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DETERMINISM in QUANTUM SLIT-EXPERIMENTS

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ABSTRACT

A mathematical model for the slit-experiments – considered to be in the heart of quantum mechanics - is developed to gain insight in quantum theory.
The proposed system-theoretical approach for the model is based on commutative mathematics and starts with spacetime functions with cause and effect relations in the statefunction Ψ; it results in determinism in the model of the experiments and is invariant for time reversal.
It predicts the patterns in the experiments by yielding functions of the energy distributions.
The quantum mechanical description of physical reality of slit experiments thus may be considered complete in the sense of [10].

At quantum slit-experiment energy level, it appears that the concept of interference in double slit experiments actually is an effect of energy (*amplitude-)modulation.* For one-slit, a modulated function is shown to give identical results of a double-slit extended experiment, by yielding two distributions as result of the convolution in the (k-space) frequency domain. This would exclude interference due to the absence of multiple slits. In principle it may be possible to experimentally verify the effect with a modulated result function of a one slit experiment.

The system-theoretical method uses generic properties of quanta and evolves into determinism in quantum mechanics slit experiments, be it with the restriction of a direct observation/measurement or direct description with variables of the individual quanta at the heart of the state-function Ψ. The mathematics handles *beables* [9,10] and allows the proposed description by avoiding directly addressing of the individual quanta through variables. The followed method yields exact, non-probabilistic results.

INTRODUCTION

Results of quantum slit experiments are usually explained with wave-theory aiming for diffraction and interference [e.g. 6] with constructive and destructive interference of waves in analogy with waves in fluids and gases. At energy levels in quantum slit-experiments, no direct interference between photons has ever been observed or predicted, and when reduced to one photon/electron experiments without possible interaction and with in time separated detections, repeated experiments also yield the pattern, indicating that interaction of particles does not play a significant role. Wave theory leads to interpretations to explain the observed patterns with interference, in violation with conservation of quantum energy and experiment practices, while in case of a source delivering electrons, similar dark-light distribution patterns are being found, and interpretations of particle-wave duality [5] are being put forward.

The purpose of models of nature, and consequently of physics, is to provide insight into what happens in reality, i.e. with quanta which although invisible, are as messenger an ubiquitous part of our reality and leave tracks, by which we may (indeed) indirectly observe them.
The result of this study is straightforward and indicates that 'Herr Gott nicht wuerfelt' with the consequence that determinism is ruling our world. This has consequences for many interpretions that seemingly use an inverse way to construct 'reality' from a framework of explanations.
The found determinism avoids directly tracing/addressing quanta in mathematical treatment by using a system theoretical approach of input-output relations.
Quanta stay invis-ables on individual basis in the heart of the state function Ψ, cannot be observed or measured and can't individually be traced by virtual/mathematical descriptions directly without violation of the Heisenberg relation. This invisibility appears to be the paradox of the found determinism, leading to proposal of a system-theoretical approach using I/O relations instead of matrix mechanics. This approach excludes thereby as well matrix operations that are non-commutative that may obstruct time reversal invariance (or symmetry).

This doesn`t make research in determinism any easier, although quanta actually are being manifest indirectly. Descriptions in a virtual reality, avoiding treatment as *observables*, may be a glimpse of light at the end of this tunnel.

QUANTUM EXPERIMENTS

1. Single-slit experiment

In this paper the quantum-mechanical description of the slit experiments takes a system-theoretical approach instead of the usual matrix mechanics; the Hilbert space and the principle of superposition stay intact for all of the states and superpositions attained in the experiment.
The system approach uses input/output relations starting from linear spacetime (r, t) functions developed in accordance with the observables and the setup of the experiment.
To calculate the energy distributions, the Fourier transformation then follows with spatial frequency $\xi = 1/\lambda$, and wavenumber $k = 2\pi\xi$.
The experiment model consists of a source i as input for the system s (manipulation in the experiment), with result g of the output, in which all functions are spacetime-functions: e.g. the momentum of a photon is $h.\nu/c$, in which h and value of c are contants. The momentum value is constant for certain λ (monochromatic source), and the functions of source and system introduce a local causality relation.

In case of separate i(r) and s(r), g(r) may be calculated by the convolution i(r) * s(r)

$$g(r) = i(r) * s(r) = \int_{-\infty}^{+\infty} i(\rho).\ s(r-\rho)d\rho \qquad (1)$$

The result of the convolution process is considered to be the weighted average outcome of the interactive effect between i(r) and s(r) over certain (limited) r. The convolution is commutative i.e. i(r) * s(r) = s(r) * i(r).
A local causal relation is thus introduced between the functions: g(r) obviously is a direct effect of i(r) and s(r) ; g(r) must be absolutely integrable on the interval $-\infty < r < \infty$ to apply integral transformations.

Since we know the approximate results of the experiments, focus is on i and s.
In the slit-experiment the system i.e. experiment setup is well known and a description of the process with the quanta is to be found *because* of the system interaction (manipulation) i.e. with the energy on quantum level in the experiment. Therefore, for the application in quantum mechanics, the Fourier transform is suitable when multiple slits are to be considered. Also the Fourier transformation - abbreviated <=F=> - is unambiguous in both directions, commutative and suitable for our purpose.
The Fourier transformed functions [8, 11] in the k-space frequency domain then are

g(r), i(r), s(r) <=F=> G(k), I(k), S(k) and

$$G(k) = I(k) \cdot S(k) \tag{2}$$

The following step deviates from the usual approach: instead of turning to vector space matrix mechanics and linear algebra, systems-theory [11, 12, 14] with its roots in commutative mathematics is applied to derive the spatial location-frequency i.e. in the (k, r) space domain to arrive at k-space frequency functions in the detection plane.

1.1 System functions in the (k, r) -space

The start is the input i for the system i.e. the source of quanta with a spatial momentum distribution that is uniform and all frequencies (m^{-1}) have the same amplitude. This source is considered ideal for the experiments, as all spatial locations at a distance r from the source at $t = t_0$ have the same energy amplitude.
Because of the patterns found in the experiments, therefore the deviation from the ideal uniform distribution of quanta in space may provide a model that describes the actual manipulation in the experiment.

The source and the slit manipulate the quanta in momentum p in the interaction and also the uncertainty in momentum Δp is reduced to p-components in the direction of the z-axis of the slit. When quanta are being captured in the slit, the assumption is made that the energy inside the slit remains unchanged i.e. there are no processes that require external energy and the boundaries of the slit do not absorb/emit energy in interaction with quanta.

The slit geometry reduces uncertainty Δr in spatial location r, however the Heisenberg relation [2] is to remain valid in the experiment with a lower boundary $\Delta r \Delta p \geq h/4\pi$.
The manipulation is in the internal energy states (degrees of freedom) of the photons.

The source is supplying the surface of the slit(s) with a uniform distribution in momentum[1] of N photons that may be repeated for a continuous input, to arrive at the result in detection (when required for clear detection). In principle the model thus is capable to fit a single photon experiment when provided by such a source repeatedly.
The energy distribution of an ideal source in terms of momentum is the normalised uniform distribution of quanta on the sphere around the point source. For quanta (photons) this represents the amount of quanta at a certain frequency i.e. the energy amplitude at the particular location.
The uniform distribution $D_p(k)$ determines the distribution of amplitudes of energy at the spatial frequencies and is by definition the Fourier transformed complex function of the ideal impuls function of momentum in the r-domain

$$D_p(k) <=F=> \delta_p(r) . \qquad (3)$$

Actually $\delta_p(r)$ is the generalised equivalent of a Dirac pulse of the momentum function p(r) with availability of all momenta at $t=t_0$ and represents the ideal source[2]. In practice, this is quite demanding for a source, however as mentioned repeating the pulse until all momenta are present is acceptable as the patterns may built in time.
During the formation of the quantum pulse inside the slit, at the input of the slit ideally all spatial angles of the momentum vectors are captured with identical amplitude of all frequencies in the slit surface.
For a normalised amplitude, $D_p(k) = 1$ in the k-space domain i.e. all frequencies have the same normalized value '1' and in principle the entire spectrum of frequencies is covered in $D_p(k)$. The detection is a summation of all quanta in time in the frequencies, therefore the phase behaviour of quanta in the process (i.e. source and manipulation) does not play a significant role.
Typical for the point source is the decreasing density of the radiation as a function of r in free space. In contrast, in the confinement of the slit, the energy inside the slit (i.e. in each 'pulse' filling the slit) does not change, until the quanta start emanating from the slit. The values of momentum of the quanta do not change as internal energy state values are conserved.
To find the ideal system function $\delta_p(r)$ of the momentum function p(r), the system-theoretical approach is followed with the convolution property[2]

$$\delta_p(r) * p(r) = p(r) \qquad (4)$$

and the requirement that $D_p(k) = 1$.

The function normalising the momentum function p(r) is introduced as $p_n(r)$ with Fourier transform $P_n(k)$. $P_n(k)$ is the inverse Fourier transform function of P(k) to arrive at the uniform distribution $D_p(k)$[3] :

$\delta_p(r) = p(r) * p_n(r)$ with $<=F=>$ $D_p(k) = P(k) . P_n(k) = 1$, => or

[1] Obviously, a non-ideal source would influence as well the frequency slit output (the frequency domain product) and thereby the (2D) graphics projected detection result.
[2] In systems theory, the measured result r of the system s(r) with input $\delta_p(r)$ actually is s(r): $\delta_p(r)*s(r) = s(r)$. The description is by I/O relations.
[3] It is not directly needed in this modelling to derive the function $p_n(r)$, only the Fourier transform 1/P(k) is.

$P_n(k) = 1/P(k)$ (5)

$\delta_p(r)$ represents the ideal momentum pulse: all quanta having momentum with components in the positive z-axis direction that are captured by the slit opening are present, propagate and start building the pulse.

In practice, 1. the source s, 2. distance d_s of the source to the slit , and 3. geometry of the slit, influence the result function g(r) to a large extent in the sense that the frequency content of g(r) is facing three low-pass momentum filters, shaping G(k) into mainly low frequency content around r = 0.

The photon energy is $E = h\,\nu = h\,c/\lambda$ of photons arriving at the surface O until the slit is filled with N quanta. When slit length is l, and the time t = l/c for the first components to emanate, the total energy E_p of each pulse inside the slit becomes

$E_p = N.h.l/\lambda$ (J) (6)

After the pulse leaves the slit, the process may be repeated to capture all of the momenta of the source until the source momentum distribution consists of all frequencies and the re-distribution is clearly observable at detection.

The model of the slit filled with quanta follows as a rectangular function s(r) of passing the emanating pulse through the slit output surface O , i.e. as the rectangular s(r) function of the pulse Π (r, t=l/c), building the pulse in surface layers of emanating quanta with their unique momentum created by the slit interaction.

Each pulse of constant energy emanating from the slit can be described by a convolution of the Dirac momentum pulse $\delta_p($ r) and s(r), because i(r) * s(r) yield the result function g(r);

with $i(r) = \delta_p(r)$, then $g(r) = \delta_p(r) * s(r)$ with transformed function < =F= >

$G(k) = D_p(k).S(k) = 1\,.S(k) = S(k)$ (7)

with S(k) < =F= > s(r)

The transformed result of g(r) <=F=> G(k) = S(k) is the frequency distribution function of the energy in case of the ideal source.
With the Fourier transform of a rectangular spatial pulse of quanta s(r), G(k) then is a sinc (k.r) with amplitude $N.h.l/\lambda$, and

$G(k) = (N.h.l/\lambda).\ (\text{sinc}\ k.r) = (N.h.l/\lambda).\ (\sin k.r)/k.r$ (8)

with Planck's constant h, slitlength l, wavenumber $k = 2\pi\xi$, $\xi = 1/\lambda$ and λ the wavelength of the used source.

The result (8) shows that a *generic* 1 slit experiment model yields *sinc (k.r) function type patterns* at detection in the (x,y | z=0) plane, which in the experiment directly depend on

1. the momentum distribution and wavelength of the source and
2. the actual geometry used in the experiment: slit length l, slit in- and output surface O (capture, confinement) and source distance d_s[4] .

1.2. Experiment & practical system functions

The source at distance d_s from the slit supplies it with quanta covering all spatial angles with a momentum component in the positive direction of the z-axis, all other quanta are blocked i.e. the slit acts effectively as a *momentum filter* for the quanta. With $d_s = 0$, and the source in the centre of the input surface of the slit, all quanta with a momentum component in the positive z- direction are present and the frequencies/locations are symmetric in x and y. A uniform distribution at slit entrance is possible however depends on the used source's capability to emit all momenta and therefore in practice acts as a momentum filter as well.

Although the model is based upon an ideal source containing all momenta within +/- 90 degrees spatially with the positive z-axis, the distance of the source has a huge impact. The angle captured by the slit is governed by sin $\varphi_m/2$, where $\pm$arctan $\varphi_m/2$ is the angle caused by slit geometry and d_s. The angle φ_m is highly depending on the source distance d_s and geometry of the slit, and thus increasing d_s acts as an additional momentum filter by restricting φ_m in the higher values and therefore functions as a potential 'low-pass' filter. The pulse then is built of momenta with a maximum in sin φ_m and thus substantially shapes the result function g(r) by restricting the frequency content in G(k), thereby creating a narrowed sinc shape around r = (x,y =0 | z=0). This may be modelled in i(r) by taking instead of the Dirac generalised δ_p(r) function, a rectangular filter function that restricts the higher frequency location components of the source.

The source, distance to the slit and slit-geometry therefore influence the pattern directly by sensitivity for higher momentum frequencies: when the momentum distribution is far off the ideal situation, creating little interaction with the boundaries inside the slit, a less broad pulse of small divergence and less frequency content emanates and vice versa, an ideal source δ_p(r) creates maximum interaction inside the slit and shows a broad diverging pulse of much higher frequency content.

2. Double-slit experiment

The result for two slits follows the one slit result. For this extension, one considers the one-slit result as an additional distribution of energy in the k-spatial frequency domain: the detection plane (x,y | z=0) of the experiments is a graphical representation of the quanta per location r i.e. an amplitude. The transformed function in the frequency domain represents the amplitude of energy in y of the frequencies locations in x, the spatial locations.
The double slit manipulation consists of *addition* of a identical second slit with therefore an *identical distribution* of quanta with shift in x. With the origin O in the middle between the slits, then

[4] Not (yet) integrated in the model as the purpose of the paper is to show (exact) predictability of the found patterns.

$\underline{+}\, x_{slit} = n.\lambda = 2\pi/k_0$ on the x-axis, which is represented by a frequency *shift* in the Fourier transform G(k) of g(r) and the two distributions are

$G(k + k_0) = G(k + 2\pi/x_{slit})$ and $G(k - k_0) = G(k - 2\pi/x_{slit})$. (9)

With spatial frequency $\xi = 1/\lambda$, wavenumber $k = 2\pi\xi = 2\pi/\lambda$ and $k_0 = 2\pi/ x_{slit}$.

Two slits thus produce 2 distributions $G(k - k_0)$ and $G(k + k_0)$, that seem to show a pattern with 'interference'. At levels of energy in the experiment, photon interference however has never been reported or theoretically predicted.

Two shifted distributions can be explained more clearly by calculating a modulated g(r) for one slit by the product

$g(r) . \cos k_0.r = m(r)$ (10)

with the Fourier transform M(k), resulting in the shifts in the k space domain by convolution:

$m(r) \Leftarrow F \Rightarrow M(k) = ½\, G(k + k_0) + ½\, G(k - k_o)$ (12)

which shows the 2 distributions due *modulation* of the *1 slit* g(r) in the amplitude of the frequencies.
The product in (10) yields in the k-domain the convolution G(k)* F<cos k_0.r>. For a limited r (i.e. possibly large but not unlimited, to be integrable $-\infty < r < \infty$), $f(r) = \Pi(r / \delta).\cos k_0.r$ and one finds the addition of the two (limited by $\Pi(r / \delta)$ 'filter' function) expected sinc functions in the frequency k – domain.
The k_0 relation in the 2 distributions of M(k) is unambiguously related to the modulation cos k_0.r ; the two slit identical result and an identical k_0 relation between slits, therefore is related unambiguously to the modulating function $\cos k_0 r$ as well, obviously with double energy amplitude because of two slits:

from (9) and (12) one finds $G(k) = G(k + k_0) + G(k - k_0) = 2.M(k)$ (13)

The foregoing is known in Fourier transformation theory as the m*odulation theorem*, in which the modulated g(r) may be considered an envelope function with k_0 the wavenumber of the carrier frequency k (m^{-1})[5].
From this theorem, one may conclude that one slit with modulated g(r) i.e. m(r), yields 2 k_0 shifted distributions, showing an identical re-distribution of quanta by the modulation effect as a two-slit experiment, creating an exactly identical pattern, however by the absence of a second slit without possibility of interference.
This rules out interference caused by a separated physical second slit, and consequently interpretations of a quantum partially being in two states at the same time [1] (by splitting up

[5] From the (k, r) domain, by substitution into the (ω, t) pair domain for ω,t >0 (of information transmission and signal theory), likewise this property of the Fourier transformation has firm roots in radio technology deployments in which frequency sideband, envelope function and carrier wave frequency $f_0 = \omega_0 /2\pi$ have (had) a prominent role in communication and broadcasting.
The sideband contains all transformed information (obviously the main reason for radio transmission), which information may fully (or partially) be recovered by de-modulation. Thus the input information contained in the frequency domain is preserved to re-build the time functions (directly in e.g. broadcast, reception, de-modulation) but also any time when the data is conserved for this purpose.

energy or other interpretations) and entering two slits leading to some kind of interference, are unlikely.

The modulation effect paves the way for explanation of the experiment when performed with mass particles e.g. electrons and single particles with randomized momentum repeated experiments, that are modulated equally into a pattern by manipulation of their momentum in the slit and thus by yielding identical patterns in the final distribution when emanating, without (any) reverting to wave properties of mass particles and interference in general.
The model is suitable for single particle experiments with many repetitions, all other things equal including sources that emit (ideally) a randomised but full spectrum in momentum of the single particles.

In the practice of the photon experiments, due to slits of say 0.1 mm distance apart (different in experiments depending on used wavelengths) and then k_0=0.05 mm, thus two distributions are present in reality with a tiny x-shift between distributions; due to this small value between slits, these are projected seemingly as one distribution with identical shape at the detection plane.

At detection of the resulting function, information in the frequency domain (sinc kr and k_0) can be preserved and may be used to reconstruct the momentum function g(r) as all mathematical operators (c.q. operations) are commutative; this means that the causality relations are invariant for time reversal [7].

The preservation of information in the modulation operation becomes more obvious in the (ω, t) pair frequency domain[5] of information transmission where all types of modulation including amplitude modulation as is the case here, are well known and widely deployed for the purpose of recovering the information e.g. of a radio broadcast locally elswhere.

Note that the arrow of time cannot be reversed in case of de- or con-structive interference, as information is lost and cannot be retrieved. This is as well the case in attemps where correlations exist between results of calculations or experiments, as the correlation operations are not commutative. This principally denies validity of (Bell, 1964) correlation functions (as well as matrix multiplications in vector spaces) eg. for invariance of time reversal in this system theoretical approach. Correlation is a one way street by definition and is separated from causality (despite a statistical relation in data(sets)) which seems not widely recognized.

This result shows that the quanta in the frequencies of the re-distribution of energy as detected in double-slit experiments, therefore become manifest because of an *amplitude modulation* effect in the k-space frequencies, which is fundamentally different from interference[6].
This result is useful to abandon - on these quantum experiments energy level - wave interpretations with interference and consequently, further interpretations thereof. Wave-particle

[6] Hence author's preference for state-function instead of wave-function.

dualism [5] and related interpretations[7] [6]) need not to be assumed nor are required to explain quantum slit experiments.

INTERPRETATION

A thought experiment of reality

In entering the slit a pulse of constant energy is created by the captured quanta i.e. the energy of the pulse does not change during the confinement in space, in contrast with the momentum functions which are heavily affected inside the slit. The interaction of the quanta with the slit is in internal energy (therefore re-active[8] or inter-re-active and requires time) and causes the re-distribution in momentum by creating a myriad of trajectories in the slit with equally different phases until finally emanating from the slit. When emanating layers of quanta of the pulse, the layers thus contain sets of quanta with a momentum distribution that differs in each layer, i.e. the sets of momentum in the layers are unique in composition due to inter-re-action of the quanta with the boundaries of the confinement: quanta with the largest momentum components in z-direction emanate first, the ones with the smallest components and most inter-re-action with the slit last, indicating that the phase of the emanating quanta does not play a significant role in the redistribution for pattern detection.

As result, the momentum distribution is re-arranged during the entire propagation of the pulse in the slit, until the layers reach the free space and momenta are 'frozen'. During propagation, the momentum vectors of quanta are in transition of their internal energy state (almost continuously, depending on momentum distribution) i.e. are in a new superposition after each inter-re-action with the slit, and attained states are deterministic however not observable, while their vector *values* of energy h.ν stay preserved. The latter strongly indicates that observation/measurement will destroy quanta and convert their energy to results in eigen*values* with consequences both in virtual treatment mathematically (i.e. by 'collapse' of a state-function) and in reality by a full transition of energy when observed/detected [9].

CONCLUSIONS

This paper started by embedding cause and effect relations in the system model and continued with the introduction of system-theory, based upon commutative mathematics (of convolutions and linear transformations) allowing reversibility in time, to derive the ideal system response in terms of k-space energy distribution. The practice of the experiments is treated by inclusion of the (low-pass) restrictions in the frequency content of the resulting functions (10).

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[7] The result indicates that the de Broglie duality relation e.g. [5] in principle explains the energy equivalence formula, relating different properties of photon field-energy and matter energy of mass particles.

[8] Inter-re-active and re-active is in the sense of local and temporal exchange of internal energy / 'degrees of freedom'.

[9] This provides support to change the way of mathematical treatment for quantum processes and gives ground to failing descriptions with e.g. hidden variables. When quanta are associated with variables, calculations and mathematical operators require e.g. momentum p and location r + related variables as exact values, thereby violating the Heisenberg relation. This leads to results in eigenvalues with passed on probability as encountered in the probability result functions from vector space matrix mechanics. For exact results, the quanta cannot be addressed individually nor be subjected to operators as for observables, and one has to rely on indirect descriptions.

It demonstrates that quantum slit experiments are deterministic in the resulting (and experimentally found) functions of patterns when accepting the deviation of the usual matrix mechanics in the vector space by the system-theoretical approach in commutative mathematics, including the in/out relations and the modulation effect. This approach excludes interference and existing correlations in the description as they cannot support time reversal invariance.

The exact results may seem ‘ímpossible’ as one cannot observe the indiviual quanta exactly in the heart of the statefunction Ψ without destroying their state, and therefore remain ‘hidden’ from observation in reality’s classical sense and as well in the virtual reality of mathematics. This led the author’s to the system theoretical approach[10] instead of vector space mechanics as in Schrödinger’s approach; it is emphasized that the system is described with input-output relations based on *commutative* convolution & transformation (only[11]) and in principle may not be unique for the described subject (i.e. physics, experiment). This however is often the case e.g. in equivalent behaviour and description of mechanical and electrical systems (apart from the variables) with identical transformed system functions.

The exact functions in the results seem to rule out any form of quantum state probability in the quantum experiments, whereas all quantum state complex energy-vectors in the experiments are part of the Hilbert space and the state function Ψ has no restrictions in evolving in *any and all* of the states. This includes all possible linear combinations of state superpositions required to represent the quantum experiment (or any operation) - the result stays deterministic by applying mathematics in an indirect system approach thus excluding a direct description (eg. observation, measurement) of individual quanta. This appears to support the expectation that *all* state functions Ψ_n in the complex orthonormal Hilbert space can have a deterministic result with the consequence that exact solutions actually exist for all Ψ_n.

The determinism found in the model may have (substantial) impact on current views and interpretations when extrapolation of the result in quantum mechanics can be verified into further aspects of the theory: from mathematical treatment to quantum computing (e.g. qubits) in subjects related to probability and interference.
When this verification can be established, probability including interpretations of quanta being “partly in each of two or more states” [1] apparently then would disappear from stage, whereas the principle of quantum superposition of states in a complex Hilbert space holds.

To date, mathematics including use of hidden variables and complex state-vector space matrix mechanics of linear algebra, are attempts requiring a direct description of quanta (and quantum-processes) leading directly to eigenvalues that do not exactly describe the actual states apparently due to a direct violation of the Heisenberg relation (or cannot comply with causality and time reversal). At the same time the introduced probability interpretation (Born) has been a blessing in proceeding with the (heavily attacked [10]) theory, rendering it one of the most successful theories in physics.

[10] Also named ‘black-box’ [11, 14]
[11] Excluding the correlation function (-operator), being not commutative.

The proposed method appears to give an indirect description leading to exact results of what one expects physics to describe in almost a classical way; the difference is that it does not trace individual quanta or reveals individual quantum behaviour in the heart of the state function and one must rely on the thought experiment[12]. We cannot calculate with or acquire information on the exact (p, r) of individual quanta, as W. Heisenberg already predicted.

Postscript

*Author's note. This deviation in description of a quantum mechanical system started from the energy of the massless photon in the vacuum experiment with (external) $E_p = h.\nu$. From the momentum of the photon we have $h.\nu / c = E . t / | \underline{r} |$ where $t / | \underline{r} |$ is a constant, describing the spacetime evolution: $\underline{r}$ represents a position vector with length $| \underline{r} |$ of a photon in the coordinate system. It shows that when $| \underline{r} |$ and t evolve identically, the field (-energy) density does not change, in contrast with spatial fields in general evolving in spacetime. The state-function evolves into *internal* states without energy density value changes. The function seems to have an identical form as in the case of deterministic systems described in [15] with a magnetic term A(x).*

[12] A.Einstein would have liked this.

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