Quantum Particle Diffraction by a Classical Method

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Numerical simulations of the double slit experiment with electrons, done by Al Rabeh, are repeated and improved. As well, the simulations go from moved Coulomb charges. These tests are extended with a proof of convergence for small time steps. Al Rabeh's idea is fully confirmed: The pattern on the target comes from diffraction of charged particles, though it does not distinguish from interference pattern. In context with other results like that from Afshar, the wave-particle duality is disproved. The issue of photons is raised.

1 Introduction

No experiment promoted the belief in the wave-particle duality more than the double slit experiment with electrons, because one sees on the target the same pattern as generated by interference of light. However, recent publications present experimental results [1, 2, 5] and derivations [4], which question the wave-particle duality. As well, the Afshar experiment [5], which validates the wave nature of photons for the resting observer (see also [4]), is controversially discussed, e.g. [3]. Al Rabeh [1] suggested a complementary idea: The pattern on the target in the double-slit experiment with electrons is no interference pattern but comes from diffraction of charged particles. He supported this idea with first numerical simulations. These simulations are worth to be repeated and improved. A proof of convergence is additionally done. – The entirety of these results will permit conclusions for the consequences in physics.

2 Diffraction Results

The classical motion of a particle in a force field being inversely proportional to squared distance has been programmed. The complete Fortran code is to see at [7].

The equations of motion in form of Hamilton equations are given by

$$\frac{\mathrm{d}\mathbf{r}_i}{\mathrm{d}t} = \mathbf{v}_i \quad , \tag{1}$$

$$\frac{\mathrm{d}\mathbf{v}_i}{\mathrm{d}t} = \sum_j k \frac{\mathbf{r}_i - \mathbf{r}_j}{|\mathbf{r}_i - \mathbf{r}_j|^3} \quad , \tag{2}$$

with a constant of interaction k. The particles are at positions $\mathbf{r}_i$ and have velocities $\mathbf{v}_i$. The positions $\mathbf{r}_j$ denote the charged centers of the atoms of the aperture material and are considered as fixed. The differential equation system has been solved by Runge-Kutta integration in two dimensions. This exceeds the linear integration scheme used by Al Rabeh [1]. In the same way as in [1], interaction has been included between the slit material and the particles only. There was no interaction between particles itself, because this leads to an immediate dispersion of the particles, and there is no observable effect of diffraction left. This approximation must be made to filter out unwanted effects. We did not use the Coulomb form of k which would be

$$k = \frac{q_1 q_2}{4\pi\epsilon_0} \tag{3}$$

for a realistic interaction where q_1 and q_2 are the charges of the slit atoms and the scattered particles respectively. We only discern the sign of k as will be explained later.

Basically two kinds of calculations have been performed, one for a single slit and one for a double slit. The material of the aperture is modeled by a monolayer of charged particles. Tests with multiple layers did not give significantly different results. The geometry of the single and double slit with the constituting "atoms" are shown in Fig. 1. A column of bullet particles has been shot on the slits with a common initial velocity v_x. The vertical component v_y was set to zero. We did not add a statistical component as Al Rabeh did because we wanted to obtain undistorted diffraction patterns. For the interaction between the barrier material and the particles we used two types of interaction: an attracting and a repulsive force by setting the constant $k = \pm 1$. The difference in the near-field behaviour around the aperture barrier is shown in Figs. 2(a) and (b). For the attractive force, particles are pulled towards the barrier border and gain a y component of their velocity. In case of repulsion, particles are pushed away from the barrier border and cross over. These are the diffraction effects which lead to a wave-like behaviour in the far field. Although the vertical shift is different in both cases, there is nearly no difference observable in the far field. The reason is that the slope of the vertical motion (i.e. the y component of velocity) is nearly equal.

Next we consider the behaviour of *imaginary* wave fronts for three different initial velocities of the single slit with repulsive force. The first image Fig. 3(a) shows the "wave fronts" (the position of all particles at a certain instant of time) for an initial velocity near to the threshold (explained later). A virtual screen has been positioned at the right end of the image, and the number of passing particles has been counted in 51 virtual "channels". This gives a histogram of the particles shown in Fig. 3(b). For the 300 particles calculated, there is a certain weak structure in the histogram which could tentatively attributed to higher orders of diffraction. As is well known from optics, the diffraction pattern has a structure of the function $(\sin(y)/y)^2$, which has one main maximum and several smaller secondary maxima. For energies (or initial velocities) beyond threshold the diffraction pattern smears out (Fig. 4) and becomes sharper for higher energies, where the diffraction effect decreases and the pattern becomes more geometrical (Fig. 5-6). All this is well known from optics.

After having discussed the results for a single slit, we show those for a double slit, see Figs. 7-10. Since the 'lattice constant' of the double slit geometry is equal to the diameter of the single slit (Fig. 1), a similar structure including the secondary maxima as for the single slit is expected. Exactly this is obtained. Finally we compare the calculations for repulsive force (all figures so far) with the same calculations for an attractive force. We only show the results for the highest energy, Fig. 11. As can be seen, there is no significant difference. Only the secondary maxima seem to be less pronounced.

3 Discussion and Conclusions

The results of the calculations show that diffraction effects of particles, which normally are considered to be an attribute of the wave nature of matter, can be obtained from a simple calculation of only classical electrical Coulomb interactions. The results of Al Rabeh [1] have essentially been affirmed, although not all patterns in his calculation could be verified. In our calculations we always obtained more or less circular or parabolic/hyperbolic "wave fronts", while Al Rabeh obtained elliptical sub-structures in the "wave fronts". We suppose that these are due to lack of numerical precision. While Al Rabeh used a first-order solution method for Eqs. (1) and (2), we used a method of fourth order (Runge-Kutta). Despite of this precision difference, we had to choose the time integration steps as small as 5×10^{-5} and less to obtain numerical convergence. The problem is that when particles come very near to the aperture barrier, the inverse distance force becomes formally very high, leading to instable paths of the particles. Their paths are curved on a very small distance, requiring accordingly small integration steps. So a false picture can arise with outer particles moving faster than inner. This seems to be the case in the calculations of Al Rabeh.

The results can be concluded as follows:

- A wave image of matter is obtained by handling matter as classical particles.
- Single and double slit geometry give essentially the same results.
- Attractive and repulsive Coulomb forces do not make a significant difference.
- Care must be taken for numerical solution of the equations of motion.
- Higher orders of diffraction could not be identified safely due to missing statistical significance.

4 Remarks on Photons

A popular view is to see photons as massless quantum particles, which are believed to reach at most the velocity of light c. An approach of dissolving the problems from this view is assuming a small but finite rest mass of this hypothetic particle [6]. Then the photon can be handled like any other elementary particle. This could make sense in the framework of general relativity, but one had to modify the equations of it.

Nevertheless electromagnetic waves can be understood from Maxwell's theory alone [4], albeit there are problems of understanding in some details: The extent of the photon is finite in $ct - x, y, z$ (see [4]). That means according to special relativity, it is infinite in t and x for the resting observer. This is proven by extremely sharp spectra of photons, which cannot be calculated from limited functions of time. The photon is a wave for the resting observer, in spite of quantization, in accordance with the experiment of Afshar [5]. – This issue cannot be explained with a dialectic philosophy. Dialectics is not a property of nature.

If stationary fields change (for example by accelerated charges), the changes in the whole field propagate with c. The resting observer sees indeed waves here, with wider spectra. This effect is technically used in synchrotrons. – That is the other case of *seeming* duality, and has nothing to do with the explorations described precedingly.

The entirety of all these results and realizations might disprove the conventional dialectic view of matter with the wave-particle duality, and rather support a more geometric view.

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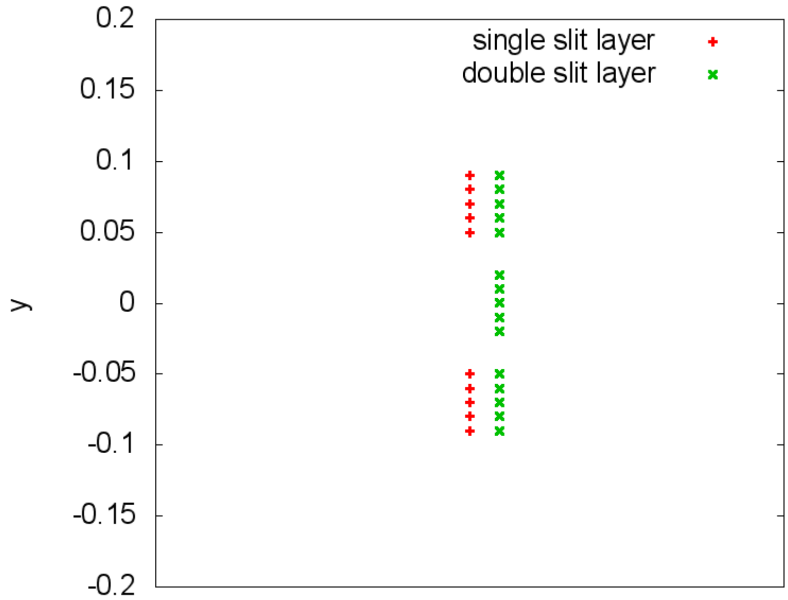

Figure 1: Monolayers of single and double slit apertures (discretized as ‘atoms’).

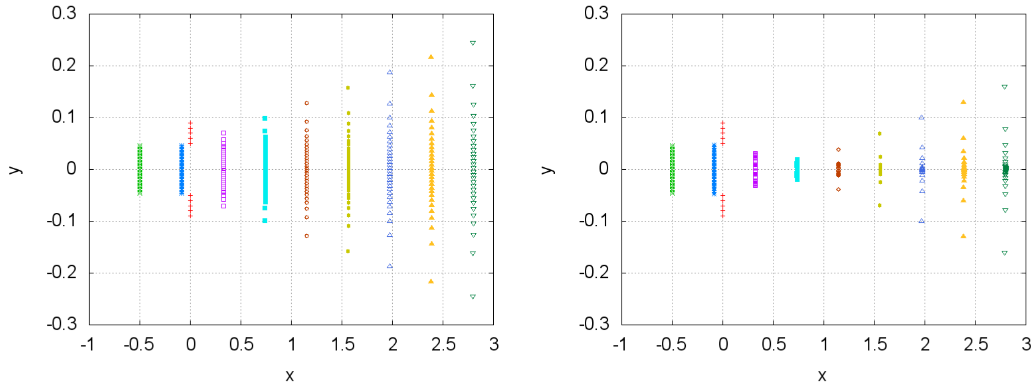

Figure 2: Particle motion near to the barrier for different kinds of forces.
(a) Attractive force, (b) Repulsive force.

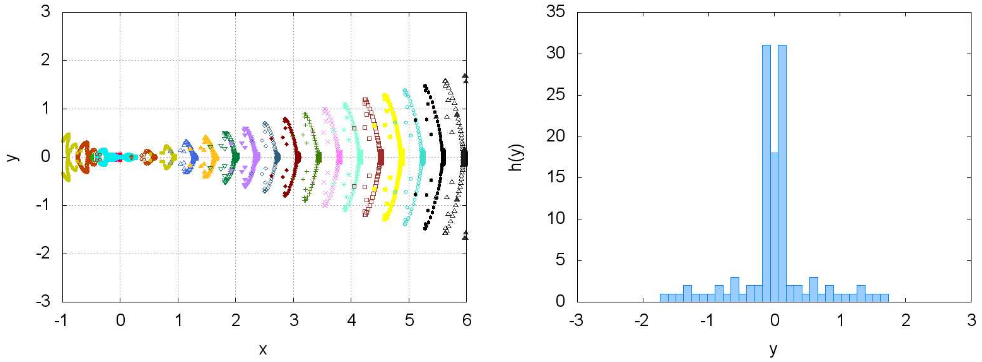

Figure 3: Results for single-slit, $v_x = 17$.
(a) Diffraction pattern, (b) Histogram.

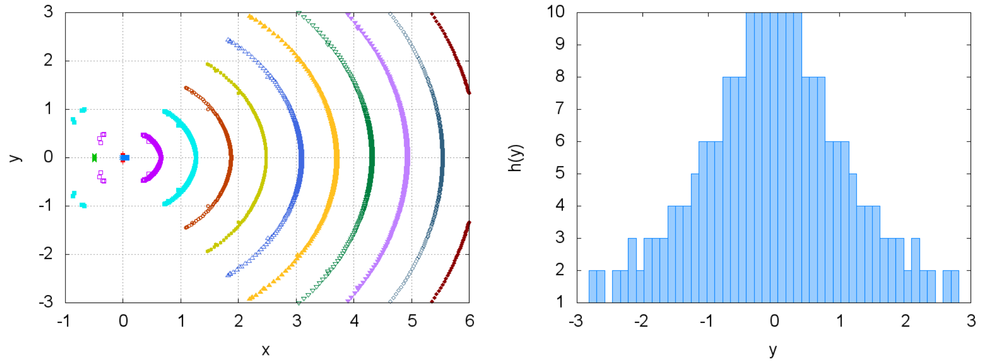

Figure 4: Results for single-slit, $v_x = 30$.
(a) Diffraction pattern, (b) Histogram.

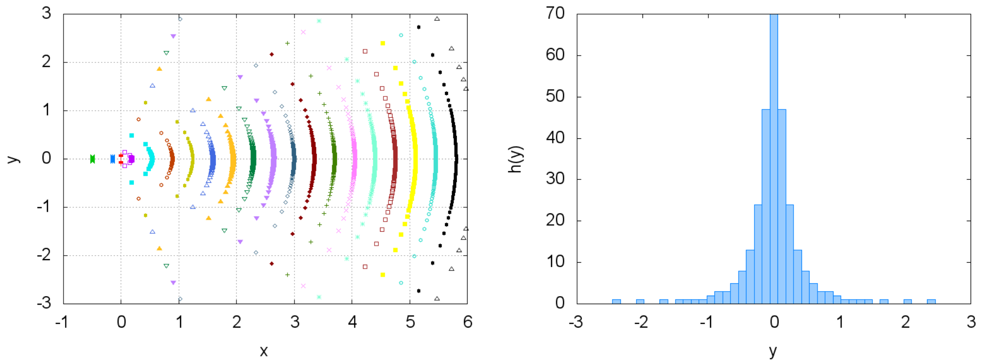

Figure 5: Results for single-slit, $v_x = 70$.
(a) Diffraction pattern, (b) Histogram.

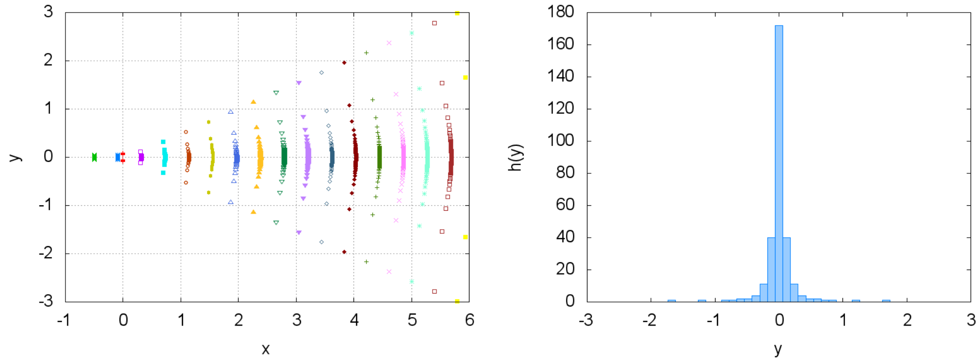

Figure 6: Results for single-slit, $v_x = 110$.
(a) Diffraction pattern, (b) Histogram.

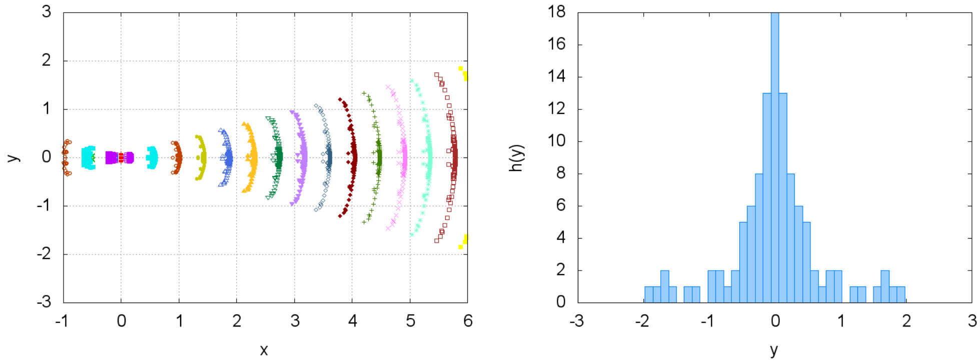

Figure 7: Results for double-slit, $v_x = 28$.
(a) Diffraction pattern, (b) Histogram.

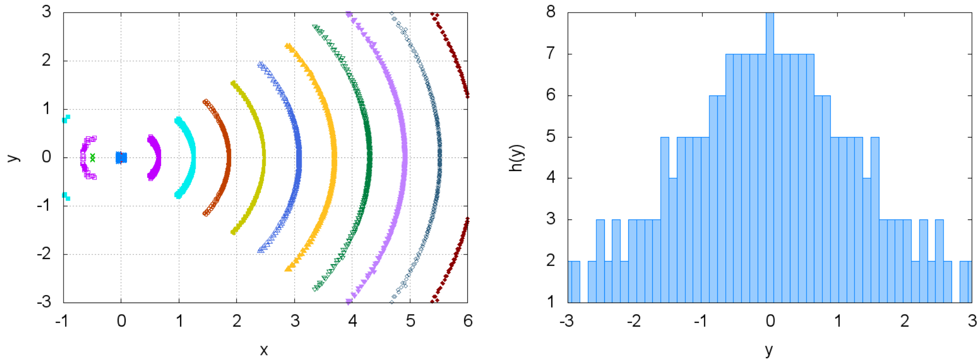

Figure 8: Results for double-slit, $v_x = 40$.
(a) Diffraction pattern, (b) Histogram.

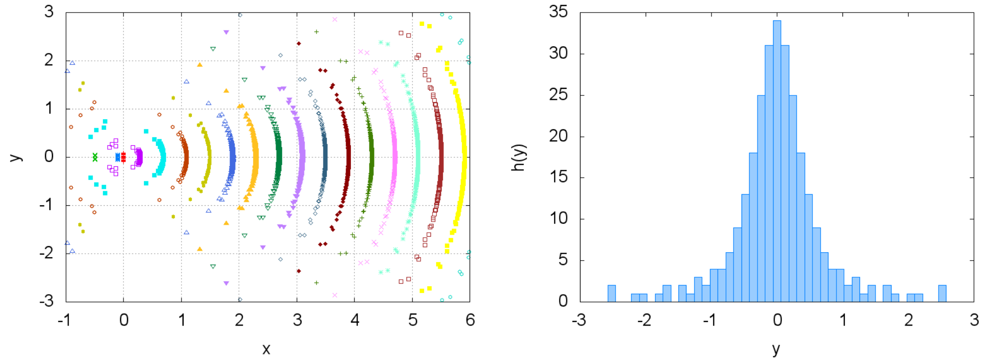

Figure 9: Results for double-slit, $v_x = 80$.
(a) Diffraction pattern, (b) Histogram.

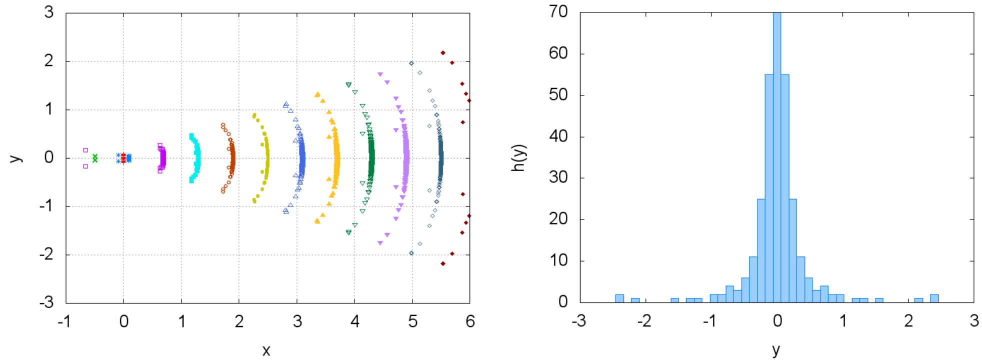

Figure 10: Results for double-slit, $v_x = 120$.
(a) Diffraction pattern, (b) Histogram.

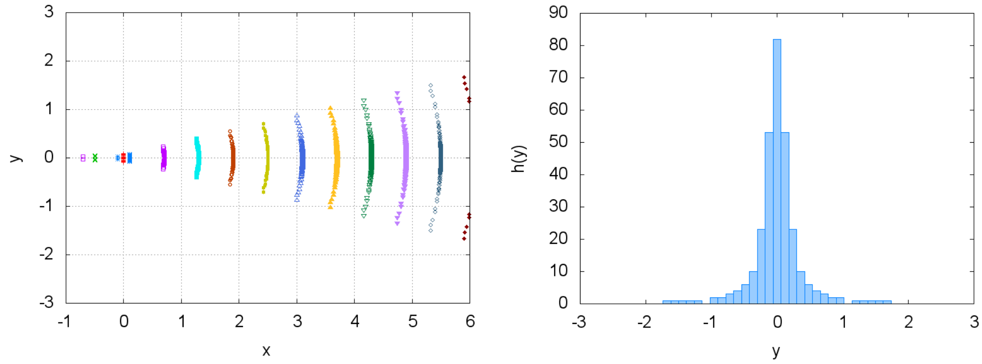

Figure 11: Results for double-slit, attractive force, $v_x = 120$.
(a) Diffraction pattern, (b) Histogram.

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