STATUS ON LINACS DEVELOPED AT INSTITUTE OF ATOMIC PHYSICS-BUCHAREST, ROMANIA

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Abstract

The features and physical characteristics of two linacs, ALIN- 10 and ALID-7, built in Romania, as well as their applications in the field of radiation research and technology are presented. Both linacs are of traveling-wave type driven by 2MW peak power S-Band magnetrons and operate with two independent switchable modulators to perform a single pulse, or pulse trains of accelerated electrons.

1 INTRODUCTION

Potential industrial applications indicate the need for electron accelerators in the energy range 0.5 MeV to 10 MeV and with currents of 1-20 mA[1]. However, according to the last conclusions [2, 3, 4] which resulted from our radiation research with regard to the polymeric flocculants (PA and PV types) production obtained by electron beam irradiation, the use of low power-high energy linacs begins to become economically attractive for this type of application. Indeed, the estimate of processing rates for a linac of 1kW output power and 5-10 MeV energy is up to 2000 kg/h for the PA type polymeric flocculants and up to 500 kg/h for the PV type. Also, our recent investigations concerning the use of simultaneous electron beam and microwave irradiation, demonstrate that some material processing, such as polymerisation and sterilization, need a lower electron absorbed dose in the case of the simultaneous use of electron beam and microwave irradiation in comparison with electron beam irradiation only.

2 THE CONSTRUCTIVE CHARACTERISTICS OF THE LINACS BUILT AT IAP

The first linac, AL-3 of 3 MeV and 200 W, was built in 1996 at the Accelerator Laboratory from Institute of Atomic Physics (IAP) to satisfy the needs of scientists engaged in radiation research. To implement the irradiation processes which provide distinct advantages over conventional processes, years of research combined with engineering activities have culminated in the development of two evolved electron linear accelerators: ALIN-10 of 6 MeV and 100 W and ALID-7 of 5.5 MeV and 700 W.

The ALIN-10 linac is designed as a laboratory installation. It is located in a horizontal configuration, its use including both, electron and X-ray beam production for fundamental research. As fixed equipment, it is adapted to specific needs of more efficient use of the electron beam treatment by using a post-acceleration beam focusing and bending to project electron beam at right angle to the accelerating structure.

The ALID-7 is an industrial equipment having a turning accelerating structure. It is now installed in a vertical position to provide more beam processing flexibility and to meet the wide needs of future applications.

Both ALIN-10 and ALID-7, are of traveling-wave type, driven by 2 MW (peak power) magnetrons (English Electric Valve) operating in S-band. The electrons are injected from diode type guns in the accelerating structure operating in the $\pi/2$ mode. The first portion of the accelerating structures (iris-loaded circular guides) is a variable phase velocity buncher and the remainder has a uniform section, for a phase velocity equal to speed of light. Except some special components, such as magnetrons and ferrite isolators, all microwave devices such as accelerating structures, mode transducers, waveguide windows, high power loads, bends and tee junctions are built in Romania. The high power loads [5] used for ALIN-10 and ALID-7 are multimode right circular cavities (200 mm diameter and 60 mm length) filled with a high loss dielectric (water cooled silicon carbide disk of 200 mm diameter and 25 mm length). These loads have a very simple construction, are compact, light, easily to match over a broad band (200 MHz) and, therefore, suitable for service at the end of an accelerating structure.

Waveguide windows are made by suitable modification of the output glass-metal cylindrical structure retrieved from the depreciated power magnetrons. The broad band matching (100 MHz) of this structure was obtained by using short cylindrical-rectangular transitions with inductive elements (small diameter metallic cylinders) symmetrically placed in its rectangular portion. Fig.1 shows the ALID-7 microwave system photograph. During and after acceleration, the electrons are subjected to a succession of electromagnetic devices for beam focusing, beam projecting through 90^o (only for ALIN-10) and beam sweeping in a horn-shaped vacuum chamber. The scanning frequency, amplitude and waveform of sweep electromagnet current, beam size, maximum permissible distance between impact of two

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pulses, pulse rate and conveyor speed were carefully adjusted for a uniform treatment to be attained. The scanner geometrical parameters are the same for both, ALIN-10 and ALID-7: 32.2^o semi-angle, 39.7cm height, 4 cm window width and 50 cm window length. The dose uniformity on the swept surface is ensured by specially designed waveforms for the scanner electromagnet current. ALIN-10 has a linear conveyor (10 m length and 50 cm width) and ALID-6 a circular conveyor (325 cm average diameter, 50 cm width).

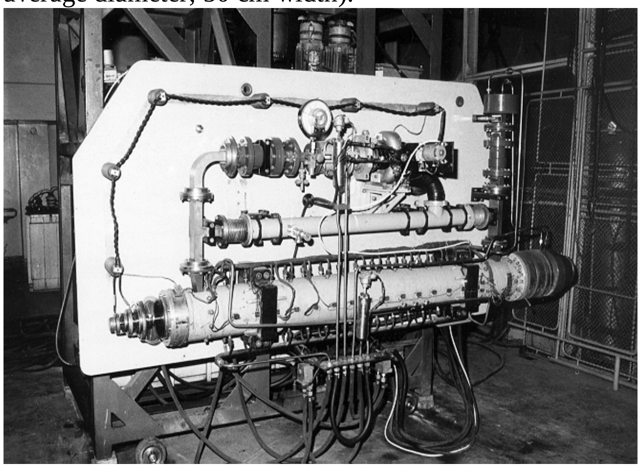

Fig.1 The microwave system of the ALID-7 linac

3 THE FEATURES AND PHYSICAL CHARACTERISTICS OF THE LINACS ALIN-10 AND ALID-7.

3.1.The features.

An important feature of our linacs with diode type guns is an original control technique [7] for obtaining programmed single electron beam shots and pulse trains, with desired pulse number, pulse repetition frequency and pulse duration by discrete pulse temporal position modulation of the gun electron pulses and magnetron microwave pulses. For this flexibility, two separate modulators are provided: a gun modulator and a magnetron modulator. This method combines the unsophisticated construction of the diode gun and better temporal flexibility of the beam, generally available when using triode type guns. A block diagram of this kind of modulation applied to ALID-7 is shown in Fig.2. The accelerator triggering system has two branches: the gun branch and the magnetron branch. The master generator MG, which synchronizes all the system units, delivers pulses at a programmed repetition rate (up to 250 pulses/s) at the monostable multivibrators MM1 and MM2. The pulses of the gun thyratron driver and magnetron thyratron driver are formed from the trailing edges of the MM1 pulses and MM2 pulses, respectively. The electronic switch ES may discretely change the duration of the MM1 pulses in the gun branch. When the electronic switch is not activated, the MM1 delivers long pulses and there is no overlapping of the electron gun and magnetron pulses an thus there is no accelerated electron beam at the accelerator output. The instabilities in the transitory regimes of the gun and magnetron are avoided by operating the accelerator a certain time without accelerated beam and then, by pushing "beam start button" the overlapping of electron

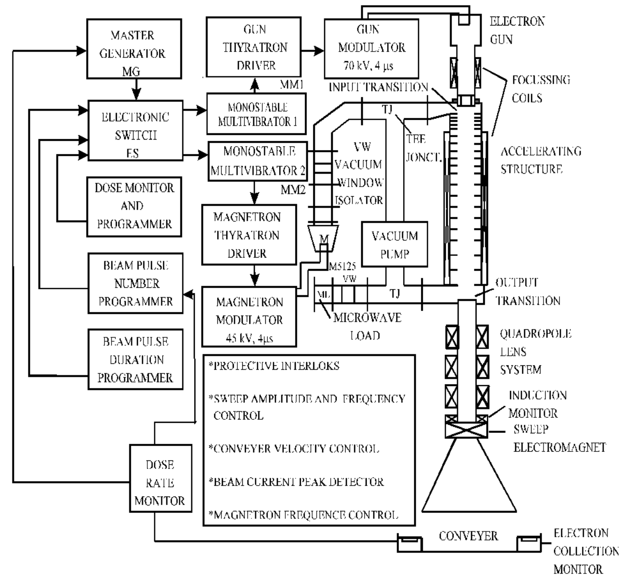

Fig.2 The system configuration of the ALID-7 linac

gun and magnetron pulses are obtained, the variation in absorbed dose to pulse to pulse being reduced. Programmed absorbed dose, programmed irradiation time, programmed beam pulse number or other external events may interrupt the coincidence between the gun pulses and magnetron pulses and then the irradiation regime. The beam pulse duration may be continuously adjusted from 0.25 µs to T_M-T_F, where T_M is length of magnetron pulse and T_F is fill-time of the accelerator guide. The duration of the short beam pulses is limited only by the values of the gun pulse leading edge and of the magnetron pulse trailing edge. Slow variation of the absorbed dose rate is composed by means of an automatic control system of the pulse repetition frequency in the master generator. Another facility, which was specially designed to be used together with our linacs, is a reaction chamber built to permit simultaneous accelerated electron beam and microwave irradiation. As an initial step, an experimental model of reaction chamber (EMRC-1), excited by a single slotted waveguide system, has been developed in order to study the chemical, physical and biological effect caused by a microwave power up to 850 W and 6 MeV accelerated electron beam in their simultaneous passage through a wide variety of material samples: monomers mixture in aqueous solution, medical products, gases mixture containing nitrogen oxides and sulfur dioxide, ammonia and water vapor and other. Fig. 3 shows ALID-7 scanner and EMRC-1 set up in series. EMRC-1 is a rectangular chamber of 50X25X25 cm^3 using an injection system consisting of a microwave power-controlled generator for a 2.45 GHz CW magnetron of 850 W maximum output power, a launcher to fit to waveguide WR430, a dual directional coupler for direct and reflected power monitoring, a tree stub tuner for impedance matching and an applicator based on five inclined series slots cut in the broad wall of a WR430 waveguide. Scanned electron beam is perpendicularly introduced to the upper- end plate of EMRC-1, passing through a 100 μm thick aluminium window and the microwave power is coupled to the chamber sidewall via the slotted waveguide system.

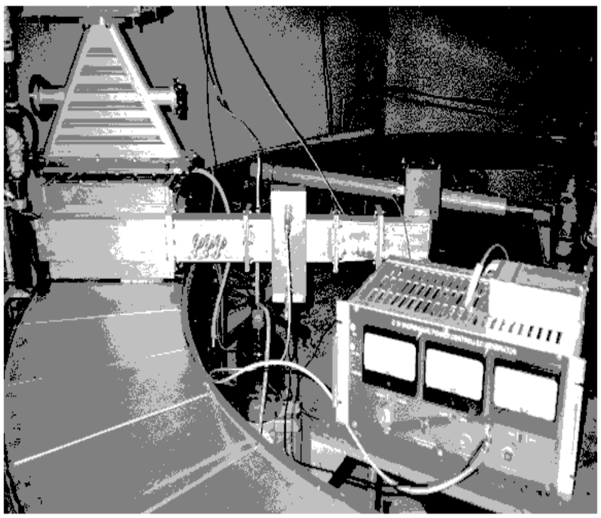

Fig.3 The ALID-7 scanner and EMRC-1 in series

3.2.The physical characteristics.

The physical characteristics of the beam which are of great interest for material processing, are: electron beam power, which represents the basic processing capability of a given source for a "required dose", and energy beam, which determines the depth to which the electron beam will penetrate the product. Along with this, the dependence of electron beam average power (P_B) on the input accelerator characteristics as well as beam loading characteristic have been investigated for the determination of the optimum values of peak beam current (I_B) and average beam energy (E_B) to produce maximum beam average power at the end of the accelerating process.

The peak beam current was measured by means of a ferrite ring pulse transformer and the average beam power by applying calorimetric method [8]. The average beam energy was determined from beam power characteristics. The calorimetric method was very suitable for electron beam power maximization as a function of the gun voltage (V_G), magnetron voltage (U_M), magnetron frequency (F_M) and peak beam current. The optimum values to produce maximum output beam power are recorded in Table 1.

Table 1

Linac	E_B (MeV)	I_B (mA)	U_M (kV)	U_G (kV)	F_M (MHz)
ALIN-10	6.23	75	43.5	68.4	2997.5
ALID-7	5.5	130	43.5	65	2998.6

4 THE ALIN-10 and ALID-7 LINACS DESTINATION

Our major research object is focused on the application of the electron accelerators to environmental engineering. As an initial step, the preparation of polymeric flocculants for waste water treatment was developed. Thanks to remarkable properties of the electron beam technologies developed over recent years in our institute for the polymeric flocculants preparation [2,3,4], it was proved that high energy linacs with modest output beam power, from a few hundred watt to one kilowatt, became economically attractive for their commercial production. The required dose for our types of flocculants , based on polymerization of the aqueous solution containing proper monomer mixture, such as acrylamide, acrylic acid and acetate vinyl, is smaller by a factor of 10 to 100 as compared to the dose requirement for other polymeric material production. Also, using the simultaneous electron beam and microwave treatment the required absorbed dose is again much decreased and some properties, as linearity and molecular weight are improved.

Our recent investigation on the sterilization of a wide variety of materials including foods and medical waste by simultaneous electron beam and microwave treatment demonstrates once more that the required beam dose level is much decreased.

5 CONCLUSIONS

The electron accelerators developed at Institute of Atomic Physics, Accelerator Laboratory, are to be used for various industrial applications at pilot-scale level thanks to the innovative electron beam technologies applied in the polymeric flocculants field. In addition to this, by using simultaneous electron beam and microwave treatment the industrial application of small-output power-high energy linacs will be more extended and the electron beam costs will decrease. Also, new and promising results are expected in material research by applying the method of the simultaneous electron beam and microwave treatment.

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