FIRST OPERATION OF A THERMIONIC CATHODE RF GUN AT NSRRC

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Abstract

A high brightness injector is being constructed for light source R&D at NSRRC. This 150 MeV beam injector consists of a 1.5-cell thermionic cathode rf gun with field ratio adjusted to produce a linear energy chirped electron beam for generation of sub-picoseconds electron pulses at GHz repetition rate by using alpha-magnet as low energy bunch compressor. This short bunch beam is planned to drive an experimental pre-bunched THz FEL in the near future. High power microwave processing of the thermionic cathde rf gun up to ~4 MW cavity forward power has been achieved. First beam from this gun has been obtained.

INTRODUCTION

A high brightness beam R&D program (the NSRRC HBI project) has been started since 2006 at NSRRC [1]. An injector system that based on rf gun technology is being constructed for light source development such as intense THz radiation sources, high gain FELs and ultrafast electron pulses. This will be a 150 MeV beam injector that consists of a thermionic cathode rf gun and a photo-cathode rf gun that share the same 2998 MHz linac system (Figure 1). In the first phase, both rf gun systems as well as the first linac section will be installed. Microwave power will be generated from two 35 MW Thales TH2100A klystrons. One of the two klystrons feeds the photo-cathode rf gun as well as the first rf linac. With a high power waveguide switch, microwave can be directed to the themionic rf gun system. Without beam loading, we expect the first linac section will give a maximum energy gain of 50 MeV at about 20 MW. The second linac will provide a maximum energy gain of 140 MeV at 35 MW with a SLED cavity in the microwave transmission system for enhancement of microwave peak power. The electron beam as generated from the 1.5-cell thermionic rf gun will be used to produce sub-picosecond electron pulses with either alpha-magnet which acts as bunch compressor [2] or by velocity bunching in the linac [3]. These sub-ps electron pulses at 3 GHz repetition frequency from the first linac will be used to drive a THz pre-bunched FEL [4]. In the second phase, the energy of electron beam from the photo-cathode rf gun will be boosted up to > 150 MeV by adding one more rf linac section. Solenoids near the photo-cathode rf gun and in the first linac section will be installed for beam emittance control [5, 6].

In this report, we presented the results of high power processing and preliminary beam test of a 2856 MHz thermionic rf gun that has been fabricated for evaluation purpose. For a collaborative effort between NSRRC and the NTHU relativistic photonic laboratory on THz radiation source and rf gun R&D, this gun will be delivered to the NTHU relativistic photonic laboratory after the beam test. Another gun that will be operated at 2998 MHz is being fabricated for the NSRRC HBI project.

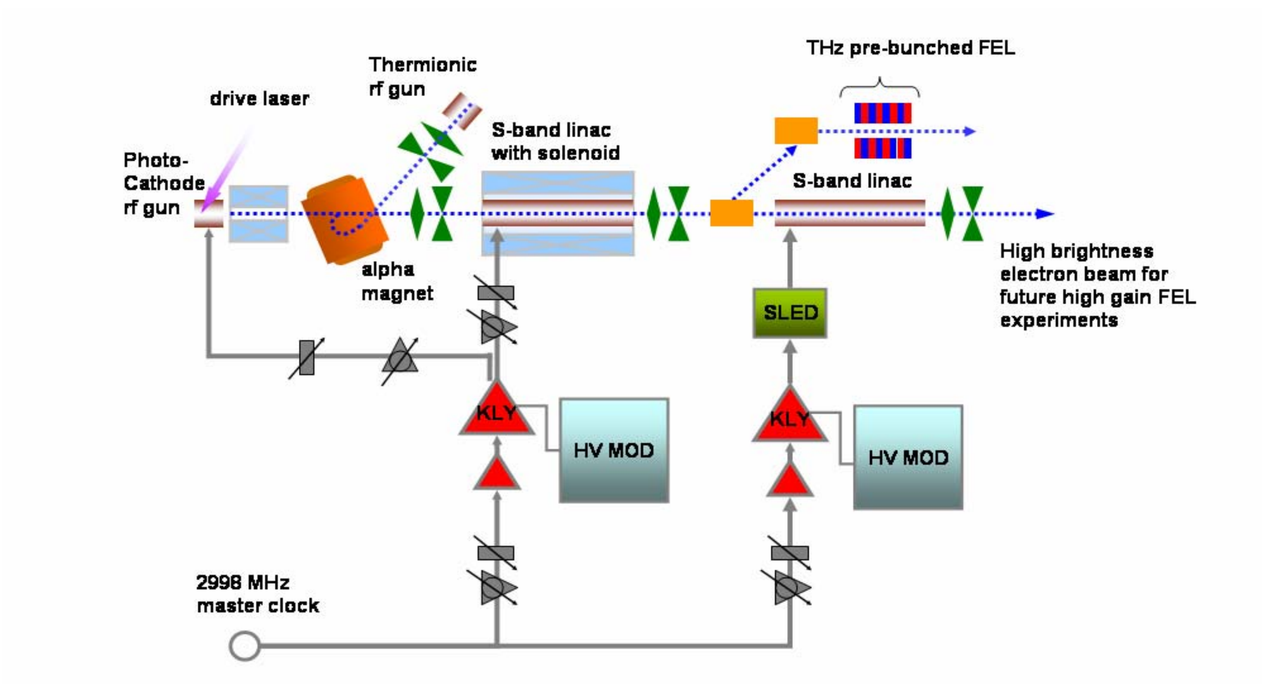

Figure 1: Schematics of the NSRRC high brightness injector

THE RF GUN TEST STAND

The 2856 MHz thermionic cathode rf gun has been fabricated for our NTHU collaborator. This gun has been installed in a test stand for high power microwave processing and preliminary beam test (Figure 2).

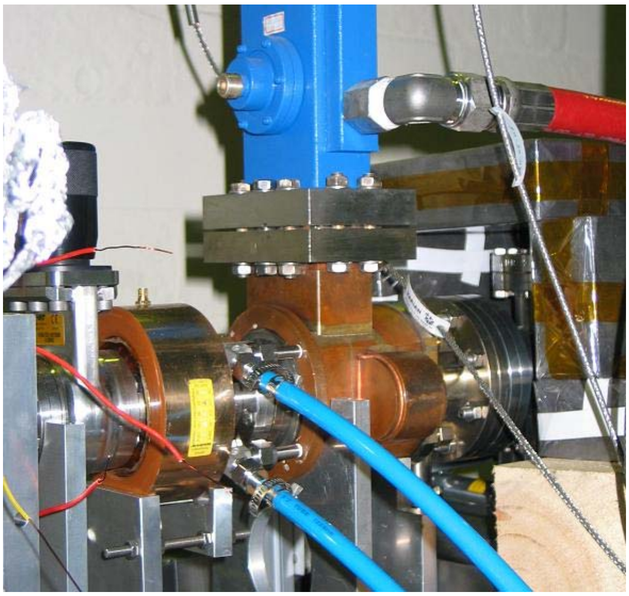

Figure 2: The thermionic cathode rf gun has been installed in the test stand for high power processing and preliminary beam test

The Thermionic Cathode RF Gun

It is a SRRL-type 1.5-cell thermionic cathode rf gun with nose cone on the cathode assembly. This nose cone is intended to focus the space charge beam in the half-cell in its original design. And this nose cone will be removed from the cathode assembly (i.e. a flat surface cathode) in our 2998 MHz gun for better electron distribution after bunch compression. Field ratio of this rf gun has been adjusted to two for generation of linear beam distribution in the longitudinal phase space for bunch compression with the alpha magnet down stream [7,8]. The cathode has been activated to 1100 °C in its surface temperature and has been operated at ~950 °C during beam test. The correspondence between cathode temperature and heater power are measured with a pyrometer.

High Power Microwave System

High power microwave is generated from a 2856 MHz SLAC XK-5 klystron that delivers a maximum output power of 14 MW. It is protected by a high power circulator in case of mistuning of microwave master oscillator. This circulator has ceramic vacuum microwave windows at both ends and has been pressurized with SF_6 gas to avoid gaseous breakdown in the circulator. The whole waveguide system (except the circulator) has been evacuated. The average pressure inside the waveguide is at ~ 10^{-7} mbar during operation. The forward power to and reverse power from the rf gun cavity are picked up from a 60 dB dual directional coupler. And the powers are monitored by calibrated microwave crystal detectors. Attenuation of the signal transmission lines are also calibrated carefully.

Beam Current Measurement

Since the electron beam emitted from the rf gun is not focussed in this installation. A Bergoz fast current transformer has been used to measure dark current and beam current at the rf gun cavity exit. A Faraday cup has been used for beam collection at the end of the beam tube. However, due to divergence of a non-focused beam, the beam current collected by the Faraday cup is not 100% of the current as measured by the FCT at the rf gun exit.

HIGH POWER MICROWAVE PROCESSING

During high power microwave processing, the incident power has been increased slowly and avoid gaseous breakdowns in the cavity by the limiting number of arcs per minute. More than 4 MW microwave power at 2 μs pulse width has been put into to the cavity at 10 Hz maximum repetition rate. The incident power corresponds to a theoretical accelerating gradient better than 100 MV/m in the rf gun cavity. The vacuum pressure has been kept under 10^{-7} mbar during processing. In Figure 3, the red trace is the forward power to the cavity at 4 MW. The yellow trace represents the reverse power from the cavity. The rf gun cavity is over coupled and characterized by the uneven transient amplitudes at the rising and falling edges. Dark current has been observed during processing. Maximum dark current of 2.4 mA has been measured by the Bergoz FCT at 4 MW cavity forward power (orange trace in Figure 3).

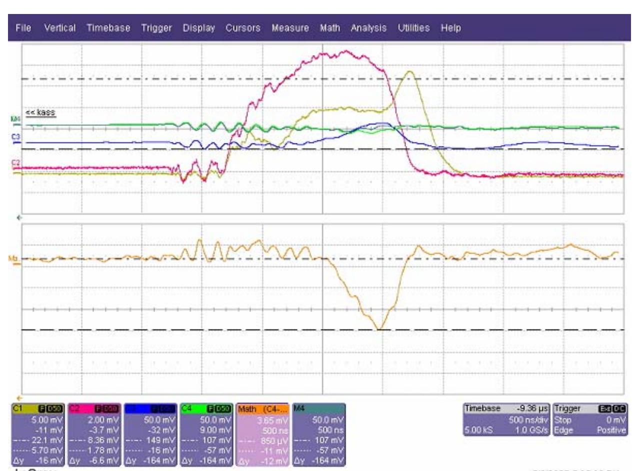

Figure 3: Observed cavity forward power (red), reverse power (yellow) and dark current (orange) signals at 4 MW cavity forward power during high power processing.

FIRST BEAM

With cathode heater turned on and operated at ~950 °C, emission beam current from the gun been observed

(Figure 4). With 4.68 MW forward cavity power, measured beam current (green trace in) at the FCT is ~30 mA. With the cathode heater turned off, no beam current has been observed. However, no indication of beam loading of rf gun cavity has been occurred from the reverse cavity signal.

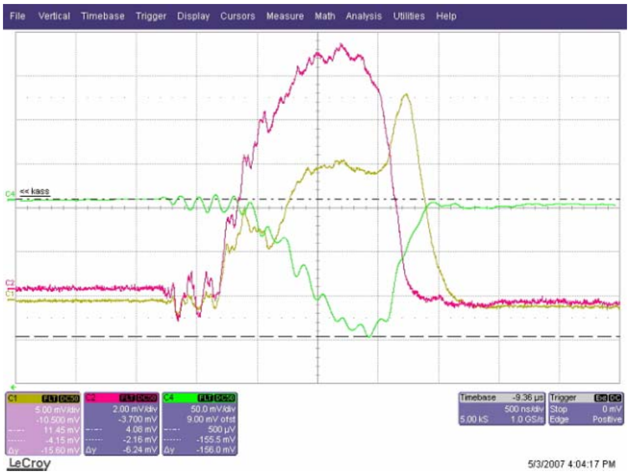

Figure 4: Observed cavity forward power (red), reverse power (yellow) and dark current (green) signals with cathode heater turned on.

SUMMARY AND DISCUSSION

A high brightness injector is being constructed at NSRRC, both thermionic cathode and photo-cathode rf gun systems will be constructed as electron sources. A 2856 MHz thermionic cathode rf gun has been fabricated for evaluation purposes and this cavity will be delivered to NTHU after high power microwave processing and preliminary beam test. High power microwave processing has been done successfully up to 4.68 MW at 10 Hz rep-rate at NSRRC. Measured dark current at this power level is ~2.4 mA. First beam has been observed from the rf gun. Measured beam current is ~30 mA. However, no beam loading phenomenon has been observed from the cavity reverse signal. It can be a poisoned cathode or mistuned cavity frequency [9]. Further investigation is required.

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