

CONFERENCES AND SYMPOSIA

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Joint meeting of the Editorial Board of the Journal "Izvestiya Vuzov. Radiofizika" and the Scientific Council of the Institute of Applied Physics of the Russian Academy of Sciences dedicated to the ninetieth birthday of Vitalii Lazarevich Ginzburg (4 October 2006)

A joint meeting of the Editorial Board of the Journal "Izvestiya Vuzov. Radiofizika" and the Scientific Council of the Institute of Applied Physics of the Russian Academy of Sciences dedicated to the ninetieth birthday of Vitalii Lazarevich Ginzburg was held in the Conference Hall of the Institute of Applied Physics, Russian Academy of Sciences (Nizhnii Novgorod), on 4 October 2006. The following reports were presented at the session:

(1) **Zheleznyakov V V** (Institute of Applied Physics, Russian Academy of Sciences, Nizhnii Novgorod). "On the Nizhnii Novgorod school of Vitalii Lazarevich Ginzburg";

(2) **Andronov A A** (Institute of the Physics of Microstructures, Nizhnii Novgorod). "Chirality: optical rotation, the detailed balance principle, and life";

(3) **Bratman V L** (Institute of Applied Physics, Russian Academy of Sciences, Nizhnii Novgorod). "Fast moving radiators and their use in high-frequency electronics";

(4) **Derishev E V, Kocharovsky V V, Kocharovsky Vl V** (Institute of Applied Physics, Russian Academy of Sciences, Nizhnii Novgorod). "Cosmic accelerators for ultrahigh-energy particles";

(5) **Frolov V L, Bakhmet'eva N V, Belikovich V V, Komrakov G P** (Scientific-Research Radiophysical Institute (NIFRI) Federal State Scientific Organization, Nizhnii Novgorod), **Vertogradov G G, Vertogradov V G** (Rostov State University, Rostov-on-Don), **Kotik D S, Mityakov N A, Polyakov S V, Rapoport V O, Sergeev E N** (NIFRI, Nizhnii Novgorod), **Tereshchenko E D** (Polar Geophysical Institute of the Kola Science Center, Russian Academy of Sciences (PGI KSC RAS), Murmansk), **Tolmacheva A V, Uryadov V P** (NIFRI, Nizhnii Novgorod), **Khudukon B Z** (PGI KSC RAS, Murmansk). "Modification of the earth's ionosphere by high-power high-frequency radio waves."

A brief presentation of reports 2 – 5 is given below.

Uspekhi Fizicheskikh Nauk **177** (3) 315 – 340 (2007)
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Chirality: optical rotation, the detailed balance principle, and life

A A Andronov

A chiral system is a system that has no mirror symmetry — a center or plane of inversion. The subject of the first part of my report — optical rotation — was not selected at random: the first scientific work by the author of this report (a 4 – 5th year student at that time) "On the natural rotation of the polarization plane of sound" [1], which was carried out at the suggestion of Vitalii Lazarevich, was concerned with the chirality problem.

Vitalii Lazarevich himself gave quite a bit of space to the natural rotation of the polarization plane in electrodynamics in his work dedicated to media with spatial dispersion [2]. In particular, in his report [3] he discussed the problem of boundary conditions in media with natural optical activity. This problem may also be formulated as follows: what takes place when a linearly polarized wave is (normally) incident on a naturally active medium? Two types of (phenomenological) boundary conditions were considered in Ref. [3]. With one type of boundary condition, the polarization becomes elliptic on reflection and with the other type it remains unchanged. What occurs 'in reality'? The situation is unclear.

As far as I know, there are only two papers in which an attempt was made to measure the rotation of a polarization plane at (normal) reflection from a naturally active medium [4, 5], the results being different. The effect is weak and, as noted in Ref. [3], any surface contamination (modification) can easily mask the result. And the phenomenology should not be in force. An example is found in the recent measurement of appreciably elliptic polarization in the reflection of linearly polarized light from a silicon surface that accommodated multiply (6×10^6 cm^{-2}) deposited chiral metallic microobjects [6]. In the absence of these objects, the effects of surface polarization variation are weak, and it is therefore expedient to study them using the methods of nonlinear optics.

The effects at a chiral boundary of semiconductors where quantum wells were grown were observed and investigated jointly by a group from the Ioffe Physicotechnical Institute and Regensburg University (Germany). An investigation was made of the chiral rectification of terahertz radiation (i.e., the emergence of current along the semiconductor surface, whose direction depends on the sense of circular polarization): the circular photogalvanic and spin-galvanic effects [7, 8]. The authors termed them the 'bicycle' effects (Fig. 1): the circularly polarized photons impart angular momentum to spins (treadles), which produce, via the spin–orbit coupling, a current in the plane (bicycles ride), the current direction depending on the sense of circular polarization in this case. These investigations actually contain many interesting details showing how all this emerges: considered is the dependence on the crystal type, the type of quantum wells, the presence of a magnetic field, the angle of wave incidence, etc. These works are a continuation of research into the photogalvanic effect in chiral media (see Ref. [9]).

The second part of my report is some speculation on the following subject: why are biological macromolecules — proteins and DNA — uniformly chiral (equally left or right for all living beings). In his review of topical problems [10], Vitalii Lazarevich placed primary emphasis on the life sciences and considered them to be the currently principal ones: "On this planet, the last basic questions that remain unanswered are the following ones: how did life originate and how did thought originate?" In the paper mentioned above, he touched upon the question of 'reductionism' — "the feasibility of explaining the living on the basis of physics, the already known physics. This is the common problem of biologists and physicists." In what followed, Ginzburg noted that physicists would more and more engage in biology, that they should move into biology. This is a rather old motivation, of course. Outstanding physicists — M Delbrück, E Schrödinger, F Crick and others — had already gone in for biology with this motivation (see Ref. [11]). But now the question of such a propensity is even more acute.

We now turn to the principle of detailed balance. It has two aspects: (i) the equal number of transitions there and back in equilibrium and (ii) the symmetry of the probabilities for scattering there and back (which may be significant under nonequilibrium conditions) [12]. The former is always obeyed. Here, we are dealing with the latter aspect. At the time when Vitalii Lazarevich was Editor-in-Chief of the journal *Izv. Vyssh. Uchebn. Zaved., Radiofiz.*, published in Nizhnii Novgorod (then the city of Gorki), submitted to the journal was a manuscript (which was widely debated later) concerned with the modeling of a Knudsen gas (the mean free path is much longer than the vessel dimensions, and molecules collide only with the rough walls in random elastic scattering) in a cylindrical tube (Fig. 2). The authors assumed a seemingly reasonable model whereby the fraction of specular reflection increased with the angle of incidence. And the gas began to rotate! The editors rejected the manuscript on the grounds that the scattering model assumed did not agree with the physical models that lead to the principle of detailed balance. Later there appeared a preprint from Dubna concerned with the modeling of ultracold neutron transfer in a cylindrical tube. Detailed balance in the scattering at the walls was taken into account and the neutrons did not rotate. And everybody calmed down.

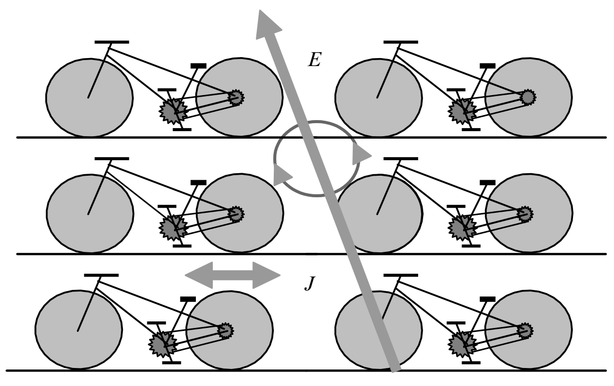
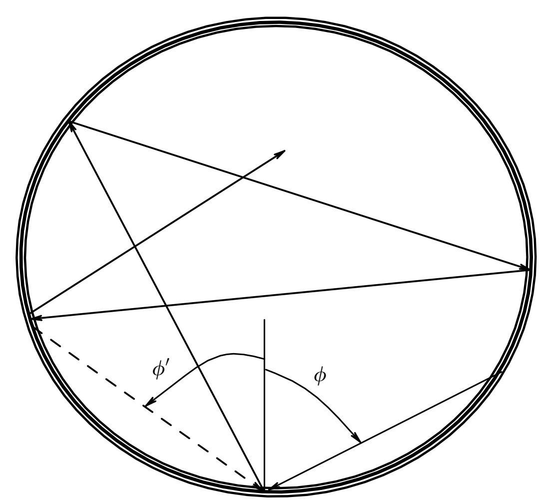


Figure 1. 'Bicycle' continuous current J under the action of circular polarization, which 'treadles': the circular photo- or spin-galvanic effects in chiral 2D structures near the semiconductor surface.



$$W(\phi', \phi) = W(\phi, \phi')$$

Figure 2. Knudsen gas in a rough cylinder subject to the condition of detailed balance at the surface in the case of equal probabilities W for the scattering forth and back.

But the principle of detailed balance is violated [9, 13–14]! However, this is not widely known (although this question is discussed in Ref. [12, Ch. 1, § 2], cf. also Ref. [13]): in the first Born approximation, the principle of detailed balance is always obeyed. Effects related to the violation of the detailed balance principle in scattering and those responsible for skew scattering are known in solid-state physics [14]. An example is provided by the anomalous Hall effect, which occurs due to the magnetization at which skew scattering occurs (and not due to the magnetic field).

What is to occur if we take a cylinder with a chiral roughness for the Knudsen gas (Fig. 3)? Will the gas rotate? This is unlikely. It is proven in Ref. [13] that in the chiral elastic scattering, too, the entropy increases and the gas supposedly must not rotate. It is likely that the relaxation to the mixed state is moderated. However, the author is unaware of works (examples) of this kind.

But if the transition to the mixed state is suppressed, this should (may) retard the transition to equilibrium of systems consisting of chiral elements. Is it not the reason for the chirality of living systems? Here, we do not discuss which spiral, left or right, occurs or what is the underlying: randomness (broken symmetry) or the action of an advantage factor (circularly polarized light, magnetic field, etc.) [15].

At the same time, Crick, who (jointly with D Watson) discovered the chiral DNA structure, never mentions (never

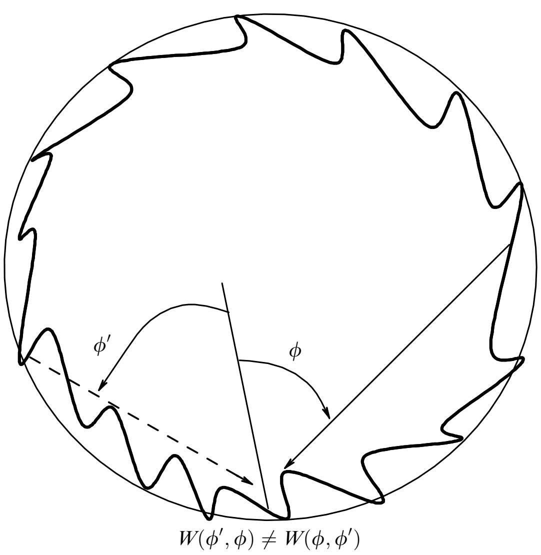


Figure 3. Detailed balance violation in the Knudsen gas in a chiral cylinder.

emphasizes) the chirality of biological molecules in his story of how he stayed interested in biology for 50 years [11]. Furthermore, he mocks at theoretical biologists who invoke a priori schemes and are preoccupied with them. He believes that evolution, or 'The Blind Watchmaker,' as referred to at the suggestion of the English pop biologist R Dawkins [16], is far from different schemes: an accident is more important. The blind watchmaker is seated in a chair in a field over which the wind is carrying parts of a watch. He is assembling a mechanism. He does not contemplate anything, he just fumbles about under the chair, finds something, inserts into the mechanism, and waits: will that do or not, will the Mechanism start going or not? Most likely, he chanced upon the left spiral and the mechanism started going, and all the remaining parts that fitted the mechanism also turned out to be left spirals. But the watchmaker could have chanced upon the right spiral or no spiral at all!

However, if spirals live longer, owing to the violation of the principle of detailed balance, they are to be in the 'initial broth,' from which the watchmaker picks up the components. Maybe therein lies, at least in part, the reason for the emergence of the chirality of biomolecules.

However, all this is speculation, of course.

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References

1. Andronov A A *Izv. Vyssh. Uchebn. Zaved., Radiofiz.* **3** 645 (1960)
2. Agranovich V M, Ginzburg V L *Kristallooptika s Uchetom Prostranstvennoi Dispersii i Teoriya Eksitonov* (Crystal Optics with Spatial Dispersion, and Excitons) (Moscow: Nauka, 1965) [Translated into English (Berlin: Springer-Verlag, 1984)]
3. Ginzburg V L *Usp. Fiz. Nauk* **108** 749 (1972) [*Sov. Phys. Usp.* **15** 839 (1973)]
4. Luk'yanov A Yu, Novikov M A *Pis'ma Zh. Eksp. Teor. Fiz.* **51** 591 (1990) [*JETP Lett.* **51** 673 (1990)]
5. Bungay A R, Svirko Yu P, Zheludev N I *Phys. Rev. Lett.* **70** 3039 (1993)
6. Papakostas A et al. *Phys. Rev. Lett.* **90** 107404 (2003)
7. Ganichev S D et al. *Phys. Rev. Lett.* **86** 4358 (2001)
8. Ganichev S D et al. *Nature* **417** 153 (2002)
9. Belinicher V I, Struman B I *Usp. Fiz. Nauk* **130** 415 (1980) [*Sov. Phys. Usp.* **23** 199 (1980)]
10. Ginzburg V L *O Nauke, o Sebe i o Drugikh* (About Science, Myself, and Others) 3rd ed. (Moscow: Fizmatlit, 2003) [Translated into English (Bristol: IOP Publ., 2005)]
11. Crick F *What MAD Pursuit. A Personal View of Scientific Discovery* (New York: Basic Books, 1988) [Translated into Russian (Moscow – Izhevsk: IKI, 2004)]
12. Lifshitz E M, Pitaevskii L P *Fizicheskaya Kinetika* (Physical Kinetics) (Moscow: Nauka, 1979) [Translated into English (Oxford: Pergamon Press, 1981)]
13. Strurman B I *Usp. Fiz. Nauk* **144** 497 (1984) [*Sov. Phys. Usp.* **27** 881 (1984)]
14. Gantmakher V F, Levinson Y B *Carrier Scattering in Metals and Semiconductors* (Modern Problems in Condensed Matter Physics, Vol. 19, Eds V M Agranovich, A A Maradudin) (Amsterdam: North-Holland, 1987)
15. Gol'danskiĭ V I, Kuz'min V V *Usp. Fiz. Nauk* **157** 3 (1989) [*Sov. Phys. Usp.* **32** 1 (1989)]
16. Dawkins R *The Blind Watchmaker* (London: Penguin Books, 2006)

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Fast moving radiators and their use in high-frequency electronics

V L Bratman

In 1946, when discussing the possibilities for mastering the then hard-to-reach region of millimeter- and submillimeter waves, Ginzburg considered several generation techniques, which turned out to be highly efficient for a substantially broader spectrum of electromagnetic radiation. In Ref. [1], he proposed the use of Doppler frequency conversion of fast moving electron oscillators as "the most interesting and promising method."

Let an electron move with a translational velocity $\mathbf{v}_{\|} = \boldsymbol{\beta}_{\|} c$ and oscillate in the transverse direction with a frequency Ω in an electric field varying harmonically in time (Fig. 1). Then, at an angle θ to the direction of translational motion, the electron radiates at the frequency

$$\omega = \frac{\Omega}{1 - \beta_{\|} \cos\theta} \, . \qquad (1)$$

For an ultrarelativistic velocity $\beta_{\|} \approx 1$, when the Lorentz factor γ of the electron is large, the Doppler frequency gain for the low-angle radiation is proportional to the squared particle energy, $\omega \sim \gamma^2 \Omega$, and may be quite high. For instance, for energies 5 MeV and 5 GeV, we obtain Doppler gains of the order of 10^2 and 10^8, respectively.

Ginzburg [1] also considered the possibilities that open up when the cyclotron and synchrotron radiation of an electron

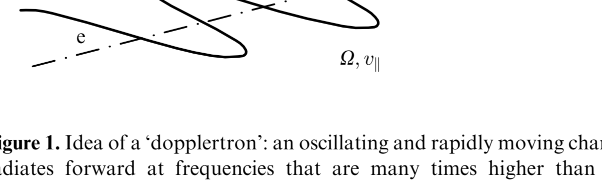

Figure 1. Idea of a 'dopplertron': an oscillating and rapidly moving charge radiates forward at frequencies that are many times higher than its oscillation frequency.