Diffusion of Individual Brownian Particles through Young´s Double-Slits

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The phenomenon of wave–particle duality could be explained classically using the concept of the spontaneous formation of selforganized structures. When the number of Brownian particles exceeds a certain critical value the diffusion action of formed waves approaches asymptotically to a characteristic value $6.6 * 10^{-34}$ Js. Diffusion of these waves through double-slits creates the interference structure. On the other hand the diffusion of individual Brownian particles through the double-slits is significantly influenced by the spontaneously formed selforganized structure of photon field radiating from the cavity. The selforganized photon field radiating from the cavity contains information about the geometrical arrangement of the experiment.

Keywords: diffusion action, spontaneous formation, selforganized structures, double-slit experiment

Diffusion action of chemical waves

There is a strong tendency for systems far from equilibrium to create spontaneously selforganized dissipative structures. They can be seen not only within the biological systems but also in physical and chemical world of inorganic substances [1]. Colloidal chemists have frequently observed macroscopic spatial patterns during the past one hundred years. Liesegang [2] observed 2D formation of patterns of inorganic substances in the presence of gelatin termed as Liesegang rings (LR). The discovery of the Belousov-Zhabotinsky (BZ) oscillation reaction catalyzed intensive research of these oscillation reactions [3].

It was found that during the evolution of successive waves the product of instantaneous propagation speed u and the wavelength *?* converge to a constant value [4,5,6]. This product u *?* depends on the type and the concentration of the polymer used in the case of Liesegang rings. There was a tendency to characterize the diffusing front by a characteristic particle mass m that is needed for the estimation of the *diffusion action* of chemical waves. The product of the characteristic mass m, propagation speed u and the wavelength *?* was termed as the *diffusion action* [7].

This approach for the characterization of the LR formation was followed repeatedly several times since then [8]. More than one hundred different combinations of cations and anions were employed for the LR formation. Because of the difficulties in the estimation of mass of diffusing particles (reaction between the molecules of outer and inner electrolytes, irreversible formation of clusters) the calculated values of the diffusion action of the order $\sim 10^{-34}$ Js could not be tuned to a certain constant value. Therefore, this concept was considered as very trivial [9]. On the other hand, several theoretical physicists contributed to this topic [10,11,12,13,14,15,16,17], too.

Several decades long experimental and theoretical research can be condensed into the following equation:

$$K k m l u = h \tag{1}$$

where *K* is the diffusivity factor, *?* is the tortuosity factor, *m* is the particle mass, *?* is the wavelength, *u* is the propagation speed, *h* is a characteristic constant of the diffusion action. The parameter *K*—diffusivity factor—describes the geometrical arrangement of the experiment. For one-dimensional space (thin glass tubes) K = 1, for two-dimensional space (thin layer in a Petri dish) K = 2, in case of the three-dimensional experiment the value *K* depends on the space angle available for the diffusion of Brownian particles from their source. If the whole space is available for the propagation of the chemical waves, then K = 4p. Many studies of the dispersion relations were performed in gels, membranes, resin beads, glasses in order to prevent hydrodynamic disturbances from the reacting media. These media help to localize the propagating bands; on the other hand they modify the diffusion path of ions. The diffusion field in these restricted environments changes by a tortuosity factor *?* that characterizes the diffusivity in porous media.

In the recent summary of this topic [18] the evolution of the diffusion actions of Liesegang rings formation, Belousov-Zhabotinsky waves and the cAMP (cyclic adenosine 3′,5′-monophosphate) waves were analyzed. The main trend for all three types of chemical waves is similar. During the evolution of successive chemical waves there is a strong tendency to self-organize their diffusion fields in such a way that the diffusion actions converge to a constant value of about $6.6 * 10^{-34}$ Js (stage 1). Diffusion actions of next waves fluctuate around this quantity of action for a long time in dependence on the capacity of the system (stage 2). When the stage 2 is over the successive waves irreversibly decay towards chemical equilibrium (stage 3) until the creation of waves stops.

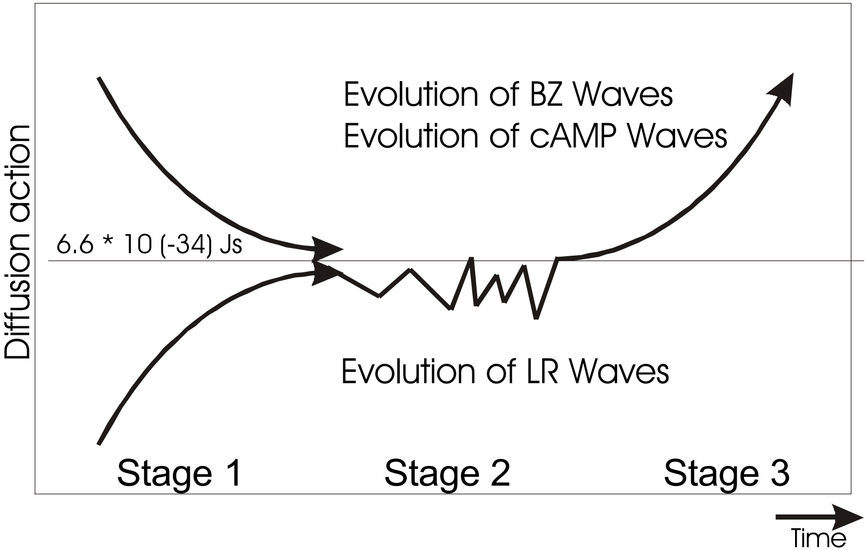

Figure 1 Evolution of diffusion actions of chemical waves

The property of vast collections of Brownian particles to diffuse into their surroundings as local osmotic waves reveals that these waves have a strong tendency to selforganize their diffusion fields. This self-organization of the diffusion field can be done via the characteristic mass *m*, propagation speed *u* or the wavelength *?* in such a way that their diffusion action tend to fluctuate around the characteristic value $6.6 * 10^{-34}$ Js. This behavior of chemical waves is schematically shown in Figure 1.

Chemical waves consist of many discrete particles that coherently diffuse into their surrounding provided that a certain critical particle concentration is exceeded. These chemical waves behave in a similar way as photon waves. Nikiforov and Kharamenko [19] studied Maupertuis´ as well as Fermat´s principles and the Snell law validity for lead iodate and silver bichromate waves. Raman and Subba Ramaiah [20] described the wave-interferences in Liesegang patterns. Oosawa et al. [21] investigated refraction, reflection, and frequency change of chemical waves propagating in a non-uniform BZ reaction medium.

Diffusion of single Brownian particles

The vast collection of Brownian particles creates a local osmotic wave that penetrates into its surroundings and self-organizes its diffusion field in such a way that the value of its diffusion action fluctuates around the quantity of action. Properties of these waves of selforganized Brownian particles are compared with those stated by the Copenhagen interpretation of quantum mechanics (CIQM) and by the stochastic interpretation of quantum mechanics (SIQM) [22,23] in Table I. There is one main difference between these three concepts: no wave is associated with single Brownian particles. The wave is associated with the groups of Brownian particles when they exceed a certain critical concentration.

For the case of diffusion of single Brownian particles through double slits the structure on the detector is formed by the interaction of Brownian particles with the spontaneously formed selforganized structure of photon field radiating from the cavity used for these experiments. The Brownian particle seems to be interacting with both slits via the formed selforganized structure of the cavity photon field. This interaction might explain the non-classical behavior of individual particles that adjusts its random trajectory according the geometrical arrangement of the experiment.

Table I Comparison of CIQM, SIQM and the colloidal interpretation of QM

	Copenhagen Interpretation of QM
1	Individual photons are particles or waves, never the two simultaneously
2	Double slit experiment with single particles: individual photons interfere with themselves, one cannot tell through which slit the photon passes
	Stochastic Interpretation of QM
1	Individual photons are real de Broglie´s waves associated with particles
2	Double slit experiment with single particles: the real wave goes through both slits, the photon goes through one slit only
	Colloidal interpretation of QM
1	No wave is associated with single Brownian particles
2	Wave is associated with the vast collection of Brownian particles, diffusion action of these waves fluctuate around the quantity of action
3	Double slit experiment with single particles: individual Brownian particles diffuse through the spontaneously formed selforganized field of photons radiating from the cavity

The unexpected appearance of the interference pattern structure on the screen for the case of single particles shows one very peculiar feature. Examination of a diffraction or interference pattern does not reveal whether it has been made by electrons or by photons [24]. This experimental evidence might be a good starting point for the introduction of the concept of spontaneously selforganized photon field radiating from the cavity. Photon field creates spontaneously self-organized structure that is dependent on the geometric arrangement of the instrument. The Brownian particles in the double slit device do not interact locally with the detector but non-locally with the matter distribution in the volume of the cavity as a whole. This behavior is schematically shown in Figure 2.

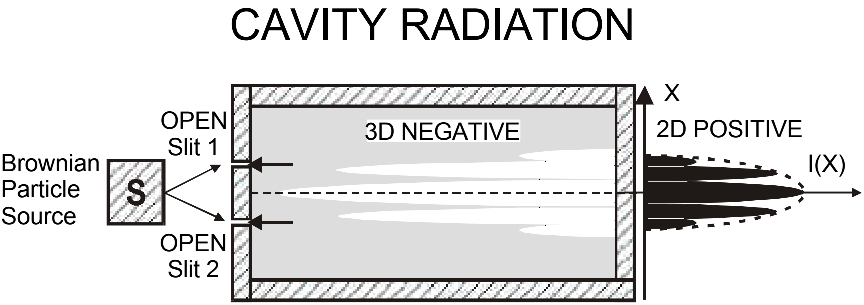

Figure 2 Spontaneous formation of the selforganized photon field radiating from the cavity via two opened slits

Closing one slit will change the matter distribution in the cavity as is depicted in Figure 3 and the trajectories of Brownian particles will lead to a single slit distribution of intensity. In this case the radiating photon field from the cavity creates a valley around the opened slit and guides the Brownian particles to a detector. This could be the way how the photon field influences the resulting trajectories of Brownian particles and gives to the Brownian particle an information about the closing or opening of the second slit. Therefore, the experimental apparatus and the observed Brownian particle cannot be regarding as separate.

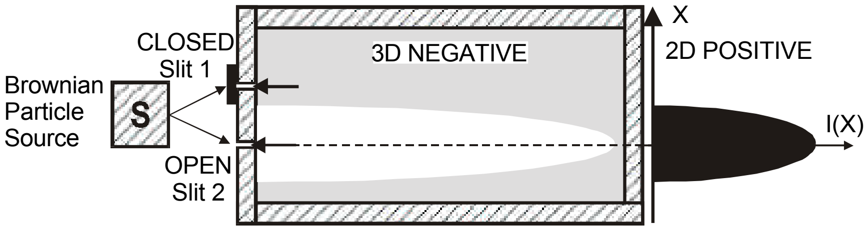

Figure 3 Spontaneous formation of the structure of photon field radiating from the cavity with one closed slit

The presence of "Welcherweg" detectors in both slits (Figure 4) can be modeled as semi permeable membranes. The penetrating Brownian particle is detected and diffuses further to the detector. The photon field in the cavity is uniform for this case while the semi permeable detector in the slit prevents its radiation through the slits. This effect might be the reason that the interference pattern structure is not observed. For the case that semi permeable detectors in the slits are not perfect, i.e. some photons radiate from the cavity through the slits, a partially self-organized structure of the photon field might be created. This effect should cause a structure on the screen detectors between both two extremes: a) both slits opened, b) both slits equipped with perfect "*Welcherweg*" detectors.

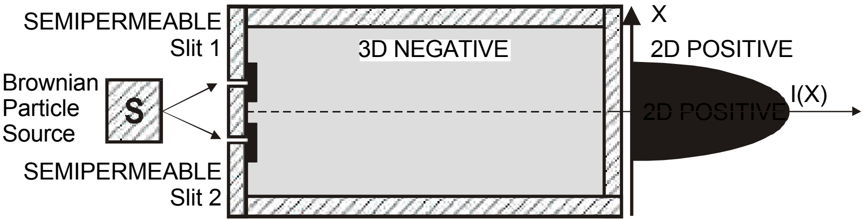

Figure 4 Uniform photon field in the cavity with two perfect semi permeable "*Welcherweg*" detectors in both slits

Therefore, the motion of single Brownian particles is inextricably linked with the structure of its surroundings. Any change in the apparatuses affects the trajectories of Brownian particles. This mechanism might explain why the individual particles "feel", "smell" or "respond" to the geometrical arrangement of the instrument, e.g. opening of one or both slits.

The global structure of selforganized radiating photons could be compared with a 3D negative through which individual particles diffuse and create the 2D positive on the screen. This selforganized photon field creation in the cavity might explain why the matter distribution consisting the detector should be Fourier analyzed but not the matter distribution that constitutes the particles.

The introduction of the concept of the selforganized structure of radiating photon field from the cavity might be observed as a further development of the idea of quantum Brownian motion [25,26,27,28] where the Brownian particle interacts somehow with its surroundings.

This concept of the diffusion of individual Brownian particles can be experimentally testified in the following observations:

1. The resulting structure for diffusing individual Brownian particles is independent on the mass of particles.

2. The pattern structure is influenced by the geometry of the instruments. The addition of another slits or pinholes in order to enable photon radiation from the cavity and not the diffusion of Brownian particles should modify the resulting pattern structure on the detector.
3. The structure of radiating photon field consisting from bipolar photon particles should be modified by the presence of additional electromagnetic fields.

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