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APPLICATION OF NEAR-IR LASERS TO MEDICAL INTRASCOPY TESTS

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Abstract

Near IR laser radiation is used for intrascopy of some types of human tissue. In particular, a tooth defect was studied by various methods of filtration of quasi-CW radiation scattered inside the object. The crucial points of this study are the employment of an electro-optical intensifier (EOI) and parallel processing of video information.

1. Introduction

Medical-biological visualization is used for detection, identification, and diagnostics of such objects as, e.g., tumors inside a tissue. The physical basis of the visualization is the difference between the intensities of light passed through a normal tissue and that with incorporated objects, e.g., tumors.

Understanding how light propagates through a strongly scattering medium is an important step toward the solution of the problem. Light is both scattered and absorbed inside tissue, which results in a diffused transmission. The incident radiation intensity, coherence, and polarization vary when light is absorbed and scattered inside the tissue. The degree of these variations depends on the light wavelength and the type and width of the tissue.

The transmitted light consists of unscattered (or coherently scattered), weakly scattered, and multiply scattered photons. The coherently scattered or ballistic photons propagate in the direction of the incident beam, retain most of the characteristics of the incident photons, and carry maximum information on the inner structure of the scattering medium. Our approach is to select the photons that carry information on the background of multiply scattered photons (which smooth the pattern) and then to amplify them by means of a special experimental technique [1–4].

In choosing the optimal wavelength, one should make allowance for additional factors. First, light of shorter wavelengths provides better spatial resolution; however, it is absorbed by defects. Second, for obtaining a clear pattern, the light scattering should be reduced. Finally, the wavelength range should provide detection of the principal chemical substances which are indicative of living activity. Near infrared (IR) wavelengths in the range 700–1300 nm seem to be a good choice.

We suggest a working installation with a high-sensitivity multichannel detector for quasi-CW intrascopy of tooth tissue possessing defects (channels or damages).

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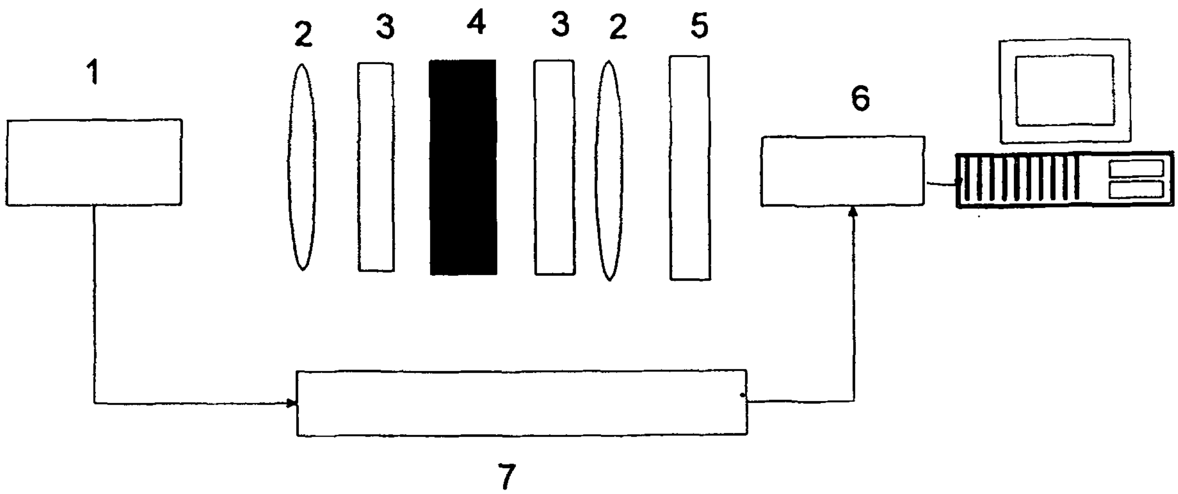

Fig. 1. Schematic diagram of the experimental setup: 1) laser, 2) lenses, 3) polarizer, 4) sample, 5) spatial filter, 6) electro-optical converter, and 7) synchronizing signal.

2. Experiment

The quasi-CW approach has been realized in a picosecond laser system 1 with a repetition frequency of 76 MHz of 70-ps pulses at an average laser-beam power of 1–100 mW and vertical (V) polarization of the radiation. This laser system is intended for further operation with a time selection system suppressing light scattering [5]. The incident beam is expanded by a telescope system 2 for better illumination of the object under study. After passing the object, light through an optical Fourier filter 6–7 falls onto an electro-optical intensifier (EOI) 8. Then the signal is digitized for further processing in a computer. The optical Fourier filter gain is 1.2. The polarizer 5 cuts off multiply scattered photons with a changed polarization. The diaphragm 4 of diameter ~0.5 cm is used to eliminate light scattered on peripheral elements of the optical system and light passed far from the object.

For test objects, we used aperture masks made of wire placed in milk and a chicken wing. The main results were obtained using a human milk-tooth with a drilled channel.

3. Results and Discussion

An image example of the tooth with a channel is shown in Fig. 2. The sensitivity of the detector is high enough to show the inclusion inside the tooth with a good contrast. An estimate of the average macrocontrast gives a value of 0.85. The characteristic diameter of the inclusion is 0.8 mm. At the first stage, images of the object have been obtained for two perpendicular polarizations and then the image with the horizontal (H) polarization was subtracted from that with the vertical (V) one. In this way, we excluded the light scattered in the Fourier filter. Then the image was converted for obtaining better macrocontrast. It is worth noting that the initial V-polarized image was (as is required) rather bright, whereas the H-polarized image was dark in order to keep valuable information in the final picture. Our software provides an optional possibility of printing optical densitograms. In Fig. 2, one can see changes in the optical density corresponding to the channel inside the tooth. Thus, an estimate of the spatial resolution of our method gives a value of ~0.5 mm (the latter depends on the sample under investigation).

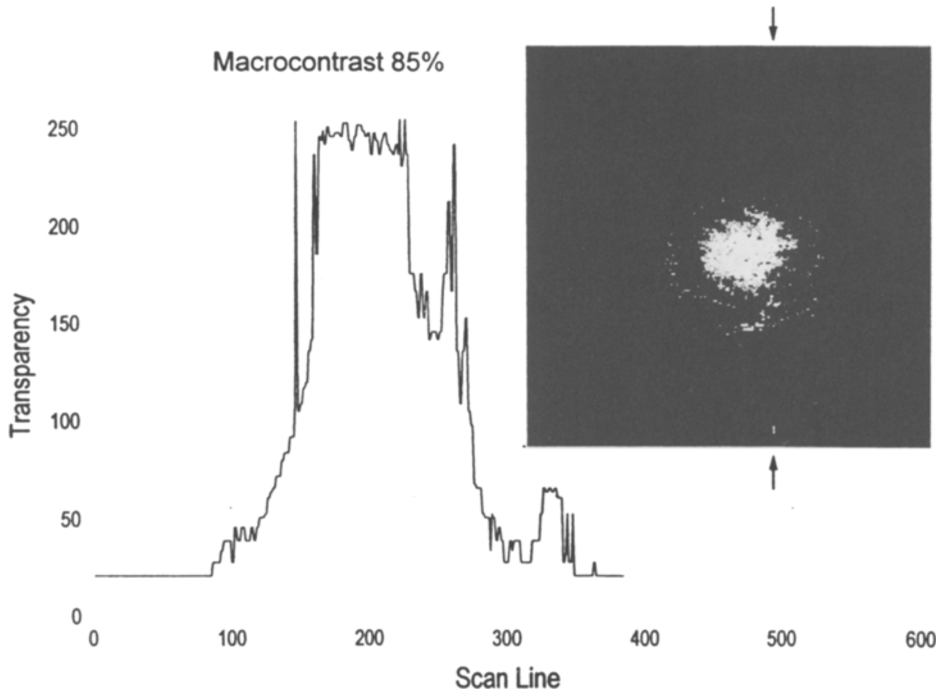

Fig. 2. A densitogram of the image.

4. Conclusions

We used a red-color laser beam for intrascopy of certain types of human tissue. Actually, we investigated a tooth defect by using various methods of filtration of the scattered light in a quasi-CW regime. The main features of the approach presented are the use of an electro-optical intensifier and parallel processing of image information. By means of a simple experimental technique, we obtained a spatial resolution of 0.5 mm. The results obtained can replace expensive and dangerous x-ray methods in stomatological practice and express diagnosis.

Acknowledgments

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