Observation of Wakefields in Coherent Synchrotron Radiation at the Canadian Light Source

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Observation of Wakefields and Resonances in Coherent Synchrotron Radiation

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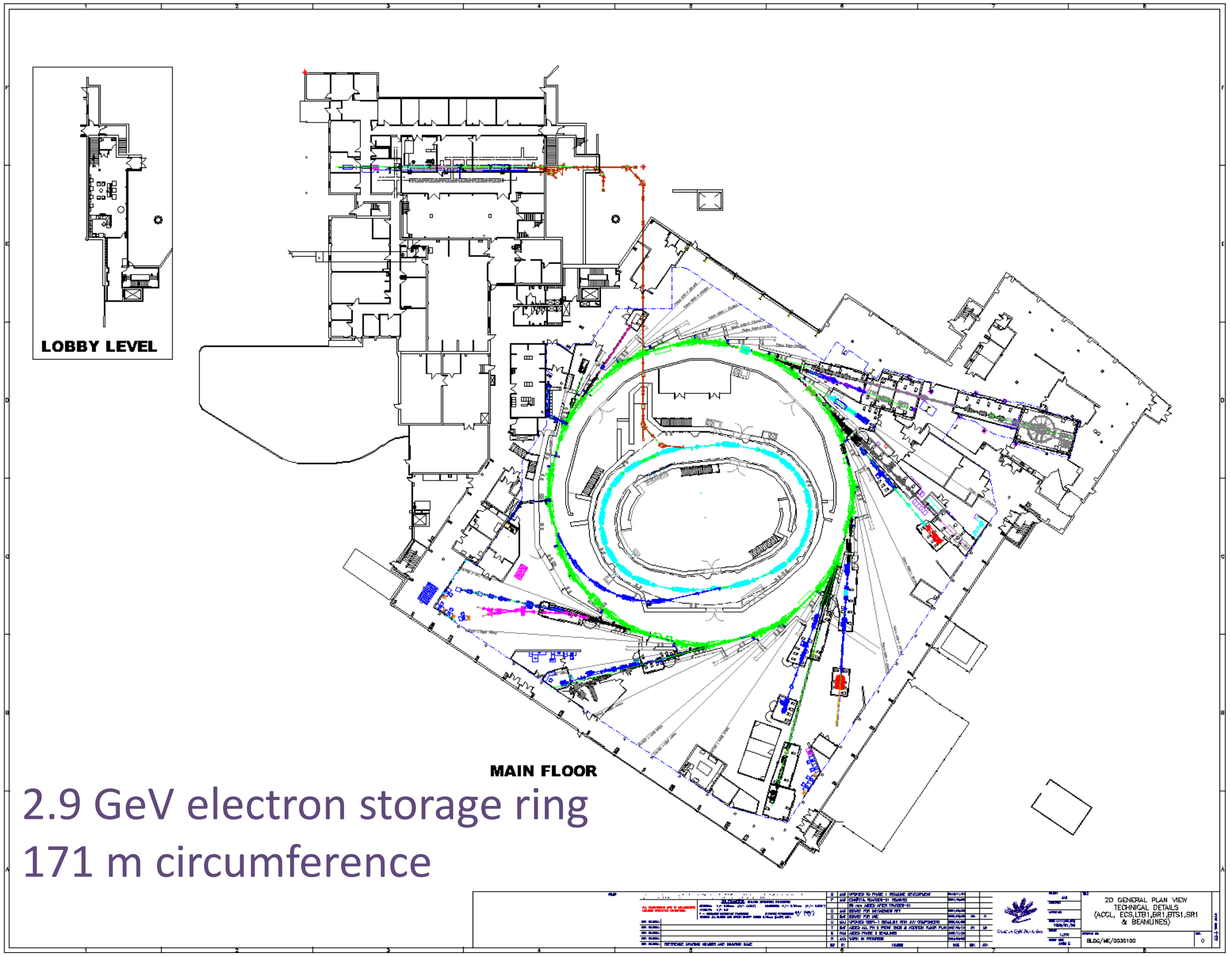
Introduction

- Electrons in a synchrotron have an electromagnetic wake
- We can observe radiation from these wakefields in the GHz and THz frequencies
  - Michaelson interferometer
  - RF diodes
- We can calculate the structure of these wakefields and compare against observations

Synchrotron Radiation Facilities



2.9 GeV electron storage ring
171 m circumference

Coherent Synchrotron Radiation (CSR)

- Electron synchrotrons produce electromagnetic radiation – synchrotron light – with wavelengths from the far-infrared to the hard x-ray
- Normally, the electrons radiate incoherently, so the radiated power is proportional to the number of electrons, N
- If the wavelength of radiation is on the same order of magnitude as the length of the electron bunch, the electrons radiate coherently and the power is proportional to the square of the number of electrons, N^2

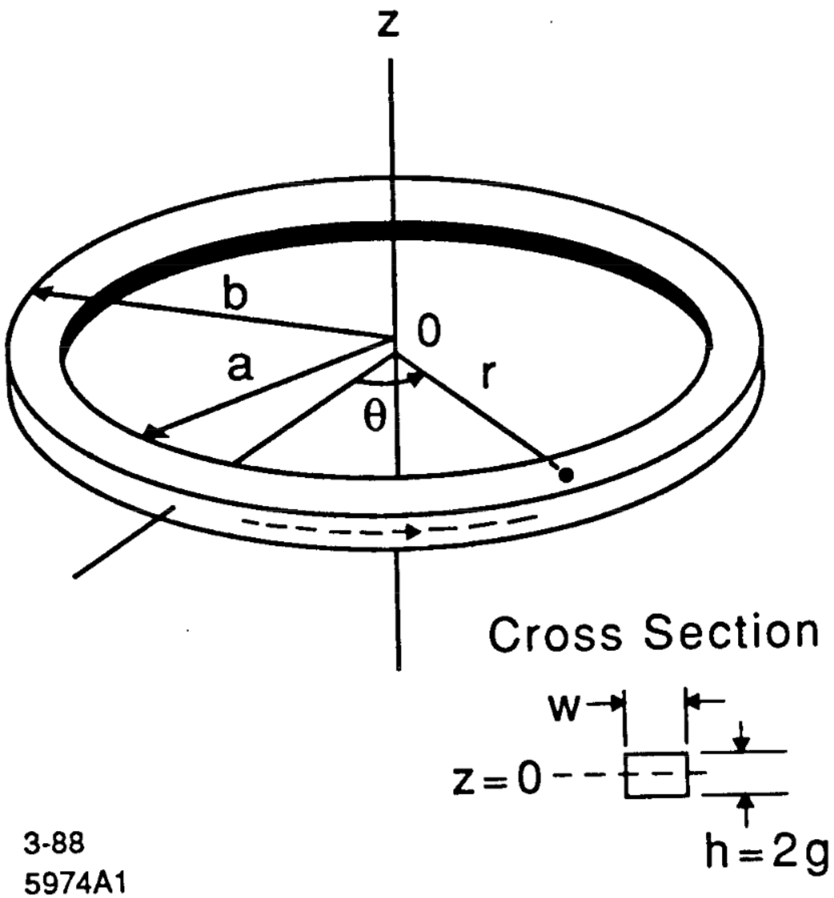
Wakefields

- A relativistic particle bunch moving along a curved trajectory within a conducting metallic chamber is accompanied by an electromagnetic wake generated by the interaction of the bunch with the chamber

Toroidal Model

- We can model the storage ring as a idealized torus
- Wakefield consists of a train of equally-spaced, localized pulses

$$\Delta z \approx \frac{2}{3}\left[\frac{8(b-r)^3}{r}\right]^{1/2}$$



R. Warnock and P. Morton, SLAC-PUB-4562, Figure 1

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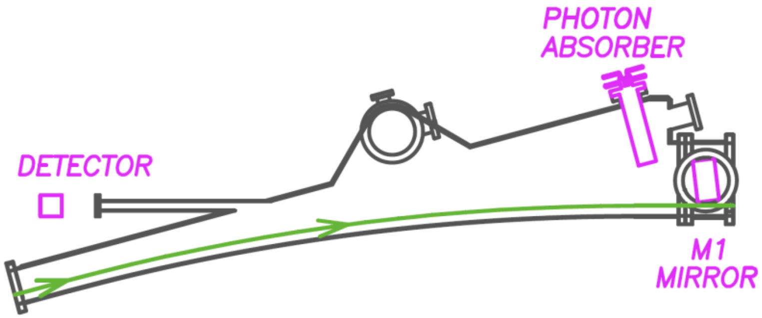
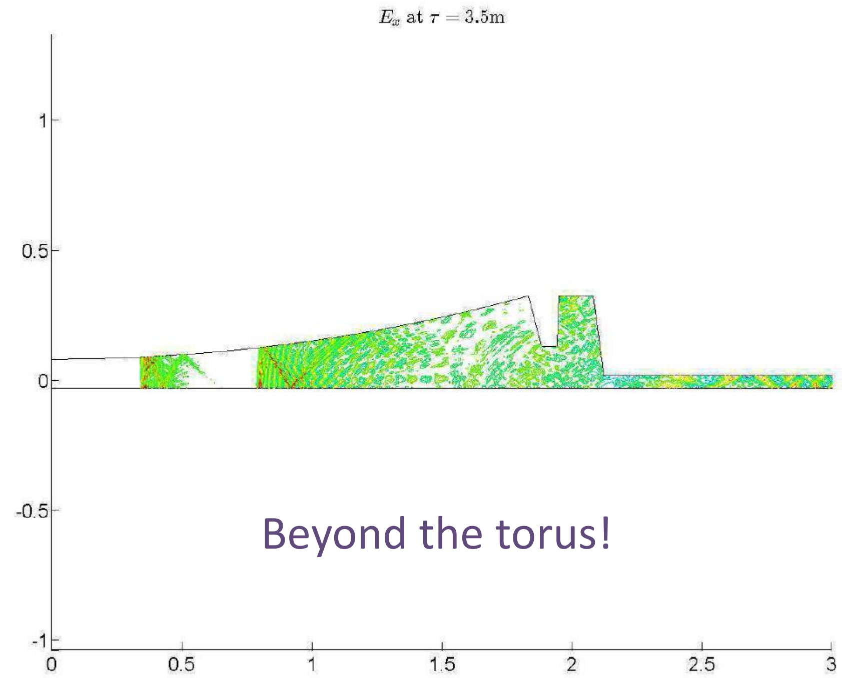
Vacuum Chamber Geometry

Real Chamber



Definitely not a torus…

Finite-Element Simulation Chamber



Beyond the torus!

Interferometer Measurements

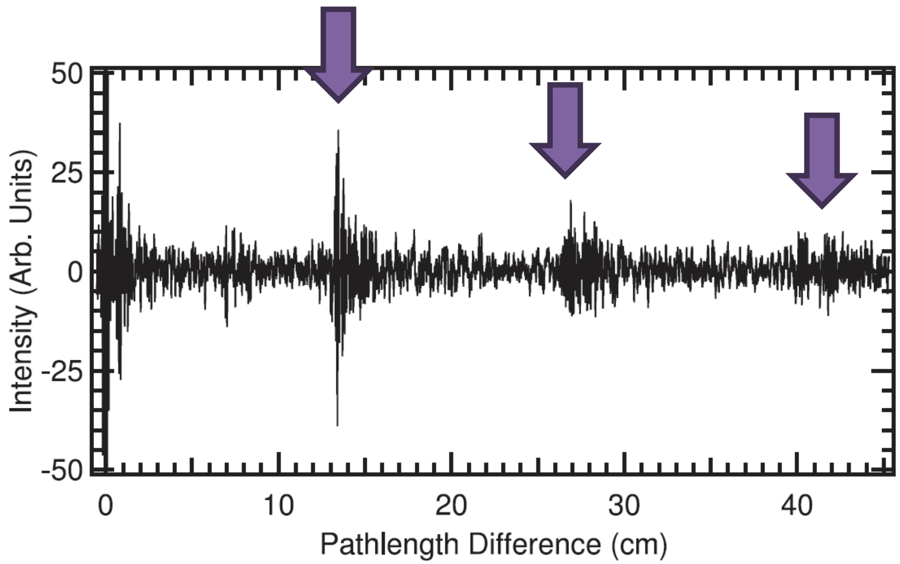


FIG. 1. Interferogram as a function of path length difference.

Michaelson interferometer on the FarIR beamline at CLS during CSR production

Note the strong interference patterns at 13.5 cm, 27 cm and 41 cm

The Fourier transform shows fine structure at wavenumber spacing 0.074 cm^{-1}, the reciprocal of 13.5 cm. This structure is very stable under changes in machine configurations.

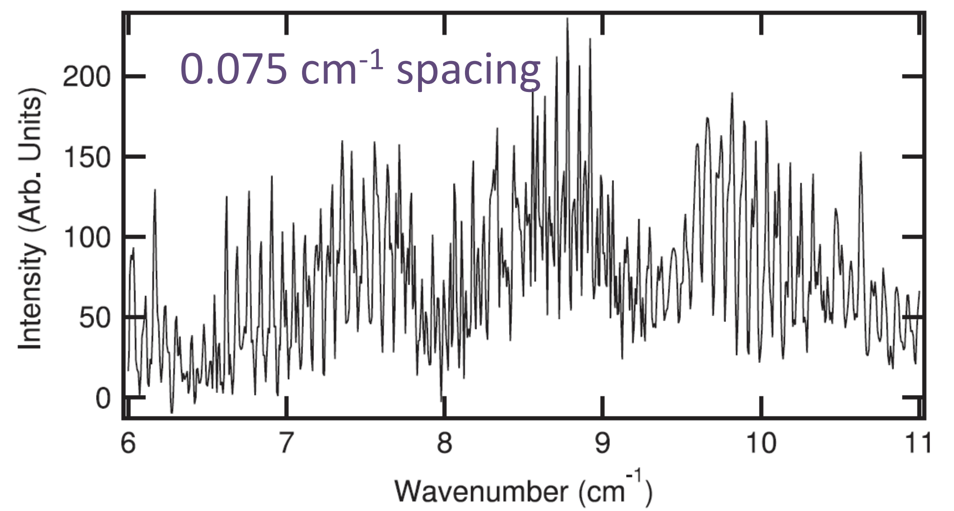


FIG. 2. Fourier transform of the interferogram.

RF Diode Measurements

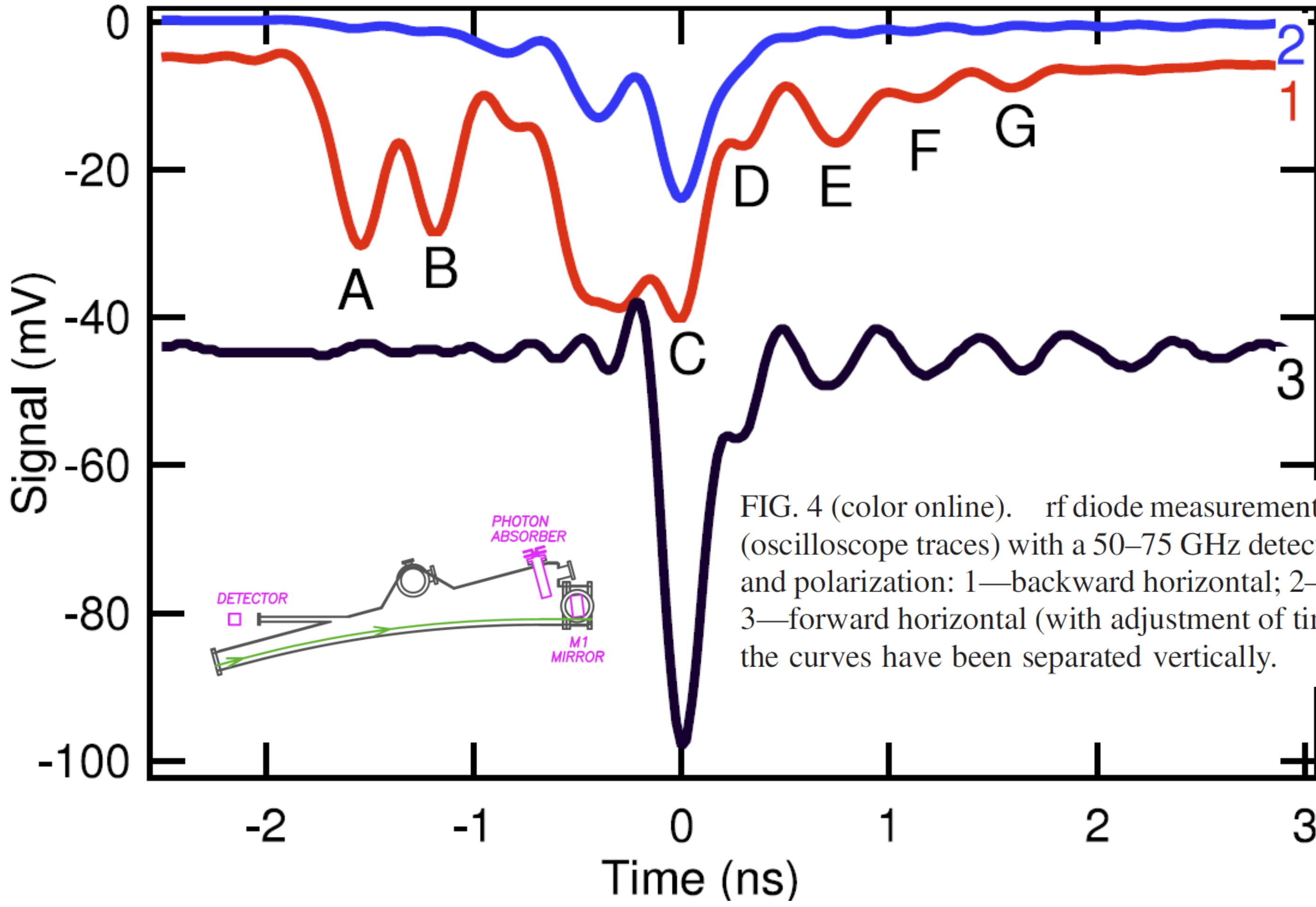
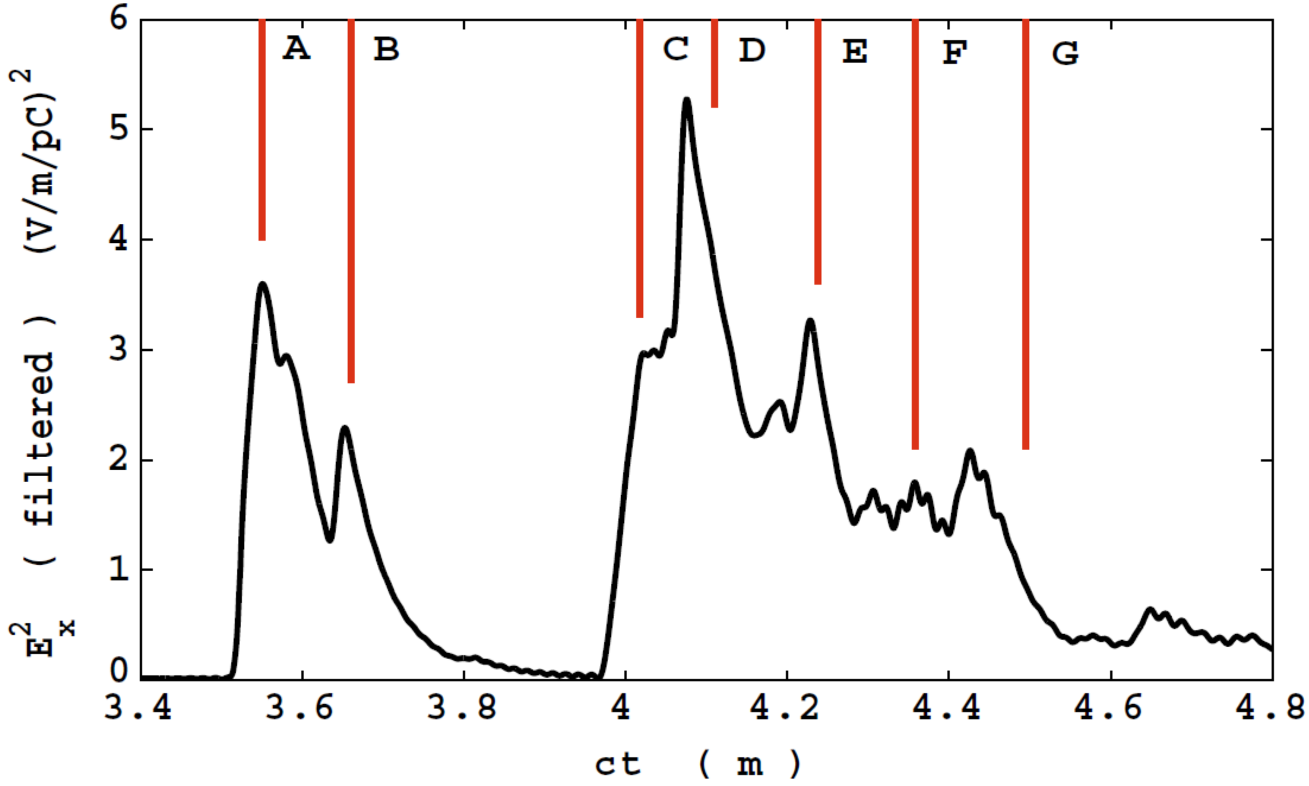
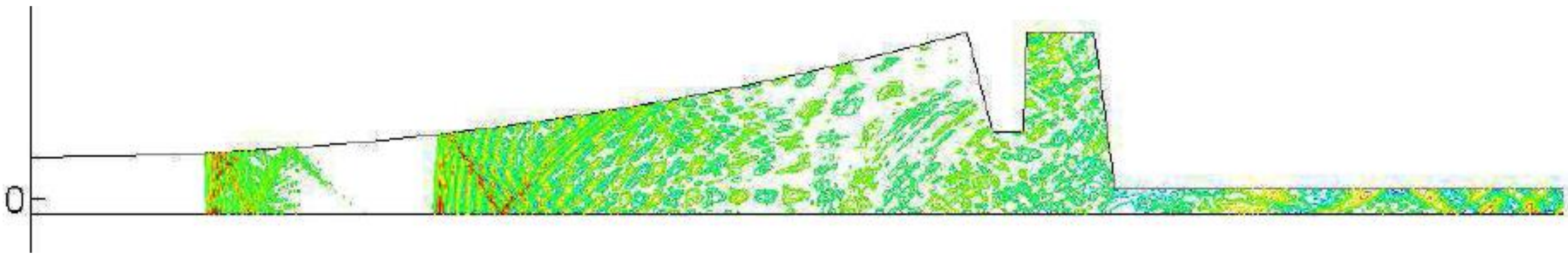


FIG. 4 (color online). rf diode measurements in the time domain (oscilloscope traces) with a 50–75 GHz detector. Diode mounting and polarization: 1—backward horizontal; 2—backward vertical; 3—forward horizontal (with adjustment of time base). For clarity the curves have been separated vertically.

Simulation Results





Conclusion

- In view of our rudimentary modeling of the reflecting structures, the resemblance to experiment seems quite satisfactory
- The simulation techniques, validated here, can be applied to next-generation machines such as high-intensity colliders
- We can potentially design a vacuum chamber that supresses the wakefield radiation, which is a significant problem for high resolution infrared spectroscopy with CSR

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