Exploring the Single Slit Diffraction Experiment - some meaningful extensions

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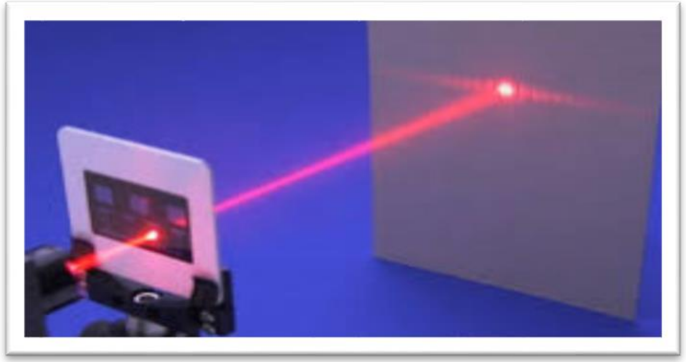
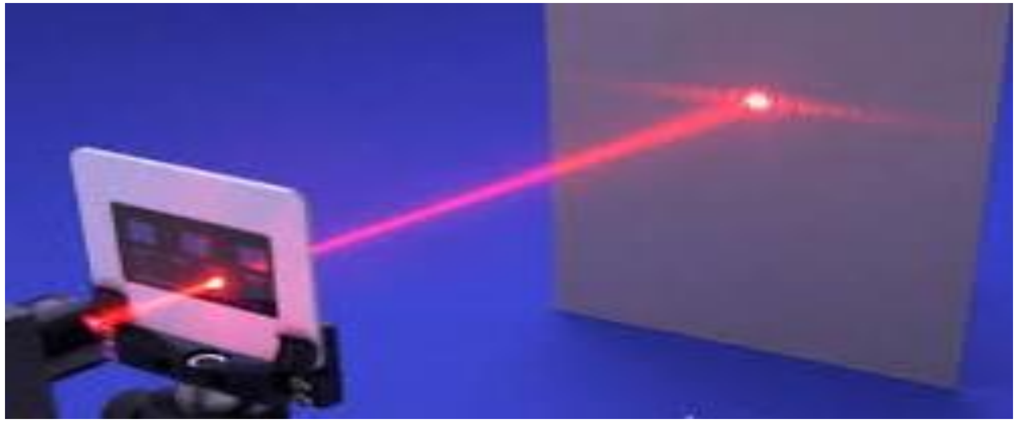
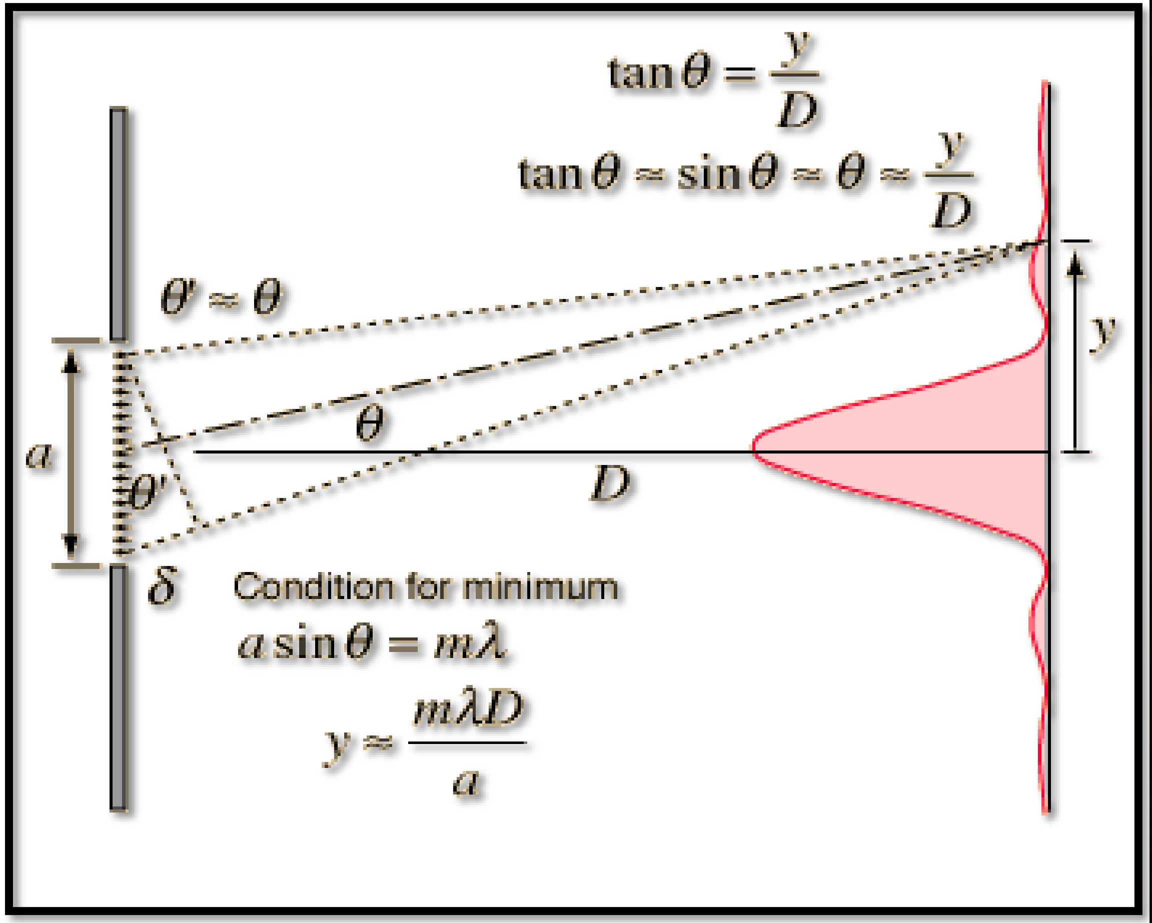
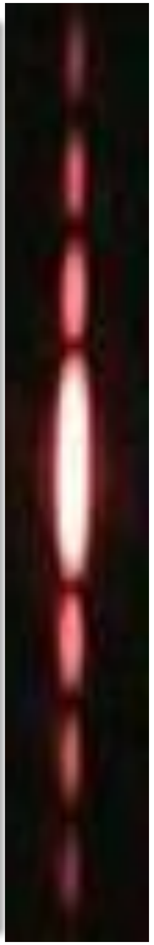


The usual Fraunhofer diffraction by a single slit experiment



Single-slit diffraction due to a plane wavefront





Fraunhofer Diffraction:

The light incident on the slit has a plane wavefront - the screen is at a distance large compared to the size of the diffracting structure.

Pattern: Central Maximum at θ = 0,

Secondary maxima at θ = ±1.43π, ±2.46π, ±3.47π

Minima (equispaced) at θ = mπ; where m = 0, ±1, ±2…

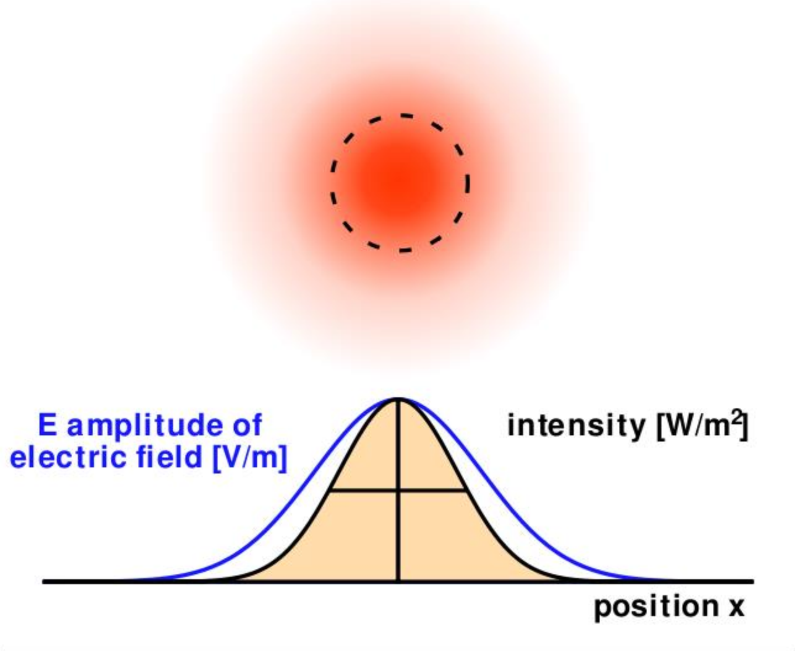
1. Uniform intensity Profile vs Gaussian Beam Profile at slit

- In a uniform beam profile the intensity distribution and electric field amplitude are uniform.

  $E = E_0$ (across the width of the slit)

- In a Gaussian profile, the intensity distribution and the electric field amplitude follow the Gaussian distribution.

$$E(r,z) = E_0 \frac{\omega_0}{\omega(z)} exp\left(\frac{-r^2}{\omega(z)^2}\right) \text{ (simplified)}$$

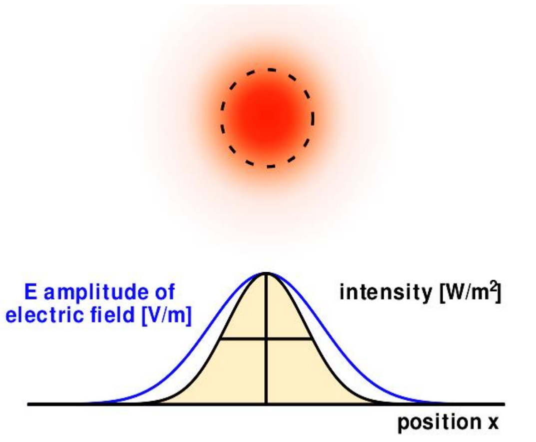


Uniform light intensity at slit				
$I_{centralmax}$	First minimum position (rad)	$\frac{I\ centralmax}{I\ sec\ max1}$	$\frac{I\ centralmax}{I\ sec\ max2}$	$\frac{I\ centralmax}{I\ sec\ max3}$
1	±3.14	21.1815	60.441	117.744

Numerical solution of the single slit Fraunhofer diffraction Integral.

- A C program was written to solve the diffraction integral of single slit diffraction by using Simpson's 1/3 rule, for uniform intensity of light across the slit width
- The numerically calculated pattern gave exact results as expected for the single slit Fraunhofer diffraction

Gaussian profile effects



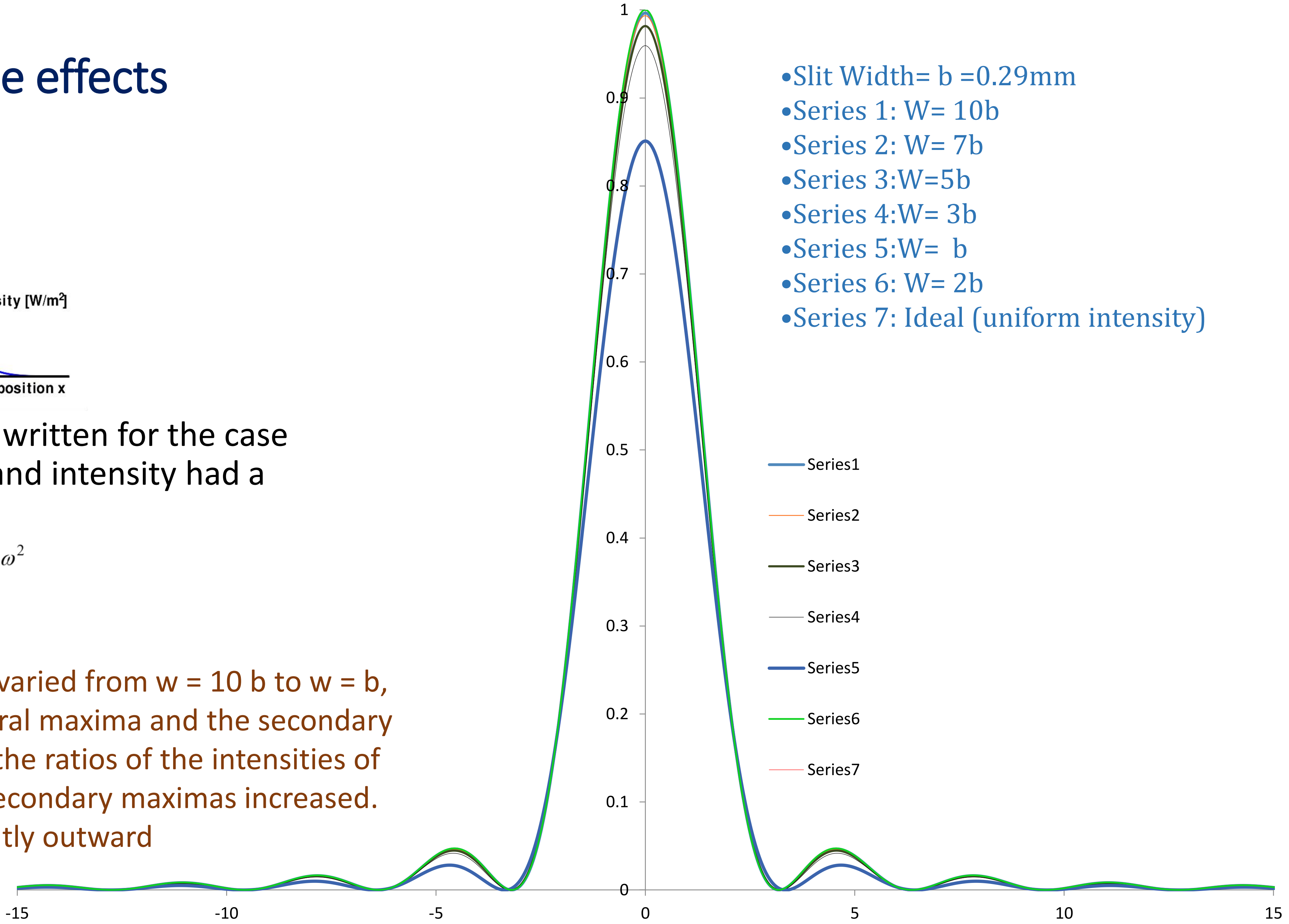
Next the C-program was written for the case where the electric field and intensity had a Gaussian profile.

$$E = E_o\, e^{-s^2/\omega^2}$$

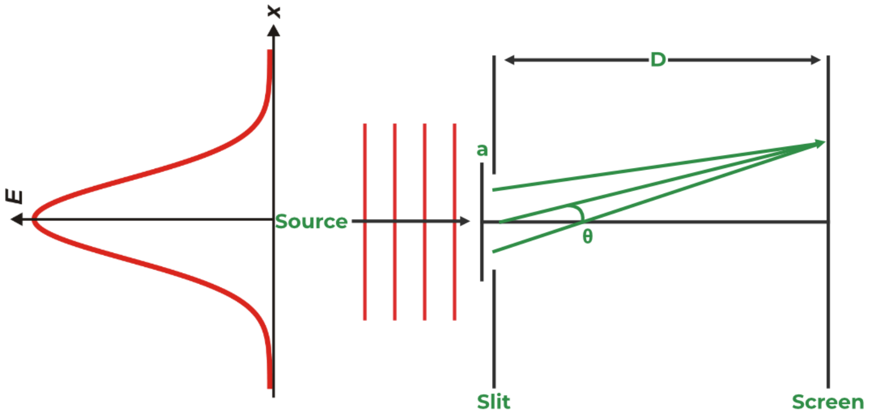
Results obtained:

- As the beam width was varied from w = 10 b to w = b, the intensity of the central maxima and the secondary maxima decreased and the ratios of the intensities of central maxima to the secondary maximas increased.
- The minima moved slightly outward

- Slit Width= b =0.29mm
- Series 1: W= 10b
- Series 2: W= 7b
- Series 3:W=5b
- Series 4:W= 3b
- Series 5:W= b
- Series 6: W= 2b
- Series 7: Ideal (uniform intensity)



Fraunhofer diffraction from single slit numerically computed result table – Electric field having Gaussian profile incident on slit



Beam width (mm)	Slit width (mm)	$I_{centralmax}$ (units)	$\frac{I_{centralmax}}{I_{sec\ max1}}$ (units)	$\frac{I_{centralmax}}{I_{sec\ max2}}$ (units)	$\frac{I_{centralmax}}{I_{sec\ max3}}$ (units)
2.9	0.29	0.998335	21.252	60.641	118.132
2.03	0.29	0.996607	21.326	60.85	118.544
1.45	0.29	0.993364	21.467	61.246	119.323
0.87	0.29	0.981719	21.991	62.713	122.195
0.58	0.29	0.959521	23.053	65.707	128.055
0.29	0.29	0.851121	30.14	85.129	165.458

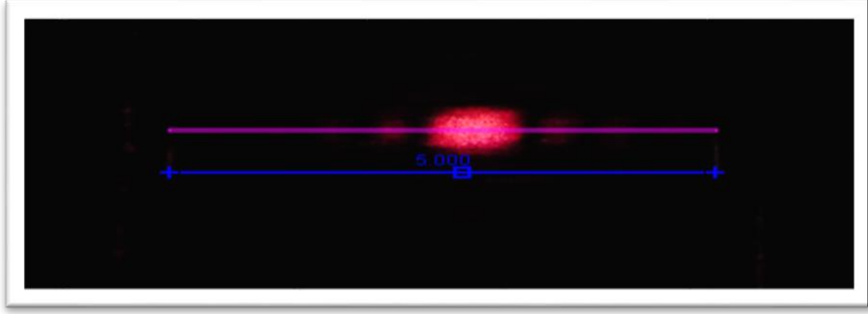
Beam width (mm)	Angular position (rad) of the	
	1^{st} minimum	2^{nd} minimum
2.9	-3.2	-6.35
2.03	-3.2	-6.35
1.45	-3.2	-6.35
0.87	-3.2	-6.4
0.58	-3.25	-6.4
0.29	-3.35	-6.45

2. Effect of distance between the light source and slit

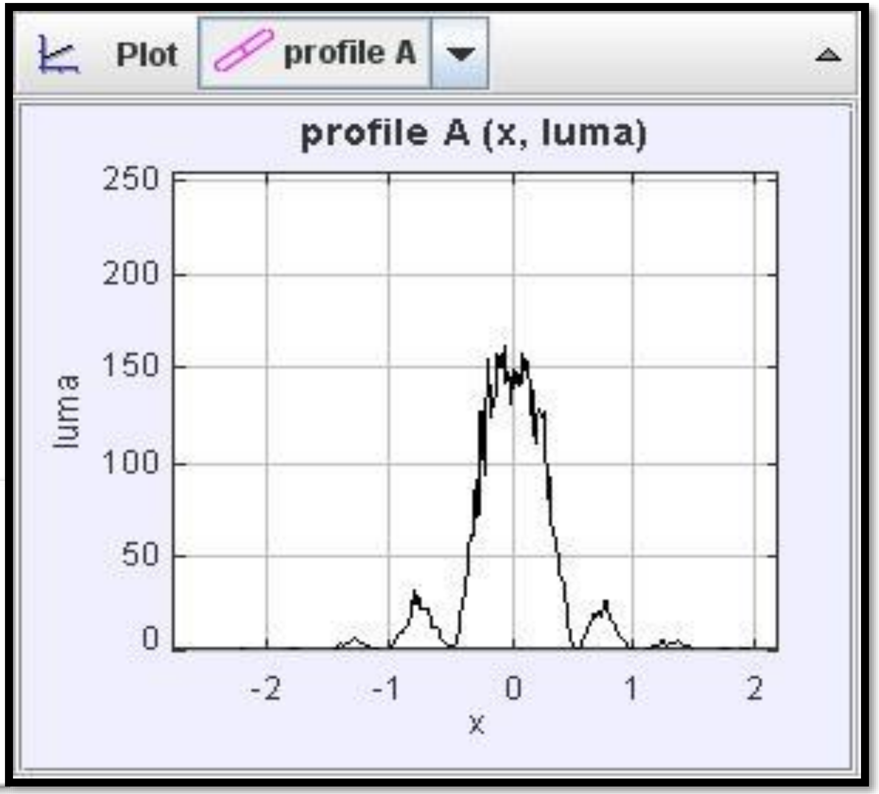
- In Fraunhofer diffraction, the distance to the screen is kept very large and Fraunhofer diffraction limit is mostly studied only by varying the slit-screen distance. The source-slit distance is often neglected.
- We studied the pattern by changing source slit distance, while keeping the slit-screen distance large, fixed.

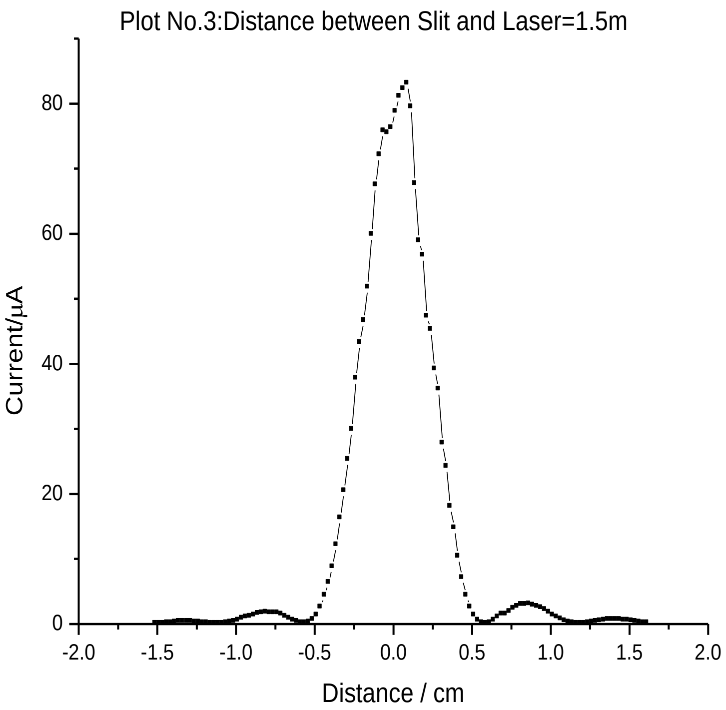
Source used: He-Ne Laser (632.8nm)
Distance between slit - screen=146 cm
Slit width= 0.29 mm
The experiment was done for 5 different laser-slit distances

Analysis was done using
(1) Photodetector
(2) Tracker line profile software analysis



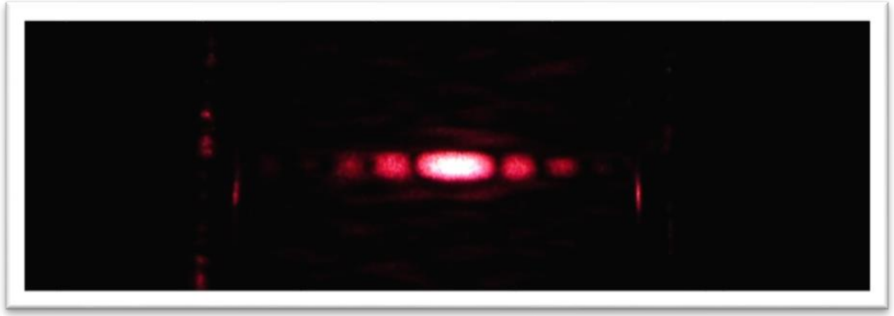
i) Laser to slit distance = 150 cm

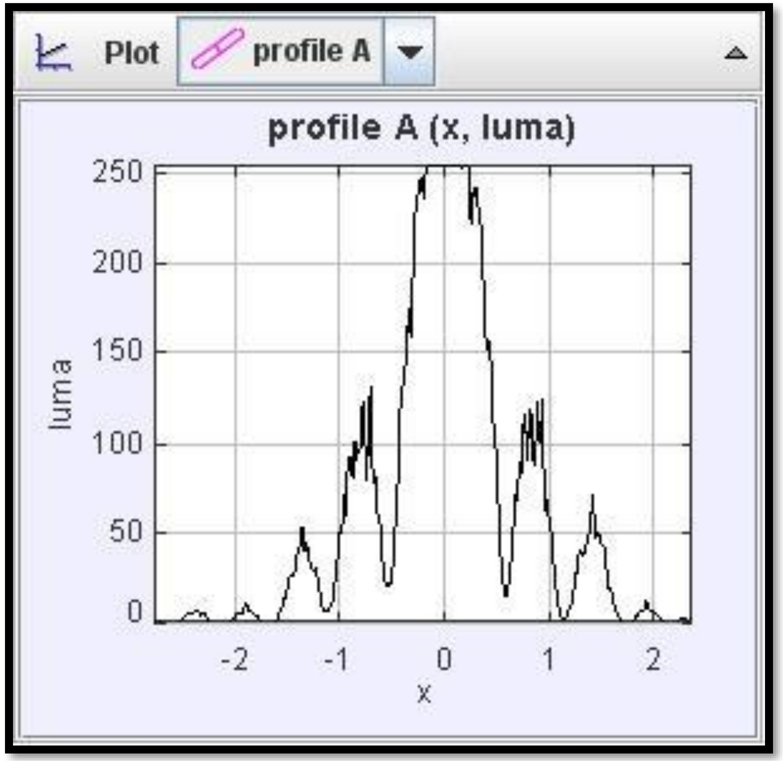




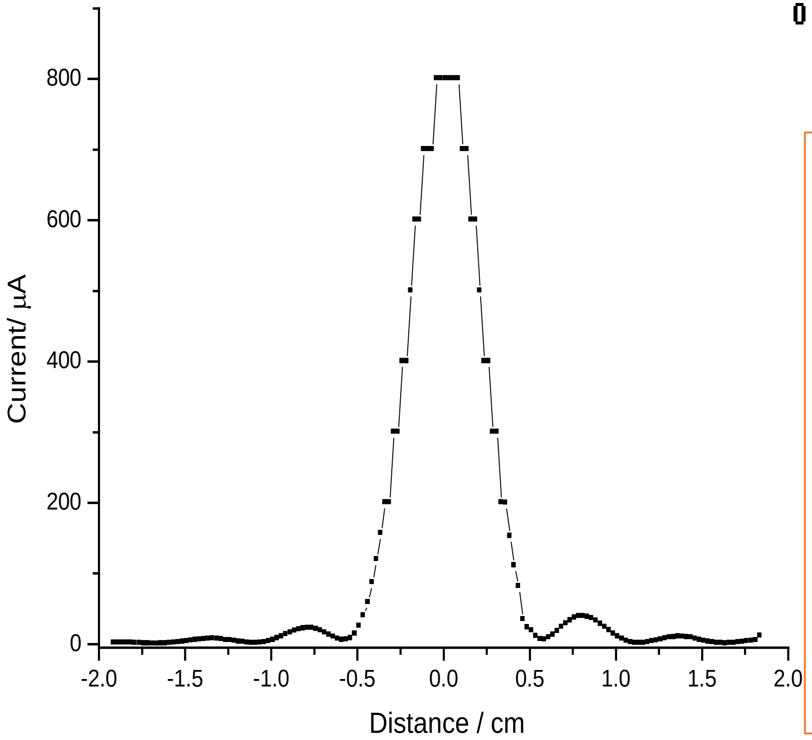
ii) Laser to slit distance= 21.7 cm

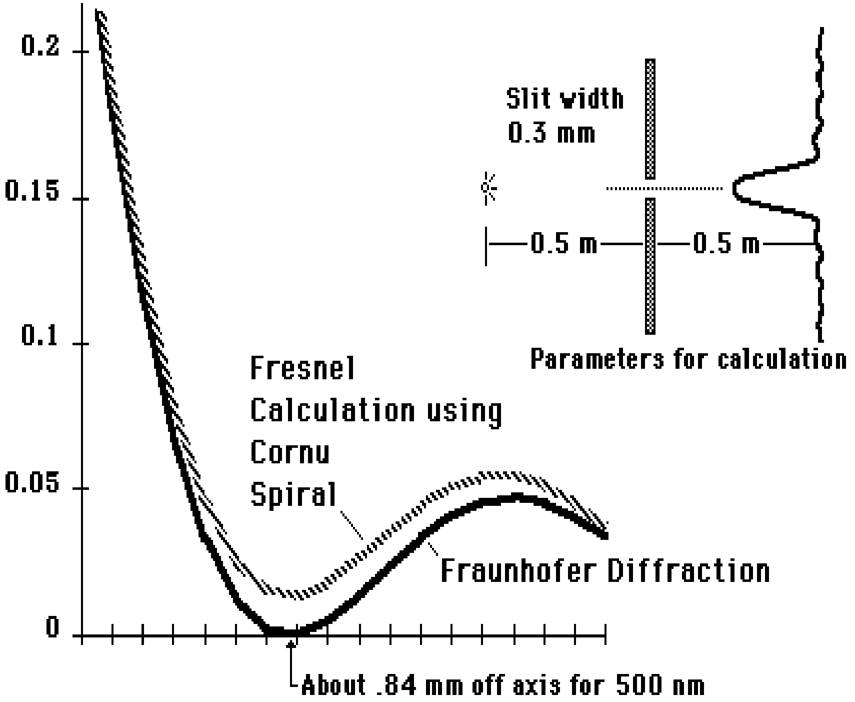
Slit – screen distance = 146 cm





Plot no.1: Distance between slit and laser=21.7cm



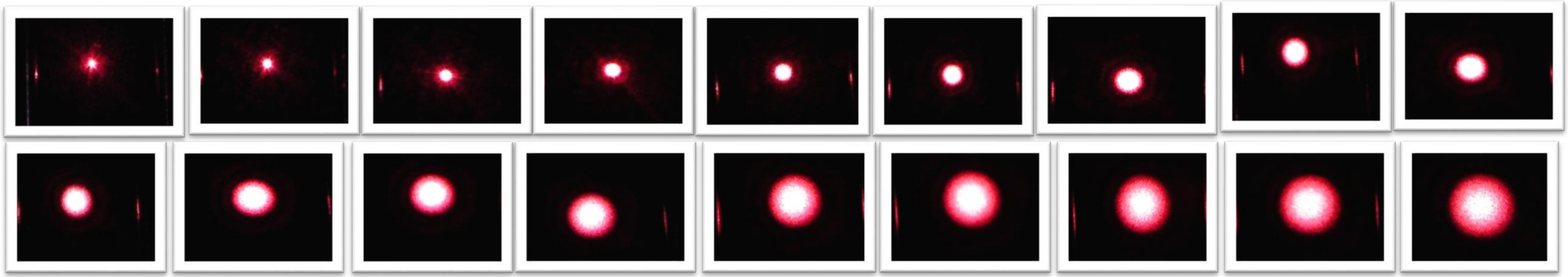


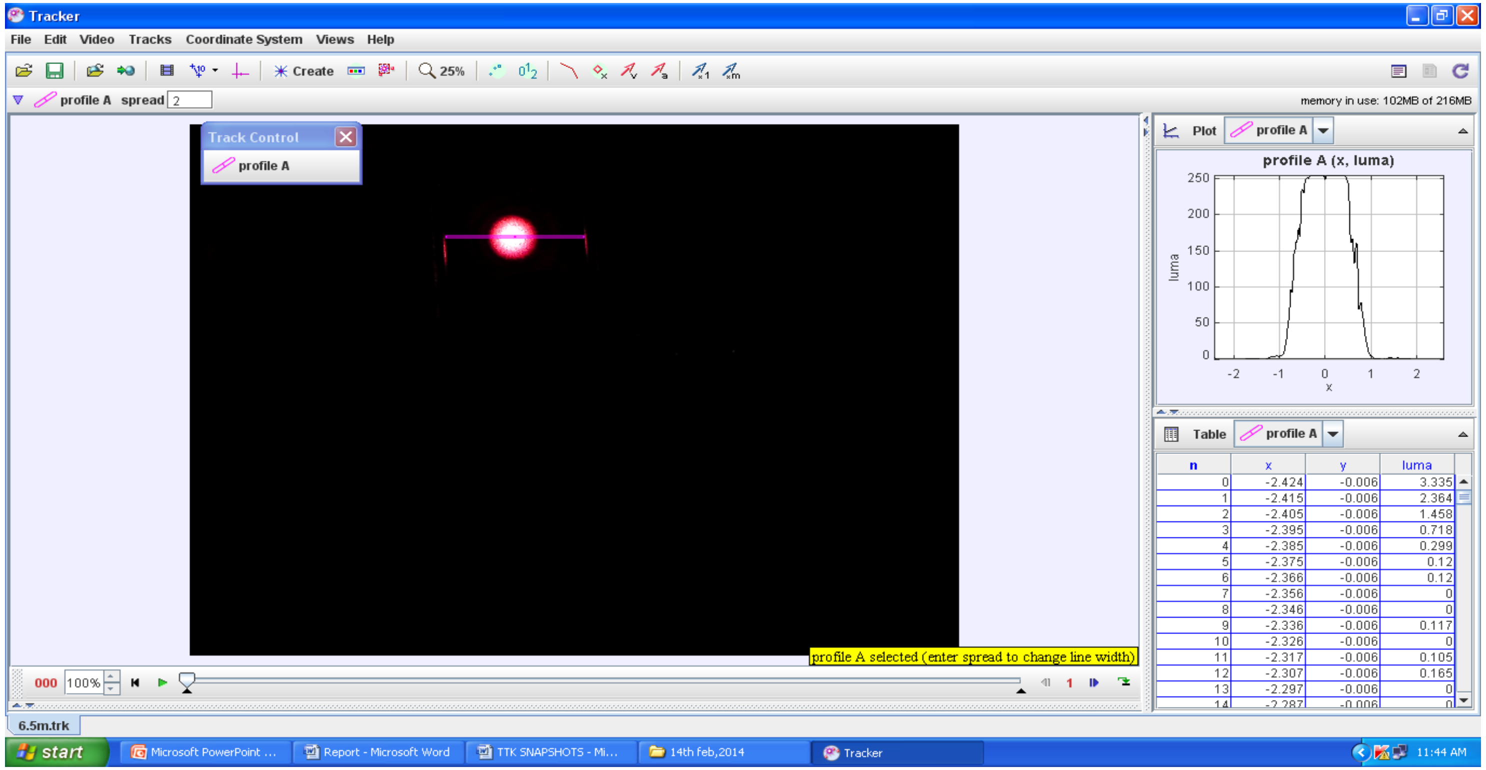
At ≈20 cm source-slit distance, the pattern shows features of Fresnel diffraction - $I_{min} \neq$ zero.

Conclusion:

1. Source-slit distances matter too.
2. Only at large distance from laser, the beam profile across slit becomes constant.

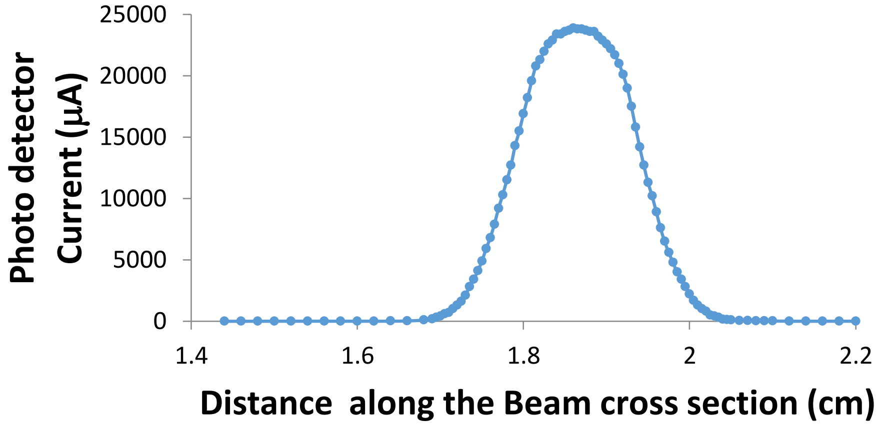
Variation of spot size of the laser beam with distance





Tracker

Photodetector



THANK YOU