Scientific Demonstration of the Uncertainty Principle

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The uncertainty principle of quantum mechanics is defined as

$\Delta x \cdot \Delta p_x \geq ½ \hbar$

This is one of the most fundamental principles in physics, and to understand it completely takes time. The basic idea of the principle is that because of the wave property of particles it is impossible to know precisely a particle's position and momentum along an axis. This uncertainty Δ is in physics defined as the standard deviation σ. The inequality above states the theoretical lower limit of the product of these two standard deviations.

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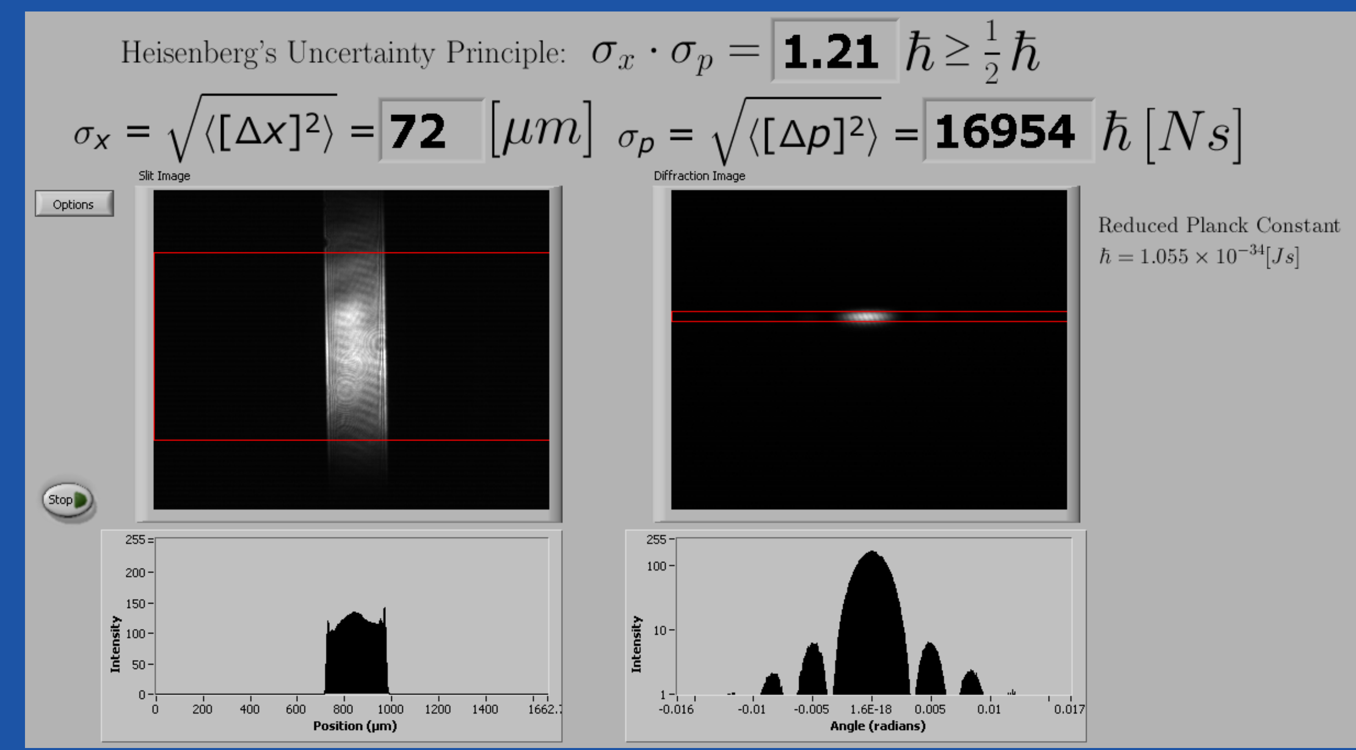
For younger students it is hard understand and realize that quantum mechanic effects are real. With this demonstration we wish to show tangible quantum mechanic effects and educate high school students in an usually very alien field of physics. The focus points of this demonstration were to make it simple, clear, intersting and understandable.

Methodology

These quantum mechanic effects are shown with the help of single slit diffraction of light, which results in a diffraction pattern because of the light's wave-particle duality. By studying the slit opening and the resulting diffraction pattern, and displaying the images of these on a computer, the information of the standard deviation of the light's position and respectively its momentum are acquired. The product of these two values are then compared to the Heisenberg uncertainty limit, $\sigma_x \cdot \sigma_p \geq ½ \hbar$. ħ is the reduced Planck constant and equal to $1.055 \cdot 10^{-34}$ Js.

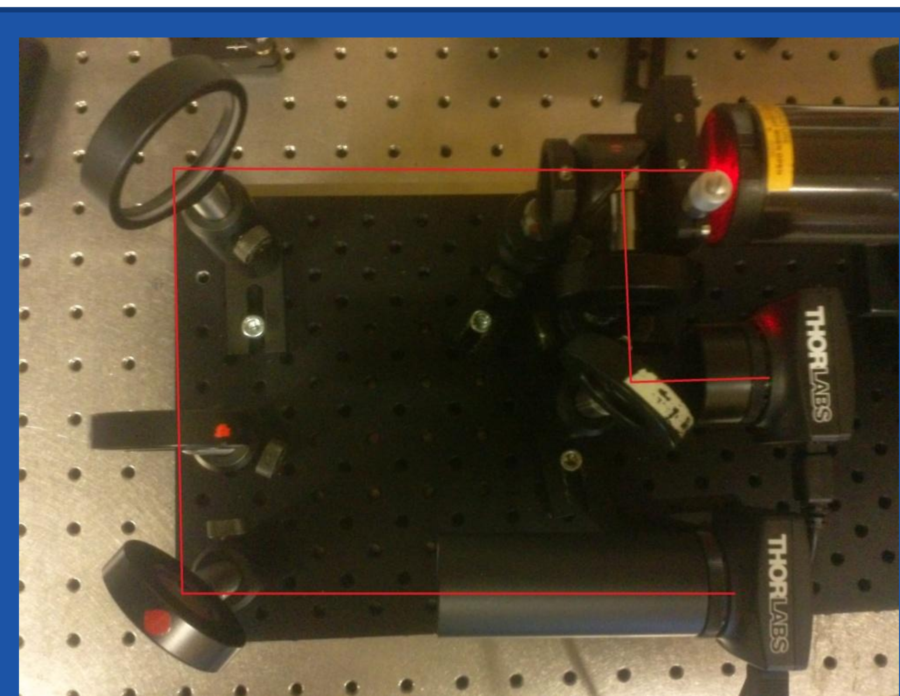


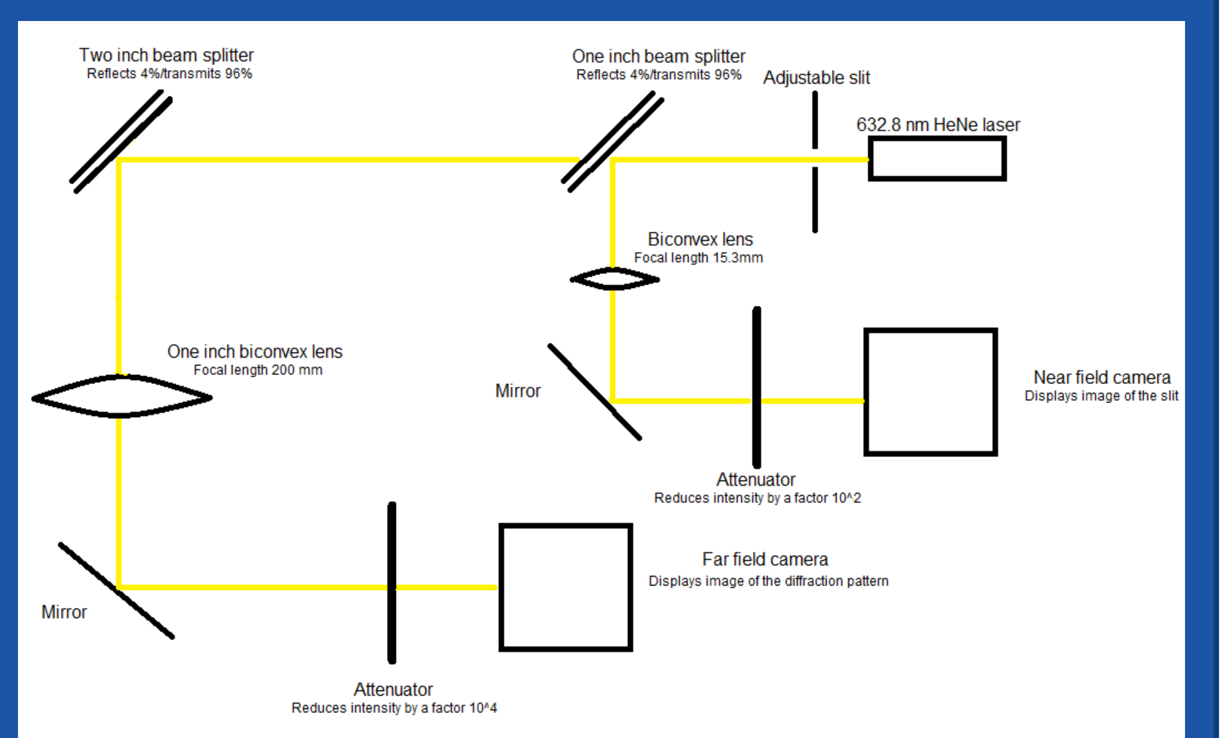
User Environment

The figure above shows the user environment, with the caracteristic image of the slit, left image, and diffraction pattern, right image and under them their respective light intensity graph. In the right graph the higher order maxima are clearly seen even though they are hard to spot in the image.

Physical Setup

In the two pictures shown you can see a schematic of the setup and its real world counterpart. The demonstration's purpose is to diffract the light from a laser through a single slit, and then project two different images onto two cameras.





Conclusions

In our results, that were measured with the help of our setup, we found no reason to believe that the Heisenberg uncertainty limit could be violated. We saw that the values of the uncertainty product increase with decreasing slit sizes and that the lowest value is acquired when the slit is fully open and the laser emits an almost Gaussian wave, which should result in $\sigma_x \cdot \sigma_p = ½ \hbar$. This makes us beileve that our results are correct and solid.

Hopefully this demonstration will prove instructive for young students interested in science and give them an introduction to quantum mechanics.