(This is a part of the book The Concept of Reality.pdf)

Contents:

3. Local and objective Interpretation of Quantum Theory

3.1. Preliminary Note

The simplest way to outline the structure of quantum theory and, at the same time, to demonstrate the problems of its interpretation, is via paradigmatic application cases. Prior to quantum mechanics, such examples served for understanding the connection between the respective formalism and the underlying *actually occurring* physical process. But in quantum mechanics they serve the opposite: they are meant to demonstrate that the attempt to explain which real events are hiding behind the formalism is pointless.

Therefore, as introduction, two well-known scenarios shall now be presented – at first in the usual form to expose once more to which strange, not to say: absurd assumptions nature seems to compel us. Such a reminder is perhaps not completely superfluous – the frictionless working of the quantum mechanical formalism could easily push the interpretation problems all too far into the background.

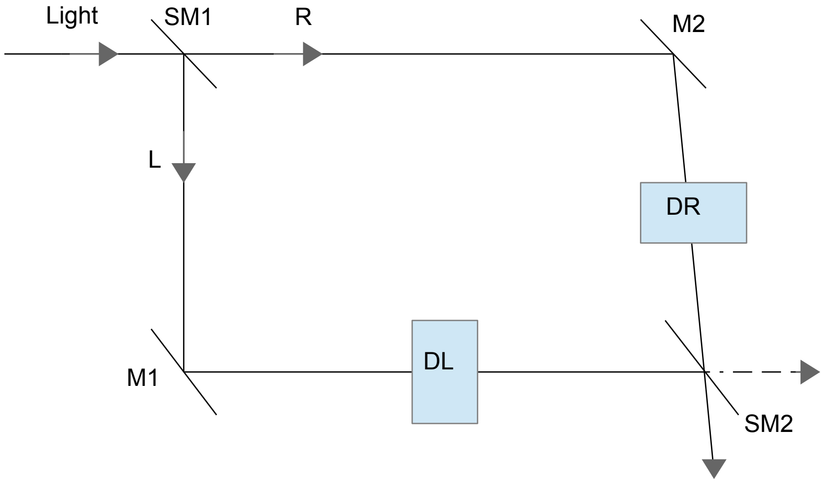
Afterwards, step by step the tools will be developed which are needed for a local and objective interpretation of quantum mechanics. Later, the same scenarios – and some other ones – will be placed into the new interpretational framework and explained in such a way that all absurdities are eliminated and it becomes comprehensible what *actually* happens. Moreover, the new interpretation does not only avoid the oddities of the usual view but is even closer to the formalism.

As just before, in the explanation of special relativity, formal tools can almost completely be dispensed with; it is again a purely interpretational issue.

3.2. Introduction: two Examples

Paradox of the Two Paths

Let us look at the following experiment:



(S1)

A light ray (starting top left) passes through the depicted test arrangement. The intensity of the light is chosen so low that almost certainly only one single photon is present within the diagrammed area.

At first the light crosses the semi-permeable mirror SM1. On both paths L and R it is redirected by mirrors M1 or M2 in such a way that the rays reunite at a second semi-permeable mirror SM2. The lengths of the paths L and R differ, such that at SM2 the phase of the ray propagating along L does not coincide with the phase of the ray propagating along R and one of the two rays disappears due to destructive interference. In both paths photon detectors (DL and DR) can be inserted.

The experiment reveals the following – in the common approach unsolvable – absurdity:

If the detectors are *not* in the light paths, then we observe *interference* after the second semi-permeable mirror, that is: the photon – or the light wave – must have taken both ways; otherwise interference would not be possible.

This fact deserves particular attention:

There must **always** *be something underway in both paths – otherwise one could not observe interference after the second semi-permeable mirror if both paths are free.*

However if we now insert the detectors into the paths, then in any case only *one* detector at a time responds: since the photon is indivisible, it can only choose *either* L *or* R (with a probability of ½ each).

This fact deserves particular attention too:

There can **never** *be anything on the way in both paths at the same time, because the two detectors do never respond simultaneously.*

Obviously these two facts contradict each other.

How is this contradiction "solved" within the standard interpretation? In the following way:

If a photon appears in one of the detectors, the wave phenomenon on the other path is vanishing instantaneously! – it is considered kind of non existent, it has been nothing but a "probability amplitude", whatever that means.

This is the so called *reduction of the wave function*: Only one of the diverging wave-like possibilities – in our example there are only two – becomes real, und all others vanish instantaneously, no matter how distant they may be.

If the amplitude squares of these quantum mechanical probability waves only represented probabilities, as in a dice game, then there wouldn't be a problem – nothing would vanish because in any case there would exist but one reality: namely the dice on its way, from the very beginning of the cast, and because the probability of one sixth for each option would only point to the fact that we simply don't know the definite path of the dice.

However Quantum mechanical possibilities cannot be interpreted like that: They *interfere* – there is interference if the detectors do not stop the light rays. This *must* imply that something exists in both paths. And something which exists cannot just vanish!

Still, it does vanish. And we have to resign to this fact – at least according to general conviction. Indeed this paradox is not conceived to explain anything but rather to demonstrate that nature behaves in a way which is totally incomprehensible to us.

But hold on! Perhaps the photon "knows" what we are doing? If the information whether the detectors are inserted or not existed in some way at the first semi-permeable mirror SM1, then the photon could decide whether to take *one* way or *both*.

But even this conjecture – which itself does not seem very plausible – does not offer a solution to the problem.

This is because we can defer the decision whether or not to insert the detectors into the light paths up to the moment when the light has already passed the first semi-permeable mirror, that is: after the decision whether it takes only *one* or *both* ways has already been made. Also in this case, the experiment proceeds in the same way: without the detectors, we observe interference, but if the detectors are inserted, no simultaneous response but a random sequence of alternating events in both detectors occurs. However, as the decision whether the light takes one or both paths must already have been made, we seem to be able to determine retroactively what it does – or has done.

The formulations offered by the standard interpretation do not clear up anything, rather they remind of flower-garlanded speech bubbles. E.g. it is stated: "The events cannot be described isolated from each other. They form a single entity which is divided only by measurement." Or: "Nothing is an event before it is observed."

In actual fact, such statements do not at all mitigate the absurd rigidity of the paradoxical, essentially unacceptable fact that in this scenario – just as in all quantum theoretic descriptions – something which gives proof of its existence by interference is vanishing, and that this disappearance happens *without any physical causation*.

At that, this disappearance is supposed to happen *simultaneously* with the measurement, that is: *at any given distance without any delay*, where it is actually not clear what that means: In the case of observers moving relative to each other – would there occur a difference of the time points when all probability waves disappear, which do not become real?

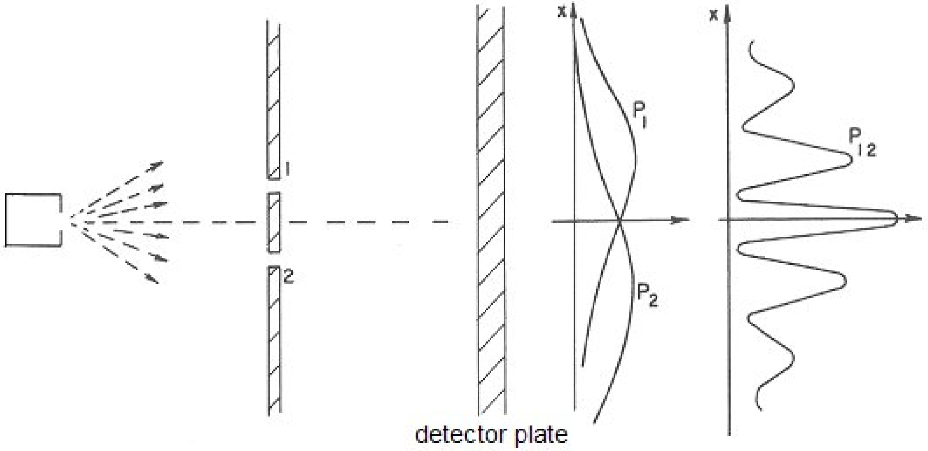
Enough with these absurdities! Surely it has become clear that the reasons by which the physicists felt themselves compelled to accept the just depicted circumstances *as an interpretation* instead of seeing them as a *reductio at absurdum,* must be judged based on the question if they are indeed strong enough to justify such an extreme decision, and that any alternative, which avoids such bizarre assumptions, must be favoured.

Double-Slit Experiment

Let us again hear Richard Feynman:

"In this chapter, we shall tackle immediately the basic element of the mysterious behavior in its most strange form. We choose to examine a phenomenon which is impossible, *absolutely* impossible, to explain in any classical way, and which has in it the heart of quantum mechanics. In reality, it contains the *only* mystery. We cannot explain the mystery in the sense of 'explaining' how it works. We will *tell* you how it works. In telling you how it works we will have told you about the basic peculiarities of all quantum mechanics."[1]

So much to the *status quo*. Now to the description of the experiment:



(S2)

On the left side of the outline there is a device for generating some kind of particles, e.g. electrons (or photons, or whatsoever. The following applies to *all* kinds of particles). If this apparatus is activated, then at the detector plate an erratic sequence of dark points will appear. However in the course of time, the well-known interference pattern will emerge. (P_1 shows the distribution of the points if only slit 1 is open, P_2 if only slit 2 is open, $P_{1,2}$ if both slits are open.)

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[1] Feynman, Leighton, Sands, *"Lectures on Physics"* Vol. 1, 37–2, Addison-Wesley 1965.

Usually, the collapse of all attempts at explanation is described in the following way:

On the one hand, electrons (or photons etc.) occur only as indivisible units. Thus they must be described as particles, which means: they pass *either* through slit 1 *or* through slit 2. But $P_{1,2}$ is not the sum of P_1 and P_2 – there is interference, which is impossible in the particle image. Thus we must, on the other hand, use the wave image of electrons in order to describe this interference. In *that* picture, a wave passes through both slits, is diffracted by them, then interferes with itself, and at last arrives at the detector plate. Depending on the distance between the plate and the double slit, this wave can be arbitrarily extended.

However now we do not observe a continuous gradual increase of the plates blackening according to $P_{1,2}$ but a sequence of narrowly localized events, that is: of single tiny black spots each of which is triggered by a single electron, which now, accordingly, corresponds again to the particle image. Only a great number of such local events will form the interference pattern.

Once the particle manifests itself, the whole wave phenomenon disappears instantaneously. (This is again the *reduction of the wave function:* again only one of all wave-like expanding possibilities remains, that is: the one which becomes the observed event. All others disappear.)

Particle image and wave image are incompatible. However both are required for the description. Thus we seem to be forced to admit the limitation of our concepts and our reasoning and retreat into the mathematical scheme.

Surprisingly, this scheme is very simple: the procedure is described by a function Ψ. Ψ satisfies a wave equation. In fact, $P_{1,2}$ corresponds exactly to the distribution which would also occur due to the interference of normal waves – of course with the exception that in the case of normal waves, a continuous increase of the blackening would be observed and not a sequence of point-like events.

For this reason, the amplitude of Ψ is not interpreted as amplitude of an actually existing wave but as a so-called *probability amplitude.* Its square specifies the probability (or in the continuous case the probability density) of the events.[2]

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[2] If you want to know right now what *actually* happens in the double slit experiment, you must read on in Section 3.6.

3.3. Back to the Roots

Before 1900, the physical reality was divided into two categories of phenomena, which were based on different model conceptions: the ones that exhibited wave-like and the ones that exhibited particle-like behavior. However on this basis it was impossible to describe the interaction between light, which was seen as a wave, and matter, which was conceptualized as consisting of particles, in accordance with the experiment. For that it seemed necessary to assign particle attributes to light. Not much later it was realized that reversely wave attributes must be assigned to particles too.

Suggested by some observations, antecedent to quantum theory a new classification of the phenomena was established: At any kind of motion – e.g. propagation of radiation, motion and distribution of atomic or sub-atomic particles – objects were supposed to behave wave-like, which manifests itself particularly by diffraction and interference, whereas at interaction processes – absorption and emission of light, acceleration of electrons by electromagnetic radiation, diffraction of light on electrons – objects were expected to act particle-like.

The connection between the two models, which now *both* – though they are incompatible – had to be applied to all objects in the microcosm, was regulated by the equations

$$E = h\nu \quad \text{and} \quad p = h/\lambda$$

where h is the constant that Planck had determined in his attempt to describe the black body radiation. (He succeeded only under the condition that an oscillator with frequency ν cannot absorb any amount of energy but only integer multiples of the energy $h\nu$.)

Because of the wave-character of particles – more precisely due to the definition of momentum by an inverse wave-length – the simultaneous existence of position and momentum got lost. The minimum of uncertainty of their simultaneous determinability was given by the equation

$$\Delta x * \Delta p \geq h$$

– the so-called *uncertainty relation.*

I assume you are asking yourself why this is told here once again. This has the following simple reason:

The structure of quantum theory ensues from the fact that it integrates all the just mentioned experimental experiences.

Therefore, if one aims at re-interpreting quantum theory in a new way without changing its formal structure, then it is necessary to first re-interpret exactly those experiments, which gave rise to it and could be described by it.

This will be carried out in the following.

In the opinion of the majority of physicists, the theoretical constructs of physics in the first decades of the 20th century must be understood as results of a series of formally and logically necessary steps. I do not wish to repudiate this. Much rather I try to show that the *initial* step was wrong and that, accordingly, the mistake has always been *presumed* from the very beginning.

So let us turn towards this initial step and reconsider, after more than a hundred years, the question about the nature of the interaction between light and matter, as it presented itself to Albert Einstein in the year 1905.

3.4. The Photoelectric Effect

The experimental facts of the photoelectric effect:

If a metal plate gets irradiated by UV-light with a frequency ν above a certain limit ν_{min}, electrons are set free without any delay. The kinetic energy of these electrons depends only on the frequency ν of the radiation.

This is in blatant conflict with the wave model of the light, according to which the displacement of electrons should take place at any light frequency and their energy should depend on the intensity of the light. Furthermore, an enormous delay (under realistic conditions thousands of hours) until the displacement of the first electron would have to be expected, if one assumes that the energy radiated onto an area of the extent of an electron cross section should have to mount up to the required value.

As is well known, Einstein’s solution was to assume an interaction between light and matter in the form of an *impact process* of particles, i.e. of a light-quant with the energy $h\nu$ and an electron bound with the energy A. Then from the energy balance the following equation results:

$$h\nu = A + mv^2/2 \qquad \text{(A … displacement work)} \qquad (1)$$

This equation describes the process in accordance with the experiment. Insofar it is justified to call this a correct and successful description.

However one would surely prefer to know *how* this magic metamorphosis of a wave into a particle occurred – at least it is decisively proven that light is a wave.

For comparison, imagine the following scene: a magician places an empty top hat on a table, puts a trumpet into it and speaks his magic formula – and out of the hat jumps a pig! – And now all you know is the velocity of the pig. In spite of the undeniable benefit – you would probably be able to sidestep the next pig – you would hardly be content with this knowledge!

What really matters is that, in this case, indeed nobody would assume that the trumpet has *actually* been transformed into a pig. Why not? Plain and simple: there is no magic.

So why do we accept the transformation of the wave into a particle as a fact?

The usual commentary – which pretends to be an explanation – reads as follows:

Our thinking applies only to the medium-sized world. It is not suitable for understanding anything very small.

Let us simply replace this untenable assertion, which, as a standalone assumption, is out of thin air, by the general

No-Nonsense Hypothesis: There is no witchery. There is altogether no nonsense within nature.

Armed with this hypothesis, we turn again to the Photoelectric Effect.

It is completely ascertained that light is a wave. Therefore *it is* a wave. And as there is no witchery, it does *not* turn into a particle – thus it must enter the interaction as a wave.

On the other hand, we know that it is not possible to describe the Photoelectric Effect as interaction between wave and particle.

This means there is only one way out: the electron must be a wave too.

But the electron is a particle! So, with the assumption that now it is a wave, aren't we also guilty of believing in witchery?

Not at all. As follows:

A particle is not *logically* associated with its attributes (interactions) but *only by definition.* Accordingly its definition changes, if the description of the interaction changes. This means: if we succeed in describing the interaction under the assumption that the electron is a wave, then its definition has changed – in other words: then it has already before been a wave.

In contrast, a wave is *logically* associated with its attributes (interactions): its attributes *ensue* from its dynamics. Thus with a wave, there is no possibility for another definition. A description of the interaction, where the wave appears as a particle – as is the case in Einstein's model – can therefore not change the definition of the wave; in this case the assumption of a transformation – i.e. of duality – is unavoidable.

Thus the No-Nonsense Hypothesis has led us to the assumption that both light and electron are waves.

How can waves interact *as waves?*

The easiest way is by superposition. Thus we will describe the interaction as superposition of the two waves.

At first a preliminary consideration. Let us assume, in an electron exists an oscillation with frequency ν. What follows with respect to this oscillation, if the electron is at rest? It follows that the oscillation is in-phase, because if the oscillation has everywhere the same phase, then there is no motion. Therefore, for an electron at rest, we must set:

$$y = \cos 2\pi \, t \, \nu$$

(This is de Broglie's well-known train of thought.) Then for an electron with velocity v the Lorentz-Transformation leads to

$$y = \cos 2\pi \left(t \, \nu \frac{1}{k} - x \, \nu \frac{v}{c^2} \frac{1}{k} \right) \qquad \left(k = \sqrt{1 - \frac{v^2}{c^2}} \right)$$

Thus the frequency ν_e of an electron moving with velocity v relates to the frequency ν_{e_0} of an electron at rest as follows:

$$\frac{\nu_e}{\nu_{e_0}} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{k} \tag{2}$$

In the case of non-relativistic electrons, v is small against c, and therefore

$$\frac{1}{k} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \approx \frac{1}{1-\frac{v^2}{2c^2}} \approx 1 + \frac{v^2}{2c^2} \tag{3}$$

Now we proceed to the description of the interaction. At first, we look at the interaction between light and a free electron.

Let ν_{e_0} be the frequency of a free electron at rest before the interaction, ν_e the frequency of the electron moving with velocity v after the interaction.

We form a superposition of the in-phase oscillation which represents the electron[3]

$$y = \cos 2\pi\, t\, \nu_{e_0}$$

and a plane wave that represents the light

$$y = \cos 2\pi \left(t\, \nu_L - x \frac{1}{\lambda_L} \right)$$

From the identity:

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[3] Of course it cannot be claimed that the electron *is* this oscillation. However from the occurrence of this oscillation conclusions can be drawn.

$$2\cos a \cos b = \cos(a+b) + \cos(a-b) \tag{4}$$

follows that, as a consequence of the superposition, we obtain two waves with the frequencies

$$\nu_{e_0} \pm \nu_L$$

(where ν_L is the frequency of the light).

The higher frequency must be the frequency of the electron *accelerated* by the interaction; thus, according to (2), it follows that

$$\nu_e = \nu_{e_0} + \nu_L = \nu_{e_0} \frac{1}{k} \tag{5}$$

(The second wave will be discussed subsequently)

Then $\nu_L = \nu_{e_0} (\frac{1}{k} - 1)$ and according to (3)

$$\nu_L = \nu_{e_0} \frac{v^2}{2c^2} \tag{6}$$

Thus also here, the square of the speed of the electron is proportional to the frequency of the light.

(For the second wave we would have to set

$$\nu_e = \nu_{e_0} - \nu_L = \nu_{e_0} k \tag{5'}$$

However according to (3) $k \approx 1 - \frac{v^2}{2c^2}$

and we obtain again $\nu_L = \nu_{e_0} \frac{v^2}{2c^2}$

The frequency of the second wave would therefore correspond to the frequency of an electron, whose velocity is *reduced* by v as a consequence of the interaction. Since we assumed a stationary electron – so that ν_{e_0} cannot be reduced any more – this part can be omitted.)

Up to now, we have only used simple wave-mathematics. In order to return into the world of physical modeling, we multiply (6) by h:

(It should be emphasized, however, that this multiplication is only necessary due to "dimensional" reasons, i.e. for crossing over to the "mechanical" description. The fact that h is a fundamental *unit* has nothing to do with our considerations. We will discuss this point later.)

$$h\nu_L = h\nu_{e_0}\frac{v^2}{2c^2} = m_e c^2 \frac{v^2}{2c^2} \tag{6'}$$

Eventually we obtain

$$h\nu_L = \frac{m_e v^2}{2} \tag{7}$$

In order to transfer our idea to the interaction between light and a bound electron, now we only have to insert the frequency difference δ_ν between a bound and a free electron into (5)

$$\nu_e = \nu_{e_0} + \nu_L - \delta_\nu = \nu_{e_0}\frac{1}{k} \tag{8}$$

and to carry along this δ_ν, therefore

$$h\nu_L - h\delta_\nu = h\nu_{e_0}\frac{v^2}{2c^2} = m_e c^2 \frac{v^2}{2c^2} \tag{8'}$$

So we get to

$$h\nu_L = \frac{m_e v^2}{2} + h\delta_\nu \tag{9}$$

which is identical with (1).

Let us now compare the two models – the usual one, which is analogue to a mechanical impact, and the one proposed here, which is conceptualized as wave-superposition.

In the mechanical impact model, the fact that the velocities and, accordingly, the energies of the electrons after the interaction are always identical and depend only on the light frequency necessitates the well known interpretation, i.e. light particles, which are defined by frequency and are always identical and indivisible, interact with electrons. (If the light particles were divisible or different from each other we should see also electrons with different velocities after the impacts.)

In the wave model, on the contrary, this fact is self-evident: here, the "electrons" leave the metal plate in a continuous process, *as waves,* whose frequency follows from the superposition of light waves and electron waves. Thus, according to equation (4), after the interaction no other frequencies (i.e. no other energies and velocities) are possible – wave superpositions do not permit other results.

This means: in the wave model it is obvious why the amplitude of the light and its intensity don't matter, and also why no delay occurs until the first measurement takes place: the superposition process starts immediately.

The assumption of indivisible light particles can be dispensed with.

However the most important point is the following one, because here for the first time the core of the new interpretation becomes visible:

The equation
$$\nu_L = \nu_{e_0} \frac{v^2}{2c^2} \qquad (6)$$

contains already the essential result: the square of the velocity of a free electron after the interaction depends only on the frequency of the light (in the case of a bound electron, on the left side the term $-\delta_\nu$ has to be inserted).

For the derivation of this equation, only two presuppositions are required:

1. Both light and electron are waves.
2. The Lorentz-Transformation applies.

Besides these two, *no other physical prerequisites* are needed.

Only after the multiplication by h, that is: at the step from (6') to (7):

$$h\nu_L = h\nu_{e_0} \frac{v^2}{2c^2} = m_e c^2 \frac{v^2}{2c^2} \qquad (6')$$

$$h\nu_L = \frac{m_e v^2}{2} \qquad (7)$$

and for the physical interpretation of (7), the concepts *energy* and *mass* are required, as well as the relation between those concepts and the frequency

$$h\nu = mc^2 = E$$

In other words: For the description of the interaction between light and electron in the Photoelectric Effect the assumption is sufficient that both partners are waves. Not only the assumption of light quanta is superfluous, indeed *all* physical concepts and relations can be dispensed with. Only at the transition to a mechanical description of the usual kind, the concepts appear, which otherwise are the indispensable basis of the description: mass, kinetic energy, total energy.

Therefore, here the descriptions by waves and by particles are not at the same level. Instead they have a hierarchical relationship: The wave description comes first – it is *fundamental*, the particle description is subordinated – it is *derivative*.

Thus in this case the equations $E = h\nu$ and $p = h/\lambda$ do not prove the wave-particle dualism; they are **definition equations** of the quantities energy and momentum.

The concept *energy* is **reduced** to the concept *frequency*, and the concept *momentum* to the concept *wave-length*.[4]

It is obvious that, if this interpretation, which arises quite naturally at the Photoelectric Effect, is sustainable, then *formally* nothing changes, but conceptually *everything* changes.

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[4] However this reduction is only complete, if mass is eliminated as an independent concept, so that h loses its role as link between the wave- and the particle-realm. This will be carried out in the Second Part. (In 6. A Universe without Mass.)

Let us summarize. It has been demonstrated that the Photoelectric Effect can be described in two ways:

> 1. According to the mechanical impact model. Both interaction partners are understood as particles.
>
> Then either a *dualistic* position has to be taken (quanta which carry the whole energy are embedded in the waves – this was the point of view of Einstein, de Broglie and later of David Bohm), or *complementarity* has to be assumed (this is the so-called Copenhagen interpretation). The dualistic position leads to explicit non-locality, the Copenhagen interpretation leads to the relinquishment of any kind of understanding.
>
> 2. By superposition of waves. Both interaction partners are understood as waves.
>
> Concerning radiation, the interpretation difficulties connected with the positions mentioned in Point 1 disappear. Neither dualism nor complementarity need to be resorted to.

For the moment, all of that applies only to the Photoelectric Effect. The next step we must take at our branching off from the historical path of physics is testing our model assumptions at the scattering of high frequency light (X-rays) on electrons.

3.5. The Compton Effect

At the scattering of X-rays on electrons, two effects are observed, which also do not seem to be in accordance with the assumption that light is only a wave.

1. The wave-length of the scattered radiation is greater than the wave-length of the incoming radiation.

2. The scattering angle distribution is asymmetrical with respect to the forward and backward direction.

In 1922, Arthur Compton described the scattering of X-rays on graphite as impact process of light-particles and electrons.

He derived the measured, on the scattering angle ϑ dependent difference between the wavelength λ_2 of the scattered and the wavelength λ_1 of the incoming radiation

$$\lambda_2 - \lambda_1 = \lambda_C \,(1 - \cos\vartheta) \qquad (\lambda_C \text{ Compton wave-length of the electron})$$

under the assumption that light particles are scattered on electron particles.

The difference between the Compton Effect and the Photoelectric Effect, seen from the conventional viewpoint, is that at PE the photon is absorbed, i.e. its total energy is passed to the electron, whereas at CE the photon is deflected and loses only a part of its energy.

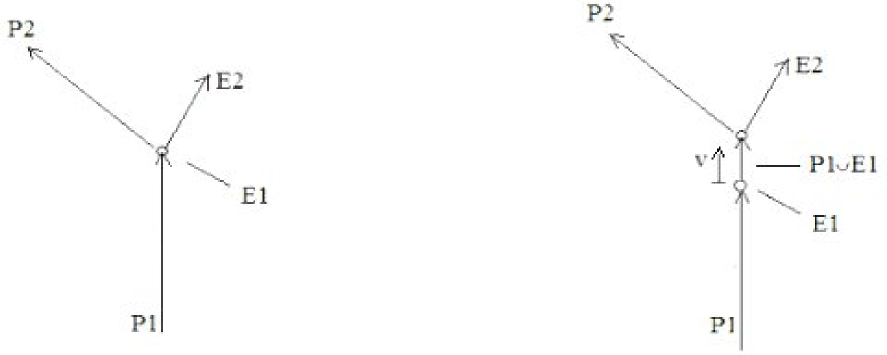
From our viewpoint, the difference between the two effects consists in the fact that at PE both waves form a persistent superposition, whereas at CE they separate again.

Therefore, seen in this way, the scattering process photon-electron proceeds in two steps:

A: The photon hits a resting electron. Both waves form a superposition.

B: The two waves separate again.

In the following outline, to the left the scattering seen as particle impact, to the right our two-step variant:



(S3)

$P1 \cup E1$ denotes the short-time state where both waves are united.

Thus the whole process can be described as follows:

The resting electron E1 unites with the photon P1. Hence it turns into E_+. ($E_+ = P1 \cup E1$). E_+ moves with velocity v. E_+ emits the photon P2 and turns into the electron E2.

Let us denote the laboratory system as the reference frame S. Now let us look at the scattering process from a reference frame S', which moves with velocity v relative to S, and with respect to which E_+ is at rest. (Thus E1' moves with -v relative to S'.)

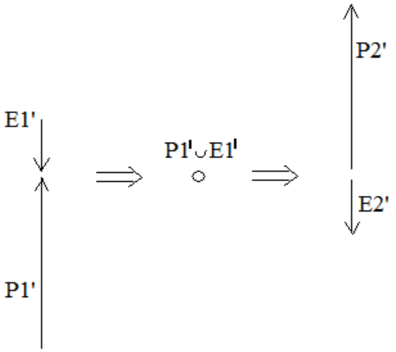
An electron moving at v possesses a de Broglie wave-length

$$\lambda_B = \lambda_C \frac{c}{v} k \qquad (\lambda_C \text{ ... Compton wave-length of the electron, } k = \sqrt{1-\frac{v^2}{c^2}})$$

Therefore with respect to S' applies:

(1) The wave-length of E1' is $\lambda_C \frac{c}{v} k$.

We remain in S'. We look at first at the case where both waves separate exactly along the straight line on which P1' was moving towards E1':



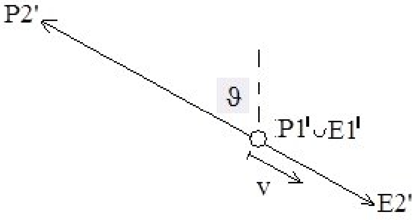
(S4)

Obviously, in this case, the separation process SP(0°) represents the inverse of the uniting process UP, and this leads to

P2' = P1' und E2' = E1'.

Thus E2' moves with velocity -v with respect to S'. (exactly as E1' before); in the usual description, P2' would be just an *unscattered* photon.

Now we turn to an arbitrary separation direction ϑ. With respect to S', after the separation P2' and E2' again move away from each other along a straight:



(S5)

Compared with the separation process SP(0°), the separation process SP(ϑ) is only *rotated*, but unchanged in any other respect. Thus it is the *same* process, and the absolute value of the velocity of E2' in S' is therefore again |v|, and the Photon originating from SP(ϑ) is – except for the direction – identical with the one that originates from SP(0°).

Combined with what has been said just before, it follows:

(2) With respect to S' holds: Except for the direction, the light waves P1' and P2' are identical.

Thus $\lambda_{P1'} = \lambda_{P2'}$ for all scattering angles ϑ.

At last we need the following:

In S', E1' moves with velocity -v. E_+ is at rest.

Now the question is: E_+ is the superposition state of the two waves P1' and E1'. If E_+ is at rest, what follows with respect to P1?

The de Broglie wave-length of the electron: $\lambda_B = \lambda_C \frac{c}{v} k$ is a relativistic phenomenon: Due to the Lorentz transformation of an in-phase oscillation to a system moving with velocity v, the phase coincidence is canceled and a phase-wave with just this wave-length emerges. If the movement generated in this way should disappear, then this phase-shift must be annulled.

Let us look at the short-time superposition E_+ of the waves representing P1' und E1':

According to (1), E1' is represented by (f_e ... frequency of the resting electron)

$$\cos 2\pi \left(t \ f_e \frac{1}{k} + x \frac{1}{\lambda_C} \frac{v}{c} \frac{1}{k} \right) = \cos 2\pi \left(t \ f_e \frac{1}{k} + x \frac{1}{\lambda_B} \right)$$

P1' is represented by

$$\cos 2\pi \left(t \ f_{P1'} - x \frac{1}{\lambda_{P1'}} \right)$$

If we now set the wave-length of P1' equal to the one of E1':

$$\lambda_{P1'} = \lambda_B = \lambda_C \frac{c}{v} k$$

then, according to the identity

$$2 \cos a \cos b = \cos(a + b) + \cos(a - b)$$

we obtain, as the result of E1' $*$ P1', *two waves* (in the same way as at the Photoelectric Effect):

In the first wave, the x-term disappears, which means that the phase shift is in fact canceled and that, therefore, the velocity of E_+ is indeed equal to 0.

The second wave would move, seen from S, opposed to the direction of the incoming photon, but at the same time its frequency would be reduced compared to the frequency of the electron E1 that rests in S, which would be impossible. As in the Photo Effect, also here this second possibility is inapplicable.

Thus we can state:

(3) With respect to the reference frame S', the incoming photon P1' possesses the wave-length

$$\lambda_{P1'} = \lambda_B = \lambda_C \frac{c}{v} k$$

Now we must just transform from S' back to the laboratory system S.

In order to calculate the wave-lengths of P1 and P2, we need the relativistic Doppler Effect with respect to an arbitrary angle ϑ, which has the following form:

$$\lambda' = \lambda \left(1 - \frac{v}{c} \cos\vartheta\right) \frac{1}{k}$$

In our case is $$\lambda_{P1} = \lambda_{P1'} \left(1 - \frac{v}{c}\right) \frac{1}{k}$$

and, because of (2) $$\lambda_{P2} = \lambda_{P1'} \left(1 - \frac{v}{c} \cos\vartheta\right) \frac{1}{k}$$

From this follows $$\lambda_{P2} - \lambda_{P1} = \lambda_{P1'} \frac{1}{k} \frac{v}{c} (1 - \cos\vartheta).$$

If we now insert the value of $\lambda_{P1'}$ from (3), we get to

$$\lambda_{P2} - \lambda_{P1} = \lambda_C (1 - \cos\vartheta)$$

and this is the desired result.

What about the asymmetry of the distribution of the scattering angles? In S', all scattering angles are equiprobable, which means: equally distributed between 0 and 2π. For the laboratory system S follows then the observed, with the frequency of the incoming photons increasing asymmetry of the distribution of the scattering angles.

Thus also in the description of the scattering of high frequency light on electrons it was possible, without any physical resources and prerequisites, only based on the assumption that both light and electron are waves, to derive the correct result. Since this result is given here in the form of a wave-length difference, it was – other than at the Photo Effect – never necessary to change over to the usual "mechanical" description. We did not even need to mention the concepts energy and mass.

As could be seen, symmetry assumptions were applied. However they did not serve, as usual, for substantiating conservation laws, but for the assumption that, with respect to S', only the propagation direction of the two waves changes after they have separated, whereas in every other respect they remain identical.

Everything which was said at the end of the previous section, applies identically or analogously also here. Therefore, a summary or a commentary is superfluous.

Thus we have described the two experiments, by which the wave-particle dualism was brought into physics, solely by wave superpositions. The assumption of light particles could be dispensed with.

The next step will be to eliminate the dualism of matter. This purpose seems to be precluded by the fact that this dualism represents downright the basis of the quantum mechanical formalism and its interpretation.

3.6. The Reduction of the Wave Function: what actually happens

"Unter den [...] Gegnern der 'orthodoxen' Quantentheorie nimmt Schrödinger insofern eine gewisse Ausnahmestellung ein, als er nicht den Teilchen, sondern den Wellen die "objektive Realität" zusprechen will und nicht bereit ist, die Wellen nur als Wahrscheinlichkeitswellen zu interpretieren. [...] Freilich kann Schrödinger [...] nicht das Element von Diskontinuität aus der Welt schaffen, das sich in der Atomphysik überall [...] äußert. In der üblichen Deutung der Quantentheorie ist es an der Stelle enthalten, wo jeweils der Übergang vom Möglichen zum Faktischen vollzogen wird. Schrödinger selbst macht keinen Gegenvorschlag, wie er sich etwa die Einführung des überall zu beobachtenden Elements von Diskontinuität anders als in der üblichen Deutung vorstellen will."[5]

("Among the objectors of 'orthodox' quantum theory, Schrödinger takes insofar a certain special position, as he wants to assign not to the particles but to the waves the 'objective reality' and is not willing to interpret the waves just as probability waves. However, Schrödinger is not able to eliminate the element of discontinuity that appears everywhere in atomic physics. In the usual interpretation of quantum theory, it is incorporated at that position where the respective transition from possibility to

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[5] Werner Heisenberg, Phys. Bl. 12 (1956), S. 300.

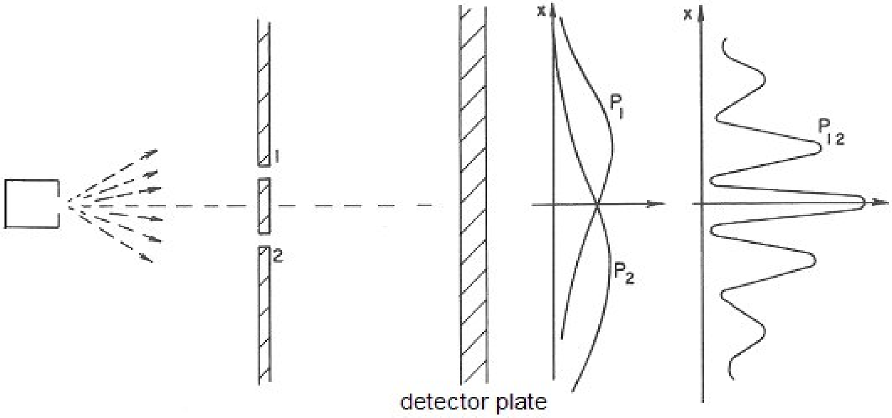
reality occurs. Schrödinger himself presents no counter-proposal how he would imagine the introduction of the everywhere observable element of discontinuity other than in the usual interpretation.")

In 1926, Schrödinger found his "wave function". It was his intention to relate it to anything "real". For this purpose, he considered it necessary to construct wave packets that do not disperse but maintain their spatial extent. In other words: he aimed at modeling *particles*. However after it had become apparent that, with the exception of the harmonic oscillator, the wave packets disperse at *all* quantum mechanical systems, he abandoned this project.

The essential question is: *Is the possibility to construct wave packets that do not disperse in fact a necessary condition for assigning an element of reality to the wave function?*

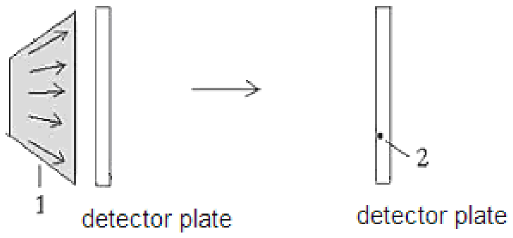
The answer is *no* – but substantiating this answer requires a radical adjustment of our conception of the (atomic) reality. The following explications are meant as introduction to this adjustment. At first a model will be presented, afterwards the model assumptions will be generalized, and at last – in section 3.9 – some possible counter-arguments will be discussed.

What Heisenberg meant by the discontinuity that occurs at the transition from possibility to reality is of course the *reduction of the wave function*. It can be illustrated using the double slit experiment:



(S2)

This time we focus on the following point



(S6)

To the left, labeled as **1**, the state of the particle – say: of an electron – at the moment of its impact on the detector plate: *an extended wave* that has emerged from diffraction at the double slit and subsequent interference.

To the right, labeled as **2**, the observable consequence of the state of the same particle at the next moment: *a black point.*

So now we are standing before the innermost secret of quantum mechanics, i.e. the question:

Why disappears the extended wave and turns into a particle? Or, with Heisenberg's phrasing: How turns possibility into reality?

What is the reduction of the wave function?

The No-Nonsense Hypothesis, which we established just before the description of the Photoelectric Effect, leaves again only one possibility of interpreting the *real* proceedings.

Initially, I shall repeat my argument concerning the so-called wave-particle dualism.

There is nothing which can be wave *and* particle. Therefore, if objects exhibit attributes of both, then the two concepts must be in a dependency-relationship with each other, i.e. one of the two concepts must be *derived* from the other one, and the notions connected with it must be understood as *defined* by the notions connected with the other one.

However the problem is not symmetrical. A wave is defined as a dynamic shape. All wave attributes, as e.g. diffraction and interference, are inseparably associated with this definition. They cannot be reduced to anything different. So if the concept *wave* is replaced by anything different, the attributes connected with it get lost.

In contrast, a particle *as such* is not at all defined – it obtains its definition only by the attributes assigned to it. Thus it appears just as the carrier of these attributes, with which it is – other than a wave – associated only *by definition* and not logically.

Therefore, the concept wave cannot be substituted by a different one, but the concept particle can be substituted without loss, if the attributes are retained at this substitution (e.g. localization, discreteness).

If one looks at the double-slit experiment under these conditions, then one realizes almost immediately that the wave concept provides indeed an explanation for everything observed. As is well known, *all kinds* of waves appear in two shapes: as propagating waves that exhibit diffraction and interference, and as standing waves that are spatially limited by boundary conditions and can only exist in certain discrete states. Exactly those two shapes appear at the double slit experiment, and also the transition between them is basically a matter of course.

However as the general thinking is frozen here in an outright magic torpor for already more than a hundred years, it seems appropriate to explain the whole procedure explicitly. This shall now be carried out.

After what has just been said, the electron *is* a wave. Therefore, it does exactly what waves do: it propagates through *both* slits, is diffracted by them so that it disperses, and interferes after the double slit (as is the case also in Schrödinger's description).

Then the electron-wave hits the detector plate. But this plate is also a wave, or, to say it more precisely: a wave-field. Thus the penetration of the electron-wave into the wave-field "detector plate" will lead to wave superpositions.

As regards their spatial limitation, the atomic electron shells correspond to simple standing waves, where it is determined by boundary conditions in which stationary states they can oscillate, in other words: at which oscillation states they are stable.

What happens to a standing wave, if the excitation conditions are continuously altered?

Let us look at a standing air-wave in a pipe. At first, the continuous alteration of the excitation conditions effectuates nothing observable (hearable) – we hear a constant tone; however if the alteration exceeds a certain limit, the standing wave *jumps* into the *next stable state*: we hear the adjacent overtone. If we counted the waves in the tube, we would see that *after* the jump there is an additional vibration node in the tube (or one less). However it is evident that not just a single oscillation-area has been added but that the standing wave *as a whole* has reorganized itself according to the boundary conditions.

Therefore, also in the case of a *continuous alteration* of the excitation conditions, what can be observed (heard) is a *discrete sequence* of tones, corresponding to the possible stable states of the standing wave, that is: the jump of the whole wave into a state with a partial-wave more (or less), whereas the *actual, causative* process is *continuous.*

Thus we expect similar circumstances also in the case of atoms and molecules. Accordingly, electron shells can only exist in certain discrete states, i.e. are only stable in such states. If the state of the *entire shell* – which means: of the whole oscillation of the respective space area – changes *continuously,* nothing observable happens until the alteration has reached the point where the (ostensibly) discontinuous jump into the next stable state is necessitated.

In the same way as at the standing wave in the tube, also here we observe the *discrete sequence* of possible stable states of the whole spatial oscillation area. The jump between the stable states manifests itself *locally,* as appearance of an additional node plane and, with it, an additional oscillating area. But also here, it has of course not just been added *as an individual one* (as it would be the case with the particle concept) but appears as the consequence of the reorganization of the whole spatial wave structure. And also here applies: the actual process is continuous.

Back to the double slit experiment. Almost everything needed has already been said. Now, additionally, only the following must be assumed:

That, which just before, in the case of standing air waves, was called "continuous alteration of the excitation conditions", is in the case of electron-waves the *continuous accumulation of wave intensities.*

Thus this assumption reads as follows:

The discontinuous alteration of the local oscillation state, which presents itself as measurement result, is caused by a continuous process: by waves, the amplitude squares of which add up until a transition occurs.[6] ***Thus the probability of such a transition is determined by the local wave-intensity.***

So everything is indeed very simple: waves hit the plate, penetrate into it and form superpositions with the waves of the plate. The wave intensities, the distribution of which corresponds to the quantum

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[6] It was exactly this assumption, applied to photons, which has made the local description of entangled photons possible.

mechanical probability density (the curve in (S2)) add up at the respective position of the penetration, until the spatial oscillation state (the electron shell) located at this position "jumps" into the next stable state, in the usual view: "an additional electron appears". Therefore, these transitions are the consequences of local conditions, independent of other simultaneously adding-up processes of the same kind, which *later* will also lead to transitions.

In particular, at the time of a transition, *no disappearance of other waves occurs.*

Under these conditions, formally there is no difference to the usual view – only the interpretation of the amplitude square changes: instead of a probability density, which refers to *nothing existing* and represents a purely formal tool, there is now a probability density, which owes its existence to *a physical quantity:* the intensity of a real wave. The result is in both cases identical.

To achieve complete congruence with the quantum mechanical specifications, our model needs only an element of chance. However this is in fact already there, because it cannot be presupposed that, before the arrival of the electron-waves, all electron shells are in *exactly* the same states.

To illustrate that, we look again at the analogue circumstances in the case of standing air waves. Imagine a great number of identical tubes, in which the air oscillates at the third harmonic. From this does not follow that the states of the air columns are identical in all pipes. In some cases, the slightest change of the excitation conditions could trigger a jump into the second harmonic, in some other cases a jump into the fourth harmonic, while some others are insensitive to small alterations.

Analogously, we have to assume that, within the whole range where the oscillation states do not change abruptly, the electron shells are randomly distributed.

With this, all quantum mechanical facts and predictions regarding the double slit experiment are explained by continuous, local and objective processes.

In this simple local and objective model, there are no secrets. All absurdities have dwindled away: there is no *reduction of the wave function* – at least not in the sense that anything vanishes, the assumption of *objective probabilities* is superfluous, nothing has to be *wave and particle,* the *measurement act* has no special relevance, no *observer-awareness* intrudes, the *universe does not split* into infinite nearly identical copies of itself, and so on and so forth …

We can see very clearly how and where we have been deceived: There are no particles. Electrons, as well as all other elementary particles, are by no means "indivisible units". We succumb to this illusion only because *they appear as such in all observations.* ("Events" are always transitions!)

Actually, they are continuous, dispersing waves or wave-packets, which only under certain conditions that are met within matter occur *localized* and in an always identical form.

The reduction of the wave function – the disappearance of an arbitrarily extended wave phenomenon and ostensibly discontinuous occurrence of a localized event – does not take place. In the wave model, it turns into a normal physical process.

So from wave-particle dualism we have come to wave monism. However, this is not a loss – what was previously referred to as "particle" actually remains *the same phenomenon*: localized, discreet and always formally identical. Only the definition has changed: objects, which originally were designed according to the idea of macroscopic things but failed to fit into this model already from the beginning and were therefore basically undefined, are now seen as stationary wave states or transitions between such states.

Thus, in actual fact it turns out: the inability to abandon mechanistic ideas (particles, impacts etc.), which endures already more than a hundred years, has led the interpretation of physical theories onto a wrong path and has forced physicists to move along this path ever further.

Notes

1. The explanation of the double slit experiment is so simple that one can hardly believe that up to now it has not existed. Why is it that it could remain undetected for so long? The cause is the following suggestive idea:

Suppose a person A throws a ball to a person B. Then, of course, there cannot be the slightest doubt that the ball, which B catches, is *the same* ball, which A has thrown. This fact is so obvious that it does not even appear mentally: no one would ever think to ask whether it is the same ball – this question would be simply absurd.

Precisely this concept, however, – including the just mentioned unquestioned obviousness of the identity of the thrown and the caught ball – has been transferred to the double slit experiment. The reason for this complete transfer is the *particle idea*: If the electron is regarded as *particle*, then the conditions at the double slit experiment appear analogous to those at the ball throwing.

However the electron *is not* a particle but a wave or a transition between two wave states, and the transition called "electron", which appears on the detector plate, *is not* identical with the wave called "electron", which directly before has passed through the double slit and then reached the detector plate. This transition, i.e. the observed event, contains indeed not only parts of *this* wave, but also of waves that have arrived *earlier*, and also of waves that have been there already before the start of the experiment (with the consequence that many oscillation states have already been close to the border above which a transition occurs, before the experiment began).

In other words: **The electron, which is now detected, is not identical with the electron which has been generated immediately before** – or, to put it more precisely, it is not *substantially* but only *formally* identical with it.

In the ball-throwing analogy, this would mean: *The caught ball is not identical with the thrown ball,* it just looks the same.

As long as one remains bound to this analogy, it is obviously impossible to understand the double slit experiment, and the same is true for all other quantum-mechanical measurements.

2. In the standard interpretation of the double slit experiment, there are no continuous processes inside the detector plate but only discontinuous transitions. But in the new interpretation, these transitions are caused by continuous processes.

What processes are these? Exactly those which *always* occur with waves: if the frequencies of the incoming waves and of those already present are identical, then the amplitudes add up, if they are different, then combination frequencies evolve.

It is possible to define the energy proportional to the amplitude square. Then also to the states, which lie between the stationary states, a definite energy can be assigned. (In principle, this proportionality exists also in the standard interpretation. Think e.g. of the Photo Effect: although here the energy of the emitted electrons is independent of the light amplitude, still the number of the detected electrons depends on it.)

3. I presented the simplest version of the model. Various additions are necessary. At least one of them appears important enough to deserve a short note:

It is determined by boundary conditions which oscillation states are stable. These states must be understood as *attractors*. (This applies to standing wave states in general.) This means that a local oscillation state will approach the attractor if the point of the state space by which it is represented lies within the basin of attraction.

Let us assume, a local wave system (an electron shell) is exactly in an attractor state. If now waves from outside penetrate and add to the ones that are already there, then the system is in a certain distance from the attractor. It will then try to approach the attractor again, i.e. it will try to emit waves. Where? To the adjacent wave systems. Thus *exchange processes* will take place, to which the following simple rule applies: The nearer the state of a local wave system to the attractor, the stronger its tendency to approach the attractor. This means: in the case of two spatial oscillation states adjacent to each other, the one whose state is at a smaller distance from the attractor will pass the surplus waves to the other one. However if the state of a system is pushed above the border between the basins of attraction of the actual and the next higher attractor, then this system will try to approach this next attractor, i.e. it will absorb waves from the surrounding systems.

Regarding our basic thought trains, nothing is changed by this additional hypothesis. However the dynamics of the proceedings is modified.

As an example, we look at the distribution P_1 of the outline (S2). For the moment we ignore all random fluctuations and assume that all systems are exactly in attractor states.

Let us now look at two adjacent systems (local oscillation states, electron shells), which are located at an arbitrary position on the surface of the detector plate. In the one system, which is farther from the maximum of the curve P_1, the amplitude square of the penetrating waves (according to the curve P_1) will be smaller than in the other one. Thus this system remains nearer to the attractor state, and therefore it will pass the surplus waves to the other system. This process takes place simultaneously at all pairs of adjacent systems. Therefore, all waves will eventually land at the system that lies exactly at the position where P_1 has its maximum. In this system, all amplitude squares of the waves that have penetrated into the plate will be added up and cause a transition.

However this would only be the case if there were no random fluctuations at all, and therefore it can never happen in this form. Yet this idealized example shows that the waves, which penetrate into the plate, can trigger a transition not only at the point where they hit the plate, but that they can also be transported through exchange processes into some distance and contribute to transitions there.

In some cases, the attractor concept and the associated hypothesis of exchange processes are possibly needed for the explanation of the sequence of events – e.g. in the Photo Effect in order to understand why never several electrons are detected simultaneously.

4. What has been said about the *detection* of electrons on the surface of the detector plate, applies analogously to the process of their *generation*:

Thus if on the left side of the outline (S2) electrons are generated, this does not mean that one particle after the other disengages. Instead it is a *continuous* process.[7] A continuous radiation of waves takes place, until somewhere a transition occurs – a local oscillation state, i.e. one electron shell *as a whole,* changes into a different state that has one node plane less. This changeover appears again *dis-continuous.* In the usual view: an electron is generated. (Also here, it would be possible to assume exchange processes as described in point 3.) The wave packets which are now underway do not originate from one single transition, in other words: they do not correspond to one electron. Instead they contain waves from many such transitions that are defined as electrons.

5. What has been said about electrons applies also to photons.

3.7. The Reduction of the Wave Function: Generalization

In order to generalize our model assumptions, we have to make a short excursion into the formal part of quantum theory.

Let $\Psi(x)$ be the state vector of an object T. An attribute of T is to be measured that corresponds to the operator A.

Let be $A\Psi(x) = \sum_{i=1}^{n} s_i U_i(x)$ (U_i eigenfunctions, s_i coefficients)

Let a_i be eigenvalues of the corresponding U_i. Then the result of the measurement will be one of the a_i.

So much to the quantum mechanical specifications, the validity of which is verified to such an extent that they can be considered facts. But now the area of interpretation begins:

If the value a_j $(1 \le j \le n)$ is measured, then T – i.e. *the very object* that has been represented before by $\sum_{i=1}^{n} s_i U_i(x)$ – is supposed to be in the state U_j: the whole sum $\sum_{i=1}^{n} s_i U_i(x)$ has been reduced to the one term $s_j U_j$.

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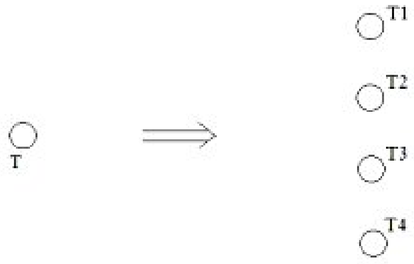
[7] Exactly as in the Photoelectric Effect (Section 3.4).

Let us call this hypothesis (H1). It is the fundament of the contemporary interpretation of quantum mechanics:

(H1) *The state function after the measurement, which is reduced to one single term, represents* ***the same object*** *as the state function before the measurement. The one term corresponds to the state of this object after the reduction.*

A simple illustration:



(S7)

T is the object, on which the attribute A is to be measured. T1, T2, T3 and T4 represent 4 different possible states of T after the measurement. If j = 3, then T3 becomes the measured reality. T1, T2 and T4 disappear.

Thus hypothesis (H1) says: **T3 is the same object as T**. T is the state of the object ***before*** the measurement, T3 is the state of the object ***after*** the measurement.

In contrast, the model presented here is based on the following hypothesis (H2):

(H2) *The object that after the measurement is in the state* U_j ***is not the same object*** *as the one which was represented by* $\Psi(x)$ *before the measurement. None of the eigenfunctions* U_i *with* $i \neq j$ *that belong to the representation of the object T disappears; instead they will all contribute to subsequent measurements, where other, with T formally identical objects (e.g. electrons) will be measured. Thus there is no "reduction", at least not in the sense that anything disappears.*

(H2) means:

1. *A part* of T – the one, to which T has been "reduced" according to (H1) – contributes to the *actual* measurement result, i.e. to the value of the attribute A, *all other parts* of T contribute to *other, future* measurement results.

2. In general, the measurement result is caused not only by waves of T but also by waves that stem from other objects which are formally identical with T.

Thus in the scheme depicted in (S7) applies – in contrast to the usual interpretation:

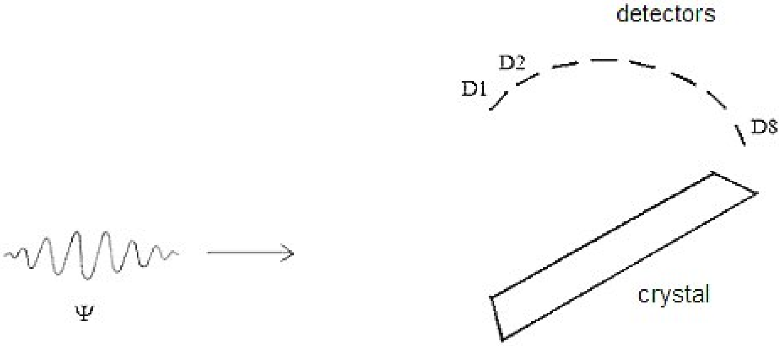
T3 is *not* the same object as T. On the one hand, T3 contains not only waves of T, and, on the other hand, T contains also waves which do not contribute to the event T3, but to (possible) future events T1, T2 and T4.

This can be illustrated by the following example:

Let T be an electron. The momentum of T is first to be calculated and then to be measured.

To determine the probability distribution of the measurement values, the momentum operator must be applied to the wave function Ψ which represents T. This procedure is a *spectral analysis:* Ψ is split into sine waves with different wave-lengths, and the according amplitudes are determined. Their squares give the desired probabilities.

In the experiment, the wave-packet must *actually* be split. This splitting could be carried out e.g. by the following arrangement:



(S8)

The wave packet Ψ is dispersed at a crystal, which means that the waves with different wave lengths contained in Ψ are diffracted at the crystal surface. This surface acts as a plain diffraction grid which decomposes the wave packet into virtually monochromatic radiation bundles. Near the crystal surface all waves interfere, yet at a sufficient distance the rays separate, such that all waves that arrive at a certain detector have a (nearly) identical wave length. So we have sorted the wave packet by wave-lengths (momentums).

Thus the *formal* division by the application of the momentum operator corresponds to the *real* division of the wave packet into sine waves with different wave-lengths by the experimental setup.

According to the usual interpretation, the measurement has the effect that one of the eigenfunctions of the momentum operator leads to the measurement result, that is: it becomes *real,* whereas the others *disappear.* In one detector we now have an electron with a certain momentum – which did *not* exist before –, in the other detectors we have *nothing*.

In the interpretation proposed here, there is no reduction. None of the eigenfunctions disappears. All eigenfunctions will contribute to future events (measurements). The amplitude squares of waves with a certain wave-length add up in the respective detector, until a transition occurs – a momentum measurement has been carried out (which in general is again not the consequence of a single wave-packet but requires the adding-up of amplitude squares of many wave packets that had arrived earlier).

Also here it can be seen clearly that quantitatively nothing changes. The wave packets are divided into sine waves with different wave-lengths, which arrive at the corresponding detectors. If now, according to our basic assumption, the characteristic re-organization of a local spatial oscillation state – i.e. the appearance of an electron – is *caused* by the adding up of wave intensities, then the probability of the events in a certain detector must depend on the amplitude square of the waves that *actually* hit this detector – exactly as predicted by quantum mechanics.

Doesn't it somehow contradict the QT formalism to assume that a particle develops somewhere and later *the same* particle appears again – even if formally (*and* experimentally) a partition takes place and the parts are displaced arbitrarily far from each other? It would not be totally absurd to call this an interpretation *against the formalism*.

At that, only under these preconditions paradoxes appear, e.g. if we ask "which way" the "particle" takes at the double-slit experiment.

In contrast, my proposal keeps close to the quantum mechanical formalism and permits connecting the concepts of the formalism with a local reality:

If a particle X is generated at a certain position *before* the measurement, and *after* the measurement an identical particle appears at another position, then this is not *the same* particle; the waves originating from the decomposition of the characteristic oscillation pattern X split up according to their formal description – they *actually* diverge – and contribute to the development of another oscillation pattern X, which however deserves to carry the same identifier X not because it is *substantially* but *formally* identical with the first one.

3.8. The central Assumption of the local and objective Interpretation

The objective and local interpretation of quantum mechanics is based on one single assumption. Everything else can be reduced to it. It reads as follows:

If event probabilities can be determined by a quantum mechanical wave function, then there is an ***actually existing wave*** *which causes these events.*

Accordingly, quantum mechanical amplitude squares are not just formal tools: they represent probabilities only because they correspond to intensities of real waves.[8]

From this follows directly that there is ***no reduction of the wave function***: what exists, cannot disappear.

It follows also that ***there are no particles***: since wave functions, which represent particles moving outside of matter, diverge in general, a realistic interpretation forces the abandonment of the particle concept in its usual form. It is replaced by another particle concept which is defined in the following way:

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[8] What about the probability amplitudes of events that will *not* occur? (E.g. the state of a radioactive nucleus is a superposition of the states *decomposed* and *not decomposed.*)

The answer is: If amplitude squares are defined as probabilities, then the introduction of amplitude squares is necessitated, which represent the complementary probabilities. It is this formal act of completion to which those – in this sense – "complementary" amplitudes owe their existence. Still, it can be stated that they relate to real waves, however only via this formal intermediate step.

Particles are stationary states of waves or transitions between such states, caused by waves.

Therefore, dualism and complementarity appear only in the area of the phenomena. The fundamental, causative layer of reality is wave-like.

3.9. Objections

In this section some objections shall be discussed which could be brought forward against the realistic interpretation of the wave function (and which have actually been alleged in the historical discussion), and also some objections against the hypotheses derived from it.

1st objection

The description takes place in the multidimensional configuration space. Therefore the elements of the description cannot be real.

This is a strange argument, not to say: not at all an argument. It is never the case – not at any mathematical description of an area of reality – that the representation is simply identical with the real scenario. In some cases, this assumption would be outright ridiculous. As mentioned before, the temporal development of a fish population in a pond can be represented by the logistic equation. But the logistic equation *is not* a fish population, and fish *are not* real numbers. Nonetheless nobody would consider this fact as a reason to doubt the real existence of fish.

Thus the realistic interpretation of a mathematical formalism does not mean *identifying* elements of the description with elements of reality, but assuming that there is a *connection* between elements of the formalism and elements of reality.

Therefore, in the case of a realistic interpretation of quantum mechanics, it is not necessary to assume that the waves which appear in the quantum mechanical formalism *are* real waves. The following weaker assertion is sufficient:

The state vector Ψ is *not only* a mathematical tool. For any Ψ there is an actually existing wave with which Ψ is connected in the following way: Every possible event, the probability of which can be determined using Ψ, is caused by the real wave connected with Ψ.

2nd Objection

There is no physical concept with which the amplitude of the Schrödinger equation can be associated.

This assertion is correct. *What* actually oscillates in this equation cannot be answered within contemporary physics.

Accordingly, this objection is not directed against the realistic interpretation of the Schrödinger equation but points only to the fact that, in order to determine *what* the subject of the equation is, one must leave the area of usual physical concept formation.

However this is a matter of course, because it must be assumed that Schrödinger's wave-function describes in fact the *fundamental layer* of reality, and therefore the question is involved, how *existence* is to be defined in physics.

With this it is clear that that, which the amplitude of the Schrödinger equation relates to, cannot simply be identified with any known element of physical modeling.

3rd Objection

There are quantum mechanical quantities, which cannot be interpreted as attributes of actually existing objects

An example of such a quantity is the *spin,* which could indeed be called the "most quantum mechanical" of all physical attributes.

A part of the argument, by which this objection can be invalidated, is already contained in the scheme which has served for the local and objective interpretation of quantum mechanical scenarios. I cite from section 1.4, where the local reconstruction of quantum mechanical predictions on entangled photons has been presented:

"The measuring result must not correspond to the attribute of an object. Instead only the accumulation of objects should trigger an event."

And further below:

"What does it mean, in this model, that *a photon with a certain polarization direction* is measured? It has the following meaning: waves that have passed through a polarizer adjusted at this angle cause a transition. To this transition – i.e. the "photon" – can then be assigned the attribute *polarization at this direction.* Only in this sense we can speak of the attribute *polarization of a photon.*"

Therefore it can be asserted:

Paradoxes appear only because measurement results are interpreted as *object attributes.* It is impossible to interpret the spin as attribute of an actually existing object "photon".

In the case of photons, this explanation is sufficient, as photons are just *transitions* between localized, stationary oscillation states and *not* objects.

However electrons are not just transitions between oscillation states but these oscillation states themselves, and the problem is, that also if they are interpreted in *that* way, apparently they cannot be understood as real objects. It seems as if it were impossible to interpret their spin realistically, even if they are seen as oscillation states instead of "particles".

This problem will be cleared up in the Second Part. Here I will only shortly comment on the question: *What means "real"?*

Current physics has developed from experiences on existing objects. Its concepts and abstractions originate from the realm of the existing. Within the limits of this conceptuality, it is indeed impossible to understand the spin realistically: it is not a thinkable attribute – neither of a particle-like object nor of an oscillation state.

In the Second Part, physics will be built up from the *other side,* which means: not from the realm of the *concrete* but from the realm of the *most abstract.* Here, it is necessary at first to reconstruct that which exists. Along this path, which begins at the *origin of everything* and extends to the elementary objects, the spin appears as a simple geometric concept. Thus, if one starts from the abstract foundations of existence, it proves a necessary element of the reconstruction of the world of things,

Representational or *objective* means: existing as object in space and time.

But *real* is a much more abstract concept:

Let us assume we succeeded in reducing that which exists to something elementary, the necessity of which can be realized, and, moreover, we were able – starting from this elementary and proceeding with steps, the necessity of which can also be realized – to arrive at the realm of the existing, then it can be defined in the following way, what *real* means:

Real is everything which appears on this path.

Therefore *real* means: *Following with necessity from the necessary preconditions of existence.*

Exactly in this way, also the spin is real, and, if it appears on this path, it becomes geometrically understandable.

That which is described by quantum mechanics lies on the border between the pre-objective and the objective realm. Only as seen in this way – by looking at it from both sides – a quantum object can be understood and interpreted realistically.

However it should be mentioned that for solving the paradoxes of the interpretation of quantum mechanics, it is not at all necessary to go into the difficult issue of defining *real* – it is completely sufficient to assert that something which exists – whatever its definition may be – cannot just disappear.

4th Objection

The amplitudes of the wave function are complex numbers. Therefore, they cannot relate to something existing.

Here applies again, what has just been stated at the third objection: only if physics is built up from the abstract conditions of existence it can be explained why complex numbers are needed for constructing objects.

5. Technical Objections

There are some objections against realistic interpretations of the wave function, which relate to "technical problems" that occurred at historical attempts of such interpretations.

An example: Also before quantum mechanics, the atomic spectra could be described with good approximation, if they were understood as partial frequencies of an overall oscillation state that is decomposed by Fourier analysis – but only with the exception of the amplitudes: at the Fourier analysis, they must be definite, but at the experiment they fluctuated.

I chose this example, because it demonstrates that, in some cases, such problems dissolve just by suspending an unnecessary strong condition. If one understands the oscillation states as attractors, as we did in 3.6, then it becomes immediately clear that the Fourier analysis can only contain the amplitudes of oscillation states which lie *exactly* on the attractor. All other states – those which lie in the basins of attraction but not on the attractor itself – *must* have different amplitudes.

In our model, the "continuous alterations of the excitation conditions" relate to waves that arrive and form superpositions with the waves that are already there, and, under this assumption, fluctuations of the amplitudes are a matter of course.

However, as was the case in my previous deliberations, I will restrict myself to actually fundamental arguments and not discuss further technical questions.

6. Other Objections

The hitherto discussed objections were all directed against the realistic interpretation of the wave function. The most important reservations against the hypotheses that follow from it – that there is *no reduction of the wave function* and that *particles are not elementary objects* but wave states – have already been invalidated in the previous sections.

We have shown that the abolition of the reduction of the wave function does not change anything as regards the quantum mechanical predictions for event probabilities. What is usually understood as "reduction" is replaced by a common physical process. Therefore, the absurd assumption of the non-local disappearance of wave-phenomena, which have proven their existence by interference, is no longer necessary.

As reason for the assumption that *particles* are *elementary objects,* it is usually pointed at the fact that they are *indivisible,* i.e. they appear always as a whole and in identical form.

However this is also true under the condition that particles are stationary wave states or transitions between such states; and moreover, it is even *explained* by this hypothesis. From this definition follows directly that "particles" must *always* appear as indivisible phenomena. How should it be possible to divide a stationary wave state? It can only exist as a whole, and also regarding a transition between two such states it would be nonsensical to speak of a "division".

Again the analogy of standing waves can be helpful: if constant boundary conditions are presupposed, then there is only the discrete sequence of possible frequencies and wave lengths, and there are the transitions between the elements of this sequence, which appear discontinuous to the observer. Thus, the observable phenomena are in any case discrete, indivisible and indistinguishable.

The second important element of the usual particle concept is spatial limitation. However exactly this limitation is indeed the basic element of stationary wave states: they are *defined* as spatially limited, and they appear only under respective boundary conditions, which are only realized within *fields*. Outside of fields there are no stationary states, and therefore the waves assume again their other shape – they propagate through space and diverge.

3.10. Explanation of Uncertainty; Interpretation of the Formalism

Any object has anytime and anywhere a definite position and a definite velocity – however only if objects are seen as entities that occupy at any time a well-defined spatial volume. This was exactly the idea which physics was based on before the 20th century. Therefore, the fact that it is impossible to determine both position and velocity of very small objects at the same time provoked enormous amazement. At the beginning, this fact was considered a limitation of measurement, but in the course of time it became evident that it is a limitation of nature itself.

The local and objective interpretation of quantum mechanics started with the alternative descriptions of the Photoelectric Effect and the Compton Effect (in sections 3.4 and 3.5). They were carried out without using any physical concepts and relations, only based on the mathematical definition of waves and on the assumption that both partners of the interaction, light and electron, are waves that form a superposition.

With this, it is demonstrated that, in the case of interaction between radiation and matter, the wave concept is fundamental and the particle concept is derivative. This means, that here the equations

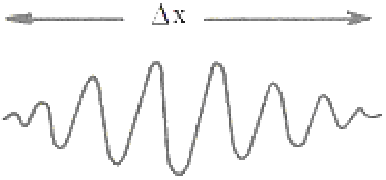
$$E = h\nu \quad \text{and} \qquad p = h * 1/\lambda$$

do not point to duality or complementarity but must be understood as *defining equations* of energy and momentum.[9]

---

[9] In a wave-like world, it is a matter of course that the non-directional quantity *energy* must be defined by frequency and the directional quantity *momentum* by wave-length. In section 2.6 has been demonstrated that constructing motion by wave superpositions leads directly to the de Broglie matter waves, and from this follows the definition of energy and momentum – with the exception of the constant h, which will be substantiated in the Second Part.

To the quantity *momentum* defined in this way, in connection with the quantity *position,* must then apply an "uncertainty relation", simply because, as is well known, in the case of spatially limited wave trains (wave packets) as depicted in the following outline



(S9)

always an "uncertainty relation" of the form

$$\Delta x * \Delta(1/\lambda) \geq 1$$

applies. Such wave trains just *do not possess* a definite wave length. Instead, they are composed of waves with different wave-lengths. The smaller the spatial extension is, the greater is the interval of the required wave-lengths. Reversely, the more exact the wave-length – and, in our case, at the same time the velocity – the greater is the uncertainty of the position Δx. If this fact is connected with the equation

$$p = h * 1/\lambda$$

then follows

$$\Delta x * \Delta p \geq h\,.$$

Of course this has already been said often enough. Nonetheless it had to be mentioned here again, because in the usual interpretation of quantum mechanics, it must be seen as a purely formal fact and not as an explanation. It can only turn into an explanation if it is assumed that particles are stationary wave states and that, accordingly, momentum is *defined* by wave-length.

Thus for the quantities momentum and position, the following applies:

1. Both quantities are *defined* as wave attributes, and they correspond to certain wave categories: momentum is assigned to sine waves, position to pulse waves (i.e. waves, the amplitude of which is only in one point not equal to zero).

2. With respect to both quantities, an uncertainty relation applies. *This uncertainty is a purely wave-mathematical fact.* It is *transferred* to the physical quantities via their definition.

As regards position and momentum, everything that seemed strange from the conventional viewpoint has disappeared. While, in the usual interpretation, it seems outright absurd that a particle should not possess exact values of position and momentum at the same time[10], in the alternative interpretation – where objects (wave packets) simply *do not have* a definite spatial volume – it is just an evident fact.

The question is if this scheme can be transferred to all physical object attributes.

The answer is *yes.* Strictly speaking, nothing at all has to be transferred – quantum mechanics *is* exactly this scheme. Thus what has to be done is just re-interpreting the formalism.

Let us look at the quantum mechanical scheme in its simplest form:

Quantities to be measured are observables. They are assigned to operators. By applying an operator to the vector in Hilbert space, by which the state of the object to be measured is represented, this vector is decomposed into a series of eigenfunctions, i.e. a *spectral analysis* is carried out: eigenfunctions are waves the form of which depends on the kind of the operator. (E.g. de Broglie matter waves are eigenfunctions of the momentum operator, spherical harmonics – i.e. standing waves on the surface of a sphere – are eigenfunctions of the angular momentum operator.)

Therefore, assigning observables to operators is tantamount to assigning them to *wave-categories*.

However in any set of wave categories, in which a wave superposition can be decomposed, there are pairs of categories to which – in the same way as to sine waves and pulse waves – an *uncertainty relation* applies. [11] Thus this must also be true at the spectral decomposition of the state vector. And this uncertainty is again transferred to the physical quantities *defined* by these wave categories.

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[10] Just try to think of a car that is neither located at a definite position nor has a definite speed. That's impossible. However the conventional particle concept is just an abstraction of such objects! It carries in it the idea of *material substance*.

[11] At a division in two such classes of waves, the product of the bandwidths cannot be smaller than 1.

This means: the scheme that applies to position and momentum – which has been described just before – applies to *all* physical attributes (observables). They are defined by wave categories, and the uncertainty relation that applies to so-called canonically conjugate attributes is a purely mathematical fact, which is transferred to the physical attributes by their definition.

So how is this formal scheme to be interpreted?

The most important elements of the interpretation have already been described and explained. Here is a short summary:

The object that emerges as a consequence of the measurement is *not* the same object as the one to be measured; the object to be measured is (in general) a wave group, the partial waves of which will contribute to various measuring events. (See the scheme in 3.7.)

The state vector represents the object to be measured. Thus it relates to the wave packet *before* measurement, and accordingly the spectral analysis relates to the decomposition of this wave packet into waves, which belong to the category which the attribute to be measured is assigned to.

As the wave category in which the state vector is decomposed is freely selectable, the vector contains all measurable attributes *as possibilities* – however not in the Heisenberg sense as another independent kind of (non-)existence but in a completely ordinary sense: each of the waves contained in the wave packet, which belong to any wave category, can contribute to the formation of an object, i.e. of the object of the actual measurement or an object of subsequent measurements.

At the experiment, it is (in most cases) necessary to *actually* decompose the wave packet, as was explained with the example at the end of 3.7. The distribution of the measured values will then, as elucidated in this example, correspond to the distribution of the amplitude squares of the waves contained in the state vector.

The measured object – the carrier of the measured variables – is in any case, provided it is an object of atomic or molecular magnitude, a *newly formed object,* which owes its existence to the measuring process.[12]

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[12] An interesting question is how big and how complex the objects can be, which during the measurement (as e.g. at the double slit experiment) are decomposed into partial waves and then formed anew at different positions and times. The limit must be where the *shape-information* – which is contained in the frequencies, wave-lengths and phase-relations of the waves – gets lost, so that the new formation of formally identical objects is no longer possible.

Only due to this *new-formation* of measuring objects, the waves contained in the state vector can become measured attributes, in other words: can possibility become reality.

As can be seen, some of the well-known formulations can be transferred identically into the realistic interpretation – only their meaning changes: statements which are meant to point at the impossibility to conceive what actually happens turn into statements about a comprehensible reality.

Of course it must be in any case explainable *why* an attribute is assigned to a wave category, i.e. what the physical reason for this relation is. In the case of energy and momentum, most of this explanation has already been accomplished. Here is a short recapitulation:

Motion (velocity) of objects has been defined by *superposition of waves.* Thus the existence of uniform motion becomes a matter of course. Change of motion is caused by alteration of frequencies. With this, the conceptual basis for defining energy and momentum already exists, and it can be realized why energy is assigned to frequency and momentum is assigned to sine waves (relativistic phase-shift waves).

Formally, these definitions were demonstrated and verified in the descriptions of the Photoelectric Effect and the Compton Effect.

Why spin and angular momentum are assigned to spherical harmonics (standing waves on the surface of a sphere) will be explained in the Second Part.

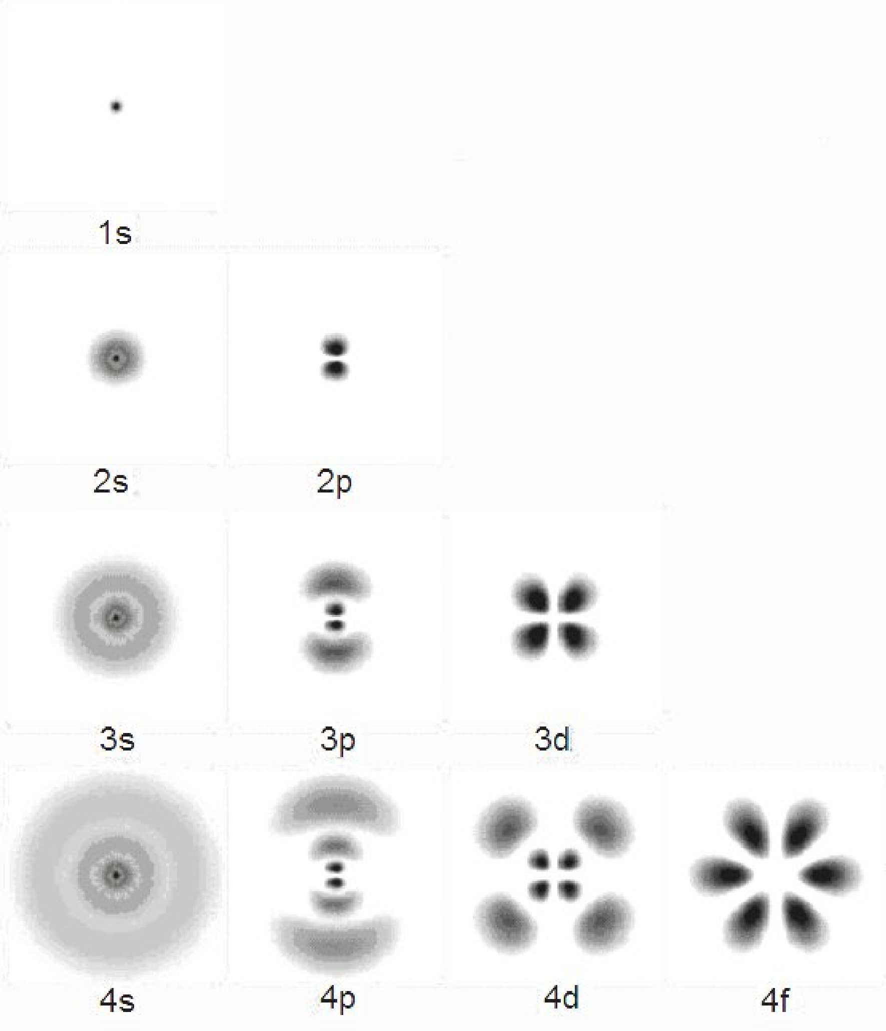
With this, the most important relations are explained in a conceivable way. However it must be added that all explanations are only complete if the quantity "mass" can be defined geometrically and if the existence of Planck's constant (e.g. in the equation $E = h\nu$) can be explained in such a way that it is no longer necessary to interpret it as proof for the fundamental discreteness of being (which will also be performed in the Second Part).

In short: quantum theory does not unite the wave- and particle-like attributes of objects of the fundamental layer of reality. Rather it is the theory where the fundamental world of waves and the object-world built from them meet one another. Therefore it is also clear that quantum theory is unavoidable: all physical descriptions – as abstract as they may be – serve ultimately for explaining experiences with objective circumstances.

Thus we can summarize: *Quantum theory is exactly the theory that allows describing the fundament of reality, which consists exclusively of waves, by quantities which originate in – and fit to – the object-world of our everyday experience.*

As has been shown, the current epistemological bewilderment is not rooted in the formalism of quantum mechanics but in its interpretation. It is the inability to abandon thought patterns that originate in the world of things, which produces paradoxes and leads to the loss of any understanding of reality.

At last, let us look at some eigenstates of the hydrogen atom. The following outline shows the amplitude squares of the according wave functions – usually interpreted as "density distribution".



(S10)

Now we can either assume that these wave functions are nothing but mathematical tools for determining the probability of the (point-like?) electron – with all the absurd consequences mentioned above, or we accept what is obvious: that the depicted shapes relate to actually existing stationary wave states.

We have the choice:

Either we choose the *coexistence* of particles and waves.

Then we have decided upon circumstances which are absurd already by themselves and which, in addition, entail a series of further absurdities: reduction of the wave function, objective probabilities, non-locality. [13]

Or we assume that particles are not indivisible as *substantial entities* but as *dynamic patterns*, because they are stationary wave states, and that, accordingly, particle attributes are *defined* by wave categories.

Then all absurdities disappear, and the whole context becomes understandable.

With this, I shall finish the general part of the local and objective interpretation of quantum theory. In the following sections will be demonstrated, how, by applying our model assumptions to well-known quantum mechanical scenarios, everything which previously seemed to be paradoxical and indeed unexplainable simply disappears.

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[13] If the assumption of the reduction of the wave function is abandoned, then Bell's inequality can no longer be derived, as will be demonstrated subsequently.

3.11. Implementation

In all of the following well-known paradoxes, the decisive step of the elucidation will be the assumption that there is no reduction of the wave function, or, to say it more extensively: that quantum mechanical amplitude squares cannot simply disappear, because they relate always to intensities of existing waves, and that they represent event-probabilities only because events are transitions, which are caused by the continuous accumulation of wave-intensities.

Under this condition, all paradoxes disappear just by themselves, and it becomes directly evident what actually happens.

Let's start with de Broglie's paradox, the

Electron in the Box

Let us assume that in Paris an electron is trapped in a box, the walls of which reflect it. After a short time, the wave function of the electron will be spread out over the whole box. Now the box is divided into two halves by a separating wall, and one half is transported to Tokyo. Then the probability of detecting the electron will be ½ for each half of the box.

If now the half in Paris is opened, then an electron will be there or not, however in any case the Paris measurement will "reduce" the whole wave function and accordingly transform the state of the half in Tokyo from a superposition of the states *there* and *not there* into the definite reality *there* or *not there.*

However from our viewpoint the following applies:

In each half of the box there are electron-waves, and therefore in each half an electron can be found. Whether this will actually be the case depends on the initial conditions in the apparatus used for detecting the electrons. If one of the stationary oscillation states (one of the electron shells) is near enough to the limit where a "jump" into the next state must occur, then an electron will be detected. (See 3.6.)

If the electron appears in one half, then the wave function in the other half does *not* disappear. Thus the connection which the paradox is based upon has dissolved.

Schrödinger's Cat

Here the circumstances are so evident that nothing must be said. There is a transition (an event) or not, and the cat is dead or not.

Not needed are: *act of measurement, observer, awareness, splitting of the universe, decoherence, toad-powder, furuncle extract etc.*

EPR-Paradox

Now then to the second round of the local reconstruction of the EPR scenario. This time we will focus on the connection between the local solution of the paradox and the central assumption of the alternative interpretation of quantum mechanics.

It will be shown:

If the assumption of the "reduction of the wave function" is replaced by the assumption that all waves contained in the wave function contribute to transitions (measuring events), then Bell's inequality can no longer be deduced.

This can be carried out in the following way:

We look again at pairs of photons, which are generated by the decay of spin 0 systems.

We assume that the measurements on one side are not influenced by the measurements on the other side.

Let α be the random angle between the polarization of the left photon and the direction of the left polarizer. Then there are two probability amplitudes: $\cos\alpha$ and $\sin\alpha$; the probability of passing through is $\cos^2\alpha$, the probability of not passing through is $\sin^2\alpha$.

If now, as usual, the reduction of the wave function is presupposed, then the probability amplitude $\cos\alpha$ disappears if the photon is not passing through, and therefore the initial conditions of the *next* measurement are identical with that of the measurement just performed. This means: the subsequent measurement is independent from the current one.

In contrast, if the reduction is abandoned, then $\cos^2\alpha$ does not only represent the probability of the appearance of a photon but is *also* the amplitude square of an *actually existing wave* that passes through the polarizer and arrives at the detector.

As this wave does neither disappear nor cause a transition, it will remain in the detector and contribute to subsequent transitions (events). Thus the initial conditions for the subsequent measurements change: these measurements will then depend not only on the waves that have arrived at the detector since the previous measurement but also on the waves that had arrived earlier.

However, the angles α are random, accordingly their sequence changes with each test series. This means: the initial conditions of the measurements are never identical, and the measuring results are therefore inextricably bound to the course of the respective test series.

But deducing Bell's inequality involves in any case statements about further, *hypothetical* measurements on the objects which are *actually* measured. The assumption of the reduction of the wave function guarantees that each measurement is independent from all previous ones and therefore also from the course of the experiment. Under this condition, information about further measurements is available.

Without reduction, however, the events cannot be separated from the specific, unrepeatable course of the experiment. Therefore, it is completely unknown what would happen if the same objects were measured once again.

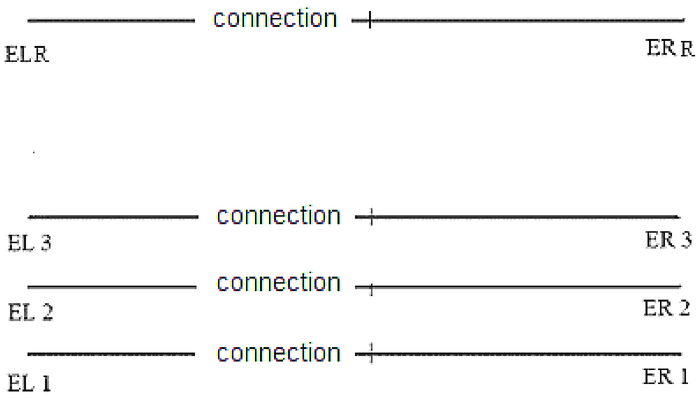
Accordingly, Bell's inequality cannot be established. (These conclusions were presented extensively in the first chapter.)

Thus the reduction of the wave function is a necessary condition for the derivation of Bell's inequality. If this assumption is abandoned – in other words: if to the waves is assigned existence so that they cannot simply vanish – then the proof of non-locality disappears.

With this, the decisive step to the solution of the paradox is made: the scenario is freed from the stranglehold of the inequality, and there is no longer any reason to assume that it cannot be described locally. The path to a local description is open.

The following two outlines illustrate these circumstances:

In the case of the standard interpretation, each event pair (EL_i, ER_i) is independent from all previous event pairs and therefore also from the course of the experiment. Thus Bell's inequality applies, and therefore it is necessary to assume a non-local connection between EL_i and ER_i, as shown in the following outline (R is the number of event pairs):



(S11)

In contrast, without reduction every event pair depends on all previous event pairs and, accordingly, also on the specific course of the experiment:

(S12)

Here, Bell's inequality cannot be derived. The *non-local* connection between *spatially separated events* EL_i and ER_i – which is unavoidable in the standard interpretation – is replaced in the alternative interpretation by the *local* connection between *temporally separated events* (in the same detector).

As has already been asserted in the first chapter, the following conditions must be met in a local description of the scenario:

The probabilities predicted by quantum mechanics must be expressed as functions of variables the carriers of which are localized directly at the position of the measurement – i.e. in the detectors. In addition, the structure of the scenario must be adopted: the objects, which carry these variables, must originate at the decay position Z, then pass through the polarizers and finally arrive at the detectors.

The modeling itself follows from the general assumptions of the local and objective interpretation presented in this chapter:

Continuous radiation of waves leads to transitions ("photons"). Thus instead of pairs of *photons* the polarizations of which are perpendicular to each other, we assume the radiation of pairs of *waves* polarized perpendicularly to each other, of which the radiated wave groups are composed.

In the local model, the number of events in a detector must be proportional to the total intensity of the waves that arrive at the detector.

Thus we define random variables as follows:

(δ is the angle between the two polarizers, α_i the random angle between the polarization of the left wave and the left polarizer, accordingly (α_i+90–δ) the corresponding angle on the right side.

$$X_i = \cos^2 \alpha_i \qquad (1 \leq i \leq n) \qquad (1)$$

$$Y_i = \cos^2 (\alpha_i + 90 - \delta) \qquad (1 \leq i \leq n) \qquad (1')$$

According to our model assumptions, the probability w_L (w_R) of a transition to the left (right) – i.e. the detection of a photon in the left (right) detector – must be equal to the expected value of the random variables:

$$w_L = w_R = E(X) = E(Y) = \frac{1}{2\pi}\int_0^{2\pi} \cos^2 \alpha \, d\alpha = \frac{1}{2} \tag{2}$$

This corresponds to the quantum mechanical prediction.

However the expected value serves only for calculating the frequency of events in one detector. It does not contain any further information. In order to determine the correlation of the events on both sides, however, information about the temporal relationship between these events is needed.

What do the time points of events depend on? Certainly on the time-varying intensity of the waves that arrive at the detectors. Thus the points in time at which photons are detected must be determined by the temporal intensity fluctuations. The degree of these fluctuations is given by the *variance* of the random variables.

The probability of events in *one* detector can be expressed by this variance in the following way: (For the moment, the factors 2 and 1/4 appear arbitrary. They will be substantiated subsequently.)

$$w_L = 2 * \mathrm{Var}(X) + 1/4 = 1/2 \tag{3}$$

$$(\text{ Proof:} \quad 2 * \frac{1}{2\pi}\int_0^{2\pi} (\cos^2 \alpha - 0.5)^2 \, d\alpha + \frac{1}{4} = \frac{1}{2} \ )$$

The connection between the time-dependent intensity fluctuations on *both* sides is expressed by the *covariance* of the random variables. This suggests the assumption that the probability W_{LR} of the appearance of *simultaneous* transitions on both sides is given by an equation analogous to (3), which contains the covariance instead of the variance. The covariance is:

$$\mathrm{Cov}\,(X,Y) = E\,[\,(\,X - E(X)\,)\,(\,Y - E(Y)\,)\,] =$$

$$= \int_0^{2\pi} (\cos^2 \alpha - 0.5)(\cos^2(\alpha + 90 - \delta) - 0.5) \; d\alpha \, \frac{1}{2\pi} = -\frac{1}{8} + \frac{1}{4}\cos^2(90 - \delta) \tag{4}$$

From this it follows that actually applies, analogously to (3):

$$W_{LR} = 2 * \mathrm{Cov}\,(X,Y) + 1/4 = 1/2 \cos^2(90 - \delta) = 1/2 \sin^2\delta \tag{5}$$

According to (4), the covariance lies – dependent on the angle δ – in the interval between –1/8 and +1/8. Thus the factors 2 and 1/4 serve only for mapping the interval [–1/8, +1/8] onto the interval [0, 1/2], which is required for the probability values.

The numbers of the random variables represent their chronological order. Therefore (5) means:

The probability of the simultaneous occurrence of photons in both detectors depends on the degree of correlation of the time-dependent intensity fluctuations on both sides.

At $\delta = 0°$, the covariance reaches its minimum, and there are no simultaneous events at all. At $\delta = 90°$, the covariance reaches its maximum: in this case the intensities on both sides are at any time equal to each other, and all events occur simultaneously.

Equation (5) can easily be generalized. Let us assume that the angle between the measured photons – which, in our model, is equal to the angle between the emitted waves – is not 90° but has the arbitrary value ζ. Then the random variables are

$$X_i = \cos^2 \alpha_i \qquad (1 \le i \le n) \tag{1a}$$

$$Y_i = \cos^2 (\alpha_i + \zeta - \delta) \qquad (1 \le i \le n) \tag{1a'}$$

(4) remains valid, if 90° is replaced by ζ, and then (5) turns into

$$W_{LR} = 2 * \mathrm{Cov}\,(X,Y) + 1/4 = 1/2 \cos^2(\zeta - \delta) \tag{6}$$

(6) leads in *all* possible cases to results which conform to that of quantum mechanics.

Essential is the following point:

The results determined by (6) are *local*.

Why? Because the random variables themselves are objective and local: they are amplitude squares of waves which originate from the decay at Z, pass through the polarizers, arrive at the detectors and cause transitions there.

The covariance itself is a quantity by which the linear correlation between two series of random variables is expressed. It is completely determined by the objective, local random variables, and there is no room for any hidden non-locality.

Thus asserting the non-locality of equation (6) is not a possible position. So if one still claims the non-locality of the quantum mechanical predictions, which are in any case equal to the results determined by (6), then the only possible way out is considering this total congruence as ***random***.

However assuming this congruence to be random is not plausible because:

1. Bell's inequality does not apply here. Thus there is no longer any reason why a local interpretation should not be possible.

2. The scenario has completely been transferred into the local model.

3. The model was established in accordance with the general assumptions of the local and objective interpretation of quantum mechanics.

Equation (6) provides not only the correct probabilities, it also meets the central condition of a local solution: according to the model assumptions, the events are embedded in the specific course of a measurement series.

Computer Simulation

To determine the convergence behavior, I carried out some computer simulations of (5).

The following table shows the results for 30, 100 and 1000 pairs of random variables and for some characteristic angles δ.

For the covariance, always three results are specified. Rightmost is the quantum mechanical desired value. All results relate to spin 0 systems.

n = 30	delta	E(X)	2*Cov(X,Y)+1/4			QM desired value
	0	0.486	-0.010	0.006	0.020	0.
	22.5	0.492	0.039	0.075	0.111	0.073
	45	0.502	0.212	0.248	0.283	0.25
	67.5	0.511	0.407	0.421	0.436	0.427
	90	0.479	0.457	0.481	0.494	0.5

n = 100	delta	E(X)	2*Cov(X,Y)+1/4			QM desired value
	0	0.497	-0.012	0.000	-0.029	0.
	22.5	0.484	0.060	0.062	0.042	0.073
	45	0.481	0.243	0.228	0.234	0.25
	67.5	0.488	0.431	0.409	0.436	0.427
	90	0.530	0.498	0.497	0.529	0.5

n = 1000	delta	E(X)	2*Cov(X,Y)+1/4			QM desired value
	0	0.499	0.001	0.004	-0.011	0.
	22.5	0.491	0.073	0.070	0.066	0.073
	45	0.506	0.251	0.241	0.250	0.25
	67.5	0.508	0.431	0.417	0.434	0.427
	90	0.509	0.502	0.500	0.506	0.5

At last it should be mentioned that W_{LR} can also be expressed by random variables of only one side:

Let $I = \{ i \mid 1 \leq i \leq n \}$ be the set of numbers of random variables in the case of n pairs in total.

Let be $I_E = \{ i \mid \text{sign}(X_i - 1/2) = \text{sign}(Y_i - 1/2) \}$, $I_D = \{ i \mid \text{sign}(X_i - 1/2) \neq \text{sign}(Y_i - 1/2) \}$.

Let be $SL_E = \sum_{i \in I_E} |X_i - 1/2|, \quad SL_D = \sum_{i \in I_D} |X_i - 1/2|$

Then follows:

$$\boxed{W_{LR} = \frac{1}{2} \frac{SL_E}{SL_E + SL_D} = \frac{1}{2} \cos^2(\zeta - \delta) \qquad (7)}$$

(The proof is similar to the proof of (7) in the first chapter.)

Further commentaries to the 2-photon scenario are unnecessary, as everything important has already been said in the first chapter.

What about other entanglement scenarios? As regards entanglement of photons, there cannot be any problem: equation (6) applies in all cases, also in the case of a single process. Therefore, every photon correlation must be reducible to the specified scheme. This means: the mechanism of photon correlations is explained. Formally, however, everything remains as before.

I didn't investigate other entanglements. However with respect to the original EPR scenario, which relates to position- and momentum-measurements, the following must be stated:

The objects to be measured (e.g. "particles") are wave packets, that is: superpositions of waves.

This means: before measurement, it is impossible to attribute a definite position or a definite momentum to the objects. Even if after the measurement on one object the measuring value of the other object can be predicted, this value still *does not exist before measurement*.

Therefore, before measurement there is neither a definite position nor a definite momentum. In this sense, the attributes "position" and "momentum" do not exist before measurement. Also in the local interpretation they are generated only by measurement – however not due to the reduction of the wave function but by a physical process. (As in the example at the end of 3.7.)

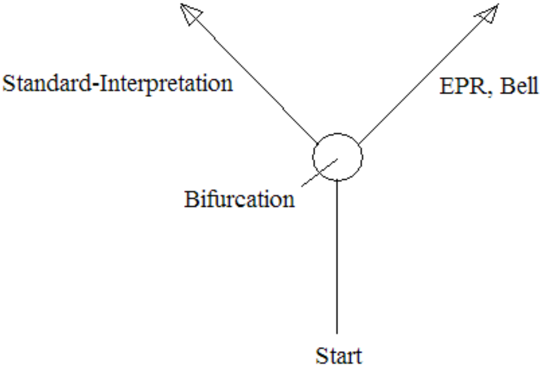
Thus the EPR assumption is wrong, and the EPR reality-criterion[14] is inappropriate. That we can predict – after the momentum measurement on one side – the result of the momentum measurement on the other side, is a consequence of the symmetry of the processes on both sides and not, as EPR assumed erroneously, a consequence of the fact that the "particle" possessed this momentum already before. Before measurement, there was no particle and, accordingly, no definite momentum.

Notes

1. Before we definitively leave the EPR paradox, we turn briefly to the question of how my arguments for a local reality differ from those which hitherto have been brought into discussion. (I'll start with the answer. The explanation follows immediately afterwards.)

The argument, which I propose for a local interpretation of entangled systems, takes place ***in a completely different area*** *than the former discussion.*

First, an outline of the structure of the usual, well-known bifurcation scenario:



(S13)

Common starting point for all variants is the quantum mechanical description of a pair of entangled objects.

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[14] "A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system." (Einstein, Podolsky and Rosen, *Can quantum-mechanical description of physical reality be considered complete?* Phys. Rev. 47, 777, 1935.)

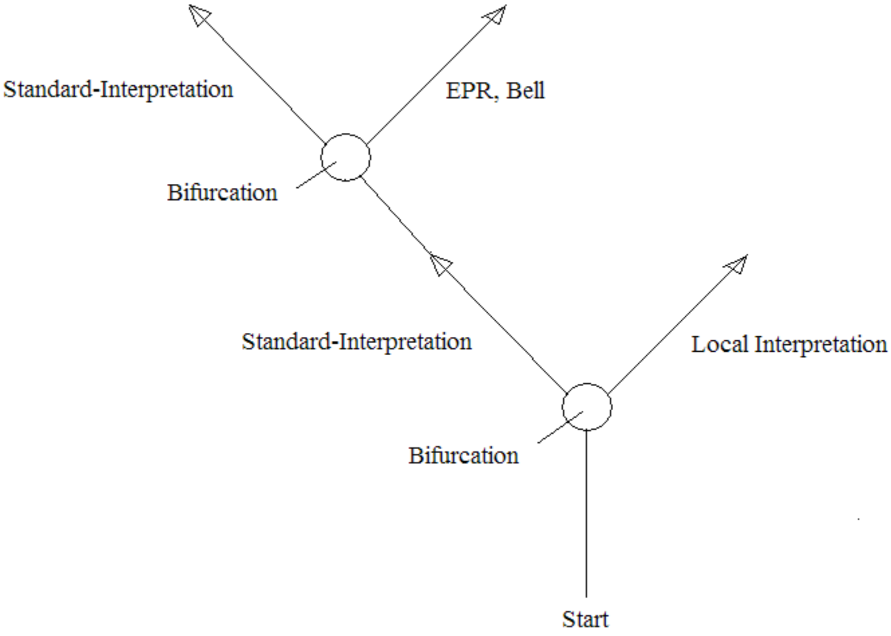
At the branch point, however, the views separate in the following manner:

The proponents of the standard interpretation assume that the two measurement events cannot be separated; Einstein, Podolsky and Rosen, on the contrary, claim the separateness of the two events; John Bell takes this position too, but only in order to derive from it a contradiction to quantum theory.

So much for the scenario in which the debate has taken place so far.

My own arguments, however, do not belong to this scenario. They engage lower, at a point where the question of whether the measurements are independent of each other or not is not even in sight.

The following outline serves to illustrate this fact. The scenario of the preceding outline can be found in the upper left part. So here – as shown in the outline – another bifurcation-scenario must be crossed *before* the usual scenario can be reached at all:



(S14)

Starting point is again the quantum mechanical description of a pair of entangled objects.

Now, however, at the first branch point, it is *not* a question of locality. Rather here a decision must be made about how the *course of the experiment* is to be interpreted, and about what an *event* is and how it comes into existence.

In the standard interpretation, each event pair is regarded as an *autonomous* element of a measurement series, which is *independent of the previous events* and thus also independent of the course of the experiment. This decision leads to the left path, and *only after this decision* the usual, well-known bifurcation-scenario can be entered.

In fact, however, then also the decision about the question of locality has already been made, because – due to Bell's inequality and numerous experiments on entangled systems – it can no longer seriously be doubted that the path which EPR proposed is definitively blocked.

From this follows that on the left path in the outline only the standard interpretation is possible. Thus, here non-locality is a certainty.

But if one chooses the alternative view of the experimental course, in which – as described at the beginning of this section – the *reduction of the wave function does not take place* and in which therefore the events in any case belong to a specific, *non-repeatable* measurement series, such that they cannot be separated from this series, then one is on the path to the right in the outline, and the usual bifurcation-scenario is not at all reached.

Thus, on this path, the question of non-locality does not even arise.

In this juxtaposition, it becomes also apparent how fundamental the changes are which the view of the quantum mechanical reality must be subjected to in order to maintain locality:

Not only must the definition of the *event* be changed, but also that of the *object*. The definition of *interaction* is likewise affected, and this list can be continued at will.

2. In the standard interpretation, the independence of the actual event from all past events is self-evident to such an extent that the question whether it can *actually* be presupposed does never arise.

Thus in the standard interpretation the first bifurcation scenario does not exist at all.

Also in this case, the reason is *ultimately*, as in all quantum mechanical interpretation problems, the binding of thought to representational analogies. It is these analogies – in particular the concept *particle* – through which the interpretation is led astray and artifacts such as non-locality are produced.

A model of the measuring process in which objects are seen as *particles* isolates the measuring process and separates it from the past, whereas the *wave model* integrates it into a total process where every event depends on the preceding events – however only if the waves are considered *real*, such that they do not disappear and, accordingly, the reduction of the wave function does not take place.

Double Miracles

Some time ago, a friend of mine and I laughed heartily about a newspaper article, which reported on a double miracle:

During a séance, a heavy statue rose from the floor and flew across the room on a complicated path with great speed. But not only that – though the room was full of objects, the statue managed somehow, with incredible dexterity, to avoid any collision and fly around all these obstacles, before it finally ensconced itself again at its original spot, so that after this magic episode everything looked exactly like before – just as if nothing had happened!

At least as much, however, we laughed about another double miracle, which physicists like to tell each other and the bewildered public.

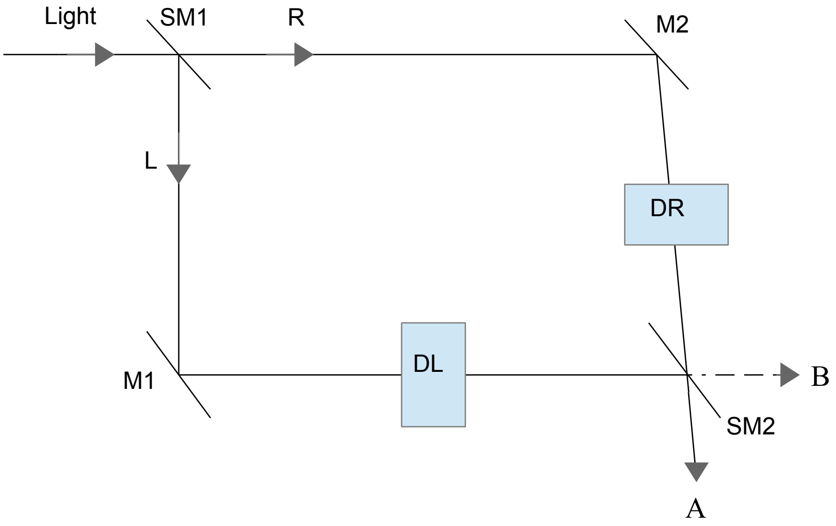
There are, so they say, mysterious connections between objects far away from each other: if Alice manipulates *her* object in a certain way, then her friend Bob's object jumps suddenly into a different state.

Awesome! – thinks the bewildered public, dreams about intergalactic sex and plans to purchase a set of voodoo puppets.

Hold on! say the physicists and tell about another miracle – a really insidious conspiracy: nature does not only arrange such magical voodoo-connections in our universe, it arranges them with incredible dexterity exactly in such a way that they can definitely not be used for transmitting any information – just as if they were not there at all!

Paradox of the Two Ways

The paradox, with which the chapter on quantum mechanics started, can be solved using the explanation scheme of the EPR paradox.



(S15)

As a reminder: In the usual view, the course of the experiment reveals the following absurdity:

a) If the detectors are in the paths of the light rays, only one detector at a time responds: as the photon is indivisible, it can only choose *one* of the two paths, each with a possibility of 1/2.

b) However if we remove the detectors from the paths of the rays, then we observe interference after the second semi-permeable mirror, which means: the photon (or the light wave) must have been on *both* paths, in contradiction to a).

Since we act on the precondition of waves, nothing must be said about b).

However we have to explain why at a) never both detectors respond, in spite of the fact that there are *always* waves on both paths.

For that we use the explanation scheme of the EPR scenario.

There, the random variables X and Y were determined by the amplitude squares of the waves on both sides. Their relationship was determined by the condition that those waves are always polarized at a certain angle to one another.

Here, random variables of the same kind can be defined in the following way:

We assume again that the wave superpositions on both paths are composed of partial waves. Let the amplitude of such a wave before the first semi-permeable mirror be 1. If it is divided by the mirror into two waves with the amplitudes A_L und A_R, then follows

$$A_L^2 + A_R^2 = 1$$

This condition is met, if

$$A_L = \cos\alpha, \quad A_R = \sin\alpha$$

The division is supposed to be random. Therefore, α must be random. (Equally distributed between 0 and 2π.)

Since the expected value of $\cos^2\alpha$ and $\sin^2\alpha$ is 1/2, the amplitude square on both sides is on average equal to 1/2. Therefore, the event probability is also 1/2, in accordance with the quantum mechanical prediction.

Now we define: $X_i = \cos^2 \alpha_i$

– where X_i stands for the intensity of a wave propagating along L. Then for Y_i, which stands for the intensity of the wave propagating along R, applies:

$$Y_i = \sin^2 \alpha_i = \cos^2 (\alpha_i - 90)$$

X and Y correspond to the random variables of the previous section, if in (1a') is set:

$$(\zeta - \delta) = -90°$$

Therefore, the probability of simultaneous events on both sides is given by equation (6):

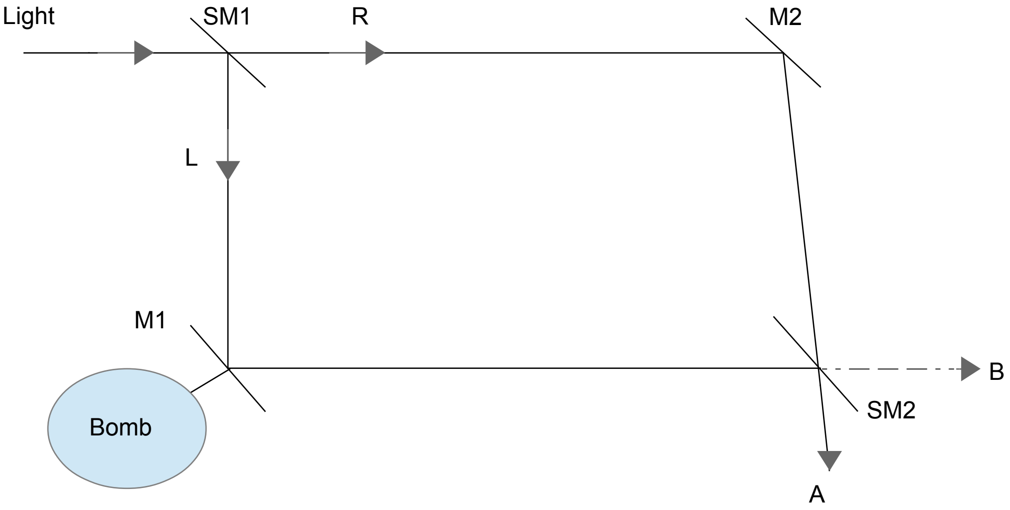
$$W_{LR} = 2\,\mathrm{Cov}\,(X,Y) + 1/4 = 1/2\cos^2(\zeta - \delta) = 1/2\cos^2(-90) = 0$$

This means: Though always waves are underway on both paths, both detectors will never respond simultaneously.

Interaction-free Measurements

Quantum mechanical interaction-free measurements are, in the usual view, measurements, where *nothing at all* happens and *yet* something is measured.

The scenario is similar to the one of the previous section:[15]



(S16)

At first the usual description – for the moment without the bomb bottom left:

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[15] It was presented – in a slightly different form – in 1993 by Elitzur and Vaidman. (Elitzur A. C. and Vaidman L. (1993), *Quantum mechanical interaction-free measurements*. Found. Phys. 23, 987-97.)

A photon propagates, starting top left, through the test arrangement. It is split by the first semi-permeable mirror SM1 into the states *passed* and *not passed,* each with probability 1/2.

At the second semi-permeable mirror SM2 both states interfere. The lengths of the two paths are adjusted in such a way that on the path to B destructive interference occurs. Thus the photon will arrive at A with certainty.

Let us now assume we had a series of bombs with the following ignition mechanism: A mobile mirror, which is connected with the igniter, triggers the detonation, if it is moved. The mechanism is so sensitive that the momentum that is transferred to the mirror by one single photon, if it hits the mirror, is sufficient to cause a detonation.

Some bombs are defect: their mirror got stuck. Our purpose is to find a functioning bomb, without letting it detonate at the same time.

Using the depicted arrangement, this can be accomplished in the following way:

The bombs are attached, one after the other, exactly in such a way, that the mirror of the ignition mechanism takes the place of the mirror M1. If the bomb is defect, the mirror cannot move, and everything remains as before: the photon arrives at A with certainty.

However if the attached bomb is functioning correctly, the mirror is movable. This means: the bomb turns into a *measuring device*: it measures which way the photon takes.

If it is on the way L, then the interaction with the mirror triggers a detonation.

However if there is *no* explosion, then it was measured by the bomb that the photon took the way R.

But now, because a measurement has occurred, the interference at SM2 must change, and this means that the probability that the photon arrives at B is no longer zero.

Thus we just have to wait until a photon is detected at B. The bomb, which is in the test arrangement at this moment, must be a functioning specimen.

Therefore, in this description, a measurement took place due to an interaction, which did not occur at all, with an object (photon) that was not there at all. We obtain information by an alteration which was caused by something which did not happen at all.

Of course, everyone who has read up to here knows how these *incredibly fascinating* circumstances are transformed by the alternative interpretation into *completely trivial and understandable* circumstances, which no further thought ought to be wasted on. However, for the sake of completeness, I shall demonstrate it one more time:

For the explanation the following is needed:

1. In the case of an interaction between light and electrons, the assumption of light particles can be dispensed with (as has been shown at the description of the Photoelectric Effect and the Compton Effect).

2. The discontinuous transitions, which are called "photons", are caused by continuous accumulation of wave intensities.

From this follows that, if no transition occurs, it can by no means be assumed that *nothing* happens or *nothing* is there. Rather quite simply the intensity of the waves does not suffice to trigger a transition.

Regarding the bomb-scenario, this means:

If – in the usual view – it is measured by the bomb that the photon took the path R, so that the interference changes and the photon can now reach B, then – as seen from our point of view – this does not mean that *nothing* happened, but that the intensity of the light waves which hit the bomb-mirror – though it did not suffice to trigger a transition and thus to induce an ignition – still caused a displacement of the mirror by a tiny distance, so that the length of the path L and, with it, the interference changed. (And it should be added that this *must* be the case if there are actually existing waves.)

From this point of view, the usual interpretation of the scenario and its embedding into the general interpretation scheme can be described as follows:

First it is stated that the discontinuous transitions between different states of electron shells are elementary and *indecomposable.* The difference between two states is called *photon.*

Accordingly, photons exist only as a whole. From this follows that, if there is not a *whole* photon, there is just *nothing.* And, of course, nothing can cause only nothing, and therefore nothing occurs.

But now, in spite of all that nothing, *something* happens.

However this is not seen as contradiction or at least as reason for some doubt; instead there is just bewilderment about this incredible magic of nature. It is said: "How strange, something which is not there causes a change. Something which does not happen is still a measurement. Forsooth this is a deep mystery!"

This can only be called a crazy prank! Think of a person A who asserts that B, who is in the same room, does not exist. Then B *says* something. Thereupon, A does not simply withdraw his assertion, but instead exclaims: "Oh dear, how is it possible that someone who does not exist can speak?"

However this is also the final point of our elucidations of quantum mechanical paradoxes. With peace of mind, we finish our tour through the quantum mechanical *freak show* – now that we have freed all freaks and transformed them back into ordinary beings.

3.12. Historical Remark

The question suggests itself why the local and objective interpretation has not existed up to now.

The most important reason is without any doubt the historically developed connection between physical concepts and the world of things. This connection is unavoidable: the measurable reality consists of things. Therefore, physics must begin with the description of attributes and behavior of objects, just as it has actually happened.

What is to be expected if the investigation of nature – which is based upon the equation

$$\text{force} = \text{mass} * \text{acceleration}$$

– in the course of its progressive conquest of the microscopic world comes across the fact that the fundament of reality is wave-like?

Exactly that what happened at the beginning of the 20th century:

The wave-like nature of being is recognized, but the particle concept cannot be abandoned, because *the whole description system* is based on it.

This leads to the paradoxical and – to put it very clearly – *impossible* idea of objects that are wave *and* particle, and this in turn entails all the other nonsense: reduction of the wave function, objective probabilities, non-locality and what else there is of absurd concept formations.

However to understand the low level of resistance which has been established against the oddities of the new approach, one has to leave the realm of physics itself. That absurdities of this kind were not only accepted but even glorified as intellectual achievements or as "deep truths" can only be understood in relation to the cultural background of that time, which manifests itself in the biographies of the first generation of quantum theoreticians and which is reflected by their convictions. Heisenberg's and Pauli's contempt of Einstein's and Schrödinger's attempts at a realistic and understandable interpretation of quantum mechanics was of exactly the same kind as a Dadaist's contempt of representational painting.

It can be seen very clearly how the cultural background intrudes into the development of physics: at first, the *formal structure* of the theories remains untouched – it is bound to the experimental verification, which does not permit any phantasms. However the interpretation, i.e. the whole conceptual and notional foundation, becomes part of the historical development and adapts to the cultural constraints. In the first decades of the 20th century, this means: it becomes "Dadaistic".

Unfortunately, that is not the whole issue. The future development is essentially determined by the interpretation. In this way, the cultural background penetrates yet into the formal part of physics, and this is the reason why theoretical physics got stuck in the blind alley where it currently resides.

In short: If particles themselves are not fundamental, then the goal of theoretical physics – the ultimate theory of everything – will not be achieved by uniting the interactions between particles.

3.13. Conclusion

We have great faith in science and in the rational discourse. And rightly so! – It's the best we have. And yet it is an unfortunate fact that just for clarifying really fundamental questions, a rational argument is not always sufficient. There are philosophical positions that are obviously absurd, but nonetheless irrefutable. Such a position is for example solipsism.

Or let us consider two other examples: the assumption of a "supernatural" being that exists "outside" of space and time, and the assumption of a mind that is independent of any material basis.

Evidently, both assumptions are nonsensical. And this certainty does not stand at the outermost limit of thought, where one arrives only after a long path – no, it follows from the *first* step, which reasonable thinking takes on its path to knowledge: to realize that nature – or being, or reality, or whatever you want to call it – is *closed in itself,* in other words: that everything which happens has a natural cause, and that nothing can lead out of this realm. The attempt to establish another principle of explanation besides the natural causality collapses immediately and absolutely at the question of the cooperation between the two principles: Where and how should this second principle apply, when anywhere and anytime the laws of nature are in effect?

This means: if we are not able to comprehend that, which exists and which happens, within a natural context, or if our model conceptions – like e.g. the so-called *big bang* – seem to point beyond this limit, then this gives *never* rise to trans-natural conceptions, but is always an indication for the inadequacy of the models or for a deficiency of the concept of nature which these models are based upon.

Thus there is no reality "outside of reality" or "behind reality". This is understandable in a trivial way and valid without any doubt. It represents, as I said, the beginning of reasonable thought.

Still, it is impossible to convince someone by argument, who has not already realized this evidence himself. Anyone can say that in the upper left corner of his living room hovers his house spirit *Xupatl,* who protects him from evil demons. Typically, he then adds to it that he could not prove that *Xupatl* exists, but that it can also not be proven that *Xupatl* does *not* exist. Any further discussion is pointless. It will not lead to success but only to a nervous condition.

In such cases one may argue and give good reasons, but eventually the argument is exhausted, and then remains as last resort only the appeal to reason. If it is missing – which is usually the case – then the nonsense cannot be eliminated.

Why this deviation?

Because the questions of locality, objectivity and identity must also be seen as such issues.

It is *perfectly obvious* that there are only connections between spatially separated objects, if they are mediated by a process at a speed not greater than that of light. Non-local connections are simply nonsense. But of course, within the horizon of contemporary convictions, first it had to be shown that Bell's proof does not apply and why this is the case.

As this has now finally been achieved, I contend that the locality of reality has already before been completely evident – just in the same way as it is completely evident that neither *Xupatl* nor any other immaterial entity exists – and that the only reasonable question would always have been the question about where the failure in the proof of non-locality lies.

The same applies to the question of the *objectivity* of reality. It is *perfectly obvious* that things are as they are, independently of whether we exist or not and whether we observe them or not. (Of course with the exception of the influence that the physical process of observation has on the observed object. However this influence can be analyzed and is not at all mysterious.)

Finally, the same has to be said about the question of *identity:* the consequences of identical facts must again be identical facts, and not just identical probability distributions of facts. There is no such thing like an objective probability. [16]

The loss of these three basic principles of any reasonable worldview was only possible because the retreat of theoretical physics into the formal scheme was so complete that any concept of being has dwindled away from physics.

But reality *is not* just mathematics, reality *exists* – thus we have to form a concept of reality that goes beyond mathematics. And in doing so, we will reinstitute reason in the area of interpretation, as indeed *any* concept of reality must meet the postulates of locality, objectivity and identity. [17]

However if one does not possess any concept of reality at all, then *anything* is possible. Then there is no *reductio ad absurdum,* because absurdity is considered real, and the downfall of reason cannot be stopped.

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[16] Actually, already the partitioning of reality into facts and consequences is wrong. Reality consists of *alterations in time* (*processes*)*,* the smallest elements of which are not time points but at least time differentials. But if time-*points* exist only within descriptions and not in the reality, then *processes* can only be divided into *open* time intervals that overlap each other. Then the concept *process* unites both facts and consequences. If now the concept of identity is applied to processes instead of facts, then there is no longer the possibility of different consequences of identical facts. More on that will follow in Parts Two and Three.

[17] Surely, notions like *electron clouds* do not deserve the label *concept of reality*, and the same applies to *interfering probability amplitudes, reduction of the wave function* etc. The *black box,* which is presented by the current interpretation of quantum mechanics instead of a thinkable reality, is simply the opposite of such a concept.

My intention was to show the following:

If there is no reduction of the wave function, then the principles of reason can be reinstituted.

Then particles are no longer elementary substantial entities but stationary wave states or transitions between such states, as long as they are part of a material structure, and otherwise diverging wave superpositions, from which in turn follows that the classical attributes position and momentum do indeed not exist – at least not in the same way as in the case of objects, which possess at any time a well-defined spatial volume.

Seen from this viewpoint, most of the discussion about the completeness of quantum theory and the questions of locality and objectivity has taken place in an altogether wrong area. The solution lies far away from the question whether the classical attributes position and momentum (and other classical attributes) could be restored as hidden parameters. Rather the following applies: if one holds on to these concepts, then Bell's inequality can be derived and, accordingly, all three principles: objectivity, locality and identity fall victim to this false view.[18]

However if, in contrast, objects are understood as wave phenomena, then it is evident that the existence of the attributes position and momentum is restricted by an uncertainty relation. In a world consisting of waves, *all* object attributes must be defined by waves, and the fact that for certain pairs of attributes an uncertainty relation applies – which, seen from a classical or a conventional viewpoint, is completely inconceivable – turns into a well-known, intelligible mathematical fact.

Note:

I conclude with a remark which, although it is self-evident and therefore in fact superfluous, still seems necessary to me – given the extreme proliferation of physical and philosophical speculation that originates from the usual interpretation of quantum theory:

With the restoration of objectivity, locality and identity, *all* these speculations become obsolete. Since both the reduction of the wave function and the uncertainty have been explained in a simple and insightful way, it is no longer justified and therefore completely superfluous, to ascribe the act of

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[18] As is well known, Einstein has been the last one of the great physicists, who held up the scepter of reason, and it is truly tragic that his strategy – the attempt to implement the classical particle concept into quantum mechanics in the form of *objective dualism* (particles within pilot-waves) – has sealed the surrender of reason by enabling Bell's proof of non-locality.

observation or measurement – or the mind of the observer – any significance regarding the existence of the observed.

Also the various diffuse further speculations that, in some way, in the quantum mechanical facts the mystery of the mind could be hidden – such that consciousness could only emerge "in a quantum mechanical manner" – have lost their justification.

4. Concluding Remarks

4.1. Brief Summary

Within the usual conceptual framework, neither in the case of special relativity nor in the case of quantum mechanics can be cleared up which reality the formalism relates to.

In the case of SR, reality has been confused with the formalism already from the beginning. Let us listen to Hermann Minkowski in 1909: "Von Stund′ an sollen Raum für sich und Zeit für sich völlig zu Schatten herabsinken und nur noch eine Art Union der beiden soll Selbständigkeit bewahren." ("From now on, space for itself and time for itself shall degenerate to shadows, and only a kind of union of both shall retain independence.")

In the case of QT, there is no interpretation at all but only explanations why there is no interpretation.

In both cases, reality has vanished. This is the reason for interpretive ambiguities and for the occurrence of paradoxes.

This deficiency has been corrected here. In both theories, the investigation of the question which reality lies behind the formalism and substantiates it has led to a consistent, realistic and understandable interpretation.

In the case of the theory of relativity, this was achieved by the following train of thought:

In various reference systems, the temporal relationships between different positions are mediated by physical processes. The times determined in this way must be unambiguous, i.e. the results must be independent of the chosen process. This is only possible, if there is ultimately only one velocity, that is: the velocity of light. From this follows directly that everything which exists and which occurs must be seen as patterns of superpositions of waves at light speed.

In the case of quantum theory, it was necessary to make up for what was missed in the first decades of the 20th century, when physics came across the fact that anything which exists behaves wave-like.

It has not been recognized that, due to the discovery of the wave nature of being, the previously prevailing description of nature, which was based on the particle concept, has turned from a *fundamental* into a *phenomenal* description. Elementary particles were still seen as indivisible and elementary entities, which should now possess wave attributes *in addition.*

However in order to achieve an objective and local interpretation, it is necessary to understand particles as stationary wave-states or transitions between such states. In this new interpretation, "elementary particles" are still elementary, however not *substantially* but *phenomenally:* stationary wave states are indivisible phenomena, and they are also elementary, yet only in the sense that they cannot be divided into phenomena of the same kind – their indivisibility is that of dynamic patterns which correspond to attractors, comparable to standing waves or flow vortices.

Thus there are no longer particles, which lose their existence between observations and turn into superpositions of states with different probability amplitudes, until they jump again into existence at the next observation *as the same particles*. They are replaced by waves, which diverge outside of matter and which, inside of matter – under the conditions given there –, organize themselves to ever the same, *formally identical stationary states*.

Events are always modifications of material structures. Thus the waves appear "particle-like" *in all observations*. Therefore we are subject to the erroneous assumption that, between observations, they would be underway *as the same objects* and, finally, would appear again as *substantially identical* entities.[19] And then, due to the appearance of interference, we are forced to assign wave attributes to these "particles" *in addition*, and accordingly that which actually happens disappears into the fog of inconceivability.

However it would be inappropriate to claim that the processes which occur in between the events are unobservable. They demonstrate their existence through interference, and, by virtue of their accumulation, they cause – as was explained in the previous chapter – the discontinuous transitions that can be observed directly.

Thus, independently from each other, the substantiations of the relativistic and of the quantum mechanical formalism lead to the assumption that reality consists of waves.

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[19] Isn't this assumption totally absurd? Why should we assume that "particles" are indivisible also between observations and, therefore, remain always *substantially identical* with themselves – even if they lose their existence and turn into superpositions of "probability amplitudes"? At that, in the case of several particles, it leads to wrong results if individuality is attributed to them. So why this clinging on the particle concept, on the idea of *substantial identity* of the observed phenomena?

4.2. Contradiction to the Standard Model

Now is the time to ask what is actually altered by the new view of the physical reality.

Regarding the theory of relativity and quantum theory, *formally* nothing changes. Here, the new view means just a new interpretation of these theories – yet one by which relativistic and quantum mechanical facts are cleared up and the absurdities of the hitherto prevailing interpretations disappear.

But from the change of the approach to the basis of reality, which has been presented here, follows *also* that the theoretical physics has moved in the wrong direction since the theory of relativity and quantum theory. This can most clearly be demonstrated using the so-called strong interaction. As follows:

A substantial element of the new interpretation is that to the waves, whose amplitudes serve for the calculation of event probabilities, is assigned *existence*, with other words: it is assumed that they cannot simply disappear and that the events are actually *caused* by them. Only through this assumption it is possible to restore the locality of the world and to understand what *actually* happens in quantum theoretical measurements.

However, if we apply this assumption to the theory of the strong interaction, we arrive at the following contradiction:

Quarks are bound together by the strong interaction. This interaction does not decrease with the distance. Therefore, quarks cannot be separated from one another.

Neutrons consist of three quarks. In a neutron interferometer, a neutron ray is divided by diffraction at a first crystal layer into two rays, which depart from each other up to a distance of some centimeters. At a second layer, the rays are again diffracted, such that they unite at a third layer where then interference can be observed.

The intensity of the ray can be chosen so low that with high probability there is always only one single neutron in the interferometer. Therefore, *single neutrons* are divided.

This gives raise to the question:

If the neutron is divided – where are then the quarks?

Of course, in the usual interpretation this question is not permitted. It is meaningless to ask what happens between two observations. The elements of the description are nothing but mathematical tools. (However, also here appears, in a most impressive manner, again the strangeness, not to say: the madness of this position: indeed, it cannot be doubted that in both rays *something must be there*, and then the question of where the quarks are is inevitable and, evidently, also unanswerable.)

However in the local and objective interpretation, the amplitudes of the neutron waves are not just mathematical tools – they are seen as *existing* (what they proof by interference!).

But obviously, under this condition, it is impossible – at least according to the current description of the strong interaction – that a neutron can be divided.

This means: the current description of the strong interaction is ontologically inadequate. *This description cannot contain the actual causal connections*.

However if the theory of the strong interaction is wrong, then the whole Standard Model breaks down. It can then no longer claim the status of a fundamental theory but only the status of a purely formal approximation, comparable to the well-known epicycle-system, which once served for the description of the planetary orbits. With this, it is also evident that all attempts to develop physical theories on the basis of the Standard Model must fail.

Here it can be seen clearly how a wrong interpretation leads to the development of wrong theories. As long as this wrong interpretation persists, it will also be impossible to correct the failures caused by it and to create more appropriate theories.

Thus we have come to the following conclusion:

The Alternative Interpretation and the Standard Model (including all theories based on it) contradict each other.

A result of extraordinary importance! However, is there a chance that the Alternative Interpretation can win this confrontation?

I think yes, and here is why: in the decisions that had to be made in the foregoing chapters, there has always been – at least in the fundamental questions – the same most basic kind of choice: *the choice between sense and nonsense*. (Think again of the question of whether waves can simply disappear or not, or the question of what actually happens in the double slit experiment, or the decision between locality and non-locality, or of the outright absurd idea of "interfering square-roots of probability densities".)

The physics of the last decades, however, has evolved from exactly those assumptions, which we have diagnosed as *nonsense*, and therefore it is irrelevant how long its evolution has already lasted and how much intellectual and financial resources have been invested.

But again: is it actually thinkable that the Standard Model is wrong, that we are indeed confronted with a historical failure of such scope?

Again yes, and the explanation lies precisely in the fact that the whole theoretical structure is built on wrong presuppositions. Exactly those deficits and errors in the interpretations of the theory of relativity and of quantum theory, which have been criticized and corrected in the foregoing chapters, have been adopted as basic assumptions.[20]

However the chance to eliminate erroneous assumptions exists only for a limited time period. Afterwards, the general attention is inevitably directed toward other issues, and the unsolved questions pass into oblivion.

Thus the next chance to correct the old errors does not appear before the problems caused by them have ultimately become so important that they can no longer be ignored. If the actual cause still remains hidden, then the whole system can break down.

It cannot be denied that the latest physics exhibits some features that indicate such a state. Not least, it is the absolute lack of success of superstring theory, which suggests this view.

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[20] Most important is again the particle concept. The theoretical physics of the last decades is based on the assumption that the group structure, which is formed by the elementary objects of the reality and the operations that can be performed with them, represents the *fundamental* level of description. This assumption carries all presuppositions that thwart the understanding of the reality: substantial identity of the objects (– this is precisely the particle idea; more on this issue follows in the next Section), non-existence of the waves, indivisibility etc. The elements themselves and the operations with them are presupposed, so that they cannot be deduced from the theory.

This idea of reality is in maximum contrast to the view presented here, where all phenomena are dynamic patterns.

4.3. Hidden Ontology

The problem to understand quantum theoretical measuring processes, in which the wave function collapses, is caused by an ontological assumption that is hidden in the standard interpretation. Its content is exactly that what we previously called *substantial identity of the measuring objects*. This means the following:

First, the measuring object is *generated* (prepared). Then it crosses the experimental setup. Finally it is *detected* (measured).

Here, however, it is unconsciously and, so to speak: completely automatically presupposed – not only within the framework of the standard interpretation but indeed by *anyone* who has ever commented on the interpretation of quantum theory – that that what is *generated* and that what is *detected* is *the same object.*

Also those who consider themselves free of any kind of ontology – no matter whether they are pragmatists or positivists – still presuppose that the *generated* and the *detected* object are one and the same object.

Therefore, even when you try to avoid any ontological assumptions and beware of interpreting the phenomena as "particles" or "waves" or whatever else, you have still made a far-reaching *ontological decision*: precisely that one which – as has been shown in Chapter 3 – makes it impossible to understand what happens.

I remind you of what *actually* goes on in the double slit experiment: After the measurement object (e.g. an electron) has been generated, it passes the double slit, interferes with itself and hits the detector plate – with an intensity whose distribution corresponds to the distribution of the measured events.

The generated object, however, is by no means identical with the detected object: The detected "object" – which is actually a transition between two oscillation states – owes its existence not only to the wave intensities that just now have been present at the position of the detection, but also to wave intensities that have earlier arrived there, and also to such ones that have already been there before the experiment started.

In the description of the double slit experiment, I stated (in the first note) that it is the unconscious application of the "ball-throwing analogy" which rules out any possibility of understanding. This analogy is also appropriate to illustrate the seemingly obvious assumption of *substantial identity* of the objects: it would be outright crazy to doubt the identity of the *thrown* and the *caught* ball. Unfortunately, it is equally crazy to transfer this identity to atomic and molecular circumstances. If this is done – and I emphasize again that up to now this has invariably been the case – then the explanation of quantum mechanical measuring processes is completely ruled out.

Therefore, it does not matter which further assumptions are made or whether any assumption at all is avoided – no, in order to thwart any kind of understanding, it is indeed entirely sufficient to presuppose the *substantial identity* of the generated and the detected object. And, moreover, as has just been shown, this presupposition induces the development of wrong physical theories with which physics is eventually led into the dead end where it is currently trapped.

I'm speaking of *substantial* identity instead just of identity, because the decisive point is the differentiation between *formal* and *substantial* identity. *Substantial identity* is a concept that can be applied to macroscopic material objects. *Formal identity* is a concept that fits to dynamic patterns.

Here is an example for the latter: A river vortex X is *formally,* but of course not *substantially* identical with another vortex Y that appears further down in the same river bed under identical boundary conditions.

The same applies to all phenomena, when they are seen as dynamic patterns. E.g. in the case of the double slit experiment, the generated "electron" is *formally,* but not *substantially* identical with the detected electron. In the same way as the vortex, the detected electron is a phenomenon that has been *newly formed* in identical shape under identical boundary conditions, and this applies also to the neutron that has been detected after the interferometer.

In the Alternative Interpretation, the world is formed by waves. Therefore, here all phenomena are stationary wave patterns, and the concept of "substantial identity" proves to be ontologically altogether wrong. However, in the realm of everyday experience, its application is rather unproblematic, because there the objects are of a magnitude in which they are long term stable, such that they remain identical with themselves in all processes – as e.g. a thrown ball.

However, in atomic or molecular magnitudes the objects are only conditionally stable. Under certain conditions, they dissolve into the waves of which they are made and lose their identity. Later, these waves can contribute to the formation of *formally identical* objects.

Therefore, the concept of *substantial identity* cannot be transferred to the world of the smallest things. If this is still done, then its ontological wrongness manifests itself through the fact that the events become uninterpretable.

4.4. Outlook

Let us now turn to the question of how the future of physics could be look like on the basis of the Alternative Interpretation; what will be the direction of the search for simplification and unification?

In the following, I shall present some basic considerations. However I will be brief, because from the position achieved so far the answer can only be guessed, while from the position that will be taken in the next part it appears quite naturally and in a distinct form.

Particles carry charges. If a particle is seen as wave state, then the charge must be attributed to this wave state. With this, an important adjustment takes place. As mentioned above, there is a fundamental difference between particles and waves: a particle is connected with its attributes only *by definition*, whereas the attributes of a wave *follow logically* from its dynamics. Thus, effects caused by a particle are just part of its definition, whereas effects caused by a wave must be substantiated by its dynamic form.

In short; waves must interact *as waves,* and if the interaction reaches out into space, then this process must be *wave-like.*

This means:

1. Every field must be deducible from the dynamics of the stationary wave states which are the sources of the field. What in the case of particles is only an act of definition, turns – due to the transition to waves – into a logical connection.

2. Every field is ultimately a wave field which is defined by frequencies, wave-lengths and phase-relations.

Let us go back to the question of the unification of interactions. How can it be achieved under the conditions of the wave model of reality?

To answer this question, the following must be taken into account:

First I shall repeat the considerations of section 2.12.

It is unknown what oscillates in the case of light waves. The answer: "The electrical and magnetic field vector" cannot be accepted – that would be the same as if, in the case of water waves, the water was removed and then stated that now kinetic and potential energy take the place of the water. The *subject* of the periodic change, which is the basis for the wave propagation, cannot simply be replaced by general description quantities.

The same question appears in quantum mechanics. What is it which the amplitude of the Schrödinger equation relates to? It is impossible to assign this amplitude to any known physical quantity.

If one accepted the – inadmissible – replacement of the *subject* of the periodical alteration by description quantities, then it would also be possible to attribute different charges to different waves. However there *must* be a subject of the oscillations. There has to be *something which* oscillates, and, as just mentioned, this existing "something" cannot simply be replaced by pure description quantities.

Therefore, even if we don't know *what* changes periodically, it is perfectly clear that, due to the above train of thought, that which oscillates must – as an existing entity – be *the same* in all waves. All waves exist in the same space, and therefore the *subject* of the oscillation must be identical in all waves; all amplitudes have to relate to the same entity: A *description quantity* can simply be superimposed over another description quantity, but *anything existing* can *not* be superimposed over anything existing: what exists claims its place in space and time exclusively for itself.

Thus we have come to the conclusion that all waves must be of the same kind – in the sense that that which oscillates is in all waves identical. At the foundation of reality, there are no different kinds of waves.

But is it possible at all that the interactions could be unified in this way? Does a single kind of waves leave enough room for the derivation of all interactions?

Seen from the Alternative Interpretation, however, this question is not admissible, because – as has been shown just previously – the current descriptions of the strong and weak interaction are nothing but ontologically inadequate approximations and have therefore lost their status as fundamental theories.

So let's resume our train of thought. We concluded that there is only one kind of waves, from which all interactions must follow.

Now we are only one step away from the *law of everything:*

If that which oscillates is in all waves identical, then all waves must conform to the same law. And as these waves are indeed everything which exists and which occurs, *everything* must conform to this law.

We are standing before the *mechanism of the universe:*

It is the law to which the propagation of the waves conforms.

That's all, and it's surely a surprise. Within the current range of interpretations, it seems even absurd. However this frame has now changed essentially, and, starting from the new interpretation, only a few steps are needed to arrive at this surprising conclusion.[21]

It may also be considered surprising that with a *law of everything* of this kind, one possesses actually very few information. In a universe based on such a law, everything which exists must be a wave pattern that has emerged by self-organization. However the propagation law of the waves alone does not provide any information about such pattern-formation processes. Patterns develop only in connection with certain boundary conditions.

Think for example of the sound of a jar: the shape of the jar determines the spectrum of the sound. The wave-pattern is completely determined by this shape; the propagation law of the disturbance determines only the speed of the propagation and, with it, the frequencies of the oscillations.

And this is also the proper analogy for the new interpretation:

There are only waves. Everything which exists and which happens is a wave pattern. The universe can be understood analogously to an oscillating body, which organizes itself into wave patterns.

But it is just an analogy, and it will be replaced by a more abstract concept in the Second Part. After all, however, it is appropriate to illustrate the contrast to the usual view, which was presented at the beginning of the introduction using Feynman's statement:

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[21] Indeed, this result is already contained in the explanation of special relativity. It ensues directly from the fact that there is only light speed and that, accordingly, everything which exists and which occurs must be understood as interference phenomenon, as wave pattern.

However, without the wave-interpretation of quantum mechanics, it would have remained entirely vague how a reality of this kind could be designed. The distance to the usual way of physical thinking is just too great.

"All things are made of atoms – little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another."

The transition between the two concepts of reality can be described in the following way:
In the usual view, the discrete, particle-like phenomena are considered fundamental.

The alternative view is based on the assumption that *below* this layer of discrete phenomena a continuous, wave-like fundament of reality exists, which contains the *actual* causal connections.

This fundamental layer, however, is by no means an invention of the Alternative Interpretation – it is just a part of the quantum mechanical formalism. The difference is that, in the conventional interpretation, it is declared *non-existent,* whereas in the Alternative Interpretation it is considered *existing*.

As a summary, it can be stated:

The conception of different fields, by which various elementary entities interact with each other, is replaced by one single relation between differentially adjacent points.

Already at the beginning of the Second Part we will deal with the mathematical form of this law, of which, for the moment, we know nothing but that it exists.