Draft

Zeilinger's quantum nonlocalilty at entanglement and the quantum modulation of electrons

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Zeilinger"s quantum nonlocality at entanglement is the discovery of one of the basic quantum mechanical properties which are unknown in macroscopic physics. This nonlocality is the reason in the Schwarz-Hora effect that the modulated electron beam could produce the patterns in the color of the laser light at the nonluminescent screen which could not at all be explained (classically) without the electron property of nonlocality. T he modulation process could be explained as a quantum mechanism at the applied medium laser intensities as confirmed also by the modulation at molecular scattering (Andrick & Langhans, Weingartshofer) and other experiments which showed the quantum property while higher laser intensities did not produce the effects. This was expected from the correspondence principle of electromagnetic interaction. The controversy about the optical pattern can now be clarified. The initial modulation experiment can be understood from the nonlocality and it is not necessary to consider the questionable experiments of Schwarz with claimed 1000 times higher electron currents as considered necessary without the nonlocality.

The properties of quantum mechanics in view of the particle and the wave picture were developed enormously during the last years in view of understanding nonlocality in connection with the measured much higher values than the Bell inequality prescribed, in relation to the Einstein-Podolski-Rosen theorem and applications to quantum computers. For the question of nonlocality the clarifications by Zeilinger[1] are taken into account in the following expressing the various views e.g. summarized by Walther[2]. Zeilinger was involved with diffraction experiments of ultra cold neutron beams[3] of which the final measurements[4] provided the necessary high accuracy for drawing conclusions. These conclusions were not at all expressed with the experimental results[4] but were seen in the reflections of the discussions of the subsequent years[1].

We focus here to the point1 that the highly accurate experimentally confirmed double slit diffraction of the neutrons was performed with such low neutron currents showing how the particle beam picture cannot be applied. This is rather well known, but it has been clarified1 that one neutron going through one of the double slit is interfering with another neutron going through the other slit even when this second neutron has not yet been emitted from the uranium nucleus. This result has consequences for the understanding of the modulation effect of electrons[5] what is one of the points which had not been understood before the last years clarifications.

The modulation effect[5] of electrons refers to the cases where electrons interact coherently with other electrons whose energy has been increased or decreased by an energy $E^* = hn^*$ where E^* can be the photon energy from a laser beam interacting with

the electron beam either in the presence of a solid material[5] or of gas molecules[6]. The coherent superposition changes the initial energy spectrum of the electron beam around its initial energy E_o e.g. from the usual Gaussian shape with the thermal width given by the temperature of the electron source into a spectrum showing the additional maxima at the energies

$$E_{\pm n} = E_o \pm nE^* \qquad (n = 1,2,...). \qquad (1)$$

This was immediately measured[6,7] or was seen from the re-emission of optical radiation of photons with the energy E* when the electron beam was hitting a nonluminescent screen[5].

A first theoretical condition for this process was the clarification that the laser interaction fulfilled the quantum branch of the correspondence principle of electromagnetic interaction, see Eq. (3) of Ref.[5]. If the laser radiation transfers to the electron at a quiver motion a momentum Δp with an average quiver amplitude Δx the parameter a in

$$\Delta p \Delta x \; a = h \qquad (2)$$

had to be much larger than unity as given in the experiments[5,6], otherwise classical interaction will occur. This criterion was seen to be valid in other cases[8] e.g. to explain the strong modulation of microwaves at lower intensity with plasma interaction[9] contrary to high intensity interaction with no effect at all because of the classical branch[10] of $a << 1$. The same criterion explains the separation between multi-photon ionization and Keldysh-(above threshold)-ionization[11]. The second condition of coherence for the modulation effect[5] had been confirmed[12].

The solidity of the result with the screens[5] can be seen from the following two facts apart from notary confirmed witnessing of the experiment by physicists. The first fact is that there was an exponential decay of the re-emission on the angle u between the polarization direction of the laser beam and the electron beam direction (Fig. 3 of Ref.[13]) where the expectation from the experiment to be a function $\cos^{2n}u$ (n = 1,2,...). It was not before the theory of the interaction process for the modulation by gas molecules in the presence of a laser beam by Krüger und Jung[14] that the function was given by a Bessel function, resulting in this special case as an exponential function as measured[13].

The second fact is the astonishing agreement of the long beating wave length Λ_{bn} where the measured value agreed with the relativistic correction[15] with the Varshalovich-Dyakonov[16] modification if from several competing models the Peierls[17] dispersion theory was used. The superposition of electron waves $\Psi(E_o)$ with $\Psi(Eo+E^*)$ and $\Psi(E_o-E^*)$ results in a beating with the beating wave length $\lambda_\varepsilon E/E^*$ where λ_e is the de Broglie wave length. Contrary to the superposition of optical waves due to the essential difference of electron waves in second order, the electron waves show a further long beating wave length[8,17]

$$\Lambda_{bn} = 8\lambda_e(E_o/E^*)^2 \qquad (3)$$

which value is from the experiment[5] results in 1.6858 cm. For the experimental

conditions, a relativistic correction is necessary[15]

$$\Lambda_{bn,rel} = 8h(Eo/E^*)^2/(2mE_o(1+E_o/(2mc^2)))^{1/2} \quad (4)$$

resulting in 1.646 cm. The measured value[18]

$$\Lambda_{bn,exp} = (1.73 \pm 0.01)\ \text{cm} \quad (5)$$

is even larger. If, however, the dielectric relativistic correction of Varshalovich and Dyakonov[16] is used[15]

$$\Lambda_{bn,diel} = \Lambda_{bn,rel}/(1 - (v^2/c^2)(1-c^2/c_M{}^2)) \quad (6)$$

with the expression of the residual photon momentum[19] for the dispersion of solids of a complex refractive index n according to Peierls[17]

$$|c_M/c| = (n^2 - 1)|1 - (n^2 - 1)/5|/n \quad (7)$$

the value of 1.740 cm is calculated from Eq. (6) based on a refractive index of 1.58 in the experiment. Since there are essentially different competitive theories to that of Peierls[17], this agreement is a mutual proof for the Peierls theory and of the measurements of Schwarz[18].

The difficulties only arrived, when Schwarz was criticized that the intensity of the light from the nonluminescent screen is about 1000 times larger than expected. Schwarz was then claiming[18] that he performed his experiment by using not one electron beam but 1000 beamlets after splitting one beam after transmission of a plate with 1000 holes. To the knowledge of the author, this experiment was never witnessed by other persons.

In view of the results of the nonlocality as clarified during the last years, especially as mention with Zeilinger's[1] clarification of his neutron double slit experiments4, the claims of Schwarz with the 1000 holes plate became questionable. Whatever he has measured or interpreted, it is for sure that he had no knowledge about the non-locality of quantum mechanics and the motivation about the 1000 holes may be considered as a mix-up of classical thinking about quantum physics. The involvement of the problems of nonlocality with the modulation effect was well suggested after the non-validity of the Bell theorem was measured[20,21] and as Rosen[22] had pointed out in a discussion about the modulation effect and its connection with the experiments of Rosenberg et al[9] of which it was clarified[8] that this was within the quantum branch of the correspondence principle of quantum mechanics.

.....The same relates to the clarification of nonlocality with the coherent-state Handel effect.....

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