INITIAL TESTING OF A FIELD SYMMETRIZED DUAL FEED 2 MeV 17 GHz RF GUN

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Abstract

A 3 cell 17.14 GHz RF gun designed and built by Haimson Research Corporation (HRC) [1] is being tested at the Plasma-Science and Fusion Center at MIT. The middle cavity consists of a racetrack design having dual-feed coupling holes for achieving highly symmetrical TM_{01} π-mode operation. The high symmetry is important for reducing the beam emittance. The power into the RF gun is supplied by an HRC 25 MW, 17 GHz relativistic klystron amplifier. A 1 MW, 100 ns input pulse is required to achieve a peak axial electric field of 150 MV/m in the cavities to provide the electron-bunch with a 1.6 MeV energy gain. A 2 ps, 20 μJ laser pulse is injected into the back of the first cell for emitting the electron bunch. The diagnostic setup consists of a YAG screen and a CCD camera for beam imaging, and a slit array, a magnetic spectrometer, and a Faraday Cup for emittance, energy, and bunch charge measurements, respectively. The RF gun is currently being fed by ~ 0.7 MW, 100 ns pulses. Our next goals are to process the gun up to 1 MW and 100 ns pulses, to inject the laser pulse and synchronize it with the RF phase, and to measure the output bunch energy, brightness, and duration. The status of the experimental results is presented.

INTRODUCTION

RF guns, or photocathode injectors, are used to produce short bunches of high-energy high-brightness electron beams. Bunches in the order of sub-picoseconds having megawatt level energy are of interest for high-energy physics research and for sub-millimeter coherent sources. Frequency scaling in RF guns plays an important role in decreasing the bunch emittance and length while increasing its brightness and energy.

Future TeV linear colliders require high quality beams to produce an interaction point of sub-micrometer spot size having luminosities $> 10^{34}$ cm^{-2}s^{-1} [2]. RF accelerating cavities at frequencies > 11 GHz may be very valuable in meeting this goal.

Free-electron lasers (FELs) are used to produce coherent sub-millimeter to sub-micron high-power microwaves that can be used for various applications such as material and biological studies. Low-emittance high-charge bunches are required for this purpose [3].

Reports on RF gun design and experimental study are described in Refs. [4, 5]. A high record of brightness, 80 A/(π mm mrad)^2, was reported in [6, 7]. Dual RF feeding ports can be used to increase the mode symmetry [8]. Dual coupling into a racetrack cavity profile (rather than circular) was suggested by Haimson in order to further increase the mode symmetry [9].

This paper presents the experimental status of the RF gun designed and built at HRC and tested at MIT. The objective of this experiment is to measure the brightness and output energy of the electron bunches. The results will be of importance for high-power short wavelength applications.

Table 1: RF gun operating parameters

Number of cells	3	
Cavity Q	4600	
Resonant frequency	17.142	GHz
Temperature sensitivity	280	kHz/°C
RF power	~ 1.5	MW
RF pulse duration	100	ns
Laser energy	10–20	μJ
Laser FWHM	2	ps

EXPERIMENTAL SETUP

The experimental setup for operating the RF gun consists of a high power RF system and a laser system. The operating parameters are described in Table 1. An HRC 25 MW, 68 dB gain, 17 GHz relativistic klystron amplifier supplies a $\sim$ 1 MW 100 ns pulse at 17.142 GHz to the RF gun (the excess power from the klystron is directed into a linear accelerator). A bidirectional coupler samples

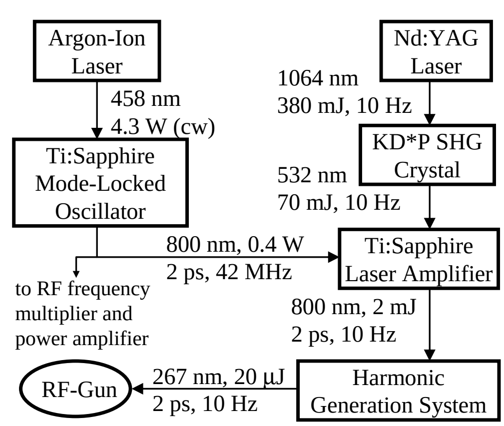

Figure 1: The laser system.

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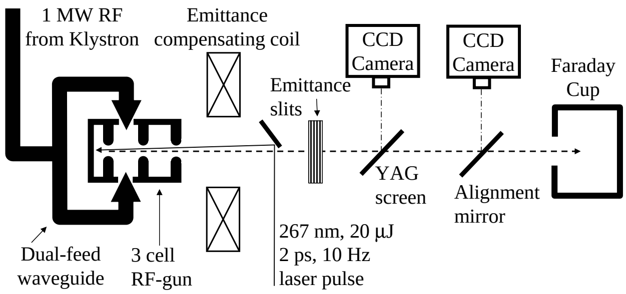

Figure 2: RF gun and diagnostic setup.

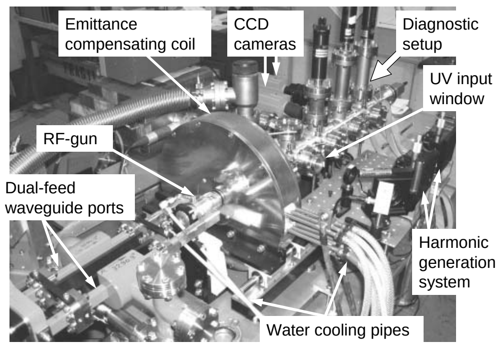

Figure 3: A picture of the RF gun and the diagnostic setup.

both the forward power into the RF gun, and the reflected power. The klystron is driven by a travelling-wave tube (TWT) amplifier where the input to the TWT is synchronized and phase-matched to the laser system.

The laser system is described in Fig. 1. It consists of a Ti:Sapphire laser amplifier that produces 2 ps 2 mJ pulses at 800 nm and 10 Hz. These pulses are tripled, by a harmonic generation system to UV light at 267 nm and are directed into the RF gun cathode. The laser amplifier is pumped by 532 nm 70 mJ pulses at 10 Hz repetition rate produced by an Nd:Yag laser and a KD*P second-harmonic generator crystal. The amplifier is seeded by 2 ps 800 nm pulses repetitive at 42 MHz from a Ti:Sapphire mode-locked laser oscillator. The oscillator is pumped by 4.3 W (cw) at 458 nm produced by an Argon-Ion laser. The Ti:Sapphire oscillator cavity is tuned around 42 MHz such that its mode-locking RF-frequency is multiplied by 408 to provide a synchronized 17.142 GHz signal that is subsequently phased-matched and amplified to stimulate electron emission from the RF gun.

The RF gun consists of a 3-cell water-cooled structure having radii of 0.2697”, 0.2722”, and 0.2713” for the first, second, and third cells, respectively. The middle cavity consists of a racetrack design having dual-feed coupling holes in order to achieve a highly symmetrical TM_{01} π-mode operation. The high symmetry is important for reducing the beam emittance. A water cooling system provides a frequency tuning ability of the RF gun cavity by 280 kHz/°C. A detailed description of the RF gun design is presented in Ref. [1].

The RF gun and its diagnostic setup are described in Fig. 2. A picture of our lab including the RF gun and the diagnostinc setup is presented in Fig. 3. The 1 MW input power from the klystron amplifier is injected into the second cavity through its dual ports. The laser pulse is directed through a UV mirror to the center of the copper end wall of the RF gun, the surface of which serves as a cathode. The electron-bunch emitted from the gun is focused by an emittance-compensating coil into a YAG screen. Steering coils are positioned along the beam-line in order to compensate for parasitic transverse magnetic fields. An image of the beam shape hitting the YAG screen is recorded by a CCD camera. A slit array can be lowered into the beam-line (or removed above it) in order to measure the beam emittance [6]. An alignment mirror can be lowered at the end of the beam-line in order to align the laser into the center of the RF gun cathode (in this case the YAG and slit array are removed up). The image is viewed by another CCD camera.

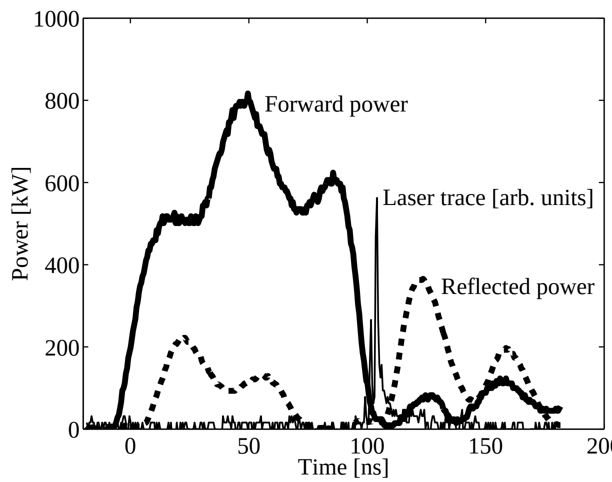

Figure 4: RF gun forward and reflected power traces (thick solid and dashed lines, respectively) and laser pulse trace (thin solid line).

EXPERIMENTAL STATUS

The RF gun is currently being RF processed up to a 1 MW power level. Scope traces of the 17.142 GHz forward and reflected power into and from the RF gun are shown in Fig. 4 in thick solid and dashed lines, respectively. It is seen that the forward pulse is ~ 700 kW for 100 ns. After 80 ns of cavity filling time, the reflected power is close to zero and the laser pulse is injected into the cavity. The laser is detected by a photodiode, and its trace is shown in Fig. 4 as a thin-solid line. (Note: due to length differences in the setup, the laser-trace lags about 20 ns after the RF traces).

For the input power shown in Fig. 4, a white spot indicating dark current was detected on the YAG screen. This image appeared regardless of the laser pulse, and disappeared at lower RF input powers. Its shape was sensitive to both the magnetic field strength of the emittance compensating coil and the steering coils. Its brightness, although not measured, appeared to be weak on the YAG screen.

FUTURE PLAN

Our future plan includes processing the RF gun up to a power level of 1.6 MW for 100 ns to achieve an electron beam energy of 2 MeV. We intend to measure the electron beam charge, emittance, and energy.

We might need also to improve a ~ 3 ps phase jitter between the RF and the laser pulses. The jitter in our system, as studied in [7] is mostly related to our laser system, and is a source of an energy jitter of the output bunch. New laser technologies can reduce this jitter to sub-picosecond levels.

ACKNOWLEDGEMENT

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