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Review Article

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Review of Non-Actual Problems: Unexpected fragmentation of light in the rib of a soap film. Stoilov's phenomenon

Stoilov Yu.Yu..

P.N. Lebedev Physical Institute RAS 119991, GSP-1, Moscow, B-333, Leninsky pr. 53

***Corresponding author**
Stoilov Yu.Yu, P.N. Lebedev Physical Institute RAS 119991, GSP-1, Moscow, B-333, Leninsky pr. 53.

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An unexpected chaotic fragmentation of light was detected in its passage through the liquid waveguide of a conventional soap film rib, which was associated with the extraordinary turbulent hydrodynamics of inaccessible for direct observation collecting solution into the film rib

The laser light of a conventional pointer, focused and introduced into a soap film, behaves in it, as previously noted /1-4/, in an unusual way. It is converted into narrow (10-20 microns) channels, tracks that can go tens of centimeters along the film without divergence. These tracks often sharply change the direction of their movement and, for no apparent reason, are reflected from the thickening at the edge of the film, from its rib /4,5/. The physics of such anomalies connected with pressure of light was considered earlier /3,5/, and here, attracted by the unusual properties of tracks near the rib, we dwell in more detail on the unexpected behavior of light, but not in the film, but in the very rib of the soap film.

Soap film is a relatively small object in order to shake the universe, but it can significantly expand our horizons. And it should be added, the horizons of everyone - from schoolchildren to academicians.

A rib (thickening) of the soap film is formed on its edge near a holding it frame or between contacting soap bubbles (Figure 1). In cross section, the rib has a triangular shape with concave faces and is an extended liquid waveguide in which light can travel due to total internal reflection from its boundaries. Due to the surface tension of the films, the pressure of solution in the rib is less than it in the films, and the inner liquid of the film, enclosed between its two fixed surface layers of soap monomolecular, is gradually drawn into the rib and goes down the cuvette along it. Fresh film has a thickness of about 5 microns. Drainage of the solution into the rib makes the film thinner (about 50 times), leading to a decrease in the visible number of interference fringes on the film until they disappear completely. Such a thin film almost does not reflect light and is called black one. By the movement of the colored stripes on a fresh film, a drainage rate of about 1-2 mm/min can be estimated. Depending on the composition of the soap solution, the film (and rib) lives for hours (sometimes days) or quickly bursts in minutes. The rib at external observation looks quite calm and stable formation. Since the drainage process is relatively long, it is difficult to expect that it can somehow noticeably affect the optical uniformity of the rib of the film with normal soap solution.

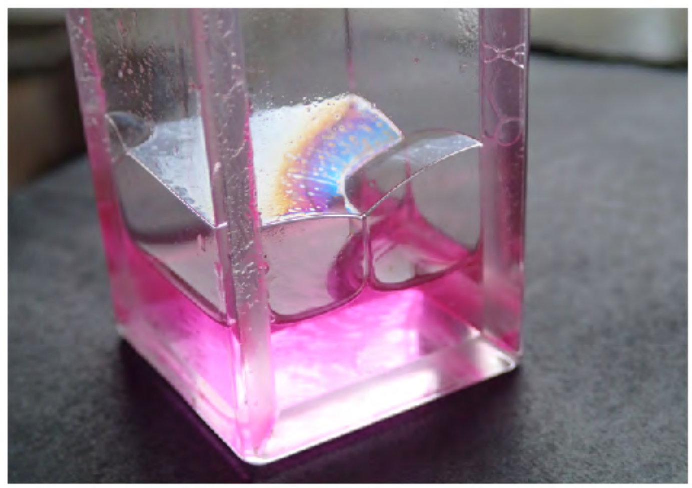

Figure 1: Photo of a curved rib between two soap bubbles in a rectangular cell with an internal size of 2x2 cm.

And rather unexpected is the actual behavior of the laser light introduced into the rib (532 nm, 1-10 mW) at the exit from it on the screen, which, as a new phenomenon, literally makes you rub your eyes (/5/). It is as if a piece of bread on your calm table began to jump and make circles in Brownian motion. Figure 2 appears on the screen (the movie is available at the site /8/), a bright central area densely filled with quickly blinking spots, surrounded by a darker wide halo of small sparkling spots that appear and disappear dozens of times per second (with an outwardly calm and motionless rib), changing their shape, brightness and position. In Figure 2 on the screen you can see many spots in the bright zone. The angular dimensions of the central region and the halo change with the laser focus and its movement on the input face of the rib and are respectively about 10 and 90 degrees. The flashing frequency of small spots in the halo is noticeably higher than in the central bright region.

Figure 2: The output laser radiation from the rib of the film on the screen at a distance of 25 cm from the output end.

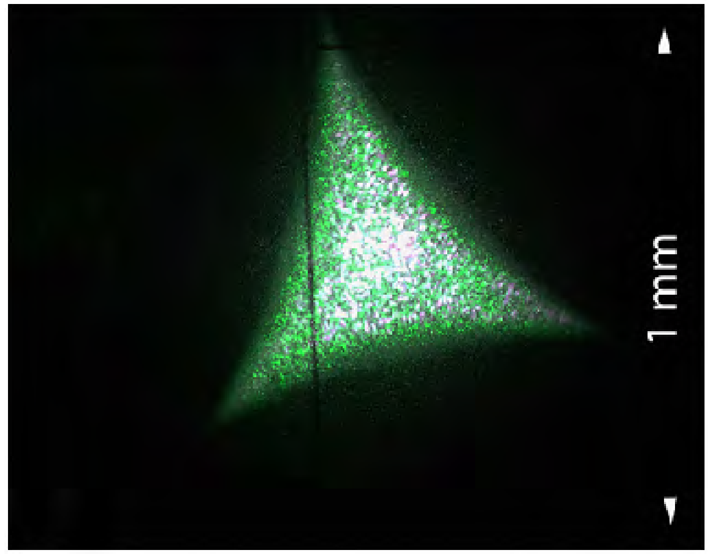

Figure 3: A view of the output end face of a rib with laser radiation under a microscope.

When earlier in laser tracks investigation an unexpected discovery was the lack of divergence, then here the discovery consists of the absurdly high frequency of blinking spots on the screen with an outwardly perfectly calm rib, caused, as will be shown, not by a smooth flow of the solution as expected, but by a fractional fragmented flow of the solution into the rib from the film.

The central area on the screen can be associated with that part of the laser radiation that reaches the exit from the rib, repeatedly reflected from its concave, but relatively even faces, and a darker halo is created by rays that penetrate deeply into the vertices and due to the converging angle are reflected from them. The angle of the peaks is constantly changing by the flow of solution from the film unevenly entering the rib. Namely this discovery of unevenness is the reason of the strange and unexpected properties of an ordinary rib. Blinking can be observed with almost any shape of the rib, and its curvature, as in Figure 1, allows to reduce the background illumination from the laser on the screen.

A view of the exit end face of the rib under a microscope, creating such a complex dynamic picture on the screen, is shown in Figure 3. The view of end face is practically independent of the length of the rib (3-30 mm) and the power of laser radiation (1-10 mW). The speed of movement and blinking of the points is especially high in the sharp corners of the end where the solution flows from the film. The interference of these many sources of different brightness and phases creates the observed complex dynamic picture on the screen. With increasing temperature of the solution, the speed of blinking spots increases. If a small aperture (0.3 mm) is placed near the end of the cuvette, thereby reducing the number of interfering sources, then the size of the spots on the screen (and in the photograph of the end through a microscope) increases several times.

As expected, the view of the end and the nature of the blinks substantially depend on the wavelength of the laser radiation used, since the penetration and reflection depth from the top of the rib depends on the wavelength of light.

With a red laser pointer (650-670 nm, 1-10 mW), the angular size of the halo is significantly smaller than with a green one, and under a microscope the output end of the rib, blinking spots are almost not visible in the sharp corners. This shows that, due to the longer wavelength, the red laser radiation does not penetrate so deeply into the corners of the rib, which is vibrating from the input flows, as with green one. With a blue laser (405 nm, 1-10 mW), the blink pattern is the same as with green one. If there is a solution with a dye fluorescent red light in the rib, then the flashing at the end with the green laser disappears when the green light does not reach the output end. It is a wonder what the radiation of such a trihedral waveguide laser filled with an active medium will look like? What modes in it will be the most active?

Thus, passing in the rib, the laser radiation reveals the unexpectedly complex hidden from the eyes hydrodynamics of the solution entering into thin vertices of the rib from the films. It became clear that the solution drainage is not at all a smooth process, but goes along the entire length of the rib in intermittent tiny portions that locally change the sharpness of the angle at the edge of the rib with the film. Along with the sharpness, the ability of an angle to reflect the light incident on it also changes.

To identify the sources and mechanism of blinking, it was necessary to carefully look at the border at the tops of the luminous rib under the microscope (perpendicular to its surface). This narrower brighter section of the contact boundary with a film is about 30 μm wide, (Figure 4, movies are available on the site /8/). In it small micron dancing points are visible, which characterize with their movement the shortness and discontinuity of the portions of the solution from the boundary regions of the film in the sections, along the length of apparently not exceeding the thickness of the film itself. The intermittent drainage explains the fragmentation of light, but as itself is an unexpected and previously unknown discovery, requiring a thorough understanding of its causes. Where else and under what conditions can it occur?

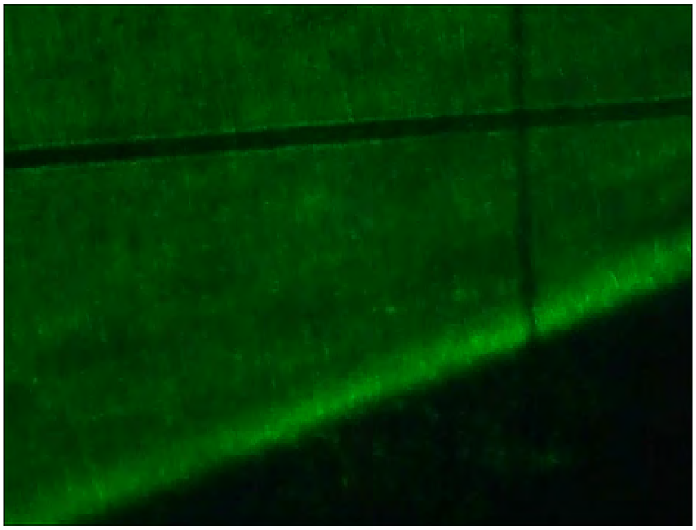

Figure 4: Side view of the contact area between the rib and the film under a microscope. The width of the light strip is ~ 30 μm.

From the width of smearing of bright points during the exposure time (0.03 s) of one movie frame over a zone of 30 μm, it can be estimated that for a fresh film, the velocity of the incoming flow into the rib is about 1 mm/s. When the films lose their color and become thinner (the so-called black films), the speed of the flow coming from them into the rib slightly decreases, but light fragmentation is preserved. A comparison of the drainage rate of the fresh film (about 1-2 mm/min) and the speed of the same stream entering the rib (about 1 mm/s) shows that the flow is accelerated between the rib and the film, i.e. there is a narrowing, a slit that reduces the film thickness by a factor of 30 and thereby accelerates the incoming stream and makes it turbulent.

The hydrodynamics of the slotted nozzle is complicated by the fact that the nozzle is formed by a deflection of the stretched surfaces of the film, which try to remove this deflection, but the pressure in the nozzle decreases due to the high velocity of the flow entering the rib again leads to its hydrodynamic narrowing.

The presence of a nozzle at a rib near thick film is shown in Figure 5 when lit from the side. It looks dark because the light does not enter it. Namely the presence of such invisible nozzle near a rib resulted in the observed early laser track reflection from the rib. And nozzle, as we understand, is always the thinnest place on soap film. Is it always the place where the film start its disrupting?

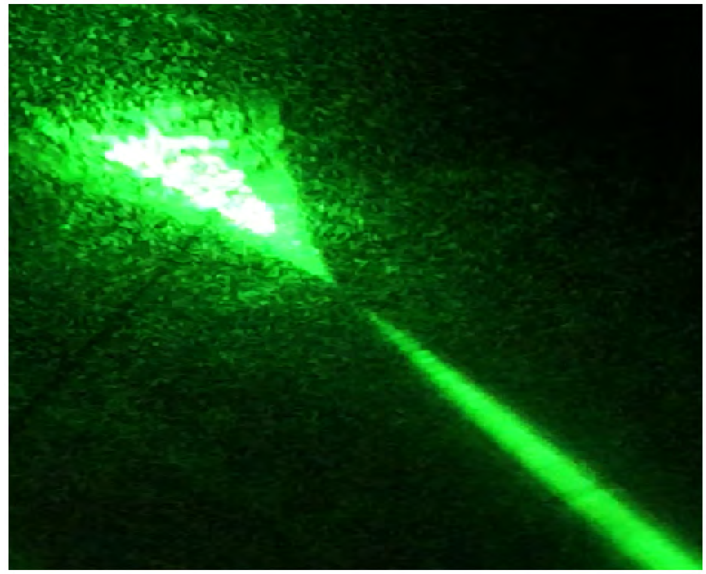

Figure 5: View of the nozzle between the rib and the film when illuminated. The length of the dark zone of the nozzle is about 50 microns.

Summing up the small portions, the drainage leads to the accumulation of thinner sections of the film near the rib, which, in the presence of gravity due to the increasing strength of Archimedes, tear off from the rib over time and, in the form of numerous round spots visible on the color film, float upward over the thicker film. If the rib is at the top of the film, then thin sections accumulate at the bottom near the rib and separate it off with a strip from a thicker film below the lying one.

It is not possible to detect any blinking of the transverse laser light passing through the edge or reflected from the edge, which is apparently due to the low intensity of the blinking against the background of bright laser light. Blinking on the screen can be seen if the laser beam is directed at a sliding angle along the rib of the film at the wall of the cell or from below through the solution with reflection from the rib of the film lying on the solution, when the light has the opportunity to go into the sharp corner of the rib.

The time for observing blinks is limited only by the lifetime of the films, which usually ranges from several minutes to several hours (but sometimes it is possible to observe blinking in a row for several days). It can be increased if the solution is replenished in the films, but this cannot be done by simply adding the solution through the rib (the solution does not go from the rib to the film) or by dropping large drops of the solution from the pipette onto the films (large drops, like the rib, do not give the solution to film, but suck in a solution from the film /4/). The films can be replenished with very small drops, the fog created by the ultrasonic atomizer, which, settling on the film, immediately diverge in it.

Selecting the composition of the soapy solution, the pattern of spots on the screen can be fixed and made completely motionless if the rib and the film are prepared from a heated, but solidifying in the form of a jelly soap solution with gelatin /6/. The fixed pattern of radiation from a trihedral rib reflects its mode structure on the screen, which is interesting for comparing the types observed on the screen with the results of calculating the modes of a liquid trihedral waveguide. The use of gelatin was also interesting in that it makes the radiation from the rib extremely sensitive to the intensity of laser radiation. Small changes in the intensity of laser light, acting on the jelly, change its viscosity, which causes the appearance of optomechanical flashes, the frequency of which changes tens of times with a slight increase in the green radiation power from about three to ten milliwatts. If the laser power after lifting is kept constant, then in a few minutes the blinks on the screen slow down and completely stop, but again they temporarily resume if the laser power is increased or decreased (!). The reason for such changes requires further study.

Thus, the laser light in the rib opens up wide opportunities for studying the physical properties of liquid waveguides of different composition and statistics (randomness, ergodicity, etc.) of the radiation from them.

A rib fragments any light passing through it. It turned out that if you let sunlight focused on the input end face pass through the rib, then a kaleidoscope appears on the screen made of a constantly dancing mosaic of colored rainbow spots Figure 6 (the movie is available at the site /8/). The use of sunlight allows us to make the following legitimate statement - the phenomenon of fragmentation in the rib could and should have been discovered 3,000 years ago, when, as you know, there were all the prerequisites for this in the form of available soap and ability of focusing sunlight with ball vessels with water.

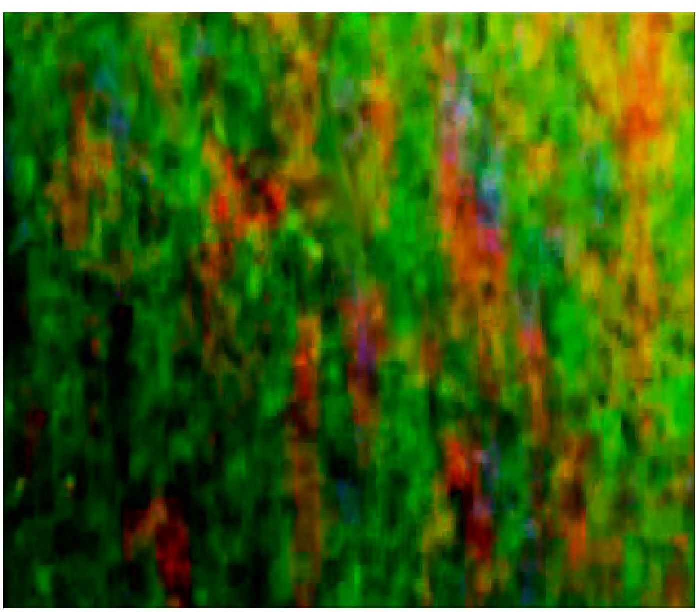

Figure 6: Blinking colored spots on the screen from passing through the rib of sunlight. Screen at a distance of 20 cm from the output end of the rib.

It is difficult to overestimate and imagine, even as a fantasy, what great benefit could be brought to mankind by this ever-changing mosaic of many colorful spots showing on the big screen the hidden features of a small microscopic invisible world, if it had been discovered 3,000 years ago, as in the field of science, so in philosophy, and areas of enlightenment, education and the development of curiosity of young people watching this phenomenon. How much would it have helped Democritus with his atomic theory of the universe, Aristarchus of Samos with his theory of color, Archimedes with the use of his focusing devices, what a stable foundation would be for Euclid's works on optics? And how many thousands and thousands of inquisitive young minds would have been ignited by a desire to understand why the blinking colored spots on the screen come from a calm-looking rib. What a giant bonfire of knowledge could be ignited by this little "match" of colored blinking spots! It remains only to regret all those billions of people who left without ever seeing the phenomenon of fragmentation of light that would be extremely informative for them.

It is surprising that in our seemingly thoroughly studied world at the time of the bosons of Higgs and satellites, a mysterious phenomenon could exist before the eyes of all people for thousands of years, for the discovery of which special conditions or some long chain of specially accumulated knowledge was not necessary, and for the discovery of which the curiosity of a simple amateur, monk or a schoolboy was enough. This is perceived as a hint of the need for increased attention to the most ordinary things around us.

Now, in order to increase brightness, powerful fluxes of the white continuum obtained in the waveguides or in the water of the rib itself can be passed through the rib using short pulses of femtosecond lasers, it is possible to fill the rib with an active laser medium and obtain laser action in it with an unusual unstable wide-angle output radiation pattern.

Although belatedly but from now on, the phenomenon of light fragmentation (called Stoilov's phenomenon) will be used to educate people in the most remote corners of the Earth for demonstrating without a microscope on the screen invisible micro- and nano-processes in a visually stable rib both in our time and in the next millennia.

On this, the description of the observed phenomenon of light fragmentation in the rib of the soap film could be completed, but in the course of the experiments one more interesting and physically less clear flashing object was discovered that was similar in shape to the rib of the soap film, but significantly different from it. We don't know the theoretical formula or description of the height of the liquid rising along the ideal right angle of the cuvette, but we see experimentally that in a tetrahedral transparent cuvette with an internal cross section of 1x1 cm, the sides of which are assembled on an optical contact (the optical contact forms an ideal right angle) soap solution poured as a thin layer at the bottom, by capillary forces rises along the corner, like a wick, to the entire height of the cuvette (2 cm) and forms a column of liquid in the corner, similar to a rib. The cross section of this column is shown in Figure 7. Green laser light (3) is focused through a transparent wall into such a column (2) so that passing through the solution it is reflected almost at right angles from its surface bent to the corner and goes (4) on the screen (5). Such a column also has wings, the pressure is also reduced in it, and so it is possible to collect the solution from the film covering the walls of the cell, lift the liquid from the bottom of the cell and evaporate it in the upper part of the cell. After tuning, when focused laser light is reflected from the inner surface of such a column, a picture of a bright horizontal non-flickering strip is observed on the screen, but above and below it for many days and weeks in a row a spotted structure is observed with constant (not as fast as with a rib) flicker on them (Figure 8, movies are available on the site /8/)).

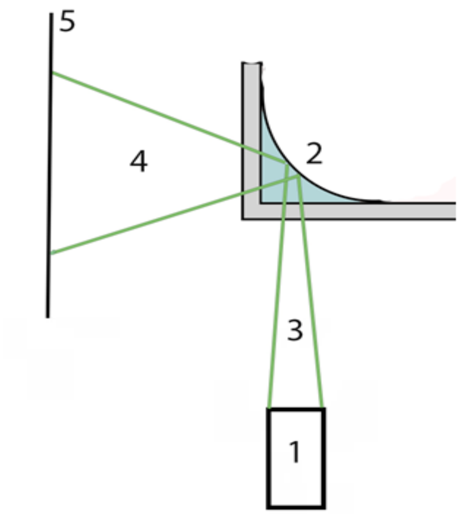

Figure 7: Scheme of the cross section of a liquid column in the corner of a rectangular cell when observing the reflection of laser light from it.

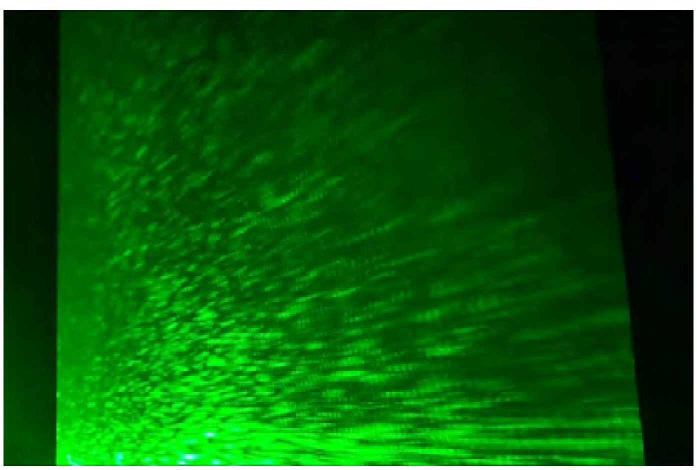

Figure 8: View of the flicker pattern on the screen from a column of liquid in the corner of the cell.

Unlike the ribs, the column in the corner of the cuvette can be made from any liquid, giving researchers the opportunity to analyze their various dynamics of flicker. Here, with increasing intensity (532 nm, 1-10 mW), the brightness increases, but the flicker frequency does not increase. And the question remains about the mechanism of such a long recharge of these scintillations and the angular diagram of their orientation. The collection of fluid in a column from the film on the walls of the cell, as in the rib, is unlikely to last more than a day. Rather, the flicker is somehow connected with the rise of the liquid from the bottom of the cell, as if by a wick. But the physics of which processes and which surface irregularities reflect these flickers? Under the microscope, bright flickering dots are visible in the corner of the cuvette, but the nature of their flicker requires clarification.

Discovered phenomena open up wide possibilities for researchers. In addition to the implementation of lively and attractive (when using powerful broadband sources) paintings, the observed phenomena are of both practical and scientific interest.

Some practical applications.

1. This is a new type of chromatic dispersion that can be used in a new type of optical equipments example of which is shown in Figure10. Such dispersion of wave may be used in new type of microwave guides with sharp tops and in sound tools with new forms.
2. Here is a new type of laser medium with an unusual modal structure,
3. A new emitter of radiation noise for masking, a sound source (when amplifying sound inside a rib). Here, apparently, it is possible to register noise such as raindrops or train passing.
4. This is a new random number generator (without repetition) /7/, a wide-angle light source for security schemes and laser location.
5. With the advent of suitable wavefront reversal devices, it will be possible to pass a chaotic output signal in the opposite direction through the rib and obtain the original laser beam for verification at the output.
6. Unusual spotty-blinking light sources have the prospect of application for revitalizing theatrical scenes, entertainment facilities and for filming science fiction scenes (Figure 9, the movie is available at the website /8/).

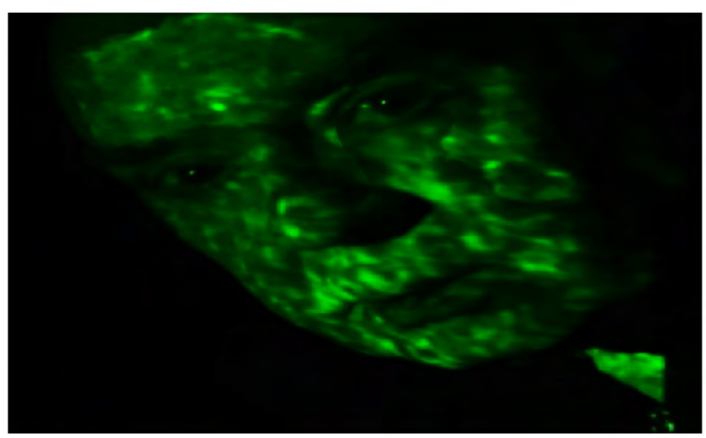

Figure 9: Spotted blinking light on the face of the observer.

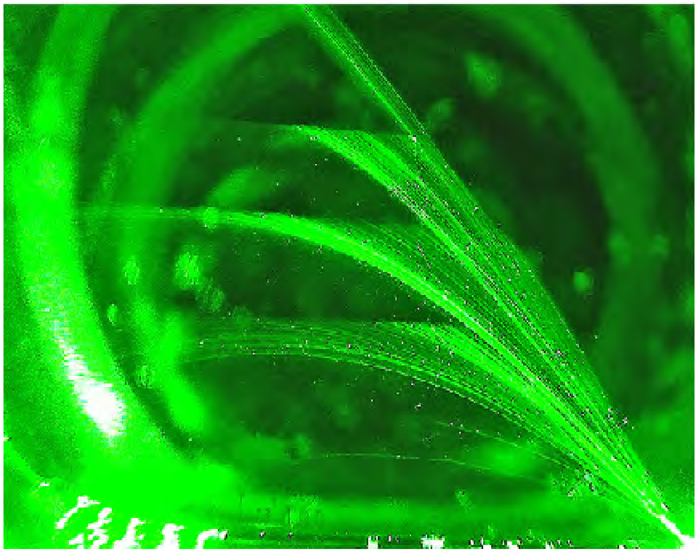

Figure 10: Dispersion of green laser pointer modes by a nozzle of vertical honey-soap film 12 cm in diameter.

From the scientific point of view, a rib as an object opens up new numerous and interesting sections of laser, waveguide, and quantum radio physics, thin-layer hydrodynamics, thermodynamic, statistical radio physics, laser optomechanics, and encryption. The laser light introduced into the rib makes it possible to study the physical causes of the unexpectedly complex hydrodynamics of collecting the solution into the film rib, the effect of the composition of the solution on it, viscosity, temperature, gravity and the possible effect of light pressure /1-4/ of lasers on the drainage (detected during the formation of tracks). What features will the effect of fragmentation light in a rib in space differ due to the absence of gravity? How will the solution be collected in the rib of the supercooled film, where fluctuating transitions between the two structural phases of water are noted /9/? An interesting analysis and theoretical description of the properties of such a liquid trihedral waveguide, amplifier, and waveguide laser with concave surfaces, the nature of its modes, the dynamics of generation and spreading of a short light pulse in it due to the physical difference in the optical path lengths for different Fourier components. It is possible to compare the calculations with the demonstrated complexity, the distribution of amplitudes and phases at the output of such a waveguide in the form of a two-dimensional diffraction structure that creates a dynamic picture observed on the screen. The detected pulse collection of the solution from the films into the rib should cause constant mechanical jitter of the rib between the films in contact with it. What noise frequencies are we talking about? The thermodynamic of the process is also interesting. What energy is spent on fragmentation of light?

In experiments with a column in the corner of the cuvette, it is necessary to analyze the causes, the energy of flickering, and the directional pattern of flickering flows. Is there any contribution to the gathering of the solution from the walls and the influence of light pressure on the surface of the liquid column in the corner of the cell? What is the peculiarity of the appearance of such scintillations in geometry with a column and how can they appear in other schemes?

It is hoped that after developing theoretical descriptions of the collection of the solution from the films into the rib with reduced pressure and flicker with a column researchers will have a chance to clarify by analogy the process of collecting the solution in laser tracks, in places where the surfaces of the film protrude, where the pressure of the solution is also lowered, but due to the pressure of light /1-4/. Can this collection, with intensive exposure, become fractional and affect the direction of the track? Is it possible to transform the energy of liquid flow in soap films into electricity?

The phenomenon of chaotic light fragmentation, found in the rib and in the column, can be used, despite the difficulties with science /10/, in teaching physics /11/ as very accessible and illustrative examples, revealing on the big screen microdynamics (such as Brownian motion but without microscopes) that are difficult for direct observation in ordinary and well-known soap film, phase transitions in films with gelatin and flicker from the surface of liquid columns with possible exposure on them, as in tracks /1-4/, pressure of light.

The descendants, as one should think, will consider a delay of 3,000 years in the discovery of the phenomenon of fragmentation of light in the rib of a soap film as direct evidence of the absence of God. Why? A rational creature (God) could not for a thousand years take away the views of billions of people from such accessible, winking, and extremely need for them a source of knowledge. So descendants will leave churches and pay more attention to science. So soap film is a rather small object to shake the universe, but it, as shown, can significantly expand our horizons. The author thanks the staff members who helped him in carrying out the experiments, relatives and friends for moral and material support, since the work was carried out with pure enthusiasm without subsidies from any funds, and in advance all interested future successors of the theoretical and experimental study of this phenomenon and its possible application /12/.

References

1. Startsev AV, Stoilov Yu Yu (2003) Quantum Electronics 33: 380.
2. Stoilov Yu Yu Phys (2004) Usp 47: 1261.
3. Stoilov Yu Yu (2011) Photonika 1: 2.
4. Startsev AV, Stoilov Yu Yu, Site “Astronomy at school” http://www.astro.websib.ru/sites/default/files/userfiles/milo_plenka.pdf

5. Stoilov Yu Yu, Site "Astronomy at school" http://www.astro.websib.ru/sites/default/files/userfiles/droblenie_stoilov.pdf
6. Stoilov Yu Yu (2015) Patent RU No. 2569845.
7. True Random Number Service, https://www.random.org/
8. Stoilov YuYu. Movies for this article: http://preprints.lebedev.ru/files/250618_stoilov/Soderzhanie(3).doc
9. Sanderson K (2018) New Scientist 26.
10. VM Kaitukov (1994) The Evolution of Dictate - Moscow: Nauka, 413.
11. L Namer (2019) Chemistry and Life No 9, 14.
12. Stoilov Yu Yu. Tags, http://preprints.lebedev.ru/files/250618_stoilov/Poslan.pdf