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ACCELERATORS OF ELV SERIES: CURRENT STATUS AND FURTHER DEVELOPMENT

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Abstract

For many years, Budker Institute of Nuclear Physics produces medium-energy industrial electron beam accelerators. Flexible (due to the possibility of completing with different systems) and reliable accelerators cover the energy range from 0.3 to 3 MeV, and up to 130 mA of beam current, with power up to 100 kW.

New accelerators of the ELV type are also being developed. Namely ELV-15 with energy range up to 3.0 MeV and power up to 100 kW. At present time accelerator was assembled and tested in Novosibirsk.

In addition, an accelerator was developed and tested with a new model of extraction device of a focused electron beam into the atmosphere. At present, various experiments are run using the installation with a new device for the extraction of the concentrated electron beam into the atmosphere for the production of nanopowders, surfacing of powder materials for metals, etc.

ELV ACCELERATORS

The ELV industrial accelerators [1] are widely used due to a number of advantages:

- High electron beam power in wide energy range
- High efficiency of electron beam (70-80%), which important for long term operation
- High stability of electron beam parameters
- Extra-long lifetime and high reliability: 24/7 mode of operation
- Wide set of underbeam equipment: for the film, and cables irradiation, nanopowders manufacturing, liquids, and gases treatment and crosslinking

Table 1 represent parameters of the most popular ELV accelerators. As you can see, a new accelerator appears here: ELV-15 with max energy 3 MeV. Also, the current range for the ELV-8 accelerator was increased up to 60 mA. The common view of the ELV type accelerators is shown on Fig. 1. Actually, the ELV accelerators are well described in [2].

Deliveries of last years

More than 200 accelerators were delivered and installed by now. Even for the last three years, under the significant influence of COVID-19, we had delivered 17 accelerators to our customers. For 2022 is about 15 accelerators now in the queue.

Two accelerators, ELV-8 and ELV-4 were delivered to Russia in 2020. One of them (ELV-8) is installed into a new foam film plant. The plant is located in the Kotovsk city, Tambov region, and is currently reaching production parameters. It should be noted that the delivery of this accelerator was carried out jointly with our partner, the Chinese company “Shanxi Yuridi”. The electron beam crosslinking underbeam technology line was supplied by this company.

Table 1: Models of the ELV Accelerators

Name	Energy, MeV	Max current, mA	Power, kWt
ELV-0.5-130	0.3-0.5	130	65
ELV-0.5-70	0.4-0.8	70	50
ELV-4-1	0.7-1.0	100	100
ELV-4-1.5	1.0-1.5	67	100
ELV-8	1.0-2.5	60	100
ELV-15	1.5-3.0	50	100

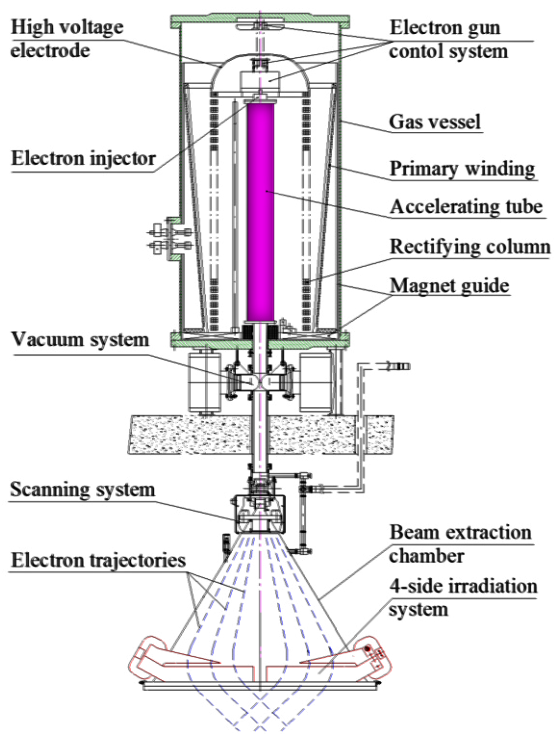

Figure 1: The ELV type accelerator view.

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ELV-15

The most important achievement in 2021 is the ELV-15 accelerator. We and our partners have long had a desire to make an accelerator with an energy of 3 MeV. Increasing the energy up to 3 MeV expands the application possibilities.

Design

The high-voltage rectifier of the ELV-8 accelerator, with a maximum energy of 2.5 MeV and a power of 100 kW, was taken as a basis. After that, the diameter and height of the primary winding, the number of turns of the primary winding, the diameter of the secondary winding coils (sections) were increased. The number of rectifying sections has also been increased (i.e. column height).

Even though the diameter of the sections for ELV-15 has been increased, nevertheless, it remains possible to use standard sections of the ELV secondary winding. In this configuration, the accelerator was successfully assembled and tested. The accelerating tube consists of 4 x 90cm parts, the number of rectifying sections is 80, the number of primary windings is 2 (the height and diameter are increased).

As a voltage sensor, as in ELV-8, a rotary voltmeter is used. The beamline, optical, and extraction system did not undergo significant changes. In the power supply system (power supply cabinet), the ability to change the frequency of the primary winding power supply depending on the requested energy has been added (to simplify the operation of the matching circuit).

Accelerating tube view and the common view of the ELV-15 accelerators are shown on Figs. 2 and 3.

Figure 2: The ELV-15 accelerating tube.

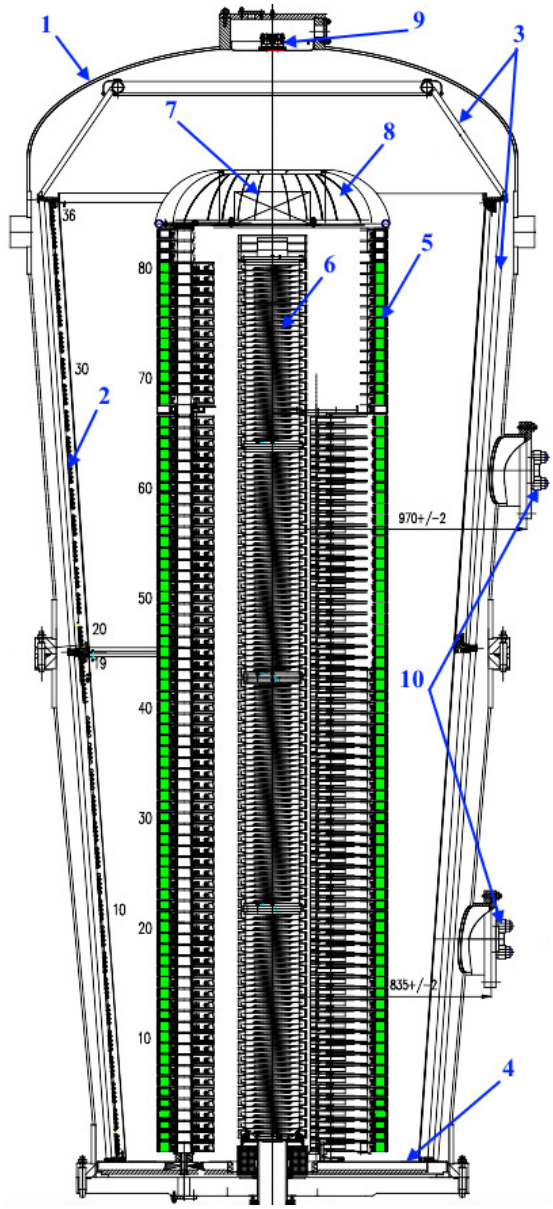

Figure 3: The ELV-15 view. 1 - vessel; 2 - primary windings; 3.4 - magnetic guides; 5 - rectifier sections; 6 - accelerating tube; 7 - injector control unit; 8 - high voltage electrode; 9 - optical channels for injector control; 10 - primary winding feedthrough.

Testing

In August 2021, all tests of the ELV-15 accelerator were completed. The maximum parameters were obtained: maximum power (100 kW) at an energy of 3 MeV with a current of 33.3 mA, and 50 mA at lower energies (2 MeV and less). Also accelerator was tested on maximum energy 3.3 MeV without load (beam).

Upon completion of the tests, the accelerator was disassembled, packaged and shipped to customers in China.

The topic of the ELV-15 accelerator will be covered in more detail in future articles.

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ELV-8 IMPROVEMENT

For the ELV-8 accelerator, the maximum current was increased to 60 mA. The maximum power remains the same - 100 kW. This improvement allows you to work with a current of 60 mA in the energy range 1.0 - 1.66 MeV. Such an improvement required a slight upgrade in the cooling of the power cabinet choke and the addition of the ability to change the capacitance of the matching circuit during operation. In the aftermath, it turned out that a more accurate tuning of the matching circuit elements allows the accelerator to operate in the entire range without retuning or changing the capacitance/frequency.

FOCUSED ELECTRON BEAM INTO THE ATMOSPHERE

A new type of gas-dynamic extraction device was designed and pre-tested. It can efficiently extract a focused electron beam into the atmosphere [3].

During the tests, stable operation was achieved at a beam power of 70 kW and a short-term operation at 100 kW. After long-term operation of the accelerator at a power of 50 kW, the diameters of the holes in the diaphragm did not change. Diaphragm hole diameter on the extraction device output is 2-2.5 mm.

4M EXTRACTION DEVICE

In cooperation with Shanxi Yuridi company, at 2019, an extraction device with a window width of 4 meters was manufactured, and tested. Such a wide electron beam raster was required to irradiate a polyethylene film up to 4 meters wide. The ELV-8 accelerator equipped with this extraction device was successfully delivered and installed to a Chinese company in Anhui province.

The four meters width extraction device shown on Fig. 4.

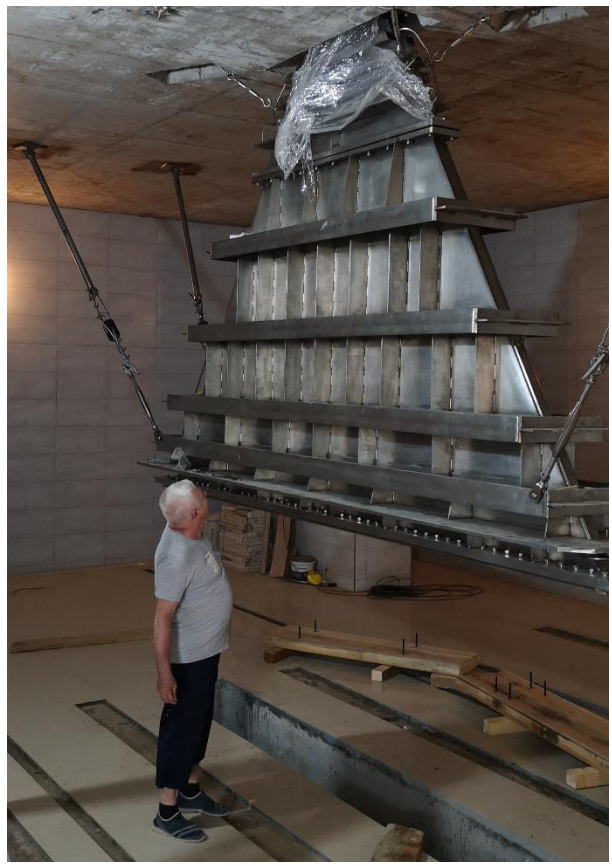

Figure 4: Four meters width extraction device.

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