Displays in USSR, Russia & Commonwealth of Independent States: Lost and Found Priorities

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ABSTRACT

Many achievements in different fields of the display engineering were made simultaneously in the USSR and oversea and sometimes Soviet inventions appeared earlier but were not known to the international scientific community. A set of examples of special television equipment and some liquid crystal materials and electrooptic modes is considered in the review from this point of view. Different reasons of the poor protection of intellectual property in the former USSR are discussed.
Keywords: intellectual property, indicators for characters displaying, television commutators, liquid crystal substances, electrooptic modes.

1. INTRODUCTION

A great Russian poet and writer **Alexander Poushkine** in 1833 wrote in his *Table-talks* [1] that all the characters for both Arabian and Rome numbers origin from this figure [1]:

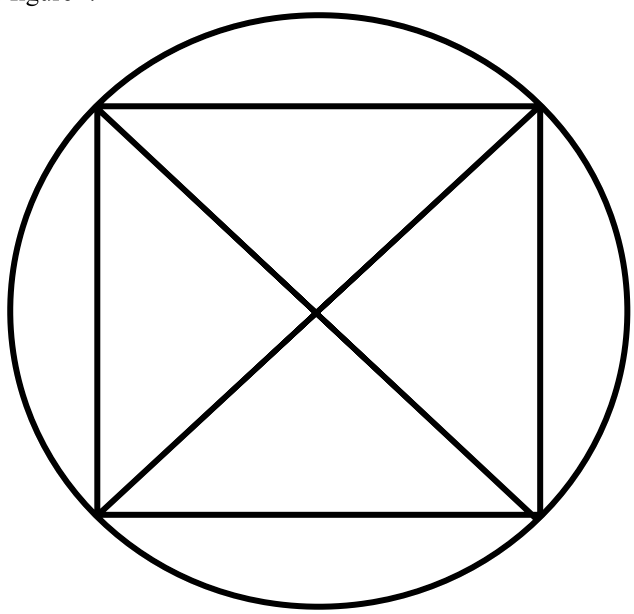

Fig.1. A primary character for Arabian and Rome numbers [1].

It is why Poushkine can be recognized as the inventor of the design of characters used in low multiplex displays. If the problem of the priority of many invention would be discussed more seriously it is to say that many devices, materials or ideas proposed and developed in USSR, then in Russia and other countries involved into the Commonwealth of Independent States (CIS) appeared earlier than in oversea countries but were not detected and/or recognized by the international scientific and engineering community. There are many reasons of such ignorance and some of them will be discussed in this paper.

Here the authors would like to review their own decades experience of the working in different display technologies from the point of view of developments priority. The authors do not intent to reconsider any problems concerning the protection of intellectual property. The matter is that during the time period discussed (1950-s - 1970-s) the information exchange between the USSR and oversea countries was very week especially from the Soviet side. Special Soviet policy in the field of the invention protection did not offer to patent many good developments efficiently. Most of inventions in the USSR were filed to obtain an Author Certificate instead of a Patent as a document, which provided the protection of the intellectual property. The Author Certificate could provide only a priority without financial obligations of the State in relation to the authors. The inventions' formula had been published in Russian in the Bulletin of inventions.

Most of research results were published in Russian magazines only, especially in applied sciences. Many journals were issued in English too. However their citation index was low and remains low until to-date. The participation of Soviet scientists and engineers in different international scientific events was extremely negligible. That means that many Soviet developments had no access to potential foreign information consumers.

Therefore we see two main reasons of the poor priority and patenting the Soviet developments abroad: lack of economical interest and hindering of abroad publications.

This is why many achievements in different fields were made simultaneously in the USSR and oversea and sometimes Soviet inventions appeared earlier but were not known to the international scientific community.

As to display devices and systems all the display technologies were developed in the USSR for different both military and civilian purposes. All the achievements were made due to very high level of the basic researches implemented in our country. Best results were obtained for VFD, PDP, some CRT and LCD.

The promotion of vacuum-fluorescent devices (VFD) was due to the delay of development of semiconductor devices in the USSR. In all the world development and production of different vacuum lamps was stopped in favor of semiconductor electronics. However in Saratov's R&D Institute Volga and Factory Reflector the development and production of these devices was continued and best brightness of multicolor VFD at very hard ambient conditions was achieved.

A laser CRT is the same vacuum lamp but with a semiconductor single crystal screen. It was developed during two decades according to increased requirements to large screens for collective use, first of all for special purposes.

The successful development of different gas-discharge devices was connected because of intensive studies in nuclear physics.

More detailed data on the Soviet, Russian and CIS displays can be found in reviews [2-6].

2. LOST PRIORITIES IN INDICATOR AND TELEVISION DEVICES

From 1958 till now 16 USSR Author Certificates for new **indicators for characters displaying** were given to V.Rostovsky, N.Vikhrov, I.Litvak, N.Shuvalov, V.Solovyov-Efimov, I.Krok et al. (Fig.2). The indicators (displays) provide detection and correction of single mistakes. No similar devices abroad till now. Till now a character display is actual with minimized number of switching segments which have underscored parts (I.Litvak, V.Solovyov-Efimov) (Fig.3). Both types of these indication displays (indicators) have applications in extreme exploitation conditions until now. The description of both types is in [7].

Some interesting results in **projection TV equipment** was achieved in 50-s and early 60-s. In 1956 it was a tour of C*omedie Francaise* theatre in Moscow. A group from Moscow Television Laboratory (Mikhail Likhachev, Rostislav Shtromberg, Igor Litvak, Theodore Gaukhman) provided the creation, tests and exploitation of 3x4 m TV screen in Concert Hall Hermitage during performances, i.e. it was the 1st television theatre in the world.

Domestic element base has been developed and manufactured at Moscow Television Laboratory (amplification and ray-scanning circuitry; voltage source for 75 kV; mounting, refurbishing and exploitation of the complex), Vavilov State Optical Institute (calculation of mirror-lens 600 mm objective, light force 1:0.6 which was better than oversea analogs; Head specialist Volosov), Leningrad Optical Mechanical Corporation (LOMO; Objective fabrication), Special Design Bureau of Electro-Vacuum Devices (9" Projection kinescope with 2 mA current and 75 kV accelerating voltage which was better than oversea analogs).

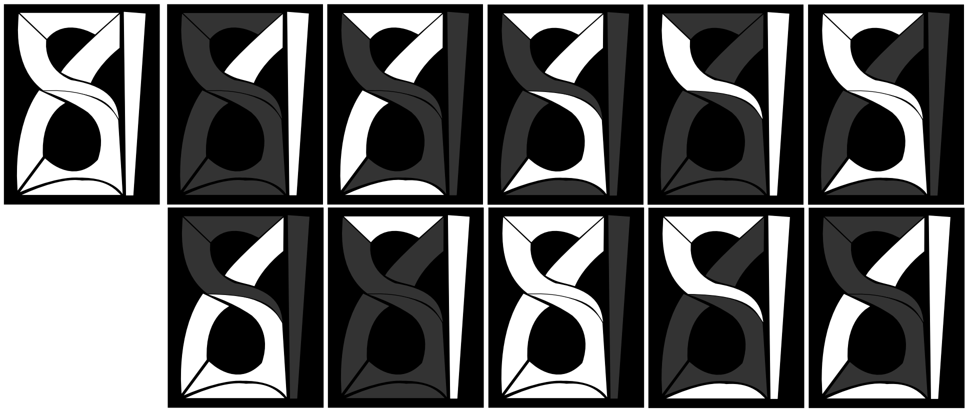

Fig.2. Indicators for characters displaying which provide detection and correction of single mistakes.

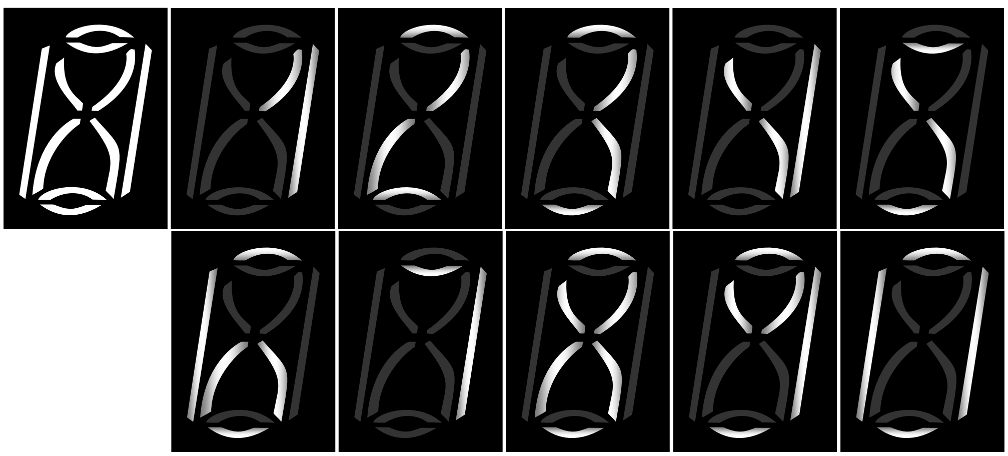

Fig.3. A character display with minimized number of switching segments.

Creation, tests and exploitation of 3x4 m and 6x9 m screens in the **Missions Control Center** was realized in 1971 in Korolev, Moscow Region (Fig.4) (see [8]).

Then a group from Moscow Television Institute (I.Litvak, A.Polonsky, L.Gribanov, B.Aronov, V.Samsonov, V.Khodak et al.) developed a **system for reserved television "TELESVYAZ"**. In the following Table its parameters are compared with the performances of similar US system for the same application [7,8].

Parameter	USSR Missions Control Center (Kaliningrad, now Korolyov)	USA Missions Control Center (Houghston)
Spatial resolution	1125 lines	900 lines
Time resolution	25 frames/s; 50 semi-frames/s	

Fig.4. Large screens in the **Missions Control Center**

Image resolution in the “TELESVYAZ” system was 4 times better than in the broadcasting television what allowed to use it for imaging texts, maps etc. The components were fabricated in organizations listed below.

<u>High-resolution TV cameras:</u>

a) running ray CRTs (Design Bureau Elektron, L’vov)

b) vidicones (R&D Institute Platan, Fryazino)

<u>Kinescopes</u>: Design Bureau Elektron, L’vov.

It is to be told especially about 100x300 **video-commutation devices** developed for the “TELESVYAZ” system in the Moscow Television Institute by I.Litvak, A.Polonsky, L.Gribanov, B.Aronov, V.Khodak, S.Natochannyi, V.Makievsky et al. The specialists Ministry of Communications of USSR protested against this development. They claimed: it is impossible due to mutual influence of separate channels!

However the commutation devices for TV signals 100x300 for 625 and 1125 lines created in 1963 had no failures within their long exploitation term. It is to note that the commutation device for 625 lines is till now under exploitation in the Missions Control Center! Similar oversea devices were not described in the literature.

The example of the hall with displays connected by this system is demonstrated in Fig.5.

In 1959-1966 **mnemonic schemes and light fields** were developed and manufactured in Moscow Television Institute & R&D Institute for Automatic Equipment by F.Sorkin, I.Litvak, A.Belyaeva, G.Klimova, K.Safonov, Y.Chuhin, N.Oschepkov, G.Tyulenev et al. (Fig.6). Industrial production was provided by the Kiev Factory of Relay and Automation. Multi-color electroluminescent displays for space-crafts developed for this purpose are under exploitation till now and have no oversea analogs till now.

Fig.5. The hall with displays connected by the “TELESVYAZ” system.

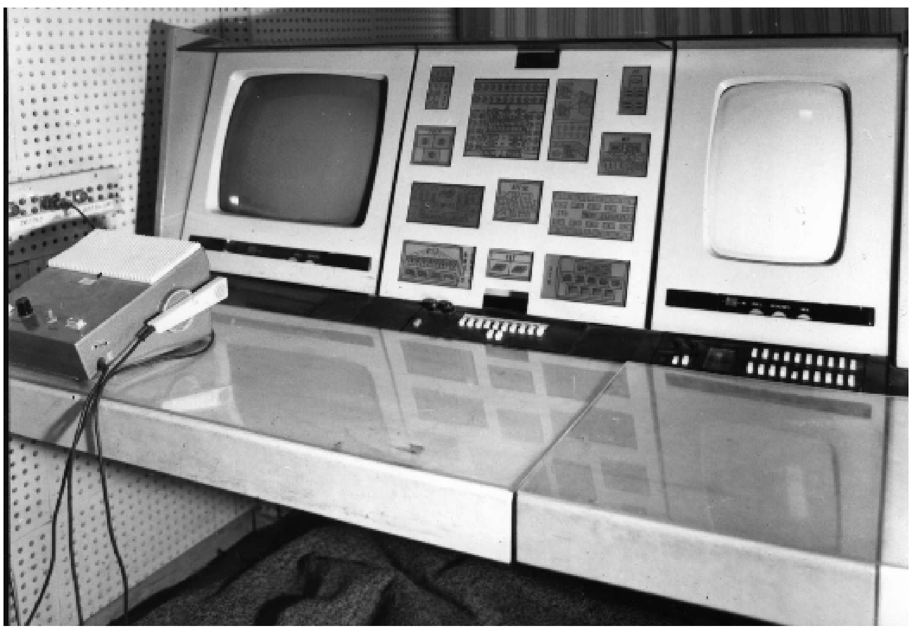

Fig.6. A display board with mnemonic schemes and light fields.

3. LOST PRIORITIES IN LIQUID CRYSTAL MATERIALS

Let us consider the problem to be discussed by using a set of examples on the synthesis of some mesogenic substances. There are some **cyclohexane and pyridine derivatives**.

It was to watch in 70-s an unusual competition of institutions in USSR (NIOPIK or Organic Intermediates & Dyes Institute in Dolgoprudnyi) and West Germany (E.Merck in Darmstadt) in the synthesis of new substances with a cyclohexane moiety. In

1976 approximately at the same time the cyano substituted phenylcyclohexanes (PCH) (Fig.7) were synthesized by both groups but the German one had patented them and the Russians did not publish their results [9-11]. Very soon these substances became the most important components of low viscous LC materials with increased temperature range and changed Gray's biphenyls in the majority of the commercial materials.

One year later other cyclohexane derivatives were synthesized in NIOPIK. There were bicyclohexanes – substances with two successive cyclohexane moieties and different terminal substituents (Fig.8). However they were patented by Eidenschink's group in E.Merck again [9,12]. Why did not Soviet specialists file them? That time the cyano substituted bicyclohexane derivatives displayed high viscosity at extremely low birefringence value ($\Delta n \sim 0.05$), i.e. NIOPIK physicists estimated substances properties for any practical usage as being very poor. Later these derivatives were used as additives for STN-materials to control their birefringence value.

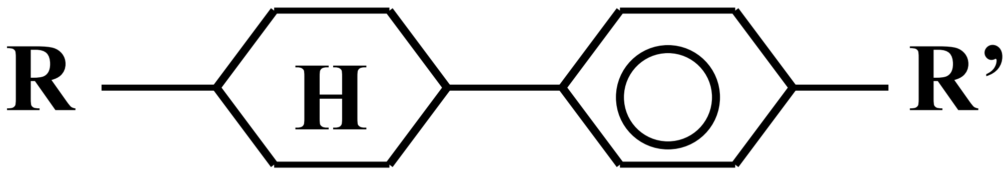

Fig.7. Chemical structure of phenylcyclohexanes (PCH)

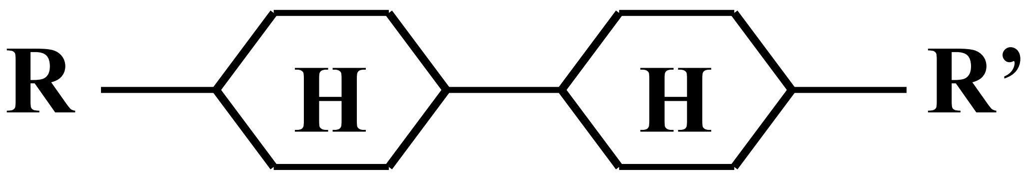

Fig.8. Chemical structure of bicyclohexanes (BCH)

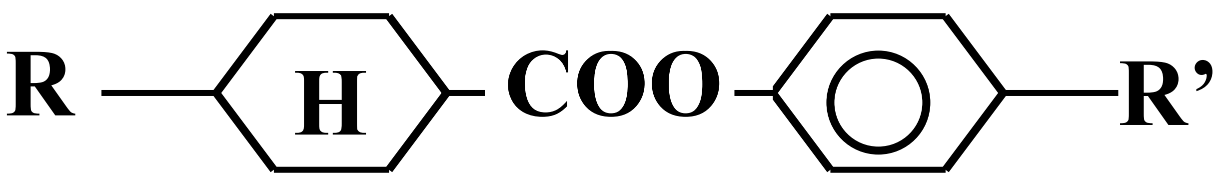

Fig.9. Chemical structure of Demus esters

The third example of a Soviet failure in the development of the cyclohexanederivatives are so called **Demus Esters** (Fig.9). They have found their main application as basic components of many low viscous LC materials

In 1981 Dietrich Demus, Martin-Luether-University, Halle, German Democratic Republic had ordered in Organic Intermediates & Dyes Institute synthesis of alkylcyclohexancarbonic acids and then synthesized in Halle new components with improved properties from these intermediate substances and patented them without Soviet participation.

Main reason of the refusal of NIOPIK patent applications for other important chemical class of mesogens, namely pyridine derivatives, was earlier publication of their chemical formulas in scientific magazines and conference proceedings.

Bicyclic cyanophenylpyridines (Fig.10) were proposed as basic component of low voltage LC materials with improved multiplexability instead of phenylpyrimidines (Hoffmann-La-Roche, Switzerland). At first time they were synthesized by A.Pavluchenko group, NIOPIK, in 1978. Then patent applications were filed in many countries in 1981. However in 1981 in a scientific magazine *Molecular Crystals and Liquid Crystals* the chemical structural formula of alkyl(pyridine-cyanophenyl) was published and all the patent applications were refused by the patent authorities of different countries [13].

A similar situation prevented to patent the tricyclic pyridine derivatives which can be used as basic component of high temperature and low voltage LC materials. The patent application was not sent because of prior publication of chemical structural formula in the Abstracts Book of 1984 Liquid Crystal Conference in Hull, UK [14].

Two abstracts of papers on properties of bi- and tricyclic pyridine derivatives were sent. After the refusal of the application on bicyclic substances a letter with a request of non-publishing the abstract on tricyclic pyridines was sent. However namely this abstract was published and the abstract about properties of bicyclic pyridine derivatives was not published.

Later an umbrella patent was applied in Japan which covered all the pyridine derivatives.

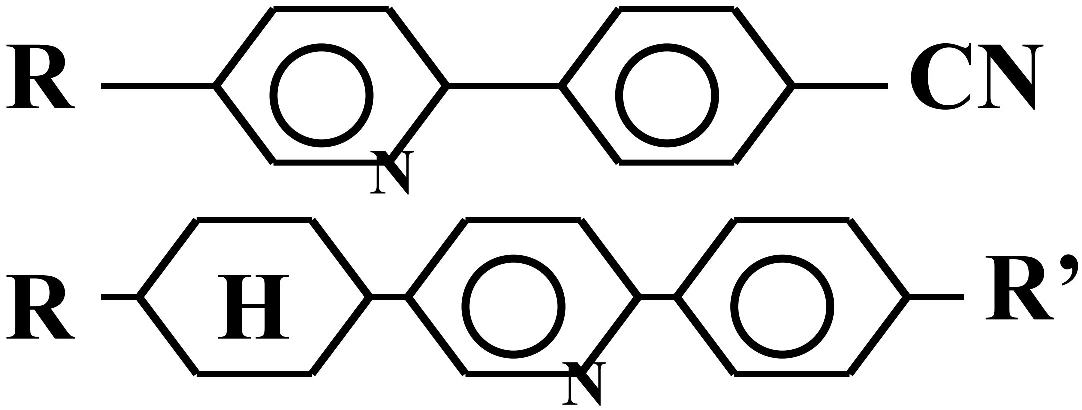

Fig.10. Chemical structure of bi- and tricyclic mesogenic pyridine derivatives

4. LOST PRIORITIES IN LIQUID CRYSTAL ELECTRO-OPTIC MODES

Development of the Soviet electronic industry in 70-s required researches of new media to control the intensity of light beams. Different electro-optic effects in nematic liquid crystals (NLC) did satisfy this task. These studies were initiated in the Institute of Crystallography of the Academy of Sciences of the USSR (to-date the Russian Academy of Sciences) by Igor Chistyakov and Leonard Vistin’, in the NIOPIK by Lev Blinov’s group, R&D Institute Platan (Fryazino, Moscow Region) and R&D Institute Volga (Saratov). Many interesting electro-optic devices and modes were developed also in Minsk (R&D Institute of Applied Physical Problems) and Kiev (Institute of Semiconductor Physics and Institute of Physics of Ukrainian Academy of Sciences; to-date NASU).

Of course the intensive researches in this field offered to detect new effects which could be used and later were used indeed in different mass production devices. Many of these effects were found earlier than in foreign companies. However the fortune of these findings was different. Let us consider the case of the LCDs in more details.

In early 70-s the dynamic scattering mode and the twist-mode were main electro-optic effects for the using in low multiplex displays. In the NIOPIK different electrically controllable birefringence (ECB) modes seemed to be attractive to provide steep transmission-voltage dependence for better multiplexability, and fast electro-optic response for light shutters.

In 1972 Igor Kompanets from the Physical Lebedev Institute and Lev Blinov from the NIOPIK were first who proposed and studied short-time switching with 1 π change of the phase difference $\Delta\Phi$ in ECB-cells ($\Delta\Phi=7\pi-6\pi$) [15]. The switch-on time was as low as 3 μs and the switch-off time 100 μs at 103ºC. At an intermediate bias voltage short 100 V pulse changed the transmission state of the cell from the complete open to the complete dark with the contrast ratio more than 100:1. In 1974 Michail Grebyonkin from the Blinov group in Organic Intermediates &Dyes Institute was the first who realized short-time switching with the change of the phase difference $\Delta\Phi$ from 1 π to 0 π [16].

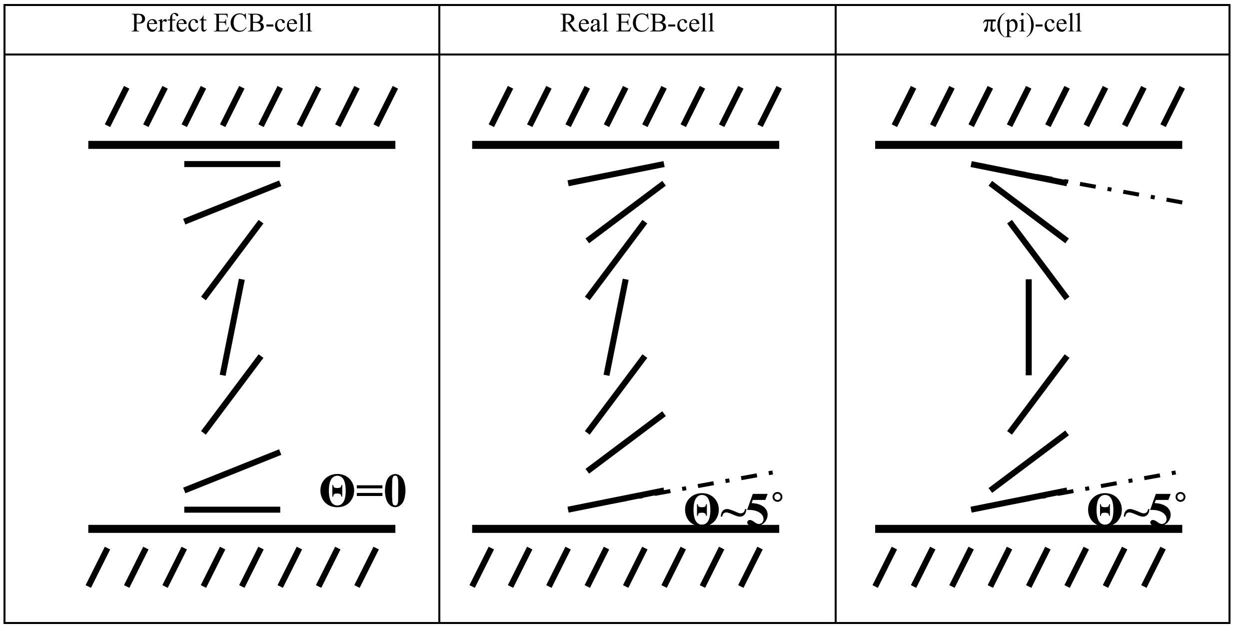

Fig.11. LC director structure inside different ECB-cells.

Only in 1983 Fergason patented the pi-cell design and description of the rapid splay-bend transformation under the action of an electric field [17]. Of course the Soviet publications of 70-s did not include the splay design of the Fergason cell (Fig.11). However taking into account a non-zero tilt angle at the cell's substrates it is to say that the probability of a mounting of the cell with the pi-cell boundary conditions was equal to 1/2 and it provided the short switch time of the electro-optic response together with the action of the back flow (the flow arising while changing the orientation of the liquid crystal). The role of the back flow was explained in 1977 and 1985 in papers by Victor Belyaev and Vladimir Chigrinov [18,19]. They described also firstly the variation of switching time in wide range from very long time (seconds and tens seconds) to very short time (microseconds) with 1 π change of the $\Delta\Phi$ value while changing the bias voltage (1977) [18].

It is to say also that main reason why the ECB-cells were not required by the Soviet electronic industry in 70-s and 80-s for fast and wide viewing angle displays was their high sensibility of the optical transmission to the gap non-uniformity and temperature variation. The impossibility to create the cells with the gap uniformity better than 0.2 μm was overcame only after 1983 when STN-technology with spacers was reduced into praxis.

In 1979 in the papers by V.Chigrinov, V.Belyaev, S.Belyaev, M.Grebyonkin the deformation of cholesteric LC in 180° and 270° twisted cells was described in very details [20,21]. A new numerical method was proposed to calculate the threshold voltage of the deformation and the period of domains appearing at this voltage. All the theoretical predictions were confirmed by careful experiments made in wedge-shape cells with 180° and 270° twist. Then this work was stopped as the Head of Laboratory in NIOPIK, Professor Lev Blinov, had lost the interest to continue it. Nevertheless he recognized this work as the latest achievement of the continuum theory for mesogens.

In 1983 T.Scheffer and J.Nehring patented electro-optic STN-mode in cholesteric cells with 180° - 270° twist. They used the results of the NIOPIK's theory to calculate the cell's geometry without the domains occurence and with steep dependence of the deformation angle on the bias voltage.

In 1979 Victor Belyaev described electro-optics of 64° and 191° cells which transformed the linear polarization of a light beam into the circular one [22]. The twist angle values were chosen after F.Gharadjedaghi calculations of ellipticity and angle of polarization rotation in the LC cells with different twist angle [23]. V.Belyaev proved the circular polarization in a wide spectrum range for both twist angle and the disappearance of this polarization after the switch-on of the bias voltage. These cells were proposed to use as polarization transformers for some optical components. If the author would propose to position a mirror behind the cell he would detect the 90° rotation of the linear polarization after the light beam passing the cell, its reflection and return passing. This mode was studied actively after the invention of the STN-mode and the searching of its usage in reflective devices. In 1990 T.Ogawa (Japan) and then a Belorussian described the one-polarizer reflective mode in 64° and 200° cells [24,25].

In 1979 a fast switching mode in cholesteric LC was found by Victor Belyaev [26,27]. He studied wedge-shaped cells with 90° angle between the directions of the boundary rubbing on both substrates to look for a regime of the bounce disappearance. The intensity bounce appears in the twist-cells while switching-off the bias voltage. At the border of the zero and first Grandjean's zones this regime was detected as well as significant reduction (8 times) of the switch time. This result was described firstly in his Ph.D. thesis and then used by Sergei Belyaev, NIOPIK to develop fast electro-optic light shutters [28]. The shutters were used, e.g., in stereoglasses with very simple design and driving [29]. It is to say that this effect was not reduced into praxis in other countries.

In 1978 Boris Ostrovsky, Arnold Rabinovich and Vladimir Chigrinov published in Sov. Phys. JETP their results on bistable switching of cells with planar oriented ferroelectric LC [30]. They presented mechanism of mesogen reorientation under the action of the electric field but they did not describe it as very fast bistable switching for electro-optic shutters like Noel Clark and Swen Lagerwall did it in their contribution to Appl. Phys. Letts. in 1980 [31]. After this publication the effect was named as the surface stabilized mode or the Clark-Lagerwall effect. Their special merit was the attraction of the explosive-like interest to the FLC.

5. … & FOUND PRIORITIES IN LIQUID CRYSTAL ELECTRO-OPTIC MODES

Nevertheless there are a lot of examples of successful patenting and other kinds of intellectual property protection of USSR, Russian and CIS developments in liquid crystals. First of all it is to mention the three groups of patents (*and their main inventors*) devoted to

a) Effect of Deformed Helix in Ferroelectric LC (DHF-mode) *L.Beresnev et al.* [32]

Fast switching of FLC in cells with the planar boundary conditions and the helix axis parallel to the substrates;

b) 100% Cholesteric LC Polarizers *S.Belyaev et al.* [33]

Very efficient circular polarization conversion of a non-polarized light beam by using of the effect of selective spectral reflection in cholesteric LC;

c) Photoalignment of LC *V.Kozenkov et al.* [34,35]

The most famous and most promising technology among all the three listed. Control of LC orientation on a photopolymeric film while changing the light beam polarization.

It was a result of the Patent agreement between Hoffmann-La-Roche, Switzerland (now ROLIC-group, *M.Schadt*) and NIOPIK (Organic Intermediates and Dyes Institute, *V.Chigrinov*). The Switzerland's company purchased all the patenting expenses and then made a set of its own developments on the base of earlier NIOPIK's ones. The license of the Russian part (9 patents) was purchased in 1997 for ~1 mln. USD.

In 1997-1998 in Sharp and Hitachi new methods and schemes for multi-line addressing of passive and active matrix LCD was proposed which offered to reduce the wires number while writing a picture by the LCD [36,37]. The pictures flicker was also reduced. However at the same time in 1998 Vitaliy Volodin patented in Russia new method of forming the driving pulses for the passive LCD [38-40]. The method provides an improvement of contrast and flicker and eliminates the parasitic effects.

It is to say a few words about the polymeric comb-like LC which are used as thin film optical elements, polarizers, selective reflectors, media for information writing, store and displaying, photo-optic and photo-chromic materials. They were firstly synthesized in Moscow Lomonosov State University, USSR by Valery Shibaev, Nikolai Plate, Yakov Freidzon [41,42]. The first publication was in the Proceedings of the 3rd All-Union LC Conference, Ivanovo in 1974. Similar substances in overseas were made only after four years by H.Finkelmann, H.Ringsdorf, J.Wendorff, Germany and published in 1978 in Macromol. Chem. [43].

Among other display technologies without analogs in the world it is to mention multicolor VFD panels with brightness up to 5000 cd m^{-2}, laser CRT which provide light fluxes for projection systems up to 10,000 lm, tiled PDP screens with brightness in the peak regime up to 1000cd m^{-2}.

6. CONCLUSIONS

- Being a closed country the USSR could create a set of new display devices and systems with record parameters
- Significant part of them was not protected because of special applications or clumsy actions of the scientists or wrong estimation of a new technology
- There are conditions to-date to develop new products with better intellectual protection

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