A LOW ENERGY THERMIONIC RF GUN LINAC FOR ULTRASHORT ELECTRON BEAM

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Abstract

A low energy linac system equipped with a thermionic cathode rf gun is being built at NSRRC to demonstrate the concept of aggressive bunch compression by velocity bunching in the rf linac to produce high brightness GHz-repetition-rate femtosecond electron pulses. A beam with 30 pC bunch charge and pulse duration shorter than 100 fsec can be produced from this linac system as predicted by beam dynamic calculations. The status of system integration is presented in this report.

INTRODUCTION

Ultrashort electron pulses with few tens MeV beam energy found interesting applications on generation of intense coherent THz radiations and ultrafast X-rays [1, 2]. An S-band linac system that employs the mechanism of velocity bunching in the early stage of acceleration in the rf linac for production of 20-30 MeV ultrashort electron beam is now under construction at NSRRC (Figure 1). In order to optimize velocity bunching, a high power phase shifter is installed for changing the linac injection phase. It is worth noting that the alpha magnet here is used as a longitudinal phase space manipulator rather than a bunch compressor. According to our calculation study, the system is able to deliver thousands of GHz-rep-rate sub-hundred femtosecond electron pulses in one macropulse with properties as summarized elsewhere [3,4]. In this report, our progress of installation for such test facility is presented. The system will be installed next to the TLS booster ring and share the same concrete shielding. Fabrication of components and integration work is in progress. This installation is scheduled to complete early in next year and beam test afterward.

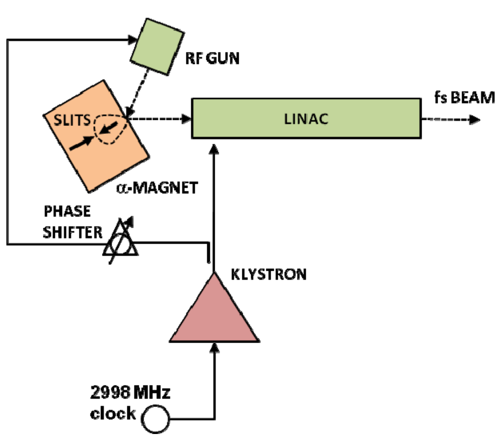

Figure 1: Schematics of the NSRRC low energy thermionic rf gun linac system for ultrashort beam generation with velocity bunching.

STATUS OF THE LINAC SYSTEM

Fabrication of the 2998 MHz Thermionic Cathode RF Gun

The thermionic cathode rf gun is a 2998 MHz, 1.5-cell standing wave structure with frequency tunable side-coupled cell provide coupling between the two accelerating cells and allows fine adjustment of the full-cell to half-cell field ratio. Therefore, the cavity is operating at $\pi/2$-mode such that the two accelerating cells are 180° out of phase. The Heatwave dispenser cathode assembly (without nose cone) will be used. Diameter of the emitter surface is 0.25". The dimensions of the cavity near the beam axis have been optimized for ultrashort bunch generation at linac exit. The field ratio will be adjusted to 2:1 to produce a linear energy chirp near the head of the bunch. Cavity parts for the rf gun cavity has been machined and is under microwave cold test and tuning before vacuum brazing.

Measurement of the Alpha Magnet

An alpha magnet has been fabricated in house and tested with adequate cooling. The vacuum chamber for the alpha magnet has been built and tested (Figure 2). A motorized collimator has been built and will be installed in the vacuum chamber for beam selection before injecting into the linac for beam acceleration.

Figure 2: The alpha magnet with vacuum chamber.

Excitation curve of the alpha magnet has been measured (Fig. 3). The magnetic field gradient is linearly proportional to the excitation current at a rate of ~ 4

Guass/cm per ampere for low currents. At 110 A, the magnetic field gradient is ~ 420 Guass/cm. It is limited by the available current of the DC magnet power supply. As mentioned above, the alpha magnet here is used as a beam selector (longitudinal phase space manipulator) and will be operated at less than 400 Guass/cm. Power supply current of about 100 A is considered to be sufficient.

Figure 4 is the magnetic field gradients versus longitudinal position which is measured from the centre of the mirror plate at 100 A. The measured maximum magnetic gradient along x-axis is at 392.27 Guass/cm. The hole-induced gradient error can be seen in this figure.

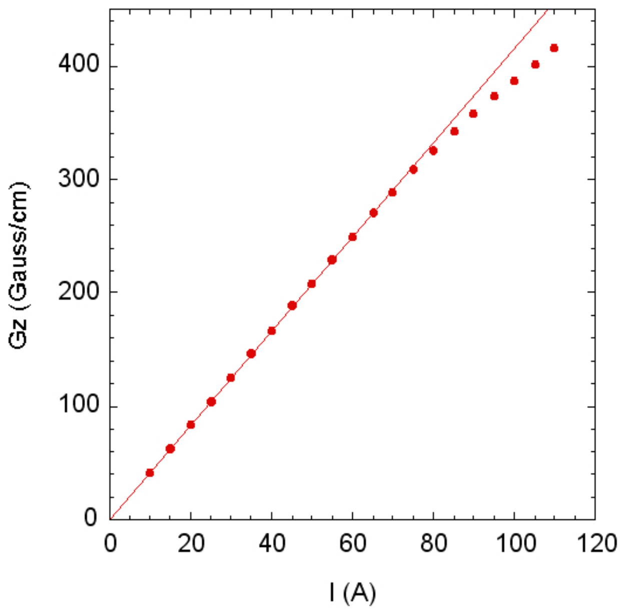

Figure 3: The measured relation of excitation current with magnetic gradient along the longitudinal direction.

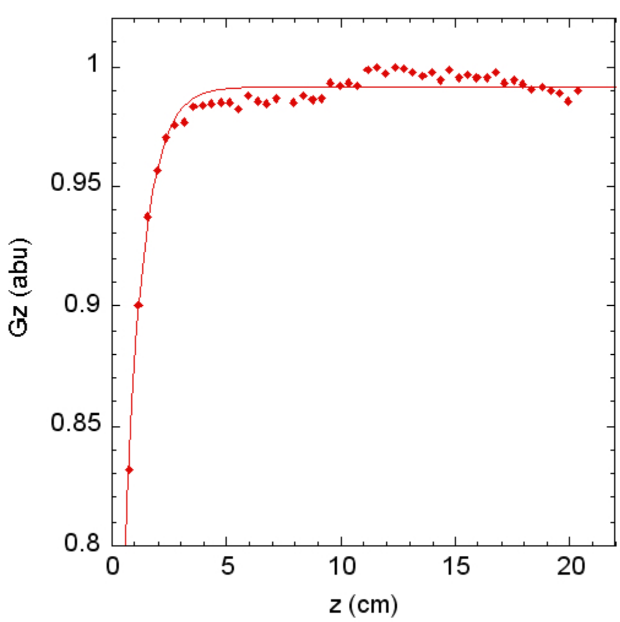

Figure 4: Measured field gradients versus longitudinal position from the mirror plate (i.e. uniformity of gradient along the longitudinal position from the mirror plate).

The High Power Microwave System

The 2998 MHz high power microwave generator is a 35 MW, Thales TH2100A pulsed klystron which is powered by an 80 MW conventional line-type high voltage pulser. The klystron and focusing magnets has X-ray shields that meet radiation safety requirements when operating outside the concrete wall of the TLS booster room (Fig. 5).

Figure 5: The 35 MW TH2100A klystron system.

Installation of this high voltage pulser has been completed and tested at high voltage. The PFN is charged resistively with a high stability high voltage power supply and therefore has a good pulse-to-pulse stability. The measured voltage ripple from voltage divider is ~ 0.01% peak-to-peak in 1 μsec (Fig. 6). The klystron has been operated stably at full power (35 MW) at 10 Hz repetition rate with a high power water load connected to the klystron output.

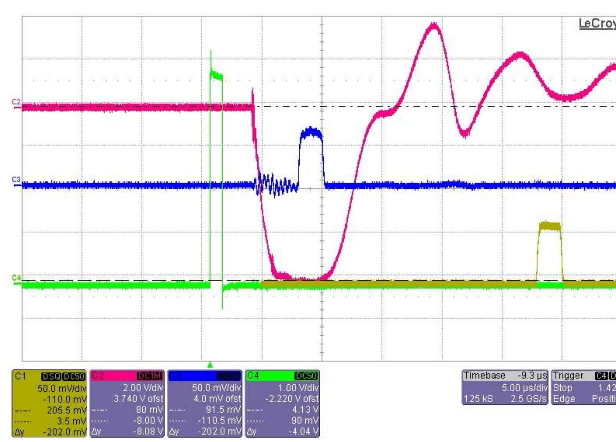

Figure 6: The klystron voltage signal (red) and the klystron output signal at saturation (blue).

A variable high power divider is installed in the waveguide system that divides the microwave power to the thermionic cathode rf gun as well as the accelerating structure. A waveguide phase shifter is installed to adjust linac injection phase for optimization of velocity bunching.

The Accelerating Structure

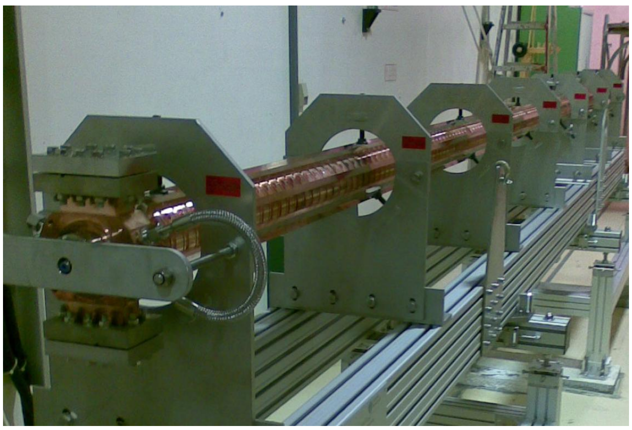

Figure 7: The S-band accelerating structure used in this setup.

The linac sections used in this system are a 5.2 m, 2998 MHz constant gradient traveling-wave structures operating at $2\pi/3$-mode. This structure is similar to the DESY LINAC-II design and is manufactured by Research Instruments GmbH. It has 156 cells that provide shunt impedance of ~50 MΩ/m but with the last 6 cells coated with Kanthal layer as collinear microwave absorber. High power microwave is coupled to the first cell at one arm with the opposite arm shorted (Fig. 6).This linac has been sitting on its supporting stands for alignment. High power test will be performed afterward.

SUMMARY

A low energy (few tens MeV) S-band linac system that equipped with thermionic cathode rf gun is being constructed at NSRRC for generation of ultrashort relativistic electron beam. High quality GHz repetition rate electron pulses of about 30 pC bunch charge and bunch length as short as 100 fsec can be produced by velocity bunching in this injector. This system will be used as the driver linac for ultrafast inverse Compton scattering X-ray source experiment.

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