SW/TW HYBRID PHOTOINJECTOR AND ITS APPLICATION TO THE COHERENT THZ RADIATION

Atsushi Fukasawa#, James Rosenzweig, David Schiller, UCLA, Los Angeles, CA 90095, USA
D. Alesini, M. Ferrario, B. Spataro, INFN/LNF, Frascati, Italy
L. Ficcadenti, A. Mostacci, L. Palumbo, Rome Univ., Rome, Italy.

Abstract

An S-band SW/TW hybrid photoinjector is being developed under the collaboration of UCLA, LNF/INFN, and University of Rome. In Parmela simulation it produces 240-fs (rms) bunch with 500 pC at 21 MeV. The bunch distribution has a strong spike (54 fs FWHM) and the peak current is over 2kA. As the bunch form factor at 1 THz is 0.43, it can produce coherent radiation at 1 THz. We are considering three types of way to generate it; coherent Cherenkov radiation (CCR), superradiant FEL, and coherent transition/edge radiation (CTR/CER). CCR used hollow dielectric with the outer surface metallic-coated. OOPIC simulation showed 21 MW of the peak power (5 mJ) at 1 THz. For FEL and CTR/CER simulation, QUINDI, which was written at UCLA to solve the Lienard-Wiechert potential, was used to calculate the radiation properties. In the contrast to CCR, their spectra were broad and their pulse lengths were short. They will be useful for fast pumping.

INTRODUCTION

A unique SW/TW hybrid photoinjector is being developed to produce a high brightness beam under the collaboration of UCLA, LNF/INFN, and University of Rome [1]. It consists of a hybrid gun and a travelling wave structure (Figure 1). They are connected in series to feed from one RF source. A hybrid gun has standing-wave and travelling-wave cells in it as shown in Figure 2. A standing-wave part works like a normal one-half photocathode RF gun. The travelling wave part acts as a velocity bunching cells. The beam was put on the zero-crossing phase by choosing the proper length of the input coupler cell (L = 5λ/12). After the gun, it enters the next travelling wave structure where it gets velocity bunching again.

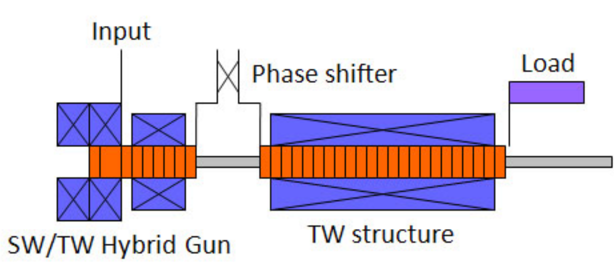

Figure 1: Hybrid photoinjector.

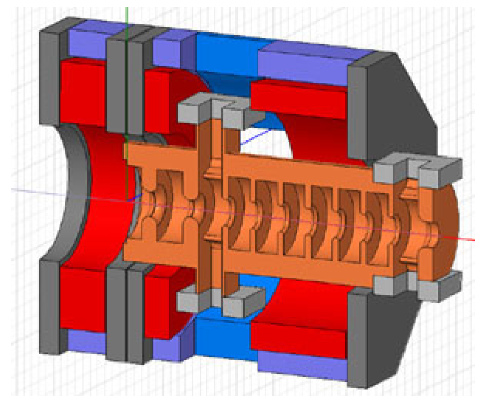

Figure 2: SW/TW hybrid gun.

CAVITY DESIGN

The cavity was designed by using HFSS [2]. The couplers have dual-feed structure to kill the dipole mode which comes from the field of the waveguide or the power flow. They have also a racetrack shape to minimize the quadrupole effect. The input power was assumed to be 25 MW, and the peak power in the standing wave structure is designed to have 60 MV/m (Figure 3). Because the standing wave cell is axially coupled, the iris size must be properly chosen to get the designed value.

The cavity design is being fabricated at INFN/LNF.

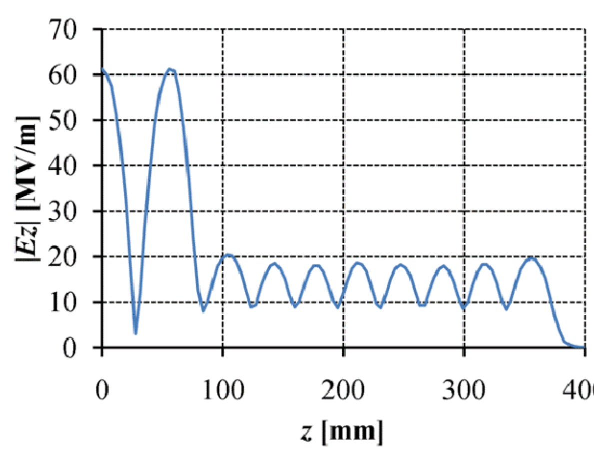

Figure 3: Field amplitude of the hybrid gun.

#fuka@ucla.edu

BEAM DYNAMICS

The beam dynamics in the hybrid photoinjector was simulated by using PARMELA [3].

The evolution of the beam in the photoinjector is shown in Figure 4. With proper phase and solenoid field, all of the beam emittance, envelope, and length are decreasing at the same time. The final beam distributions in the case of maximum bunching are shown in Figure 5 and beam parameters are summarized in Table 1. There is a strong spike in the longitudinal bunch shape. Its peak current exceeds 2 kA with 54 fs of FWHM. The slice emittance also has spikes, which is as high as 3.7 mm.mrad, at the same position due to the mixing of the slices. This bad slice emittance might be harmful to some applications like production of coherent short wavelength radiation. However, there are many applications which does not require extremely low emittance, for example, THz radiation production.

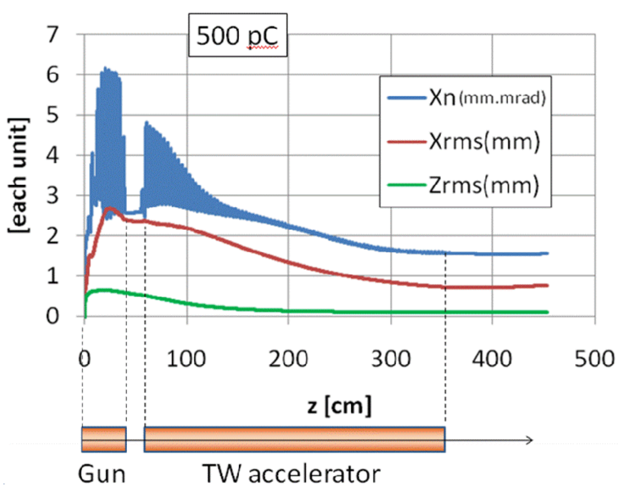

Figure 4: Beam dynamics in the hybrid photoinjector. Blue (top) is the normalized emittance; Red (middle) is the beam envelope; Green (bottom) is the rms bunch length.

Table 1: Beam parameters

Charge	500 pC
Energy	21.04 MeV
Xrms	1.48 mm
Emittance x	2.1 mm.mrad
Trms (FWHM)	210 fs (54 fs)
Erms	1.3 %
Bunch Form Factor @1THz	0.43

COHERENT THZ RADIATON

To generate coherent radiation, the bunch length must be shorter than the wavelength of the radiation. The bunch form factor of the beam from the hybrid photoinjector is 0.43 at 1 THz. This means that the beam is well compressed to produce coherent radiation at 1 THz.

There are several ways to produce coherent THz radiation. We are considering coherent Cherenkov radiation, coherent transition/edge radiation, and superradiant FEL.

Coherent Cherenkov Radiation

The coherent Cherenkov radiation (CCR) is produced as wakefield in a hollow dielectric tube with metal cladding (Figure 6). In the dielectric tube, the modes which has the same phase velocity as the beam was excited and the modes are well defined by the inner and outer radii of the dielectric layer.

OOPIC simulation was performed and the results are listed in Table 2. The peak power was 79 MW and the total energy was 5 mJ.

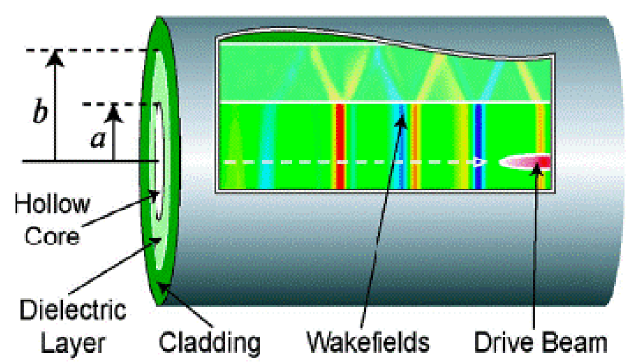

Figure 6: Dielectric tube for CCR

Table 2: OOPIC results of CCR

Charge	500 pC
Inner Radius	77 µm
Outer Raius	115 µm
Fundamental Frequency	1 THz
Peak Power	79 MW
Ez	570 MV/m
Total CCR Energy	5 mJ

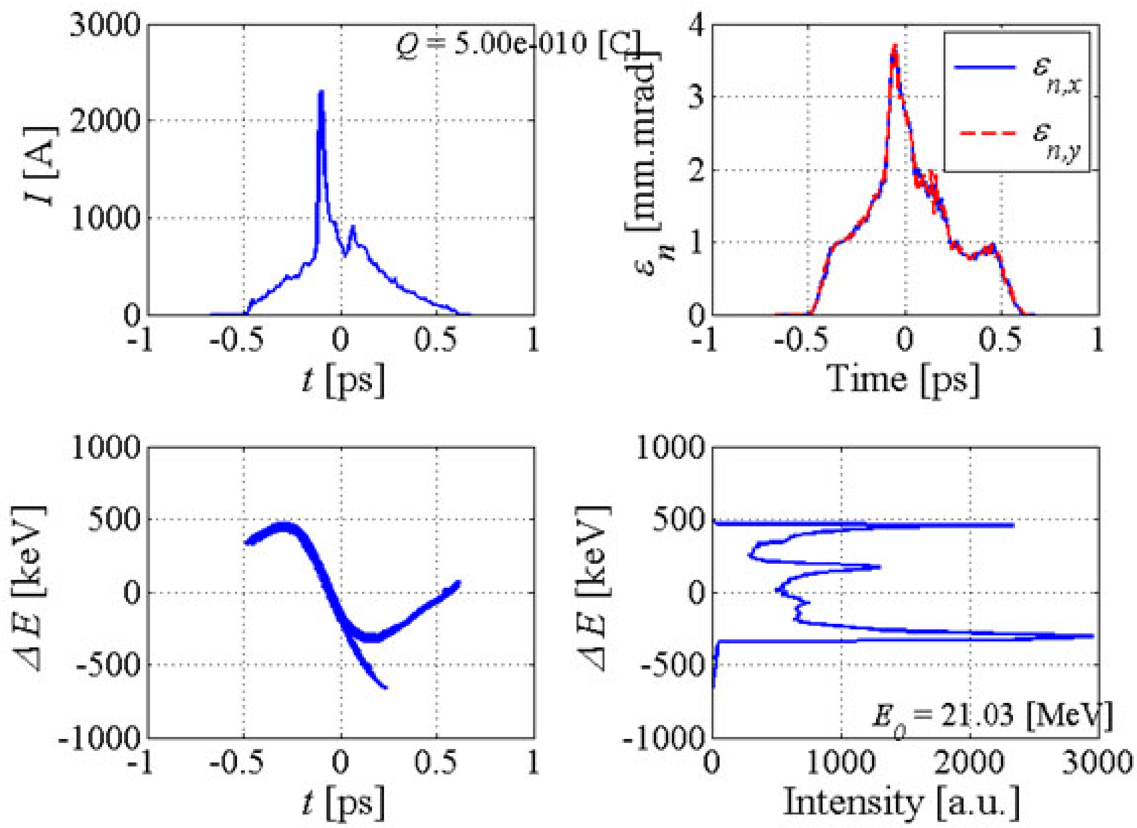

Figure 5: Beam distributions of the hybrid photoinjector. Top left is the bunch shape. Top right is the slice emittance. Bottom left is the distribution in the t-E phase space. Bottom right is the energy spectrum.

Transition/Edge and Undulator Radiation

The coherent transition/edge radiation is a very simple method to get coherent THz radiation. The undulator radiation from the beam compressed down to much less than the radiation wavelength is expected to be a super-radiant FEL. A simulation code QUINDI is being developed at UCLA to calculate a radiation from electron beam. It has succeeded to simulate edge radiation spectrum, and now being updated to simulate the coherent undulator radiation.

SUMMARY

An SW/TW hybrid photoinjector is being developed at UCLA to produce a high brightness beam via velocity bunching. The cavity design had finished and being fabricated at INFN/LNF. The PARMELA simulation showed the photoinjector can produce more than 2kA peak current with 3.7 mm.mrad of the slice emittance (the projected emittance is 2.1 mm.mrad). The bunch form factor at 1 THz is 0.43 by this beam. The OOPIC simulation shows CCR peak power was 79 MW 5mJ. QUINDI is being developed to simulate the radiation from the beam in the magnetic field.

REFERENCES

[1] A. Fukasawa et al., "Beam dynamics and RF cavity design of an standing/travelling-wave hybrid photoinjector for high brightness beam generation", In the proceedings of PAC09, Vancouver, Canada, FR5PFP056.

[2] Ansoft, http://www.ansoft.com/.

[3] LAACG Codes/Databases, http://laacg1.lanl.gov/laacg/services/serv_codes.phtml

[4] Tech-X Corporation, http://www.txcorp.com/

[5] D. Schiller et al., "QUINDI – A code to simulate coherent emission from bending systems", In the proceedings of PAC07, Albuquerque, NM, THPAS054, 3612 (2007); http://pbpl.physics.ucla.edu/Computing/Code_Development/QUINDI/

[6] G. Andonian et al., "Observation of coherent terahertz edge radiation from compressed electron beams", Phys. Rev. ST AB 12, 030701 (2009).