SIMULATING FRESNEL NEAR-FIELD DIFFRACTION PATTERNS FROM A SQUARE APERTURE USING SIMPSON'S 1/3 RULE NUMERICAL INTEGRATION

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THE PROBLEM

Two approximations are made to simplify Kirchhoff's diffraction formula; one for far-field diffraction and one for near-field diffraction. They are the Fraunhofer equation and the Fresnel equation, respectively. The latter is the focus of this experiment. The simulation aims to reproduce the diffraction patterns when incident waves, travelling parallel to the z axis, are diffracted by a square aperture and scattered onto a screen.

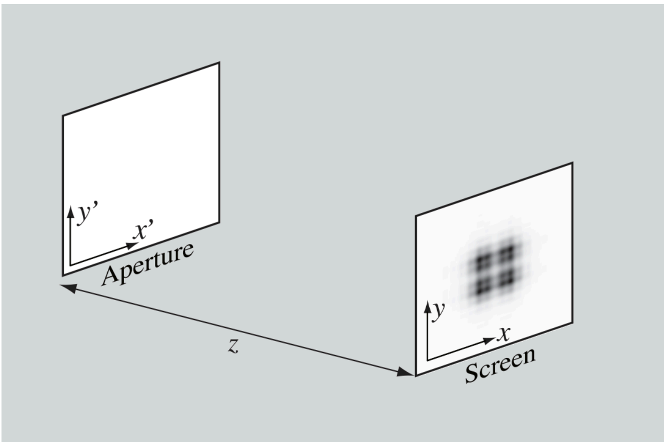

Figure 1: Experiment setup for Fresnel diffraction

METHODS

The equation for the electric field of Fresnel near-field diffraction has a double integral that is separable for x and y aperture lengths. Therefore two one-dimensional Simpson's rule integrations can be taken and multiplied together and then the observed diffraction intensity is proportional to the square of that. The calculated intensity is relative as it follows the constant E_0 is present due to the discontinuity of the equation at the aperture boundaries so can be normalised and taken to 1. A model for both.

DISCUSSION

Near-field Fresnel diffraction patterns can clearly be created by implementation of Simpson's numerical integration. It is necessary to shift the amount of integration intervals around to avoid excessive artifacting effects. This is particularly evident in the near-field region due to rapid changes in the electric field and thus intensity that are at smaller intervals than the integration steps.

The diffraction pattern becomes Fraunhofer-like at increased screen distance. It is apparent then that Fraunhofer diffraction can be considered a special case of the Fresnel diffraction equation, for large distance from the screen, so that diffracted light becomes, relative to normal of screen surface, parallel.

The limitations of the Simpson method of numerical integration for this experiment become apparent when the necessity for a greater number of integrations surpasses the need for performant speed and efficiency. It was necessary to parse the 2d integration through the 1d integration to retain an element of interactivity that is greatly desired when dealing with simulations of physical phenomena. A method to improve may be implementing a way to increase the time steps where there is smaller variation in the intensity, reducing the overall number of integrations. This does not however deal with the large number of peaks at near-field regions that necessitate dynamic time stepping in the first place. The large number of peaks in this region would actually be more efficiently computed using the trapezoidal integration rule, with results that are more accurate. The fact remains that all numerical integrators have limits to their ability to optimise for speed. Thus interactivity must be traded for accuracy when modelling physical phenomena.

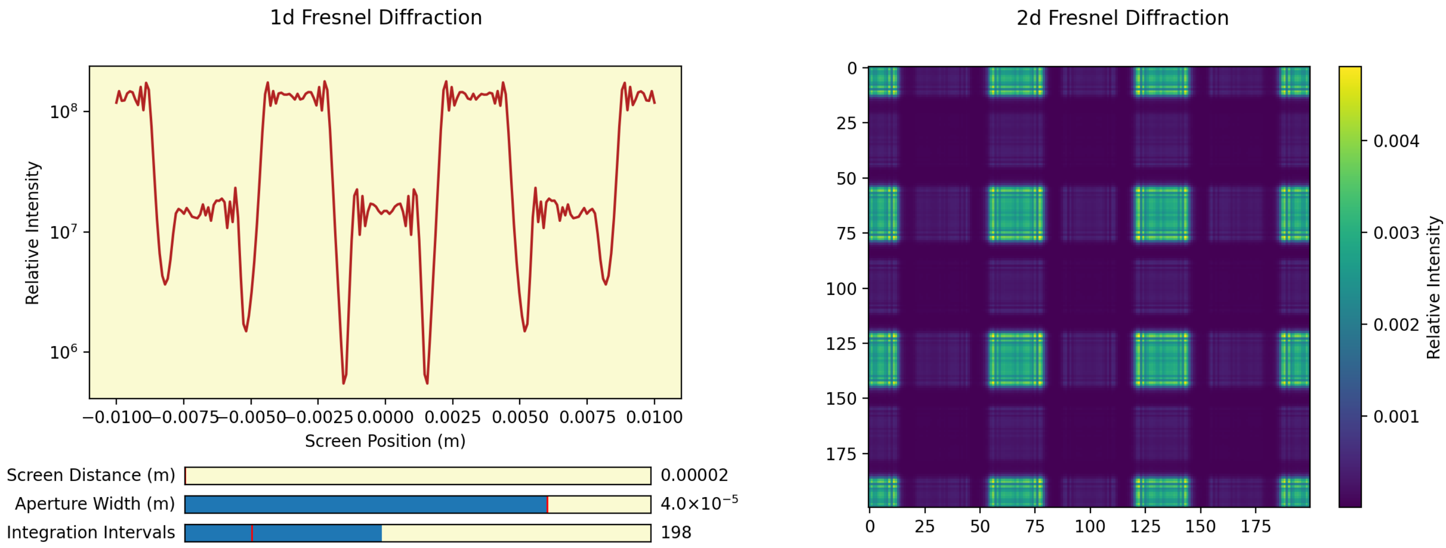

Figure 2: Best results found at short distance with wide aperture

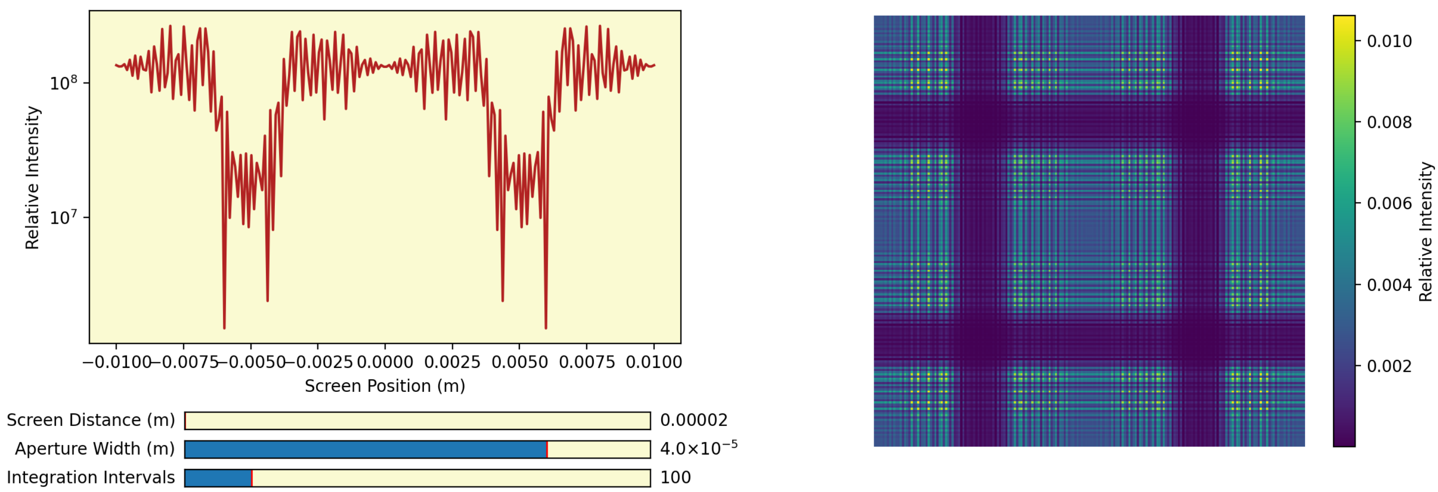

Figure 3: Artifacting from low N causes huge difference in 2D.

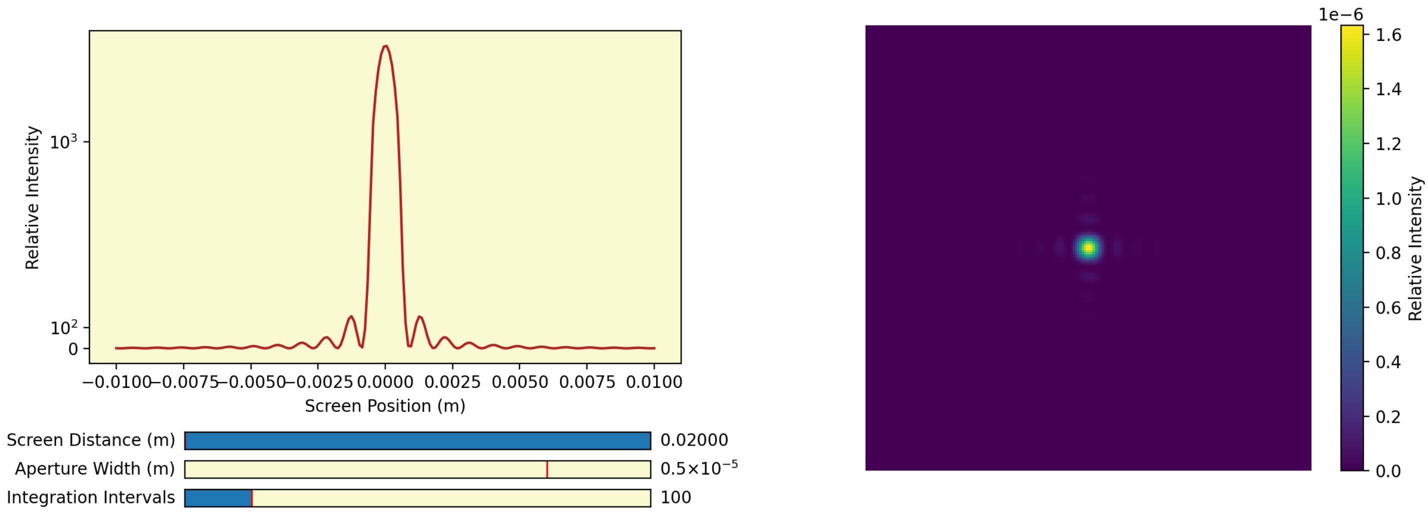

Figure 4: Far-field diffraction can be approximated also.