Electron Accelerator Control System Based on Radiation–Acoustic Effects

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Abstract

The system uses ultrasonic radiation as a source of primary information about the current status of the accelerator. The sound is generated by the electron beam and by a high-frequency electromagnetic field in their interaction with the accelerator components and with the target. The system incorporates two CAMAC crates and a computer, and it fulfills the requirements for transporting, focusing and monitoring the beam and follow-up phase-locking electromagnetic waves in accelerating cavities.

The system has been designed to control a traveling-wave linear accelerator with electron energy of 5 to 30 MeV, an electron pulse width of 10 to 4000 ns, a pulse repetition frequency of 1 to 300 Hz and with an average beam power of up to 5 kW. A block diagram of the electron accelerator control system is shown in Fig. 1. It incorporates a set of acoustical sensors with electronic preamplifiers, two CAMAC crates and an IBM PC-compatible computer with corresponding software. Crate A deals with phase-locking a h.f. electromagnetic field in an accelerating cavity to an electron injector pulse and controls the transmission of a beam through a transfer line. Crate B carries out the focusing of the beam onto a target and measuring the beam parameters. The analysis of data and the generation of control commands are executed by the computer. The crates contain facilities for digitizing signals from sensors, buffer memory devices, units for controlling executive devices, and microprocessor crate controllers.

The sources of primary information for system operation are ultrasonic waves σ_T generated by the beam and the h.f. 1.8GHz electromagnetic σ_P field [1-7]. When a pulsed electron beam hits components of the accelerator rapid heating and expansion of their materials takes place. Thus sonic waves are generated and carry information about beam parameters and about the location of the interaction spot.

Sonic waves are also generated by ponderomotive action of a pulsed h.f. field on waveguide elements. The waves carry information about the form of the pulse of electromagnetic waves and this form depends on the conditions of energy exchange between the h.f. fields and electron bunches being accelerated [6-10].

The sonic waves σ_T, σ_P detected by broadband ($\Delta f \leq 10$ MHz) piezoceramic sensors AD-AD5 (see Figure 1) placed on accelerator elements and on a target T. This sort of sensor has high sensitivity and good radiation resistance and sensor construction provides protection against electromagnetic interference. The h.f. field phase-locking is executed based on signals from an acoustical sensor AD1 placed on an absorbing load AL of the accelerating waveguide AW. The maximum transfer of energy from the h.f. field to the electron bunches is achieved when the amplitude of acoustic stress is minimal. Pulses from the sensor AD1 are led to a gated amplitude-to-digital converter in crate A. A corresponding subroutine operates through the crate controller and a relay control unit for a klystron KL phase-shifter PS servomotor to make the amplitude of σ_P minimal. Thus one strives for the maximal energy transfer.

The automatic control of beam transport is carried by multiple- cavity accelerators based on signals from acoustical sensors AD2, AD3 placed on a diaphragm in an electron transfer line. Signals from the sensors are led to both gated analog-to-digital and time-to-digital converters in crate A. If the beam is off the transfer line axis some signal amplitudes go over a preset limit. In that case the determination of beam position is made on the basis of the delays of two acoustical pulses relative to the sync pulse of the accelerator. Then corrective changes of beam positioning magnets BPM are made. Corresponding digital-to-analog converters will be used for that purpose in crate A.

Some other system of beam transport were tested on the accelerator LUE 300 in Kharkov. The beam transmission through the system is monitored by using signals from acoustic detectors placed along the accelerating waveguide. Both pulse amplitudes and the delays relative to the sync pulses of the accelerator were digitized and inputed into a computer, where the beam position was determined and the control commands for changing the currents of deflecting magnets were generated.

The current correction continues until the signals from the detectors vanish and the signal from the acoustic probe AP showing beam position appears. This procedure worked in single-pulse mode in a short time due to the high information content of the acoustical signals.

On high-current accelerator Fakel in Moscow these detectors serve for emergency protection of the beam-transport pipes against damage from the high-current beam. When the amplitude of an acoustic signal goes over a preset limit the injector is disabled preventing damage to the accelerator elements.

Focusing the beam and measuring the beam parameters are implemented on the basis of signals from sensors AD4, AD5 placed on the target T (AD5) and on an acoustic probe AP (AD4) which is on a metallic wire crossing the beam. The signals are digitized by a gated analog-to-digit converter in crate B and are analyzed by a corresponding subroutine. The greater the amplitude of the signals from AD4 and AD5 the smaller the diameter of the beam on target. The system controls the current of a focusing lens FL by a digital-to-analog converter in crate B so as to keep a predetermined diameter of the spot. On the basis of the delay of a pulse from AD4 relative to the sync pulse, the current position of the spot is determined. It allows a follow-up control of the current shape of a magnetic scan deflector BCD when a scanning beam is used. This makes it possible to keep the required dose distribution on the target. The duration and frequency of the electron bunches, the energy of the beam and the size and location of the electron spot on the target may be determined. There is a supervision program that keeps data from the experiment and presents current information on the monitor screen. It makes it possible to view signals from the sensors, to test the system, to change parameters of the beam in response to operator instructions and to calculate a dose profile on the target.

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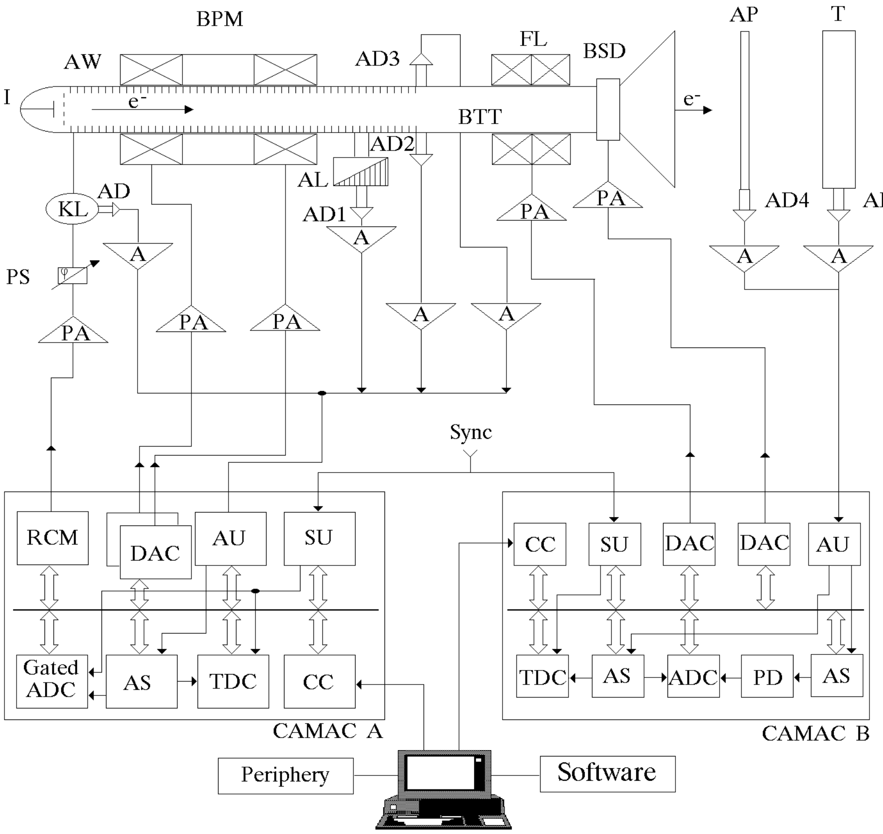

Figure 1: Block diagram of the electron accelerator control system. **AW** — accelerating waveguide; **BPM** — beam positioning magnet; **FL** — focusing lens; **BSD** — beam scan deflector; **BTT** — beam transport tube; **KL** — klystron; **AL** — absorbing load; **PS** — phase shifter; **AP** — acoustic probe; **T** — target; $\mathbf{e^-}$ — electron beam; **AD-ADC** — acoustic sensors; **PA** — power amplifier; **A** — pre-amplifier; **AU** — amplifier unit; **SU** — synchronization unit; **CC** — crate controller; **AS** — analog switch; **DAC** — digital-to-analog converter; **TDC** — time-to-digital converter; **Gated ADC** — gated analog-to-digital converter; **RCM** — relay control modulus; **PDM** — peak detector modulus.