APPLICATION OF THE SYNRAD3D PHOTON-TRACKING MODEL TO SHIELDED PICKUP MEASUREMENTS OF ELECTRON CLOUD BUILDUP AT CesrTA

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Abstract

We present calculations of synchrotron radiation photon reflection in the vacuum chamber at the Cornell Electron Storage Ring Test Accelerator (CesrTA), applying them as input to the electron cloud buildup code ECLOUD to model time-resolved local measurements with shielded pickup detectors. The recently developed synrad3d photon-tracking code employs a reflection model based on data from the Center for X-Ray Optics at LBNL. This study investigates the dependence of electron cloud buildup on the azimuthal position of photoelectron production on the vacuum chamber wall.

INTRODUCTION

This work utilizes two simulation codes synrad3d [2] and ECLOUD [1] to model the results from shielded pickups (SPU) a free electron detector placed in a drift section of the Cornell Electron Storage Ring Test Accelerator (CesrTA). Comparing the simulation to data will allow us to study the effects of the beam chamber design on the photon distribution around the perimeter of the chamber, and how that changes the the photoelectron signal in the SPU.

METHOD

Simulations

Synrad3d simulates the generation and propagation of synchrotron radiation(SR) through the storage ring [2]. The generated photons are allowed to reflect off the chamber wall, following reflectivity data from the Berkeley Center for X-Ray Optics, Fig. 1. All reflections are specular and elastic. The flux of photons around the perimeter of the ring is input into ELCOUD [1] to simulate the dynamics of the electron cloud buildup. The primary and secondary photons are assumed to produce photoelectrons with a quantum efficiency specified by the ECLOUD input. Results from the ECLOUD simulation are compared to SPU data to study the parameters of electron could buildup.

Shielded Pickup Data

Time resolved SPU studies at CesrTA use witness bunches to measure electron cloud dynamics. Witness bunch measurements use two positron bunches, the first starts the EC growth and the second excites the bunch to be measured by the SPU. Using different spacings the dynamics of the cloud can be studied. The SPU data shown in Figs. 3 and 6 use this method of data acquisition. The electron signal prior to 14 ns is created by photoelectrons generated on the bottom of the chamber walls. The photon flux required to reproduce this part of the SPU data will be discussed in this paper, focusing on radiation from a 5.3 GeV positron beam.

* Work supported by the U.S. National Science Foundation PHY-0734867, PHY-1002467, and the U.S. Department of Energy DE-FC02-08ER41538

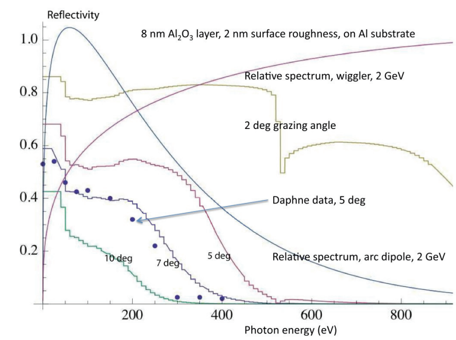

Figure 1: An example of the reflectivity of photons on a specified surface. Data was taken from the Berkeley Center for X-Ray Optics [4] and Daphne [7]. Plot courtesy of G. Dugan.

SMOOTH WALL RESULTS

Initially synrad3d simulations were done using a simplistic wall file approximating the CesrTA chamber wall as an ellipse with major and minor axes of 45 mm and 25 mm, respectively. The photon flux around the perimeter of the chamber as a function of angle, ϕ Fig. 4. The bottom of the chamber is defined by the angles π to 2π. From Fig. 2, a photon flux of 0.02 photons/m/beam particle/radian was absorbed on the bottom of the chamber surface.

The signals in Fig. 3 were modeled assuming a quantum efficiency for reflected photons of 30%. This electron flux is also seen in the detector, Fig. 3.

REALISTIC WALL RESULTS

The simulations were repeated with a more realistic CesrTA chamber. This chamber is similar to an ellipse on the

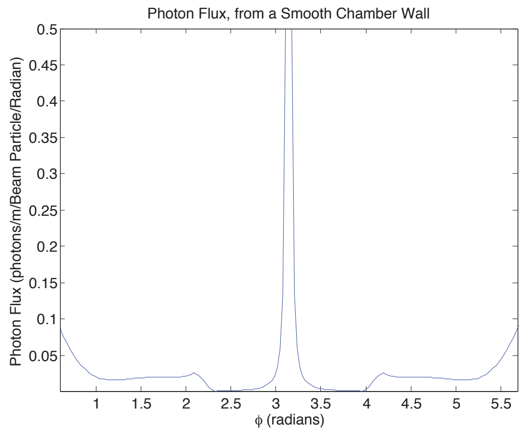

Figure 2: Photon flux around the perimeter of the chamber walls, assuming a simple ellipse.

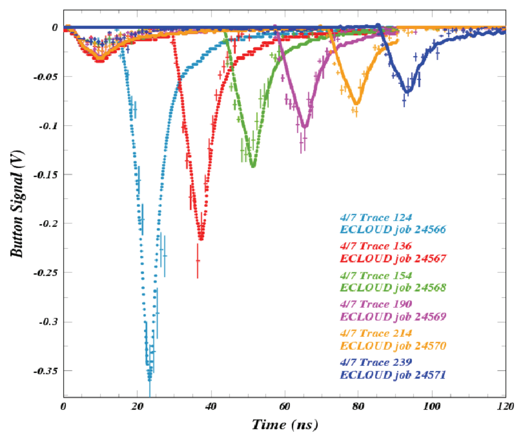

Figure 3: Shielded pickup data compared to synrad3d and ECLOUD simulation results assuming the vacuum chamber is an ellipse.

top and bottom of the chamber, but the sides are flat, Fig. 4.

The flat sides of the chamber reduces the photon flux on the top and bottom of the chamber, Fig 5. The flux on the bottom of the chamber is reduced by 70% to 0.006 photons/m/beam particle/radian, as compared to the elliptical chamber.

Simulations done with ECLOUD show no photoelectron signal at 14 ns in the detector from this low photon flux. The decrease in photon flux is from the shape of the vacuum chamber. The elliptical shape in the smooth wall allows the photons to reflect with a greater vertical angle when scattering near the y-axis. In the realistic chamber these photons are reflecting off a flat surface and not gaining that same vertical scattering angle needed for them to be absorbed on the top or bottom of the chamber wall. The photoelectron signal in the SPU is created by a process not currently being simulated. The lack of simulated signal from a realistic chamber shape shows that our elastic and specular photon reflection model is not complete.

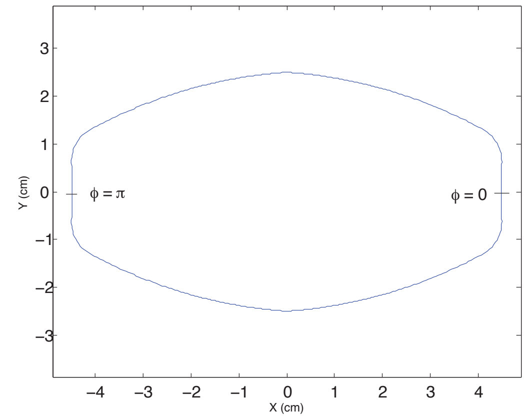

Figure 4: X-Y cross section of the realistic wall at the SPU. The angles presented are the normalized angles in the flux plots 2 and 5.

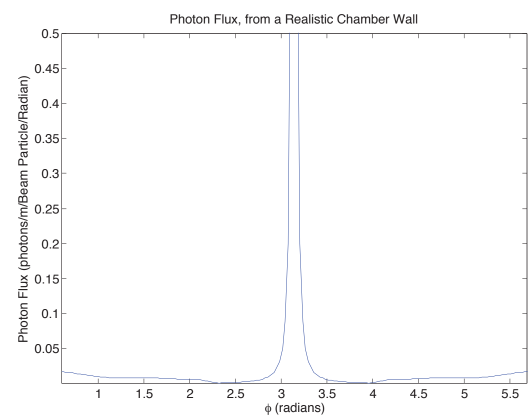

Figure 5: Photon flux around the perimeter of the chamber walls, assuming a chamber perimeter.

DIFFUSE SCATTERING

Measurements of the surface roughness of the LCLS beam chambers show that the rms surface roughness is between 75 and 400 nm [5] [6]. Currently synrad3d assumes a surface roughness of 4 nm [2]. A rough surface will increase the diffuse scattering of the photons, requiring synrad3d to be updated to include diffuse scatters. The roughness of the surface is described by σ/λ [3] where σ is the rms roughness of the surface and λ is the wavelength of the synchrotron radiation (SR), between 124 nm and 0.124 nm for CesrTA. A surface is considered very rough when $\sigma/\lambda >> 1$. In this regime there is no specular scattering and our synrad3d model is no longer complete. Currently work is being done to update the synrad3d reflection model to include diffuse scattering. The angle of diffuse scattering is dependent on the photons grazing angle, Fig 7.

The greater the grazing angle the more diffuse the photon scatters. To understand the effects of diffuse vs specular scattering a simple rectangular chamber was modeled with synrad3d. The rectangle has the same major and mi-

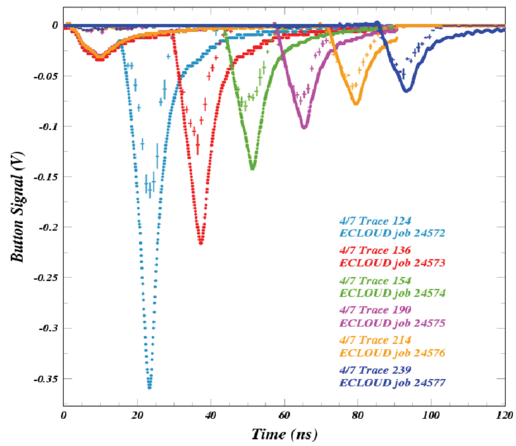

Figure 6: SPU signal compared to simulations done assuming a realistic wall.

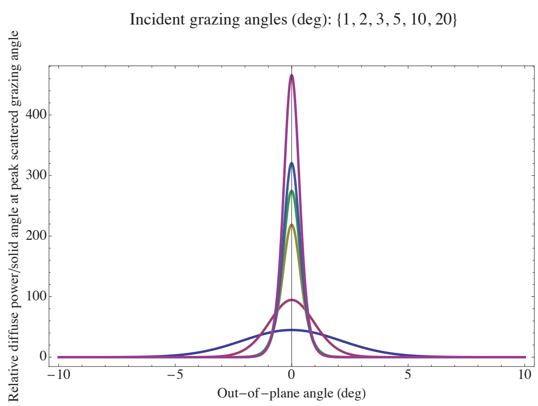

Figure 7: The diffuse scattering angle as a function of photon grazing angle.

nor axes as the ellipse, 45 mm and 25 mm respectively. The grazing angles of the photons in CesrTA are all smaller then 5°, so it was assumed that all photons had a diffuse scattering angle of 1° per reflection. Assuming the photon is absorbed longitudinally in the same location, a new x,y, absorption point was calculated for each photon assuming each photon had a diffuse scattering angle of ϕ from its last reflection. The results, Fig. 8, show that without diffuse scattering there is no photon flux on the top or bottom of the chamber. Even with simple diffuse scatter model the photon flux on the top and bottom of the chamber increases to 0.08 photons/m/beam particle/radian. The rectangular chamber wall will underestimate the photon flux on the top and bottom of the chamber.

CONCLUSIONS

Comparing the photon flux from a smooth walled chamber and a more realistic chamber design it was found that the shape of the vacuum chamber is important in simulating photon reflections. In addition to a realistic chamber

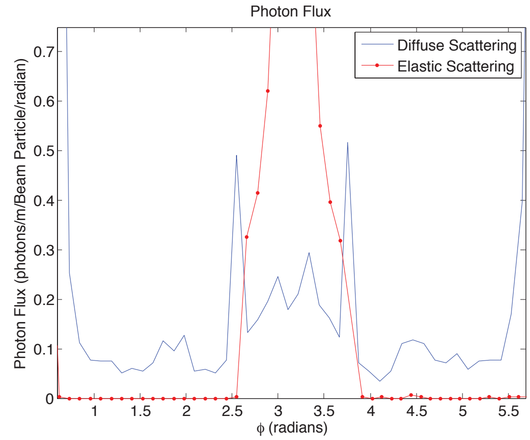

Figure 8: Photon flux around the perimeter of the chamber walls, comparing elastic scatter to diffuse scatters with a rectangular chamber wall.

wall definition the reflection difference of specular and diffuse scattering can change the photon flux and therefore the detected photoelectrons. With a very rough surface diffuse scattering dominates. Increasing the photon flux on the top and bottom of the chamber perimeter. These results will be tested with an updated synrad3d.

This work is supported by U.S. Department of Energy, Office of Sciences under contract no. DE-AC02-06CH11357. CLASSE work supported by the U.S. National Science Foundation PHY-0734867, PHY-1002467, and the U.S. Department of Energy DE-FC02-08ER41538

REFERENCES

[1] F. Zimmermann and G. Rumolo, ICFA Beam Dynamics Newsletter No. 33, eds. K. Ohmi and M.A. Furman (2004)

[2] G. Dugan, D. Sagan, "Synrad3D Photon propagation and scattering simulation", Proc. ECLOUD10

[3] G. Dugan. "Photon Reflectivity Update" Presented at the CesrTA Collaboration Meeting (August 23, 2011) https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/CollabMeetings#Meeting_Materials

[4] Gullikson, E. "X-Ray Interactions With Matter" http://henke.lbl.gov/optical_constants/mirror2.html

[5] K. Harkay and L. Boon, "Aluminum vacuum chamber surface roughness analysis - part 2," presented at the CesrTA Electron Cloud Meeting (July 27, 2011) http://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/ElectronCloud

[6] L. Assoufid, Private Communication.

[7] N.Mahne, A Giglia, S. Nannarone, R. Cimino, C. Vaccarezza, EUROTEV-REPORT-2005-013