Experimental Study of a 17 GHz High Gradient Photocathode Injector

by

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Abstract

This thesis describes experimental research on a 17 GHz photocathode RF gun. This work represents the first operation of a photocathode electron gun at a frequency above 3 GHz. Photocathode RF guns have the potential for achieving record high values of electron beam quality. The 1 1/2 cell, π-mode, copper cavity was tested with 5-10 MW, 100 ns, 17 GHz pulses from a 24 MW Haimson Research Corp. klystron amplifier. Klystron power is stable to within ±5% up to 8 MW. The klystron output was made stable by the implementation of a Bragg filter as a replacement for a short as the termination to the RF gun coupling waveguide. The output of the klystron amplifier is phase locked to the input to within ±8° from shot-to-shot and less than ±4° on a single-shot basis. Conditioning of the RF gun structure with high power microwaves resulted in a maximum surface field of 250 MV/m, corresponding to an average on-axis gradient of 150 MV/m. Field emission or “dark” current of 0.5 mA was observed at 175 MV/m, consistent with Fowler-Nordheim field emission theory if a field enhancement factor of about 100 is assumed. Electron bunches were generated by a regenerative laser amplifier that produces 1.9 ps, 1.9 mJ pulses at 800 nm with ±10% energy stability. These pulses were frequency tripled to 46 μJ of UV with an efficiency of approximately 12%. Shot-to-shot ultraviolet pulse energy stability was 20%. Faraday cup beam measurements indicate that 0.12 nC bunches were produced with a kinetic energy of about 1 MeV. The electron bunches are approximately 0.3 mm long and 1 mm in diameter. This corresponds to a peak current of about 120 A, and a density at the cathode of 8.8 kA/cm². Phase scans of laser induced emission reveal an overall phase stability of better than ±20° corresponding to synchronization of the laser pulses to the microwave field with an error of less than ±3 ps.

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