Application of the SYNRAD3d Photon-Tracking Model to Shielded Pickup Measurements of Electron Clound 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 and kinetic energy distribution of photoelectron production on the vacuum chamber wall.

INTRODUCTION

This work utilizes two simulation codes synrad3d and ECLOUD to model the results from shielded pick-ups (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 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. 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 position 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 code can be studied. The SPU data shown in Figs. 3 and 6 use this method of data acquisition. The first flux of electrons at 14 ns is created by photoelectrons

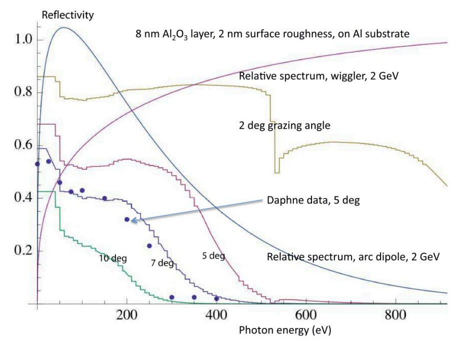

Figure 1: An example of the reflectivity of photons on a specified surface. Data was taken from the Berkeley Center for X-Ray Optics [4] and Daphne [6]. Plot courtesy of G. Dugan.

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.

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.

Assuming a quantum efficiency (QE) of 30% a photoelectron signal is detectred 14 ns after the first bunch passes the SPU. 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 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 30% to 0.006 photons/m/beam particle/radian, as compared to the elliptical chamber.

Simulations done with ECLOUD show no photoelectron

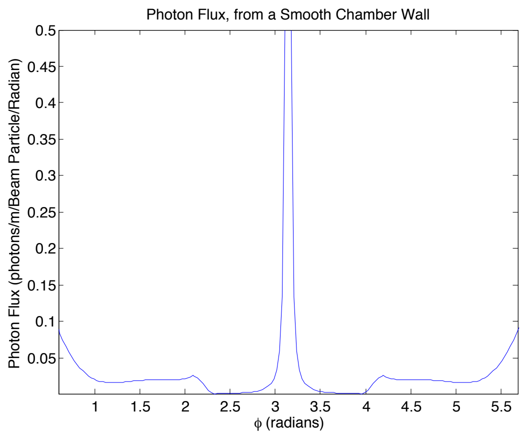

Figure 2: Photon flux around the perimeter of the chamber walls, assuming a simple ellipse.

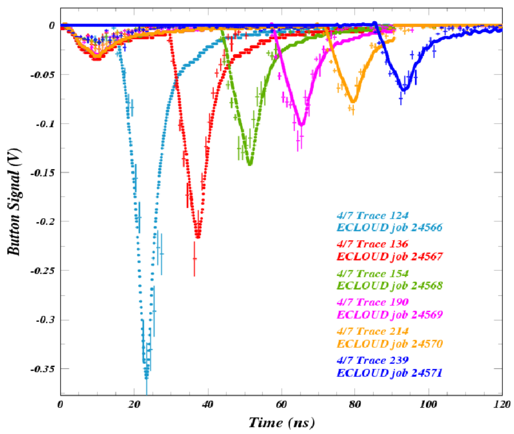

Figure 3: Shielded pickup data compared to synrad3d and ECLOUD simulation results assuming the vacuum chamber is an ellipse.

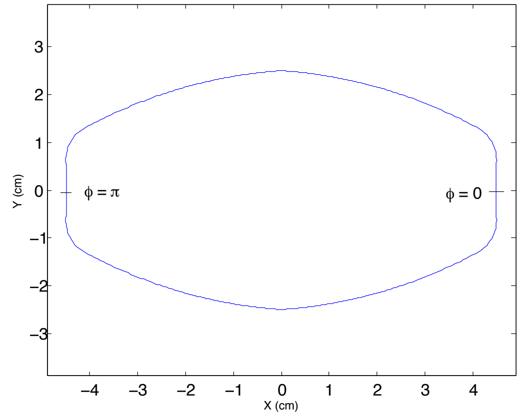

Figure 4: X-Y cross section of the realistic wall at the SPU. The angles presented are the normalized angles in the flux plots 2 and 5.

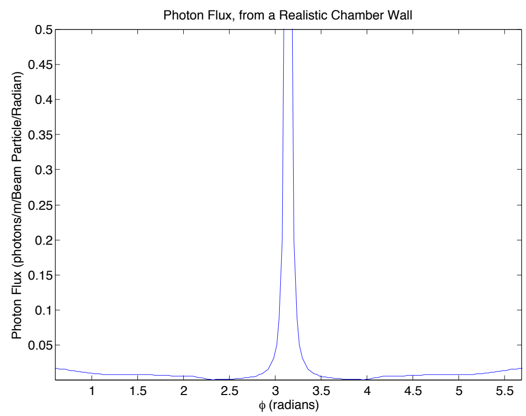

Figure 5: Photon flux around the perimeter of the chamber walls, assuming a chamber perimeter.

flux at 14 ns in the detector from this low photon flux. Which is needed to match the data. 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 seen by 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.

DIFFUSE SCATTERING

Measurements of the surface roughness of the LCLS beam chambers show that the rms surface roughness is between 75 and 400 nm [3]. The rougher surface will increase the diffuse scattering of the photons. 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 affects of diffuse vs specular scattering a simple rectangular chamber was modeled with synrad3d. The rectangle has the same major and minor 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 still had the same absorption location in s, a new x,y, absorption point was calculated for each photon assuming each photon had a diffuse scattering angle of n° from its last re-

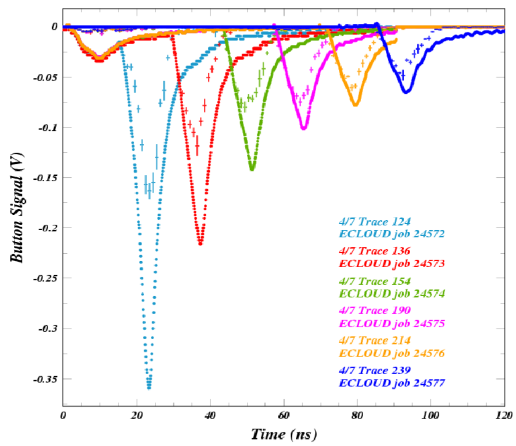

Figure 6: SPU signal compared to simulations done assuming a realistic wall.

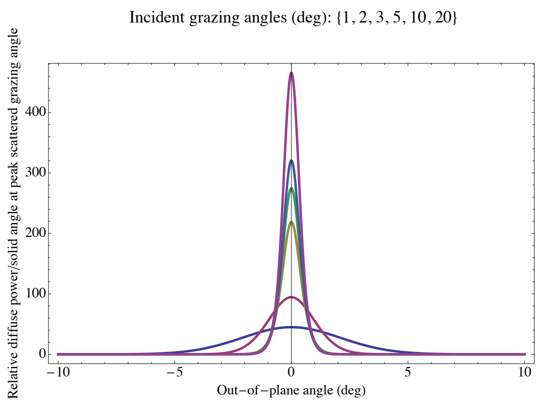

Figure 7: The diffuse scattering angle as a function of photon grazing angle.

flection. 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 diffuse scattering of the photons.

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 wall definition the reflection difference of specular and diffuse scattering can change the photon flux and therefore the shape 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.

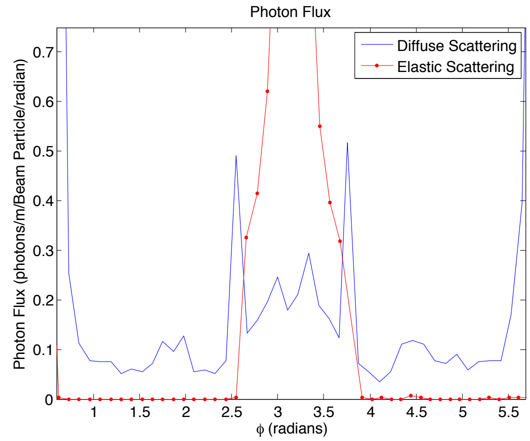

Figure 8: Photon flux around the perimeter of the chamber walls, comparing elastic scatter to diffuse scatters with a rectangular chamber wall.

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