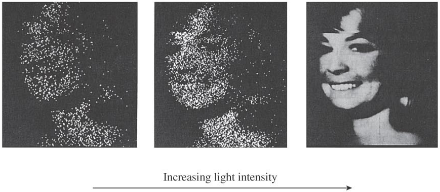
Dr. Quantum

Dr. Quantum Explains

`http://www.youtube.com/watch?v=DfPeprQ7oGc`

Photons (25.3)



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The particle-like behavior is not noticeable at higher light levels.

- The picture above is more astounding than it looks.

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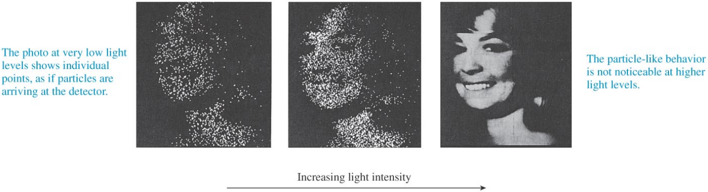

- The picture above is more astounding than it looks.
- If light was a wave, then taking a photo in very low light should produce a very dim version of the whole image. As the luminosity increases, we should see the photo get brighter.

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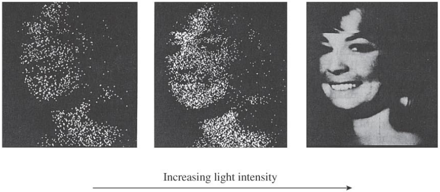

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Increasing light intensity

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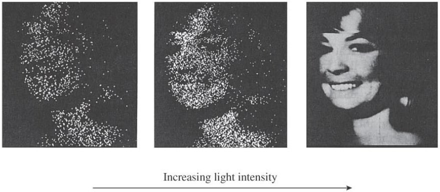
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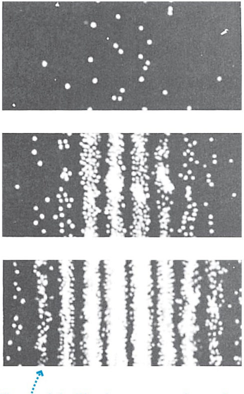
- How do we reconcile this with our models of light??

Double-Slit Interference Revisited



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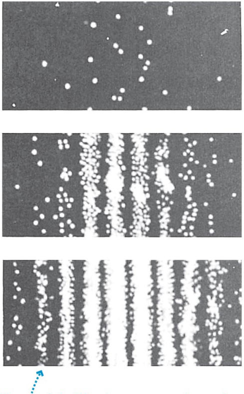

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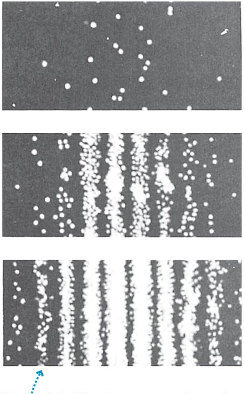

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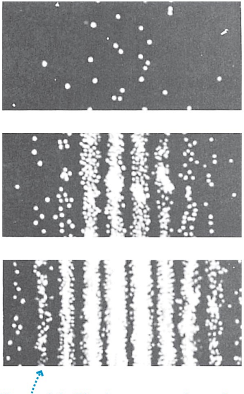

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- Instead we see the dots appearing on the screen one at a time. Eventually they form an interference pattern, but the hit like particles, not like a wave.
- So, they make a pattern like a wave despite interacting as particles.

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- The superposition of a large number of photons looks like a classical light wave. These are not your “classical” corpuscles.

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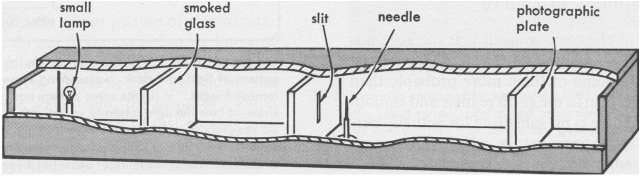

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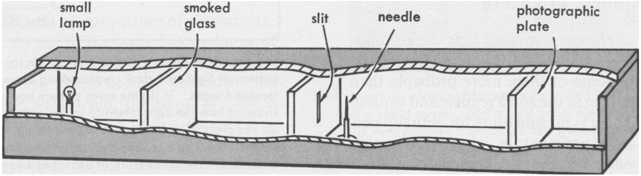

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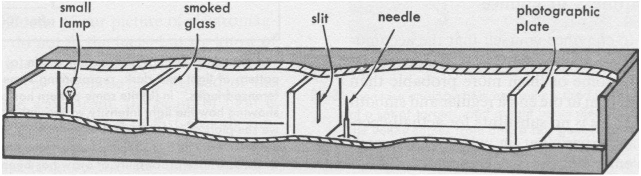

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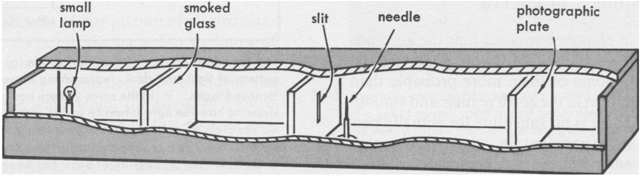

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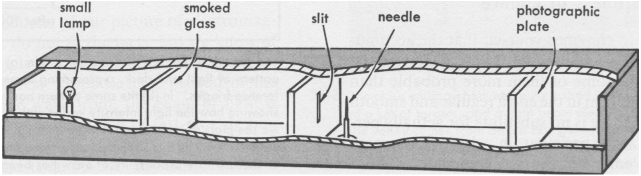

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- He reduced the intensity of the light and increased the exposure time repeatedly.
- Eventually the light was so dim that it took 3 months to get the pattern on the film. (He went sailing during the exposure.)
- He could prove that at this low light level there was never more than a single photon in the box at a time. Neverthless, an interference pattern was produced!

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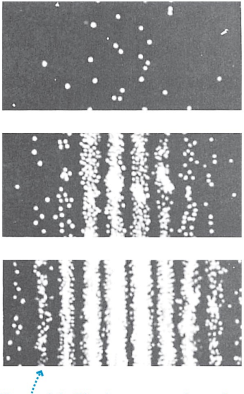

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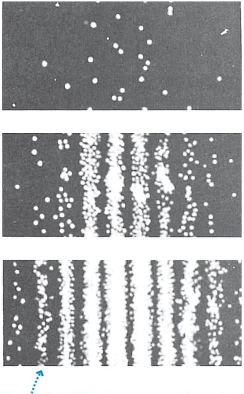

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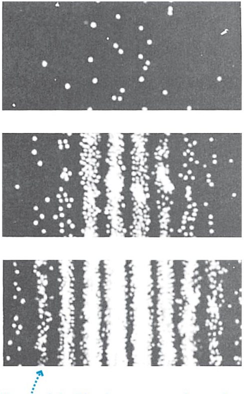

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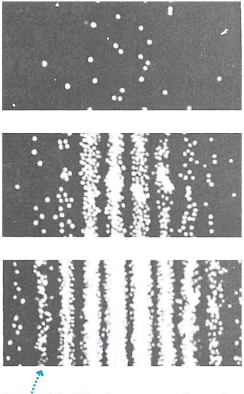

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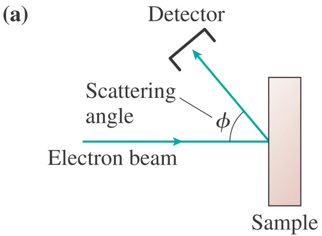
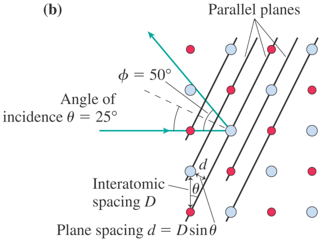
- Each photon travels through both slits....not at all like a particle.

Matter Waves (25.4)





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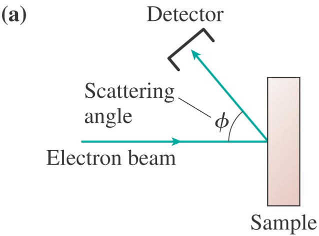

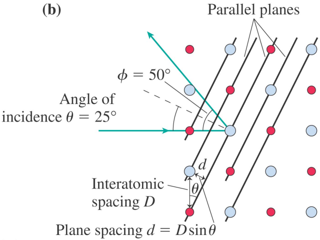

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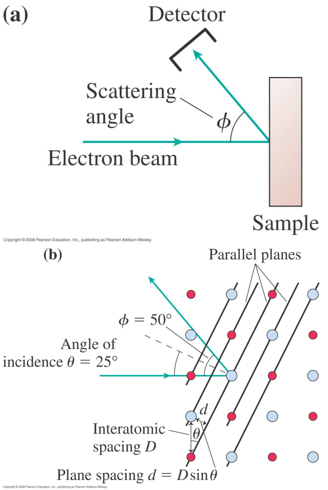

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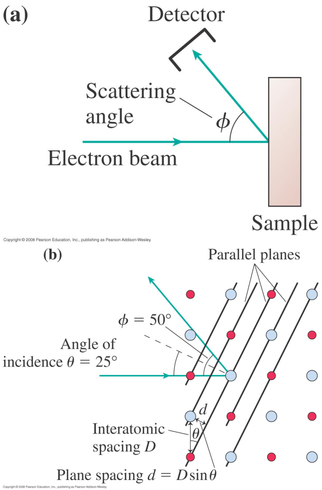

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- They could then use this “wavelength” to predict the position of all the other peaks...just as though they were scattering X-rays!!

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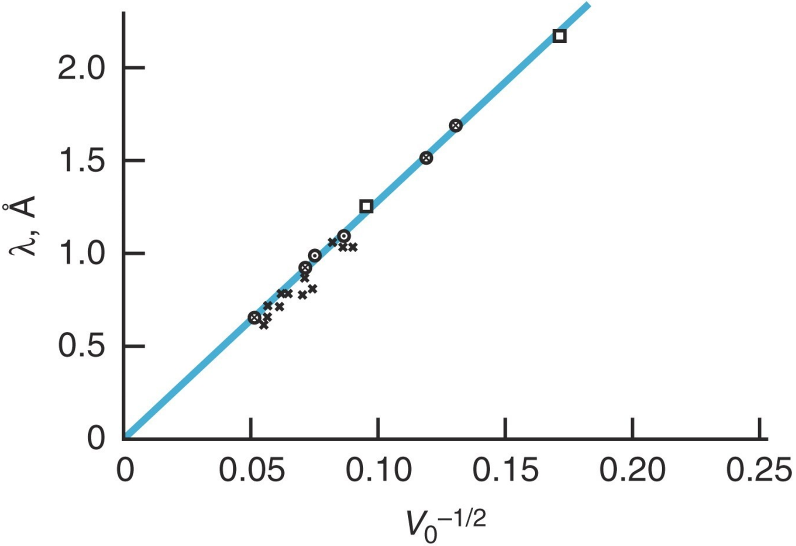
  So, he could express energy in terms of momentum.
- If he defined the wavelength of a particle as

  $$\lambda = \frac{h}{p}$$

  he could get something which worked in both models.

Davisson-Germer vs. Electron Energy



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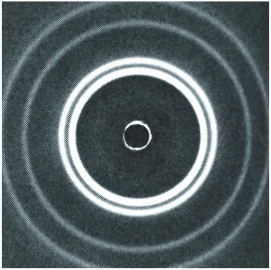
A Quote from Bohr:

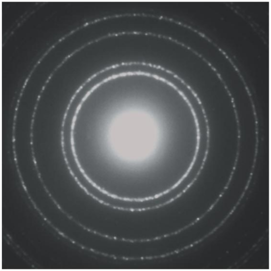
Anyone who is not shocked by quantum theory has not understood a single word.

Interference and Diffraction of Matter

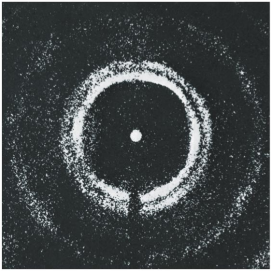
(a) X-ray diffraction pattern



(b) Electron diffraction pattern



(c) Neutron diffraction pattern



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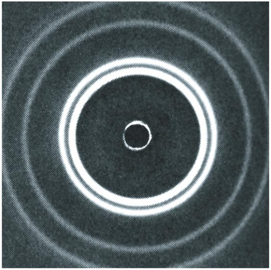
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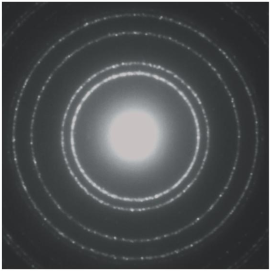
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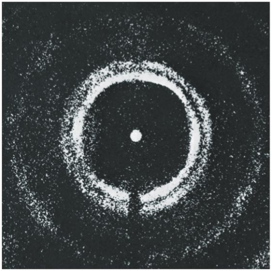
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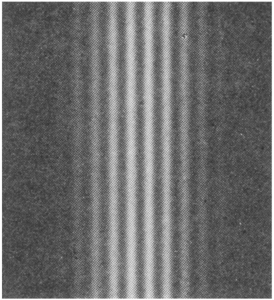
- Electrons, neutrons and whole atoms have been shown to diffract just like X-rays!

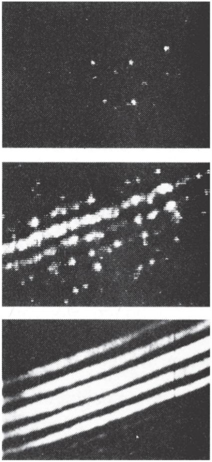
Matter in the Double Slit Experiment

The double slit experiment is what originally convinced us that light was a wave. What does matter do?

(a) Double-slit interference of electrons



Electrons double slit

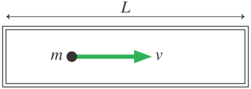


Electrons one at a time

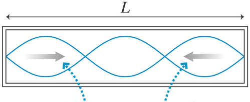
Energy is Quantized (25.5)

- We know that waves confined between two boundaries for a standing wave. What does that imply for matter confined to a box?

(a) A classical particle of mass *m* bounces back and forth between the ends.



(b) Matter waves moving in opposite directions create standing waves.



Matter waves travel in both directions.

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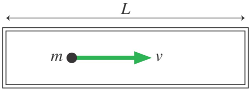

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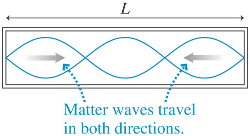

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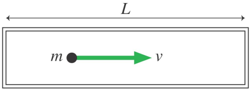

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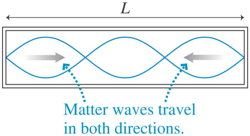

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- We also know that the particle has wavelength $\lambda = h/p$.

$$p_n = n\left(\frac{h}{2L}\right), n = 1, 2, 3, \ldots$$

The momentum of the particle has only certain allowed values!!!

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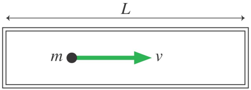

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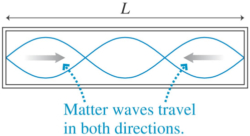

- We know that energy and momentum are related by $E = p^2/2m$ giving

$$E_n = \frac{1}{2m}\left(\frac{hn}{2L}\right)^2 = \frac{h^2}{8mL^2}n^2, n = 1, 2, 3, \ldots$$

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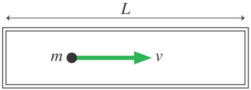

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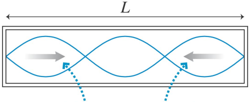


Matter waves travel in both directions.

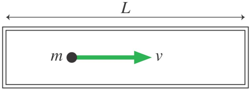
- We know that energy and momentum are related by $E = p^2/2m$ giving

$$E_n = \frac{1}{2m}\left(\frac{hn}{2L}\right)^2 = \frac{h^2}{8mL^2}n^2, n = 1, 2, 3, \ldots$$

- Particles in a box can only have certain allowed energies! This is the quantization of energy.

Energy is Quantized (25.5)

(a) A classical particle of mass *m* bounces back and forth between the ends.



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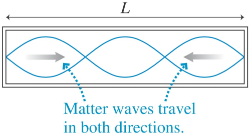

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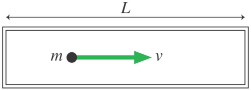

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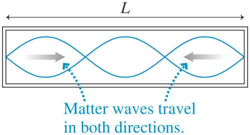

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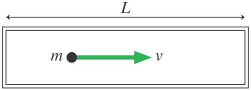

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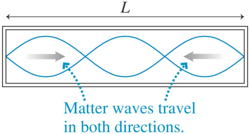

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- Matter is more complicated than it looks!

Matter Waves

A Quote from de Broglie:

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