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# Laser tracks in rainbow films on water

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***Abstract.*** **It is found that narrow non-diverging laser tracks, earlier studied in free soap films, can also arise in thin rainbow films, e.g., of petrol, on water**

***Keywords:*** *laser tracks, rainbow films.*

Coloured films are often seen on the surface of town pools and basins. Their colours are due to light interference and indicate the small thickness of the films. Similar iridescent colours are typical for thin soap films, in which the introduction of a laser beam leads to formation of nondiverging light channels – the laser tracks.

The exotic properties of laser tracks in soap films are described in [1 – 13]. They include the absence of divergence at laser power, unusually low for nonlinear effects [1, 2]; the independence of the track appearance of the wavelength and of the significant (by nine orders of magnitude) increase in laser radiation intensity; the absence of mutual influence of crossing tracks; the coincidence of the radiation wavelength at the track outlet with that of the incident radiation [3, 4]; the track appearance independence of the soap kind, surface-active substance (SAS), and solvent in the film. Moreover, the tracks are produced under the action of a train of short (femtosecond) laser pulses [5]; they are observed also under broadband pumping and pass straight through the regions of the film having different colour (i.e., different thickness), but ramify at large inhomogeneities [6, 7]; the threshold power for track production does not exceed 0.2 mW (0.01 W cm$^{-2}$, the energy $2\times10^{-11}$ J); the interference pattern, observed under grazing incidence of a probe beam on the film, changes its structure when a track appears inside it [8, 9]; the external electric fields imposed on the tracks do not affect them till the film breakdown; a steady-state single track in the film can have no branching [10]; the mechanism of track formation associated with thickening of the film by the light pressure can explain the basic properties of tracks [10 – 12]; unusual channel-switching dynamics of the radiation output from the tracks is observed [13].

Are similar tracks possible in rainbow films? Looking similar in colour, these films possess different composition. In contrast to the layered structure of the soap films, both surfaces of which are coated with densely packed layer of soap or SAS molecules with small surface tension, rainbow films on water are transversely homogeneous and do not exist in free state without water surface. At the same time, the refractive index of such films is greater than that of water and, therefore, the light can propagate in them as it does in soap films, experiencing internal total reflection.

The presence of laser tracks in such films would expand the scope of media and conditions suitable for laser track production. However, the question is whether the homogeneous film structure and the contact with water that reduces the critical angle of total internal reflection can be an obstacle for track formation.

With the aim of answering these questions we investigated a film of AI-92 petrol. Note, that all grades of petrol with any dopants possess the refractive index greater than that of water, namely, 1.37 – 1.58 [14]. The film was produced in a Petri dish (diameter 10 cm) with water, onto the surface of which one drop of petrol with the volume ~15 mm$^3$ was deposited.

The drop immediately spread into a broad spot, well visible in reflected light (Fig. 1). From the spot size it follows that the initial film thickness amounts to a few micrometres. The colours on the film manifest themselves particularly bright after nearly 1 min and then during 5 – 10 min, they disappear, i.e., the thickness of the evaporating film becomes smaller than 0.1 μm. In the open dish the coloured circles at the edges of the film indicate the fact that these edges are rugged. In a dish with the lid closed (in the absence of evaporation) the film can stay coloured for hours.

The scheme of experiments is shown in Fig. 2. The beam of a laser pointer (*1*) (532 nm, 10 mW) was focused using a

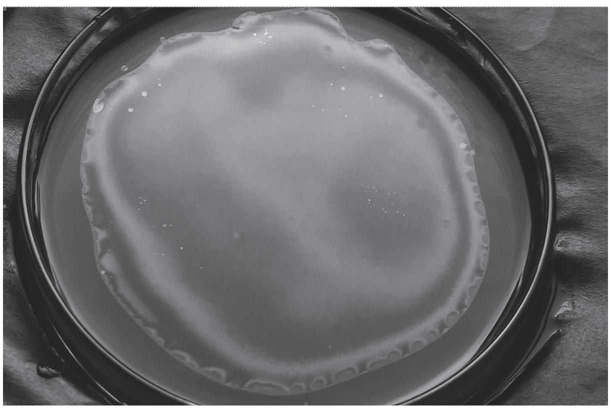

**Figure 1.** The film of AI-92 petrol on water surface in a Petri dish.

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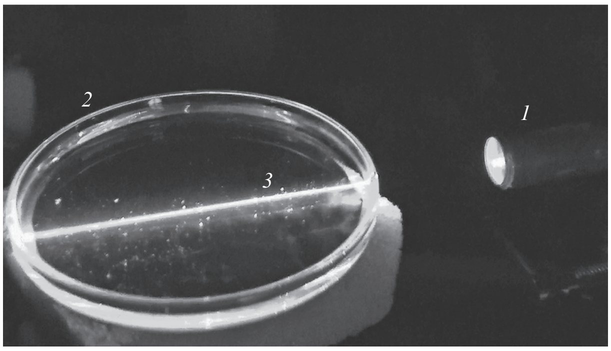


**Figure 2.** Scheme of experiment: (*1*) laser pointer; (*2*) Petri dish; (*3*) film.

lens with $F = 5$ cm through the transparent wall of the dish (*2*) onto the film edge (*3*) from below through the water at the angle ~5° with the film surface.

When the water is covered with thick (parts of millimetre) layer of petrol, the laser beam introduced into it experiences tens of reflections from the top and bottom surfaces of the layer and acquires a wavelike shape (Fig. 3). There are no tracks in such a film, but there are no tracks in a thick soap film, too; therefore, a thin rainbow film is more interesting for us. In this film, when the laser beam is precisely targeted at its edge and the entry point is properly chosen, clearly seen narrow nondiverging light tracks appear (Fig. 4). When there are fluorescent dopants in the petrol, the tracks have yellowish colouring, they change direction, ramify, disappear and arise again, i.e., behave like those in a soap film [1–13]. But, in contrast to the tracks in a soap film, they have smaller brightness and are less mobile. Sometimes one can observe tracks with the laser beam targeted not at the edge of the film, but at its middle part, but in this case, as already known from the experiments with soap films, special resonance thickness conditions should be satisfied [10]. In the film on water it is rather difficult to find the place, where these conditions hold.

Microscopic observation shows (Fig. 5) that the track widths in these experiments are different, but typically they amount to ~40 μm. Similar tracks are observed also in kerosene and kerosene-petrol mixture films on water. The variety of substances not solvable in water and possessing small surface tension, applicable for preparation of films, is rather large, and evidently one can expect track formation in rain-

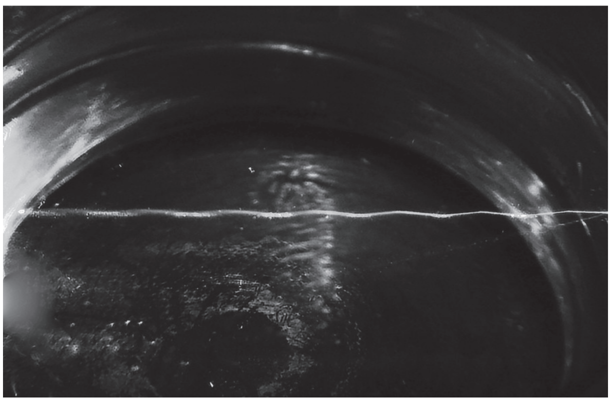

**Figure 3.** View of laser beam introduced into a thick layer of petrol.

**Figure 4.** Narrow nondiverging light tracks in the petrol rainbow film. The broad track is the laser beam, reflected from the layer.

bow films of other liquid media and their mixtures using various laser light sources.

Thus, the experiments carried out show that the appearance of laser tracks is not caused by any resonance peculiarities of the composition of liquids, and they are produced in various homogeneous rainbow films. This essentially widens the possible variety of media and conditions for studying the properties of tracks, arising, as shown in [10–12], under the action of light pressure.

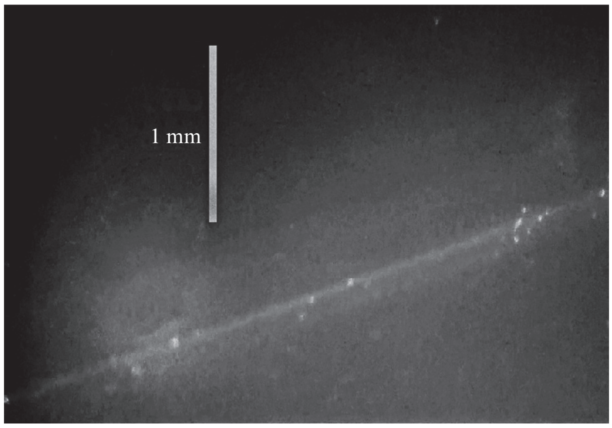


**Figure 5.** Images of tracks obtained with a microscope.

It is interesting to consider Ref. [15], where the possibility of nonlinear optomechanical formation of light channels 20–30 μm wide due to light pressure in a waveguide with two closely spaced thin longitudinal silica partitions was estimated. Theoretically, by means of the iterative calculation method, it was shown that milliwatt radiation power is enough to produce the change of the separation between the partitions by 1–3 nm and to cause essential change of the optical properties of such a waveguide.

The authors of Ref. [15] plan further estimates of the self-focusing dynamics of such light channels, their interaction and modulation stability. They do not mention laser tracks in thin films, although their approach could be useful also for theoretical description of dynamics and general properties of these spatial solitons [10]. The similarity of mechanisms of light pressure action in mechanical tuning of the waveguide optical properties and the liquid films with tracks makes it possible to consider the light pressure as a specific parameter, playing an important role both in the described phenomena and, probably, in a number of new, still not studied nonlinear optomechanical phenomena.

In the case of tracks in petrol films the light pressure mechanism, explaining the behaviour of tracks in soap films, is a hypothesis that is not yet confirmed, because the data about the tracks in petrol films are few compared with those for soap films. However, there is no essential difference in the appearance and behaviour of the tracks, which provides grounds for an assumption that the mechanism of track formation is similar in both cases.

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