Mathematically Modeling Synchrotron Radiation

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Introduction

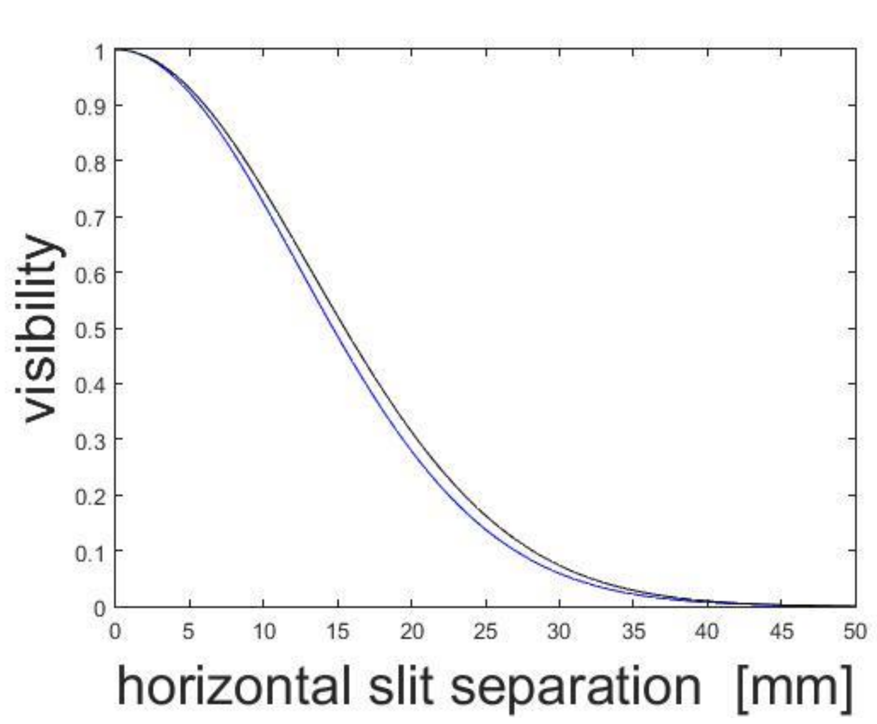
The diagnostic beam line station at the Stanford Synchrotron Radiation Lightsource uses visible light emitted from the SPEAR 3 Synchrotron in order to perform beam diagnostics, including measuring horizontal beam size.

In order to do this, an interferometer has been set up to measure transverse coherence in terms of visibility.

The mathematical model for visibility contains beam size as a single unknown variable.

We manipulate this single variable until modeled curves match the measured data.

The current model takes into account the Incoherent Depth of Field (IDOF) effect using a Gaussian approximation for the Synchrotron Radiation (SR) beam opening angle instead of the full "Schwinger equations".



Objectives

This project has three goals:

1. Replace the approximation with the correct theoretical model.

2. Understand the difference between the Gaussian approximation and the Schwinger horizontal SR beam emission patterns.

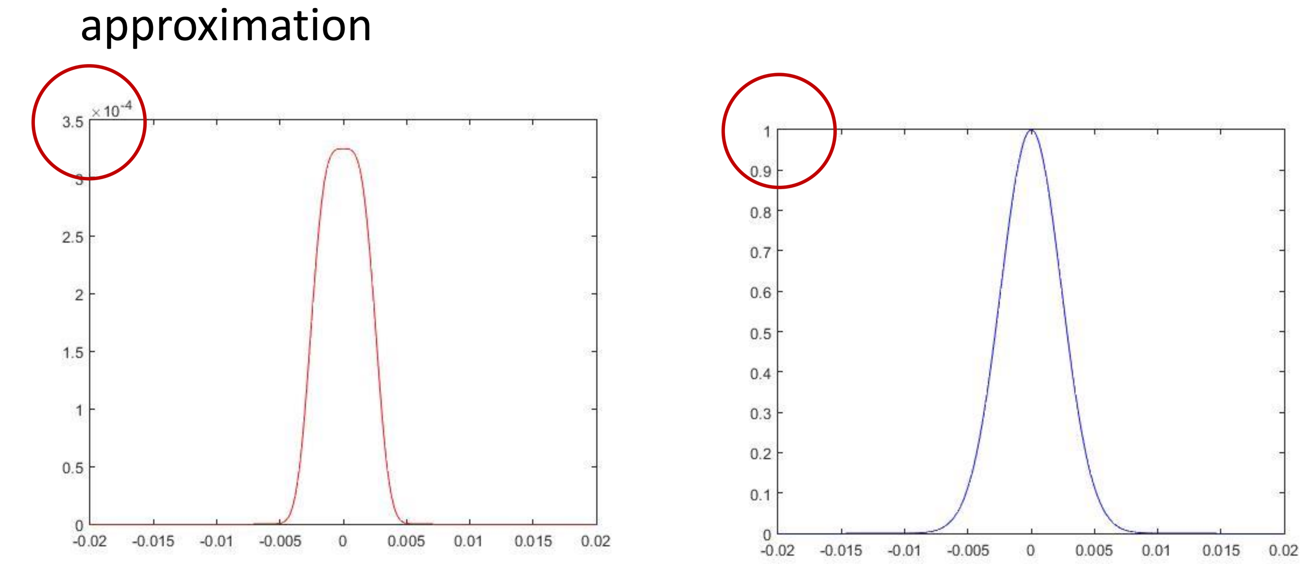
3. Compare the new model to measured data in order to infer beam size more accurately.

Methods

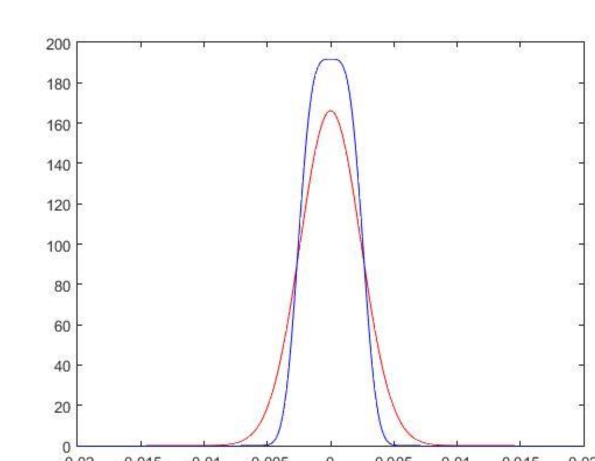
1. Understand what IDOF integral represents

$$\int_{x_1}^{x_2}\int_{\theta_1}^{\theta_2} \frac{2\sqrt{e^{\frac{-(\theta+\frac{D}{2f})^2}{2\varphi^2}} * e^{\frac{-(\theta-\frac{D}{2f})^2}{2\varphi^2}}}}{e^{\frac{-(\theta+\frac{D}{2f})^2}{2\varphi^2}} + e^{\frac{-(\theta-\frac{D}{2f})^2}{2\varphi^2}}} * \frac{e^{-\frac{(x-R(1-\cos(\theta)))^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}} * \frac{e^{-\frac{\theta^2}{2\varphi^2}}}{\varphi\sqrt{2\pi}} * \cos(2\pi * \frac{D * x}{f * \lambda})\, d\theta\, dx$$

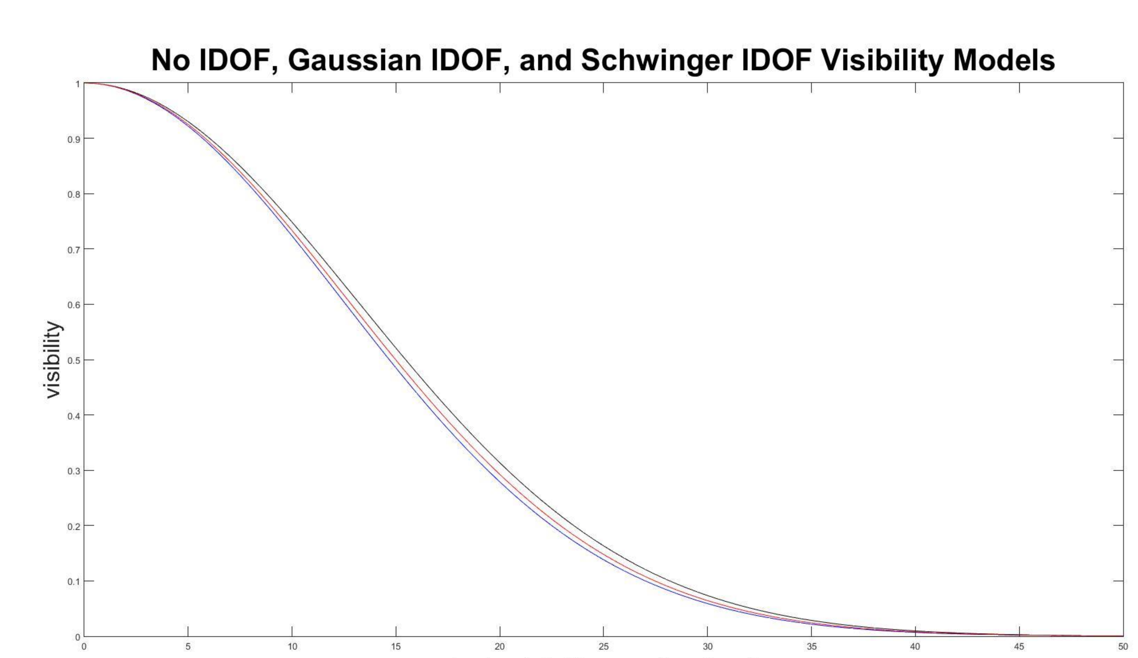
2. Compare Schwinger Polarization curve (red) to Gaussian (blue) approximation



3. Find the normalization factor for a Schwinger horizontal polarization curve



4. Replace all intensity Gaussian approximations with Schwinger curves

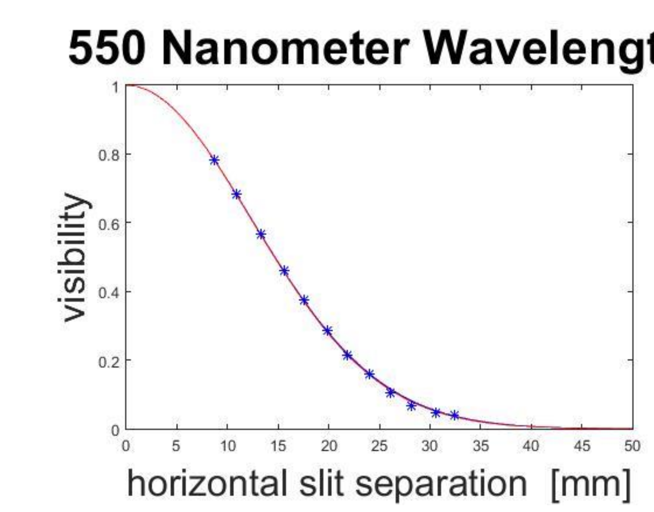


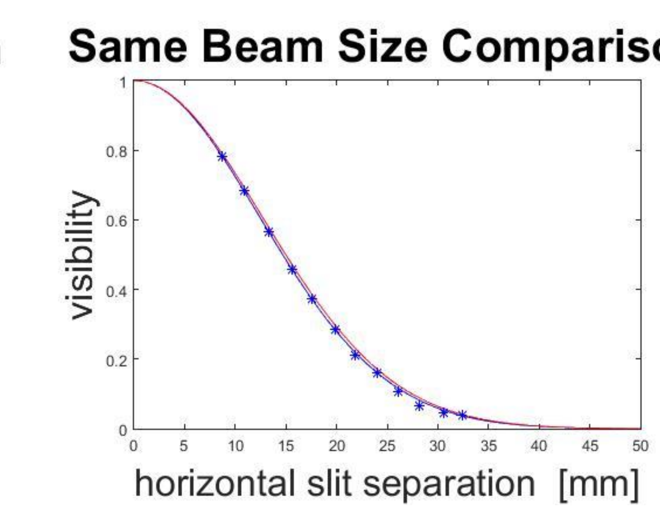
5. Analyze data with new model by adjusting the electron beam size manually to visually fit the curve to the data

6. Compare results

Results

We fit both IDOF curves to the data collected at three different wavelengths. At each wavelength, the Schwinger IDOF curve indicated that the electron beam was larger than the Gaussian IDOF curve indicated. The difference between the Schwinger IDOF and Gaussian IDOF beam size indication was 3 microns when measured at wavelengths of both 430 nanometers and 550 nanometers. This difference shrank to 2 microns when measured at 650 nanometers. Both curves appear visually to fit the data equally well.





Discussion

Schwinger horizontal polarization curves have a smaller width than the Gaussian approximation used. We attribute the larger beam size indication to this difference in width. A smaller intensity emission pattern results in higher visibility, and a curve higher on the graph. Larger beam sizes result in lower visibility, and a curve lower on the graph. By using the Schwinger curves and raising the visibility of our entire model, the data indicates a larger beam size to match the model.

Further Questions

How would the results change if we use a curve fitter instead of fitting visually?
Would the results be consistent at other wave lengths?
What is the comparison to pinhole camera measurements?

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