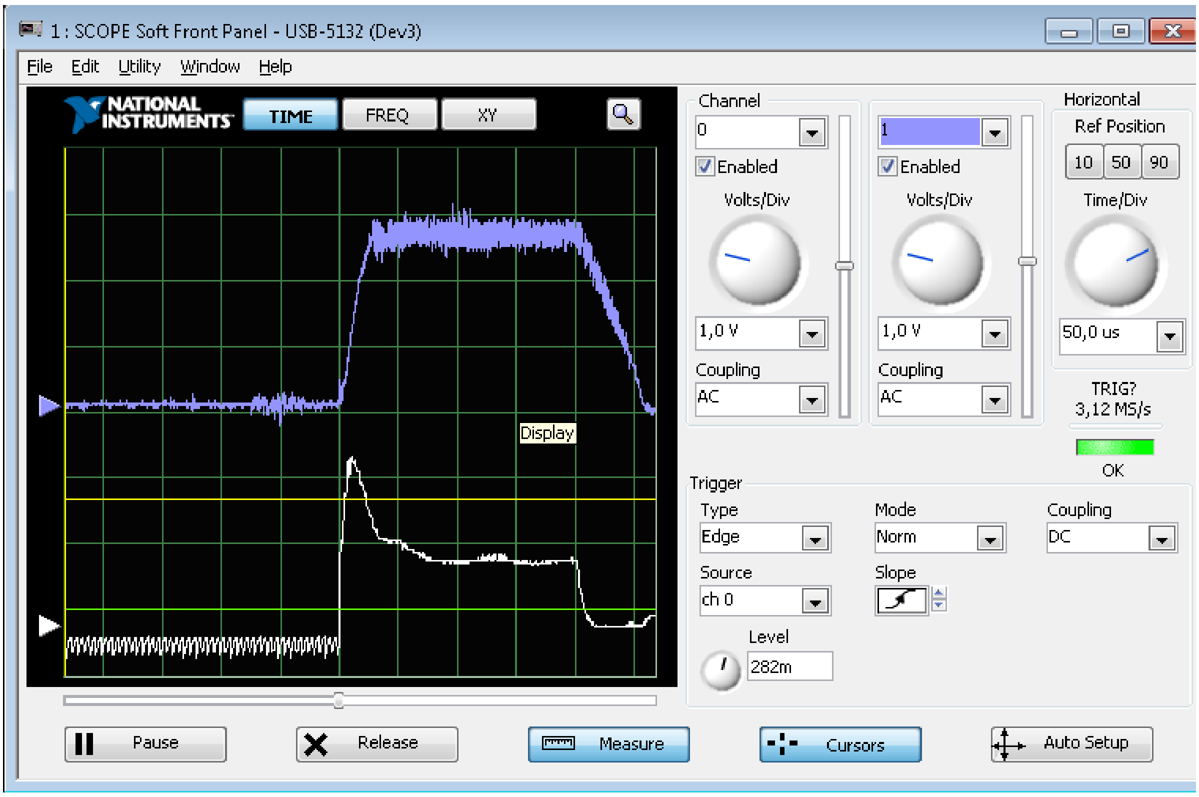

Fig. 3. Digital oscilloscope screen. The upper trace - beam current of H-(10 mA/div vertically). The lower trace – discharge voltage (100 V/div). Horizontal scale – 50 µs/div

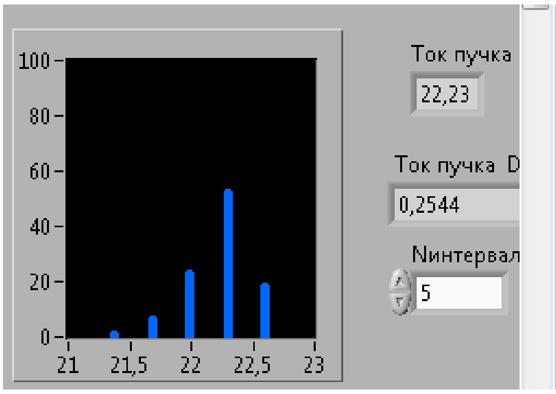

Fig. 4. Histogram of distribution of the H-beam current values (a percentage of the number of pulses). Horizontal – H-beam current, mA; vertical – proportion of the number of pulses

4. INTEGRATION IN THE CONTROL SYSTEM OF LINAC

The control computer of the ions source is plugged in the control system network of LINAC. This allows to control the source not only from the local control panel, but also with a main control panel of LINAC or remote control panel of beam transport line. In these cases, source control is carried out using a Remote Desktop server.

CONCLUSIONS

The remote control system of negative ions source can adequately control the operating modes of the source, ensuring the completeness of the resulting information on the control computer screen. The amount and type of information provided to the ion source operator in the LINAC control system network is basically the same size and type of information that he has at local control, including oscilloscope signals, which are presented with a pulse repetition rate of 50 Hz.

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СИСТЕМА ДИСТАНЦИОННОГО УПРАВЛЕНИЯ ИСТОЧНИКОМ ОТРИЦАТЕЛЬНЫХ ИОНОВ ЛИНЕЙНОГО УСКОРИТЕЛЯ ИЯИ РАН

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Разработана, изготовлена и введена в работу система дистанционного управления источника отрицательных ионов ЛУ ИЯИ РАН. Гальваническая и пространственная развязка элементов, находящихся под потенциалом 400 кВ в стойке питания ионного источника и управляющего компьютера, осуществлена с помощью волоконно-оптического удлинителя USB-интерфейса фирмы Icron. Набор многофункциональных блоков фирмы National Instruments позволяет контролировать одновременно осциллографические сигналы со скоростью до 50 Мс/с и управлять настройками источника.

СИСТЕМА ДИСТАНЦІЙНОГО УПРАВЛІННЯ ДЖЕРЕЛОМ НЕГАТИВНИХ ІОНІВ ЛІНІЙНОГО ПРИСКОРЮВАЧА ІЯД РАН

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Розроблена, виготовлена і впроваджена в роботу система дистанційного управління джерела негативних іонів ЛУ ІЯД РАН. Гальванічна і просторова розв'язка елементів, що знаходяться під потенціалом 400 кВ у стійці живлення іонного джерела і керуючого комп'ютера, здійснена за допомогою волоконно-оптичного подовжувача USB-інтерфейсу фірми Icron. Набір багатофункціональних блоків фірми National Instruments дозволяє контролювати одночасно осцилографічні сигнали зі швидкістю до 50 Мс/с і керувати настройками джерела.