PERFOMANCE OF 2 MeV, 2 kA, 200 ns LINEAR INDUCTION ACCELERATOR WITH ULTRA LOW BEAM EMITTANCE FOR X-RAY FLASH RADIOGRAPHY

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Abstract

LIA-2 linear induction accelerator is designed in Budker INP as an injector for full scale 20 MeV linear induction accelerator which can be used for X-ray flash radiography with high space resolution. This machine utilizes ultra high vacuum, precise beam optics design based on low temperature dispenser cathode of 190 mm in diameter. The results of LIA-2 commissioning are presented. The designed value of beam emittance (120 π mm•mrad, not normalized) is achieved at 2 MeV and 2 kA of electron beam energy and current.

INTRODUCTION

In spite of LIA-2 is originally designed as an injector for 20 MeV linear induction accelerator, it can be used also as an independent 2 MeV X-ray source for high resolution flash radiography. The design of this machine is focused on the main goal – to keep the minimum possible beam emittance starting from the cathode, passing through acceleration, transport and final beam focusing on the target. Less then 1 mm beam spot size (FWHM) on the target at the maximum energy and beam current has become a result of our efforts in emittance minimization.

LIA-2 PARAMETERS AND DESIGN

Basic parameters of LIA-2 are presented in Table 1. The accelerator includes electron beam forming, accelerating and focusing system, high voltage pulsed power system, beam diagnostic system, high vacuum system and control system.

Table 1: LIA-2 Basic Parameters

Parameter (Units)	Value
Maximum electron beam energy (MeV)	2.0
Maximum electron beam current (kA)	2.0
Number of pulses in the burst	2
Cathode heater DC power (kW)	2.5
Time interval between pulses in the burst (µs)	2 - 10
Pulse duration, flat top ±4% (ns)	200
Maximum repetition rate (Hz)	0.1
Min. beam spot size FWHM on the target (mm)	1.5

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The electron beam shaping, accelerating and focusing system includes 1 MV, 2 kA diode with high surface quality, low temperature dispenser cathode. The cathode assembly of the diode is mounted on 1 MV bit-slice bushing insulator. Additional 1 MV accelerating bit-slice insulator is placed just after the diode exit (see Fig.1). Both insulators operate with gas HV insulation outside (divided in four sections) and vacuum HV insulation inside. Both sections of main HV pulsed transformer (1 MV each) include totally 96 induction cells based on the amorphous ferromagnetic laminated cores with average magnetic material losses of 750 J/m^3 at 5 T/µs magnetization rate and flux swing value of 1.5 T.

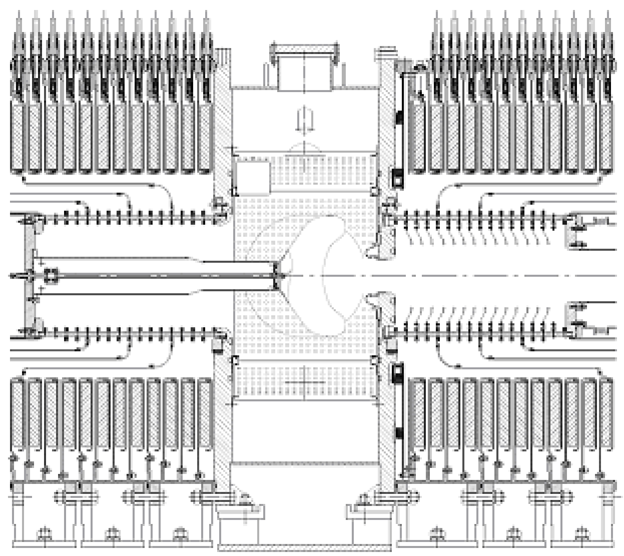

Figure 1: Scheme of LIA-2 accelerating system.

Pulsed HV system of LIA-2 consists of 48 identical double pulse modulators, two charging units (one for each pulse) (see Fig. 2) and coaxial feeding lines (20 cables for one modulator). Each modulator feeds two induction cells in parallel and includes two Pulse Forming Networks (PFN) (one for each pulse), two cold cathode thyratrons [1], bias system and all necessary ancillary circuits.

Electron beam transport and focusing system has four short focusing solenoids operated in pulsed regime and three DC X-Y dipole correctors. The beam line is finished by rotating target assembly integrated with beam dump (see Fig. 3). Target wheel is designed for about 170 radiographic pulses and separated from accelerator vacuum chamber by all-metal valve, used for target plates change.

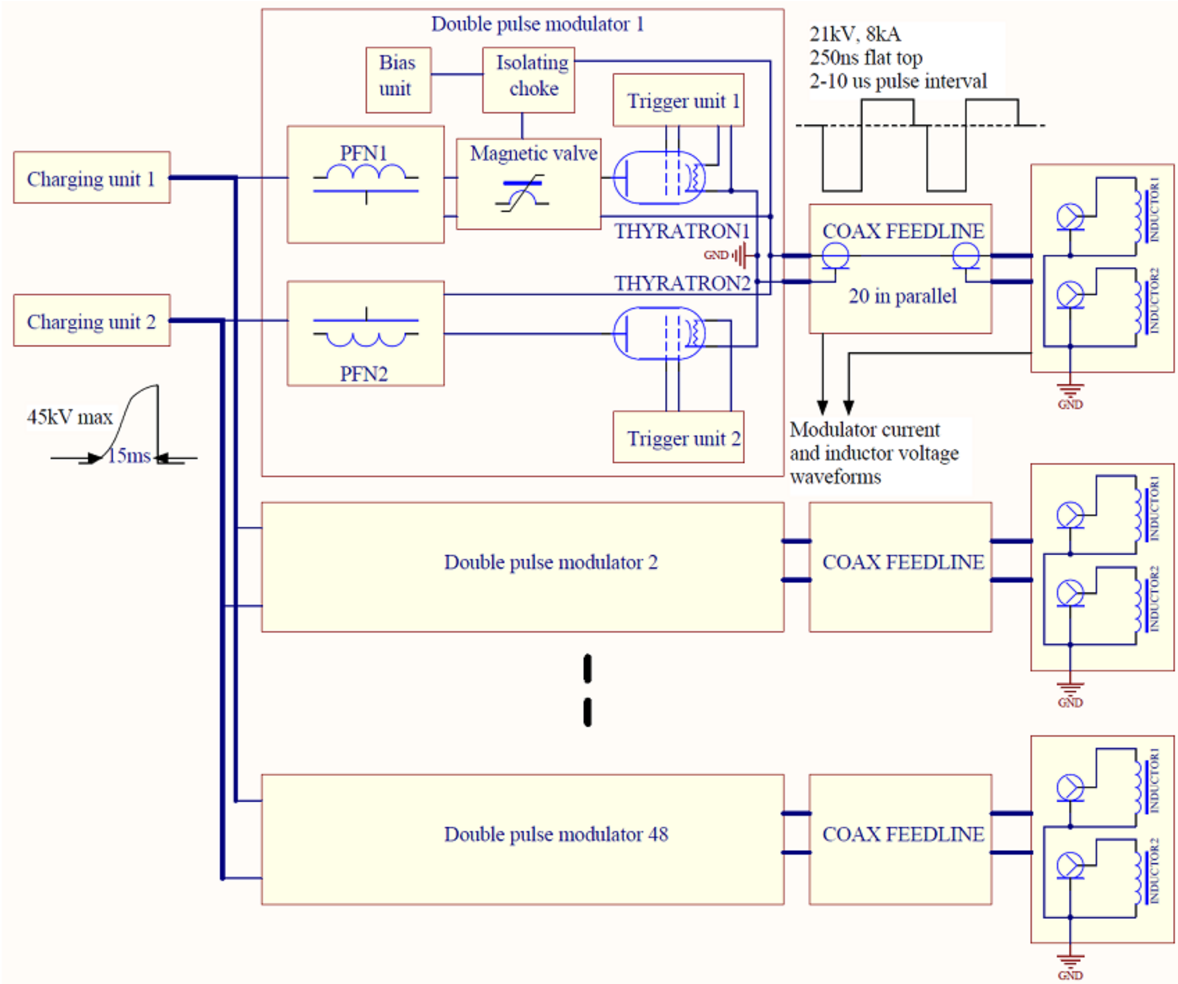

Figure 2: Scheme of LIA-2 pulsed high voltage system.

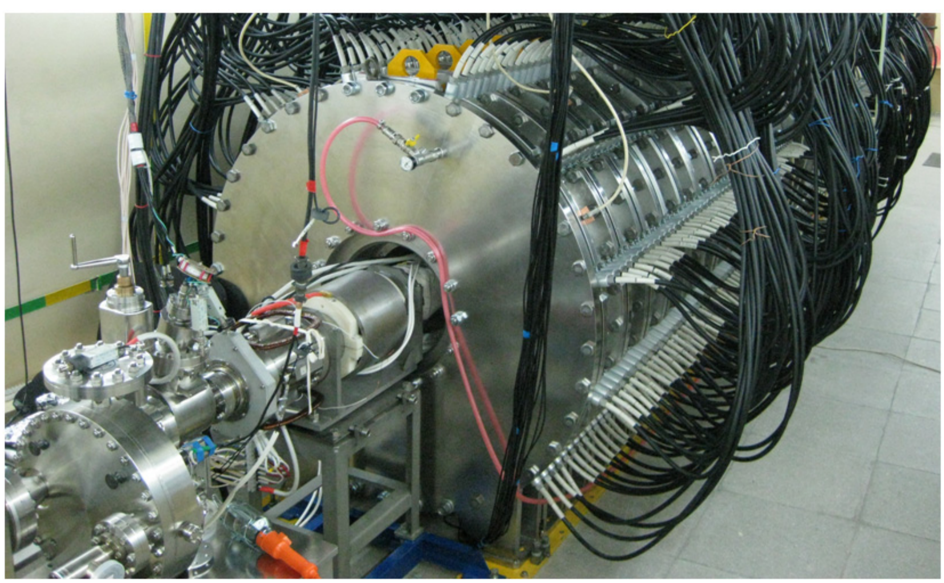
Figure 3: LIA-2 accelerating system and target assembly.

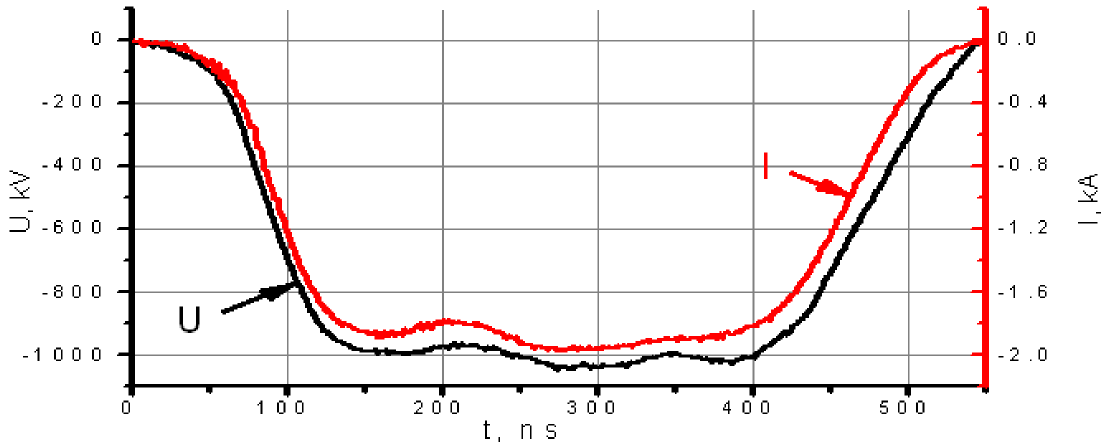

Figure 4: Oscillograms of voltage (black) and current (red) of LIA-2 diode.

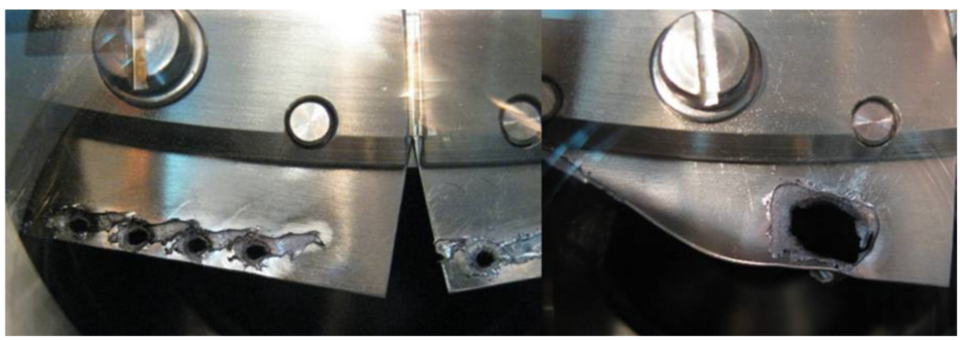

Figure 5: The results of beam interaction with 0.5 mm thick tantalum target for best beam focusing (on the left, 6 shots) and for smaller than optimum current in final focusing lens (on the right, 1 shot). All other parameters are the same for all shots and correspond to maximum beam energy and current (see Fig. 3). Bolt head diameter on the picture is equal to 8.5 mm, pin diameter – 4 mm.

Beam diagnostic system utilizes two beam current transformers, capacitor-based pulsed voltage dividers, X-Y strip-line BPM and movable Faraday cup.

FIRST EXPERIMENTAL RESULTS

First of all LIA-2 was tested at single pulse regime of operation in order to estimate the minimum spot size on the target and beam emittance. Oscillograms of Fig. 4 are obtained from capacitor voltage divider installed in the vacuum diode and from beam current transformer placed just after the anode. The results of electron beam interaction with the target are presented at Fig. 5. The estimated value of 2 MeV electron beam current density necessary for this target melting is 3 kA/cm^2 (200 ns of beam duration). The current density necessary for target evaporation is about 25 kA/cm^2. For expected beam diameter on the target of 1.5 mm (FWHM) one can obtain the typical average current density 110 kA/cm^2 and even more in the beam centre. So the diameter of the hole in the target should be grater then FWHM diameter of the electron beam. So, according to Fig. 5 electron beam diameter on the target (FWHM) is less than 1.3 mm. It corresponds in the existing beam focusing system to the emittance value better than 140 π mm•mrad (not normalized). Further experiments will continue soon on the customer site and will be focused on the improving of beam energy stability on the flat top of the pulse and on the two pulse operation of accelerator.

ACKNOWLEDGMENTS

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