COLD TEST OF AN L-BAND, 2-CELL PWT PHOTOELECTRON*

Yan Luo and David Yu, DULY Research Inc., Rancho Palos Verdes, CA 90275
T. Khabiboulline and R. Andrews, Fermi National Accelerator Laboratory, Batavia, Illinois 60510

Abstract

An L-band, 2-cell PWT gun with a coax coupler has been designed as a polarized electron source by DULY Research Inc. A cold test model was fabricated and is currently undergoing test at Fermilab, where the gun will eventually be hot tested. The cold test model is made of aluminum including an RF/vacuum sieve, 2 disks, endplates, 6 supporting rods and a 6” CF flange, clamped together during testing. Fermilab made measurements for the cavity resonant frequency and axial field distribution using bead pull. To measure the resonant frequency of the cavity small diameter probes are placed through the vacuum sieve slot into the cavity. For the real gun, active frequency and field tuner(s) can be inserted into the cavity in a same manner. This paper presents results of the cold tests and compares measurements with simulated results from 3D code Omega3p. The axial field distributions are in good agreement. Frequency deviation is less than 0.05%, well within the experimental accuracy.

INTRODUCTION

A standing-wave, 2-cell, L-band, π-mode PWT photoinjector (Figure 1) with an open cavity is formed between an iris-loaded disk that is supported and cooled by water pipes anchored to the endplates. A GaAs photocathode is placed at the opening in the center of the back endplate. The structure has an open annular space between the disk outer edge and the cavity wall. In our polarized electron PWT gun design, the outer cavity wall is a sieve that has longitudinal slots providing UHV pumping paths. The width and thickness of the slots are chosen so that the RF wave is evanescent inside. A coaxial TEM-like standing wave in the annular region is coupled to a TM01-like mode on the axis of the cavity. The RF input coupler uses a coax design similar to the TESLA gun [1]. This design allows the PWT cavity to be connected to a UHV pumping chamber housing non-evaporative getters (NEG). Two emittance compensating solenoids are located close to the cathode.

Table 1: Beam parameters at the ILC main linac entrance

Train Repetition Rate (Hz)	5
Bunches per Train	2820
Bunch Spacing (ns)	307
Train Length (ms)	1.0
Charge per Bunch (nC)	3.2
Energy (GeV)	5
Horizontal Emittance $\gamma\varepsilon_x$ (μm)	8
Vertical Emittance $\gamma\varepsilon_y$ (μm)	0.02
Bunch Length σ_z (mm)	6

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A 2-cell L-band PWT gun that operates in ultra high vacuum (UHV) can produce a high quality polarized electron beam with a peak field of only 20 MV/m on axis, powered by a 2.5 MW klystron. The beam can meet the International Linear Collider (ILC) specifications (Table 1 [2]) with a bunch charge of 3.2 nC, and an RF pulse a 1.4 ms long with a 5 Hz rep rate [3]. The normalized rms emittance of an RF gun is intrinsically better than the DC-gun. While a sufficient field gradient is necessary in these guns for the photoelectron bunches to be captured and accelerated in the RF buckets, the relatively low gradient in the PWT guns needed to produce a good emittance beam is a special feature that has beneficial effects to ameliorate back bombardment of secondary electrons at the cathode [4], and to lessen dark current production [5], both critical for the survivability of a negative electron affinity (NEA) semiconductor photocathode [6].

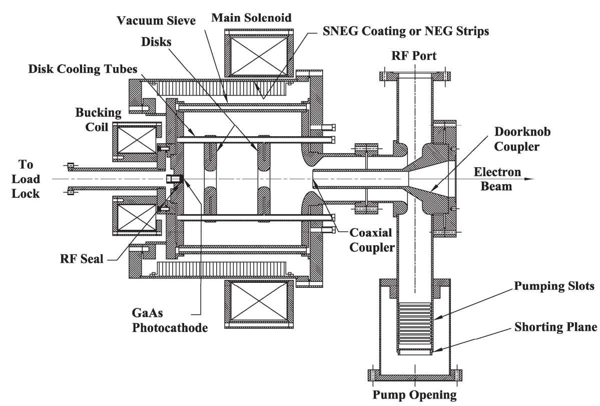


Figure 1: Schematics of an L-Band PWT polarized electron photoinjector.

The baseline PWT design comprises two (2) iris-loaded copper disks that are cooled and supported by six (6) water carrying, copper-plated stainless steel pipes. The cavity outer boundary is defined by the inner diameter of a stainless steel, slotted sieve (Figure 2) that is cooled by forty-eight (48) imbedded water-cooling channels. The coupling of the PWT cavity to external rf power is achieved by means of a coaxial coupler. It critically couples the external rf power into the cavity for the operating mode at 1300 MHz. The high-vacuum PWT structure accommodates, at the center of the back endplate, an activated GaAs cathode that produces a polarized electron beam when the cathode is illuminated by a polarized 800 nm laser beam.

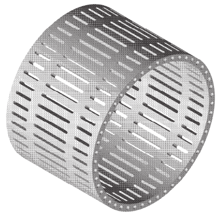
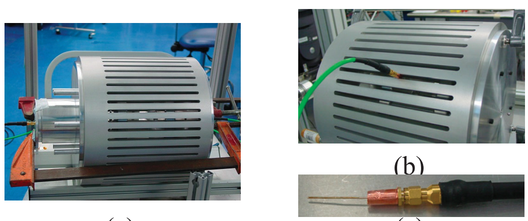


Figure 2: Isometric view of PWT sieve with segmented slots.

COLD TEST AND SIMULATION RESULTS

The cold test model was made of aluminum including a vacuum sieve, 2 disks, 2 endplates, 6 rods and a 6” CF flange. There is no cooling channel in the cold test model which is not brazed. The model is clamped together during testing. The experimental setup for cold test model at Fermilab is shown in Figure 3. PWT Cavity dimensions before tuning are shown in Table 1.



(a) (b) (c)

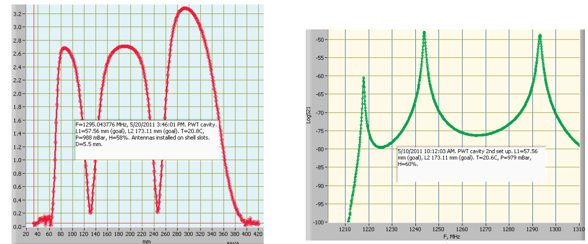
Figure 3: Pictures for cold test model (a) Set up for cold test; (b) A probe is placed through the vacuum sieve slot; (c) A field probe.

Table 2: PWT cavity dimensions (mm) with 6 supporting rods

Iris aperture (disk inner radius)	15.00
Iris thickness	26.48
Distance between two disks	11.53
Disk outer radius	97.23
Radius of the rod central position	83.26
Rod radius	6.35
Outer rounding radius of the disk	11.17
Inner rounding radius (for aperture)	4.48
Stainless tank inner radius	144.62
Initial vacuum sieve length	271.8

Comparison of measurements with simulations

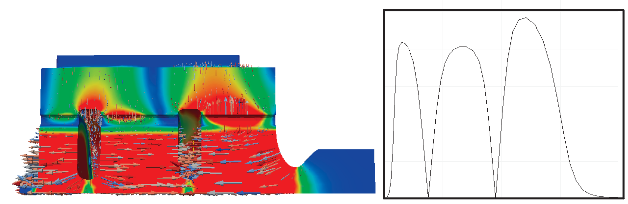
Fermilab made a set of measurements for cavity resonant frequency and axial field distribution. The axial electric field distribution is measured by pulling a bead through the openings in both endplates and measured the frequency shift at various positions of the bead on axis. To measure resonant frequency of the cavity a small size probe (diameter of 0.9 mm and length of 20 mm) is placed through a vacuum sieve slot (see Figure 3b). The results of measurements are compared with simulations using the Omega3p code with the cold test model geometry.



(a) (b)

Figure 4: Electric field magnitude vs axial distance from Fermilab measurement (a) and S-parameters (b) for cold test model.

The measured electric field profile and S parameters are shown in Figure 4a and Figure 4b respectively. There are three peaks in Figure 4b. The π mode is the correct mode we need which is at frequency around 1295 MHz before cutting sieve length to tune the frequency.



(a) (b)

Figure 5: Electric field distribution (a) and field magnitude vs axial distance (b) from Omega3p code [7].

The calculated axial electric field distribution for the cold test model is shown in Figure 5. The axial distance for simulations and measurements is about 0.38 m. Comparing field distributions from Figures 4a & 5b we can see that the field distributions are similar from measurement and simulation. The frequency measured is f = 1295.04 MHz, simulated result is 1294.9048 MHz. They are very close to each other, less than 0.05%. The significant figure from the measurement is limited, causing the difference between measurement and simulations.

Figure 4a shows the variation of on-axis electric field measured by bead–pull. The field flatness of experimental and simulation results are also in good agreement. In both cases, the maximum electric field amplitude of the last cell is a little higher (< 18%) than those of the other two cells of the rf cavity.

Tuning Sensitivity

The resonant frequency of PWT cavity can be tuned by cutting the vacuum sieve length. We made the initial length of the vacuum sieve a little longer than the design value, which is at 271.8mm. PWT cavity dimensions are shown in Table 2. The Omega3p simulation results of resonant frequency vs sieve length are shown in Figure 6. The tuning sensitivity was derived from the slope of fitted function for PWT cavity with the value of 1.188 MHz/mm. During operation, the tuning sensitivity by

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adjusting water temperature inside disk cooling channel is at 0.04 MHz/°C.

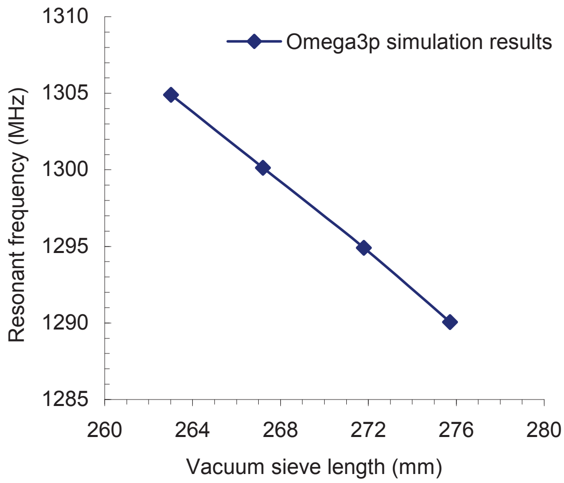


Figure 6: PWT cavity tuning sensitivity from Omega3p code.

Active Tuner

A larger size magnetic coupler can be used as active tuner. Inserting two symmetrically placed loops through sieve slots in the last cell of PWT cavity can tune the resonant frequency. The axial distance between the centre of active tuner and the surface of cathode endplate is fixed. The frequency can be tuned higher or lower by adjusting the radial position of the tuners. To simplify the modelling in Omega3p simulations, sieve slots are not included in the simulation because it does not have much effect on frequency and axial field (Figure 7).

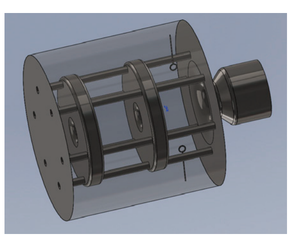


Figure 7: L-Band 2-cell PWT gun model with two probes.

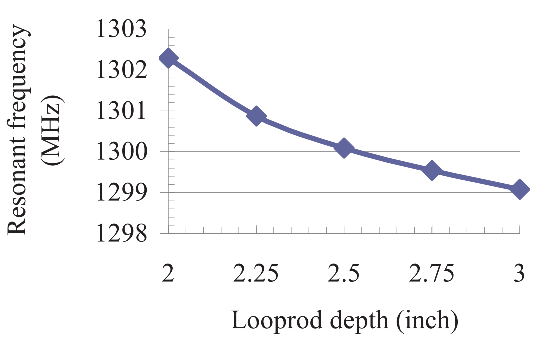
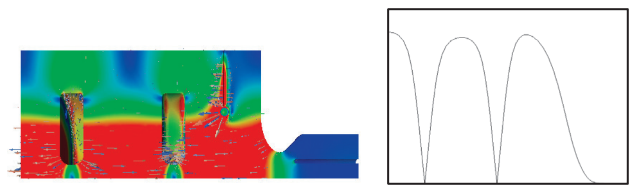


Figure 8: PWT cavity resonant frequency vs probe (looprod) depth.

We made a set of runs with Omega3p code by inserting two symmetric tuners through sieve slots. Figure 8 shows the PWT cavity resonant frequency versus tuner depth. Basically we used two tuners of rod with loop at the end. The outer diameter of the rod is 1.5875 mm; loop outer diameter is 12.7 mm and inner diameter is 9.525 mm. At the probe position of 63.5 mm, the resonant frequency is at 1300.0905 MHz that is very close to the operating frequency of the cavity. For the real PWT cavity the frequency will go down after we put the rf power into the cavity. In addition to the active tuners, another option is to use water temperature to further tune the frequency.

Another advantage of using active tuners is that it can improve field flatness of the cavity (see Figure 9 (b)). The field flatness is less than 5% with two active tuners comparing at 18% without active tuners.



(a) (b)

Figure 9: PWT 2-cell gun electric field distribution (a) and field magnitude vs axial distance (b) without sieve from Omega3p code.

CONCLUSION

A standing-wave, 2-cell, L-band photoelectron gun using the Plane-Wave-Transformer (PWT) design can meet ILC injector parameters. A cold test model was fabricated by DULY Research Inc. The cold test measurements from Fermilab are in good agreement with our simulation results with 3D code Omega3p.

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