INITIAL RF MEASUREMENTS OF THE CW NORMAL-CONDUCTING RF INJECTOR*

Frank L. Krawczyk#, Nathan A. Moody, Felix A Martinez, Gerald O. Bolme, Karen A. Young, Dinh C. Nguyen, Los Alamos National Laboratory, Los Alamos, NM 87545, USA
Lloyd M. Young, Advanced Energy Systems, Medford, NY 11763, U.S.A.

Abstract

The LANL 2.5-cell, normal-conducting radio-frequency (NCRF) injector has been fabricated [1]. We present initial results of low-power RF measurements (cavity Q, cavity field map, coupling beta, etc.) of the NCRF injector. The measured cavity Q and relative fields are found to be in good agreement with the design calculations and earlier measurements of Glidcop properties [2]. However, the coupling beta of the ridge-loaded waveguides is found to be significantly higher than the design point. The impact of these low-power measurement results on the planned high-power RF and electron beam tests will be discussed.

INTRODUCTION

A 2.5 cell, π-mode, 700 MHz normal conducting RF-photoinjector cavity has been designed and built. It is seen as a crucial building block for low emittance high average current source for a 100 kW CW FEL. The operation at a gradient of 7, 7 and 5 MV/m in the three accelerating cells requires an RF-input in excess of 700 kW. While simulations show that the thermal management of this operation is feasible, the first step is to verify the operation of this prototype cavity without generating any beam. This thermal test is presently under preparation at LANL and is well under way to be started in September and completed by the end of CY2008. The pre-start activities and findings for the test will be reported here. They include vacuum and cooling passage integrity, bakeout and low-power rf-properties.

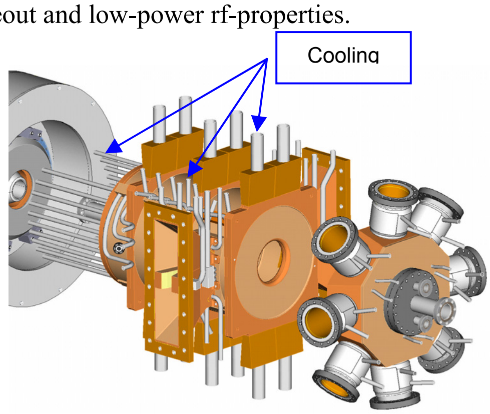

Figure 1: Exploded view of the photoinjector showing the cooling passages.

As the coupling from the ridge loaded waveguides to the cavity was different from the design point, a modification of the test setup for proper operation is provided also.

STRUCTURAL AND VACUUM INTEGRITY

Besides the RF-performance, leak tightness of the cooling channels and proper vacuum sealing were of concern. Tests of all cooling channels indicated proper flow rates and showed no leaks into the cavity volume or to the outside.

The testing of the vacuum sealing required the installation of all vacuum pumps on the unexcited fourth cell, the cathode port in the first cell and the ridge loaded waveguide (RLWG) sections. A total of 9 ion pumps, a non-evaporative getter pump and five turbo pumps have been used. The total pumping speed is 600 l/s. The challenging seal between the waveguide (SST) and the RLWG (Glidcop) has been done with an AL/CU/Ni 90 Alloy Helicoflex seal. The system showed a good vacuum seal with a leak rate of less than 1 10^{-10} Torr l/s.

BAKEOUT INFORMATION

For a first cleaning of the RF-surfaces the cavity and all secondary ports have been baked out in a two-step process. In the first baking step all cavity parts were heated up to 175^{o} C. The cavity was held at this temperature for 2 days. After cool-down the second bakeout period brought all parts of the cavity close to 150^{o} C. For homogeneity the heating was controlled by 12 independent temperature zones. The base pressure after the bakeout was 2-3 10^{-10} Torr. A cavity pressure in the low 10^{-10} Torr is needed for a good lifetime of future photocathodes.

Figure 2: Photoinjector wrapped in heating blankets for a bakeout that resulted in an excellent pre-test vacuum.

fkrawczyk@lanl.gov

* This work is supported by the Office of Naval Research and the High-Energy Laser Joint Technology Office.

LOW POWER RF-PROPERTIES

For the purpose of acceptance testing, all low power RF-properties of the cavity were measured before additional handling or installation of the cavity.

Cavity Q and Frequency

For the Q_0 measurement antennas have been added for on-axis electric coupling on the cathode cell and the unexcited fourth (vacuum) cell. The probes have been successively shortened until the loaded Q did not change anymore with the presence of the probes. From the measured loaded Q and the corrections for the coupling βs Q_0 has been determined to be reasonably close to the expected value from the Superfish [3] simulations (in parentheses). The Q_0 value thus determined is 29108 (32600) at a center frequency of 700.2 (700.35) MHz.

Field Profile Measurement

Another qualifying factor for the cavity is the proper ratio of field levels in the first 2.5 cells that needs to be 7, 7, and 5 MV/m, starting from the cathode cell. We set up a bead-pull measurement to obtain this ratio.

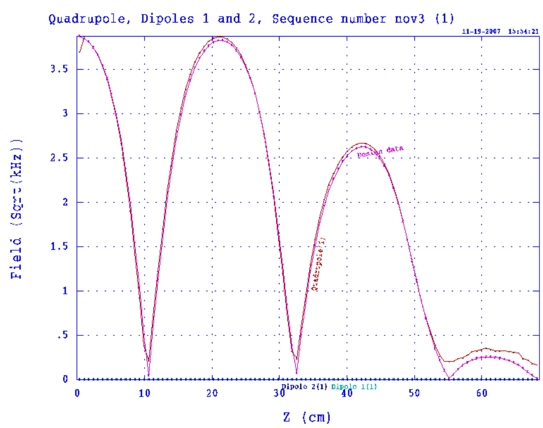

Figure 3: Comparison of the bead-pull measurement with the field distribution from Superfish. The agreement is better than 7%.

Waveguide Coupling

The high power operation of the photoinjector requires accurate knowledge of the coupling of the ridge-loaded waveguides (RLWG) to the resonator volume. As this system has two strongly coupled waveguide couplers standard s-parameter measurement procedures do not apply. Any measurement through one port will measure the response of a system consisting of the resonator loaded by the RLWG connected to the second port. The configuration in Figure 4 requires two measurements to derive the unloaded coupling βs. It also allows calibration of the connections as close as possible to the cavity. While the original design planned for under-coupled waveguide couplers, the measured coupling was slightly above unity. This variation required a modification of the original test configuration of the photoinjector without beam. While the original plan assumed a symmetric RF drive through two couplers, the as-is coupling requires a single RF-feed with the second RLWG blanked off.

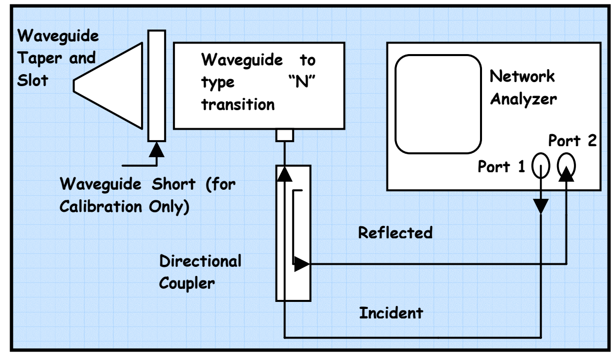

Figure 4: Calibration and coupling measurement for the waveguide couplers.

There are also some consequences for the operation with beam current. For the nominal current of 100 mA, a slightly larger reflected power than originally expected has to be handled.

Pick-up Probes

Four RF-pickup probes have been placed in cells 2 and 3 of the photoinjector. As the power into the cavity is very high, extra care has been taken to have strongly attenuated signals to protect the probes from damage. All four probes show an attenuation of –55dB or larger.

THERMAL TEST PREPARATION

Beyond the issues presented here, all facility preparations for the RF-test have been concluded. Pending the conditioning of the klystron, the test is scheduled to begin in the middle of September 2008.

CONCLUSIONS

A novel RF-photoinjector for a high average current CW FEL has been built and installed in our test laboratory. Over the last year mechanical and RF-properties have been evaluated and the test stand was configured for a high power RF-test without beam. The photoinjector has passed all inspections prior to this high power test.

REFERENCES

[1] Sergey S. Kurennoy et al., "Normal-conducting High Current Photoinjector for High-Power CW FEL", PAC05, Knoxville, USA

[2] Frank L. Krawczyk et al., "RF-Loss Measurements in an Open Coaxial Resonator for Characterization of Copper Plating", PAC07, Albuquerque, USA

[3] Los Alamos Accelerator Code Group Repository: http://laacg.lanl.gov/