# TIME DYNAMICS OF HUMAN HAIR REACTION TO LASER ILLUMINATION AND ELECTROMAGNETIC FIELD

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## 1. Introduction

Study of physical properties of human hair under the influence of different factors is important both for dermatology and for cosmetic science. A lot of papers are devoted to this subject [1,2]. At the same time the main idea in all these papers was that hair is a dead keratinized subject. In recent years the technique of dynamic gas discharge visualization (GDV) has been widely applied for the investigation of various subjects [3,4]. Many research works have demonstrated [5,6] that the characteristics of gas discharge around biological subjects carry information on their physicochemical properties.

In a lot of experiments using two independent techniques it was shown that hair parameters have time dynamics and react to the illumination by gaseous discharge and laser impulses. Data obtained opens up a new perspective in conceptual and practical applications to the study of human hair.

## 2. Materials and Methods

Swatches of freshly cut human hair from healthy volunteers and control commercial swatches of sourced, human hair were tested. For the purpose of this experiment, a panel was assembled consisting of healthy volunteers, both male and female, ranging in ages eighteen to fifty-five. All volunteers had healthy hair, without any traces of chemical treatments. Hair specimens were cut from the occipital part of the head of tested individuals at the distance of about 2 cm from skin. The samples which were taken right before the measurements were called “fresh”. “Dry” hair samples were taken more than 20 days before measurements. Two independent approaches to study human hair were used.

### 2.1. Sliding Gaseous Discharge around Human Hair

The technique of dynamic GDV measurements of hair was described in details in [7,8]. The technique can detect subtle yet significant energetic difference between hair samples. A strong electromagnetic field (EMF) was applied for 5 seconds to each hair sample, which generated photon emissions in the form of a corona discharge. Simultaneously, this corona discharge was captured by a GDV camera, and recorded as AVI (Audio Video Interleaved) files. Then the main informative parameters of GDV hair images (Area and Intensity) were calculated and analyzed.

### 2.2. Laser Speckle – Interferometry of Human Hair

The principle of coherent laser technology is that it compares images of interference patterns of coherent laser radiation scattered from a tested sample. Correlations between images allow both the comparison and contrast of sets of images based on the tested subjects’ complex structures and patterns of change through time and under the influence of external sources of radiation. The technique qualitatively and quantitatively registers the changes of phase in real time and the changes of particular components of the structure of investigated subjects. The intrinsic parameters of the subject can be investigated even when the surface is randomly distributed [9,10].

The outline of measurements is given in Figure 1. A single hair sample 1 (hereinafter called sample) was fixed between two optical glass plates 2, which reduced the influence of the external environment and provided precise positioning. Laser radiation 4 with the wave-length $\lambda$=0.6328 μm was directed at the investigated sample. He-Ne laser 3 was used with the beam diameter of 1 mm and the power of 1 mW. The interference pattern image was registered by the CCD TV camera 6 with resolution 740 x 572 pixels. The distribution of intensity of radiation scattered by the sample in the far diffraction zone was measured under the influence of short-term, 15 seconds, laser illumination of sample. The form and the dynamics of interference patterns of different types of samples were controlled within several days.

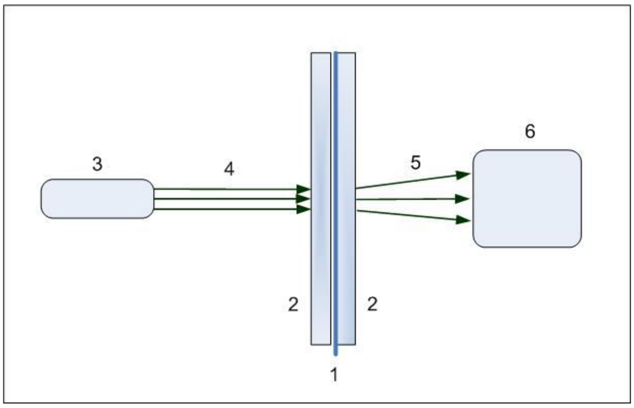


Fig.1. Laser experimental setup. 1 – single hair; 2 – optical glass; 3 – laser; 4 – coherent light; 5 – pass-through light; 6 – CCD camera.

After all measurements images were generated using the Laser Speckle-Interferometry technique – a technique that is widely used for the control of rough surfaces in microelectronics [9]. These images illustrated the spatial distribution of scattered light intensity from the tested subject. The quantitative assessment of changes in real time of these images was given on the basis of correlation analyses. The analyses are comprised of a cross-correlation function (CCF), which allows comparing two images of the same subject in the process of changes. It has maximum (in our case functions are normalized, so CCFmax = 1) when two images are equal. The more the difference, the lower is CCF. This approach allows to take into account the phase change of laser light reflection. Such quantitative analyses of these images allowed the retrieval of information on the properties of hair.

**3. Experimental results**

More than 20 different samples of hair from subjects of different genders and age were studied. Time dynamics of both gas discharge parameters around hair and laser interferometry were calculated. Fig. 2, 3 demonstrate typical graphs for freshly cut hair measured within several days. As we see from the graphs, time behavior of parameters is very similar for both techniques. We see fast decrease of a signal in the first hours after cutting, after application of gaseous discharge or laser light illumination signal rose up, reaching some saturation level, specific for different days. After some break in measurements signal dropped down, but increased again practically in every measuring session under the influence of measuring procedure.

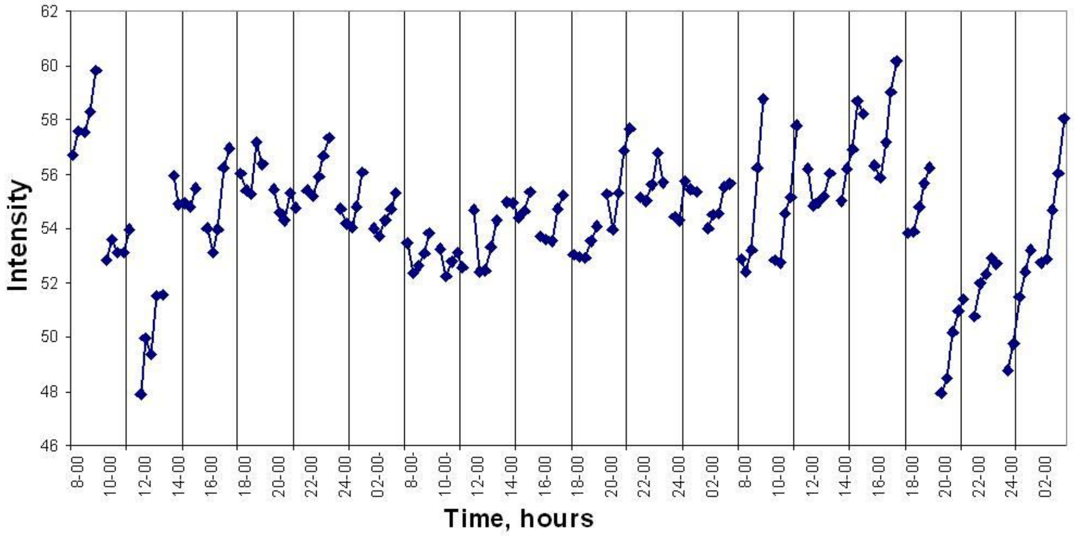


Fig.2. Time dependence of GDV Intensity of freshly cut hair during 3 days. Each 5 experimental points, connected by line, were taken with 1 minute interval.

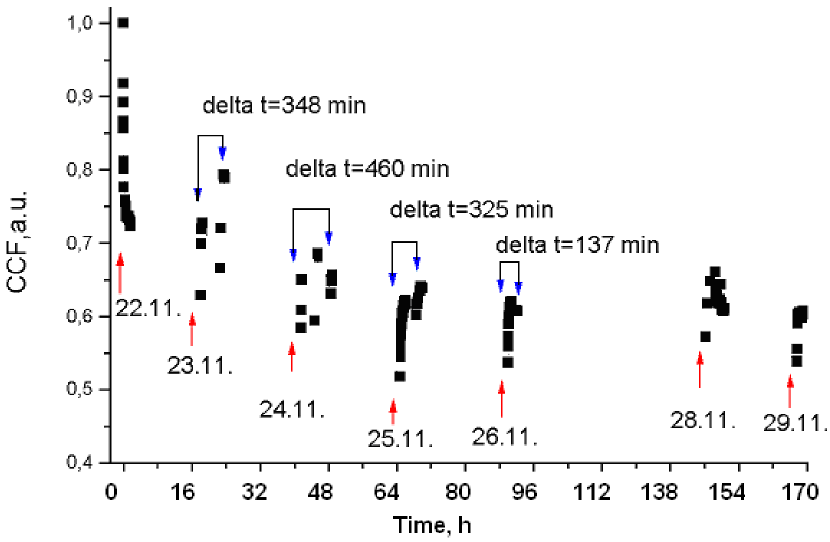


Fig.3. Mutual autocorrelation function of interference images of freshly cut hair during 7 days.

For "dry" samples of hair time dynamics was much less active (see examples at fig.4, 5). This type of time behavior was typical for different hair samples, while the level of signal was quite individual for every sample. But in all cases we were able to see the reaction of hair parameters to the application of gaseous discharge or coherent light. Control experiments both with metal wire and fiber-optics demonstrated no changes in signal.

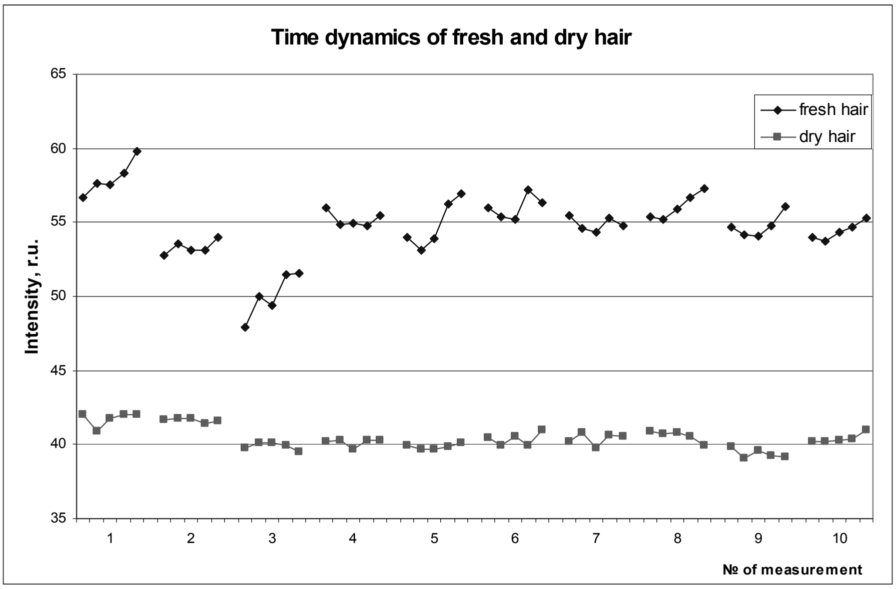


Fig. 4. Differences in time dynamics of fresh and dry hair GDV glow Intensity.

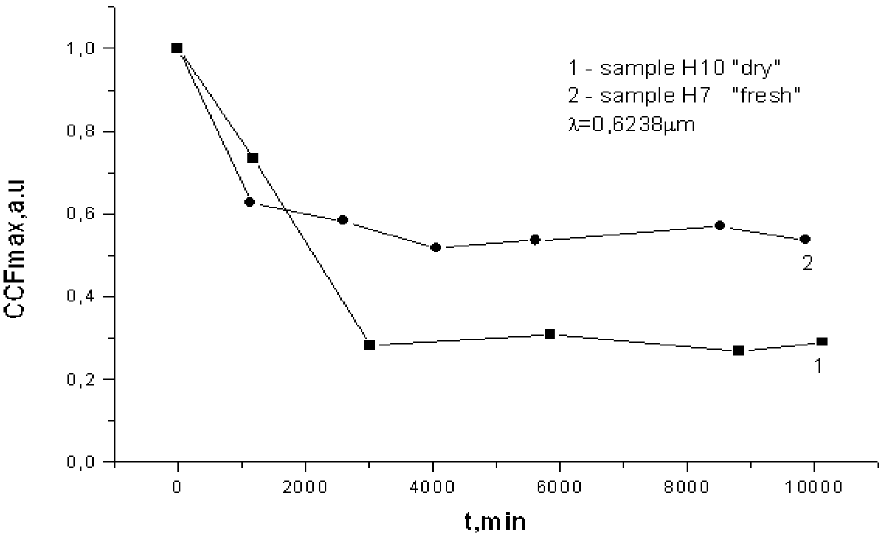


Fig. 5. Mutual autocorrelation function of interference images of dry hair sample (graph 1) and fresh hair sample (graph 2).

For laser illumination strong dependence on the laser light wave-length was found. The measurements showed that the He-Ne laser with the wave-length $\lambda = 0.6328$ μm (red light) had the strongest influence on hair (fig. 6). In this case the change of the maximum of the cross-correlation function was up to 30%. When the sample was exposed to the laser diodes' radiation, with wave-lengths $\lambda = 0.66$ μm and $\lambda = 1.05$ μm, a relatively insignificant change in the interference figure and a change of the $CCF_{\max}(t)$ value within the limits of 8% were observed. We can assume that the influence of light on the hair structure becomes weaker for light with larger wave-lengths (i.e., when the energy of the absorbed light quanta becomes smaller).

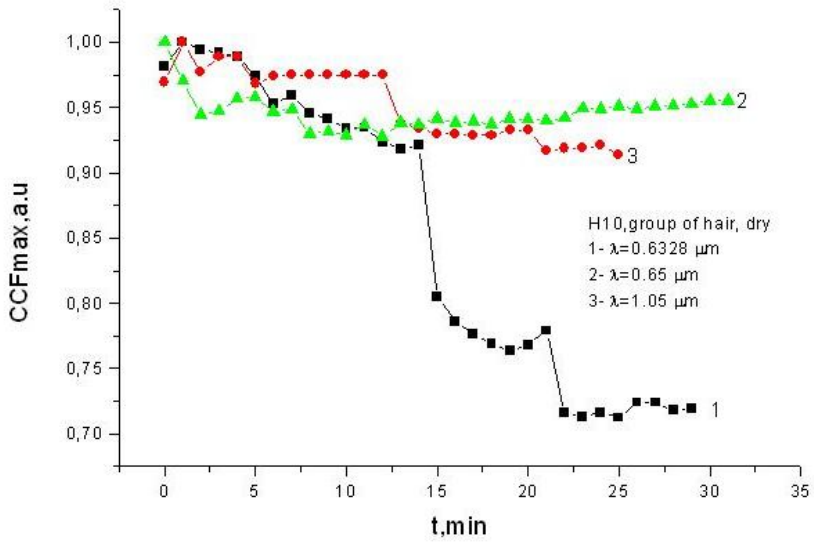


Fig.6. Mutual autocorrelation function for dry hair sample for different lasers. 1- He-Ne laser, 2- laser diode KLM-650/20, 3- infrared laser diode ESU-1005.

## 4. Discussion

Results of numerous experiments allow making several conclusions.

1. Hair is biologically active matter, which reacts to the external stimulus.
2. Under the influence of laser illumination with λ=0.6328 mcm or ultraviolet light from gaseous discharge (λ=0.3-0.6 mcm) hair increase its activity. This fact was independently revealed both in GDV and laser experiments. The effect is much stronger for freshly cut hair compared with “dry” hair. We may name it as “optical pumping” of hair.
3. Phase-sensitive optical parameters of human hair under the influence of short-term laser illumination or gas discharge depend on the “Age” of hair after cutting. Different behavioral pattern of hair optical parameters for freshly-cut and “old” hair was found.

Developed approach may be useful for cosmetic science and dermatology for studding the response of hair to different stimulus.

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