UNIFIED 1.9…4.0 MeV LINEAR ACCELERATORS WITH INTERCHANGEABLE ACCELERATING STRUCTURES FOR CUSTOMS INSPECTION

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A series of compact linear electron accelerators for 1.9, 2.5 and 4.0 MeV equipped with a local radiation shielding has been designed and constructed in the NPK LUTS, the D.V. Efremov Institute (NIIEFA). The accelerators are intended for mobile facilities used for customs inspection of large-scale containers. Results of optimizing calculations of irradiator parameters and electron dynamics, verified under accelerators' testing, are presented in the report. The main design approaches allowing the construction of unified accelerators with interchangeable accelerating structures for energies in the range of 1.9…4.0 MeV are also given.

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The main specific feature of these accelerators is the use of identical structural elements such as high-voltage modulator, control system, radiation shielding and heat exchanger. The machines differ only in standing wave accelerating structures, being a component of the irradiator unit. Outline dimensions of the structures are the same, which allows us to choose a required energy by installation of a proper structure in the irradiator with the rest units unchanged.

The accelerating structures are of equal length (~ 290 mm) and differ only in the geometry of cells in the main accelerating part. The total number of cells in each structure amounts to 15; and to make simpler the design of cooling casing, RF power is put in through the last cell № 15. Bunchers optimized for the results of performed calculations of longitudinal and transverse dynamics are identical in all the structures and consist of nine cylindrical cells with azimuth coupling slots.

Cell № 10 is a matching cell. Its length is different in different structures and is chosen so that a bunch of electrons is placed in the field maximum in the main accelerating part.

The main accelerating part in all the structures comprises cells from the 11th to the 15th. Passing through this part electrons acquire the energy gain, which under equal power of the RF generator (1.8 MW) and beam current (0.02 A) differs drastically, approximately from 1 to 3 MeV depending on the model. This can be accomplished, in particular, by intentional lowering Q-factor and shunt-impedance of accelerating cells at low energies and by increasing these parameters at an energy of 4.0 MeV. To this end, the cylindrical geometry has been chosen for cells of the main accelerating part for 1.9 MeV and 2.5 MeV models. The heights of accelerating cells and coupling cells are 10 mm and 32 mm for the 1.9 MeV model and 15 mm and 28 m for the 2.5 MeV model, respectively. In the 4 MeV accelerator, 38 mm accelerating cells are of U-shape geometry. Coupling cells with the minimum length of 4.0 mm keep more traditional cylindrical geometry. In spite of high accelerating fields (up to 40 MV/m at 1.9 MeV), no HV-breakdowns were observed during RF-processing of accelerating structures due to low overvoltage ratio and use of an ion pump with a pumping speed of 16 l/sec.

The performed optimization allowed us to attain up to 90% capture of particles in the acceleration mode at a diameter of accelerated beam less than 2 mm. In this case the beam focusing was done with only RF accelerating field without any focusing coils. The field amplitude over the buncher length was increased by a factor of 23 at a zero beam current.

The calculation curves describing the accelerating field distribution, electron energy and radial distributions of 1.9 and 4.0 MeV particles are shown in Fig.1,2. Data on the particle capture and the beam radius have been experimentally verified; however, no energy spectrum measurements were made. Measured X-ray dose rate at 1 m distance from the target for the 4 MeV energy was 0.4 Gy/min; the dose rate stability within 2 minutes was at a level of 2.2%.

At the customer's request, facilities for customs inspection must be equipped with a local radiation shielding. Block design of the radiation shielding made of tungsten, lead and steel allows easy access to the electron source, X-ray target, RF feedthrough and other components for maintenance in the process of operation (Fig.3).

Detailed computations of the shielding by the Monte-Carlo method taking into account X-ray radiation and photon scattering have allowed us to find an optimal configuration of radiation shielding blocks. Radiation background in any point at a 1m distance from the irradiator was measured for electron energy 2.5 MeV with a closed collimator aperture. The measurements have demonstrated that the leakage dose rate was no more than 2 μSv/h (specified 5 μSv/h) [2].

All the accelerators also meet the vibration resistance requirements, and due to the available conditioning system can operate under "all-weather" conditions. Another factor of primary importance for a transportable facility is minimization of its weight and overall dimensions. As a result of integrated design approach, taking into account diversity of requirements, we succeeded in creation of a rather compact 1480 kg irradiator (the shielding included) with dimensions 850×700×975 mm (Fig.4). Inside the modulator cabinet the equipment of pulse forming network is located.

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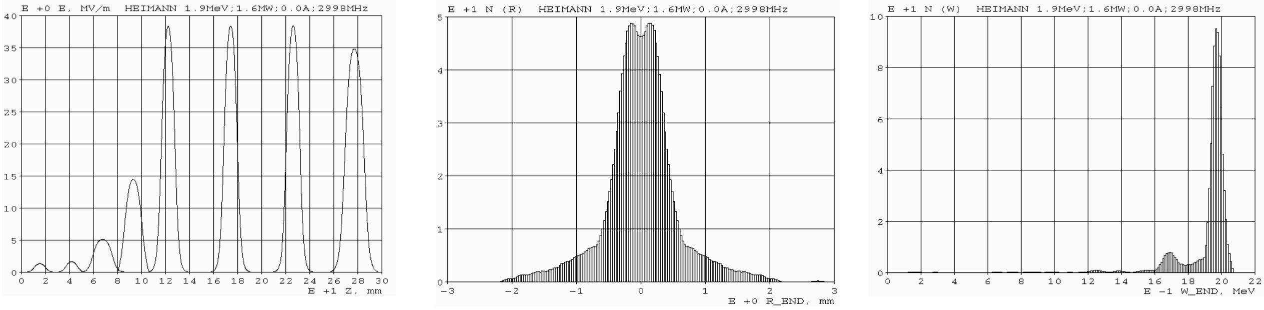
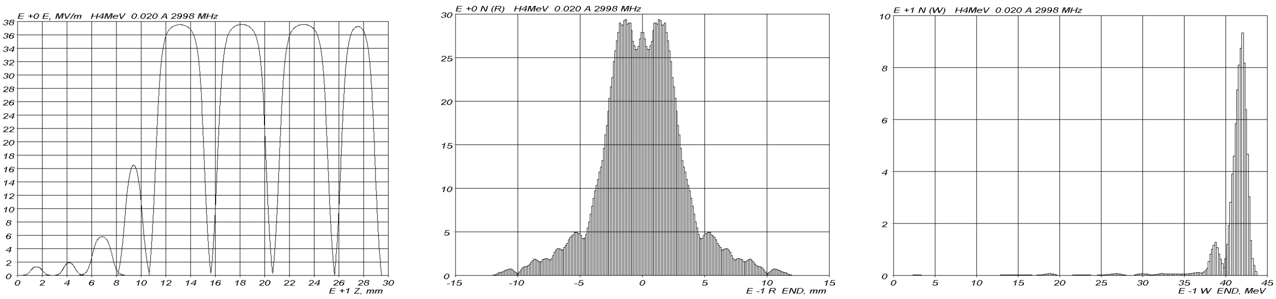


a *b* *c*

Fig.1. 1.9 MeV beam distributions: a - accelerating field; b- particle density in the transverse plane; c - energy spectrum



a *b* *c*

Fig.2. 4 MeV beam distributions: a - accelerating field; b - particle density in the transverse plane; c - energy spectrum

Modern electronic components applied in the modulator enabled the reduction of its weight and dimensions. The modulator cabinet is sealed; constant temperature and humidity conditions are kept inside it, as well as in the irradiator, due to air supplied from a conditioner. The modulator cabinet sizes are: 850×600×1375 mm; the weight amounts to 425 kg.

For temperature stabilization in the accelerating structure and magnetron (over a wide range of temperatures -25…+45°C), the ALIZE 3 SP refrigerator of the DELTA PROCESS firm is used. Inhibited antifreeze with a freezing temperature of -30°C is used as a cooling liquid.

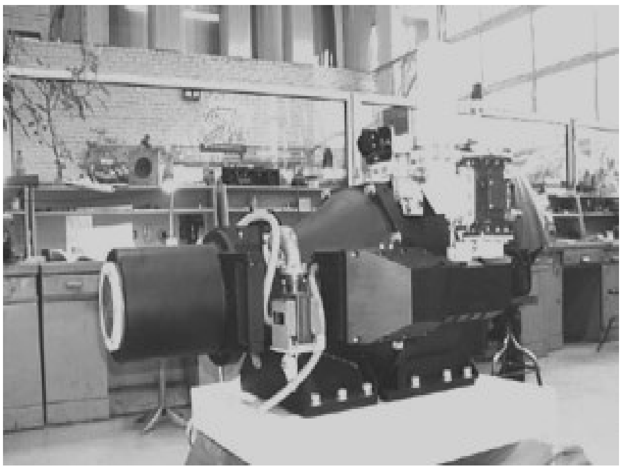


Fig.3 Radiation shielding

After manufacturing the equipment of the 2.5 MeV accelerator, factory tests and tests at the Customer's site were carried out. The tests demonstrated that:

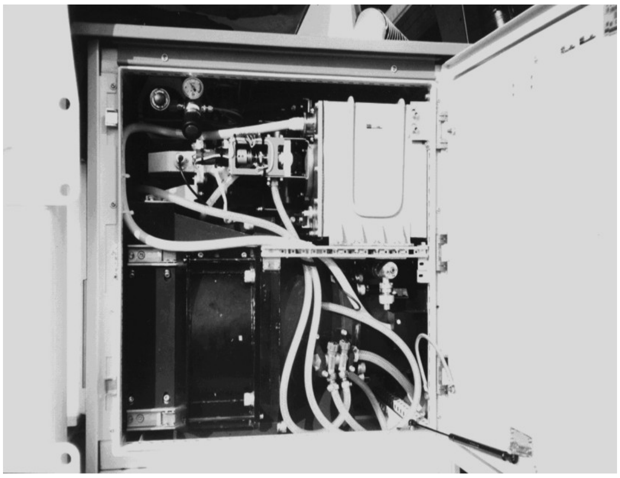


Fig.4. Irradiator

- the accelerator is made at a modern state of the art; the results of leakage radiation measurements points to high accuracy of the local shielding computations;
- measured parameters of the accelerator meet the requirements imposed on customs inspection facilities.

All said above makes it possible to claim that nowadays NPK LUTS, NIIEFA can design and construct compact linear electron accelerators for customs inspection with a high quality of the accelerated beam. All the accelerators in the aforementioned range of energy are manufactured on the basis of unified documentation in one and the same design, which makes possible to significantly reduce terms of their manufacturing and cost.

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УНИФИЦИРОВАННЫЙ ЛИНЕЙНЫЙ УСКОРИТЕЛЬ СО СМЕННЫМИ УСКОРЯЮЩИМИ СТРУКТУРАМИ В ДИАПАЗОНЕ ЭНЕРГИЙ 1.9…4.0 МэВ, ИСПОЛЬЗУЕМЫЙ ДЛЯ ТАМОЖЕННОГО КОНТРОЛЯ

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В НПК ЛУЦ НИИЭФА разработаны и изготовлены несколько моделей компактных линейных ускорителей электронов на энергии 1.9, 2.5, и 4.0 МэВ, которые предназначены для таможенного досмотра крупногабаритных контейнеров. Особенностью разработки является унификация узлов ускорителя, что позволило при использовании взаимозаменяемых ускоряющих структур в одном и том же конструктивном исполнении получать ускоренные электроны с энергий в диапазоне 1.9…4.0 МэВ. Приведены результаты оптимизации параметров облучения, которые подтверждены при испытании ускорителя.

УНІФІКОВАНИЙ ЛІНІЙНИЙ ПРИСКОРЮВАЧ ЗІ ЗМІННИМИ СТРУКТУРАМИ, ЩО ПРИСКОРЮЮТЬ У ДІАПАЗОНІ ЕНЕРГІЙ 1.9…4.0 МеВ, ВИКОРИСТОВУВАНИЙ ДЛЯ МИТНОГО КОНТРОЛЮ

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У НПК ЛУЦ НІЕФА розроблені і виготовлені кілька моделей компактних лінійних прискорювачів електронів на енергії 1.9, 2.5, і 4.0 МеВ, що призначені для митного огляду великогабаритних контейнерів. Особливістю розробки є уніфікація вузлів прискорювача, що дозволила при використанні взаємозамінних структур, що прискорюють, у тому самому конструктивному виконанні одержувати прискорені електрони з енергією у діапазоні 1.9…4.0 МеВ. Приведено результати оптимізації параметрів опромінення, що підтверджені при іспиті прискорювачів.