Studying the modes of automated destruction of malignant tumors using laser radiation

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Abstract. In this work, we have manufactured the experimental setup to study the modes of automated destruction of biological tissue in vitro. We have implemented the setup in microsurgical operations, which allows us to verify the modes of tissues destruction.

1. Introduction
Development of robotic systems for surgical applications remains challenging problem of applied physics, optics, and medical science. Robotic surgical systems are minimally invasive and characterized with high speed and precision, which significantly reduces the time of patients stay in medical institutions [1-4]. These advantages of robotic laser surgical systems lead to the increasing manifold of its use in modern robotic surgery [5-8].

One of the advanced laser surgical system is AcuPulse 40 ST (Lumenis Inc., USA). It employs the micromanipulator, and it could be easily adjusted to the operating microscope. This system could perform non-linear surgical incisions, and it is widely applied in ENT, gynaecology, neurosurgery, dermatology, plastic surgery, urology and general surgery. However, despite the listed advantages, the system could not perform automatic tissue evaporation inside specified contour.

In this paper, we study of the modes of automated evaporation of biological tissues, which form the basis for further creation of the robot-assisted laser surgical system.

2. Experimental setup
In order to study the modalities of automated laser evaporation of biological tissue, we have assembled the experimental setup, which consists of

- surgical laser system (SLS) based on CO2 laser operating at 10.6 μm;
- operating microscope Zeiss OPMI MD, with the digital camera connector;
- micromanipulator with the adapter for SLS-connection to a microscope;
- scanning devise for laser beam deflection in the required direction;
- microprocessor-based control system.
The micromanipulator and the system of laser beam deflection are mounted on a surgical microscope, see Figure 1.

Experimental setup could evaporate biological tissue inside required rectangular, triangular, or elliptical contour. The area of the contour could be varied within the field of view of $8 \times 8 \, \text{mm}^2$, and the duration of tissue evaporation is of about 2 seconds for single pass. The CO2-laser uses in the setup could operate in continuous, pulsed, or superpulsed modes with the wide tenability of output parameters.

3. Studying the modes of the automated tissue destruction

We employ the experimental setup to study different modes of automated destruction of various tissues \textit{in vitro}. By histological examining of the tissues after its exposure with CO2-laser radiation, see figure 2, we determine the optimal modes of the system operation for various surgical tasks.

To verify the destruction modes, we have carried out microsurgical operations, performed on the tissues of the oropharynx and hypopharynx. Namely, 5 operations with the hypopharynx, 10 operations with the larynx, and 40 operations with the skin tissue from the head and the neck have been performed. To improve the accuracy of tissue evaporation, the MAYFIELD skull clamp, fixing the position of the patient head towards the operating table and experimental setup, has been applied. Moreover, while operating the hypopharynx, the rigid endoscope has been applied in addition to the MAYFIELD skull clamp. Thus, the mobility of the surgical field has been significantly reduced.

Figure 1. Experimental setup in work.
The experimental results demonstrate, that (i) in equal conditions, the impact of laser radiation on tissue *in vivo* sufficiently differs from the impact on tissue *in vitro*, which originates due the presence of blood flow in tissue *in vivo*; (ii) it is necessary to adjust the laser power to the particular type of tissue to achieve the desired surgical result; (iii) in case of operating the mucosa tissue, the surface should be treated 2 or even 3 time longer in comparison to the skin tissue to achieve equal blood stop effect (this is due to the increased blood supply to the mucosa).

4. Conclusion

In this work, the experimental setup of surgical system for minimally invasive ablation of biological tissues has been developed. This setup has been applied for studying the modes of automated laser destruction of tissues. The regimes of *in vitro* biological tissues evaporation using laser radiation with different parameters have been examined, and the optimal modalities have been determined.

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References

[1] Gerhardus D 2003 *J. of Healthcare Management* 48 242–251
[2] Melvin W S, Needleman B J, Krause K R and Ellison E C 2003 *J. of Laparoendoscopic & Advanced Surgical Techniques* 13 33–36
[3] Talamini M A, Chapman S, Horgan S and Melvin W S 2003 *Surgical Endoscopy* 17 1521–1524
[4] Ahmed K, Khan M S, Vats A, Nagpal K, Priest O, Patel V, Vecht J A, Ashrafian H et. al. 2009 *International Journal of Surgery* 7 431–440
[5] Kaufman R and Hibst R 1996 *Lasers Surg. Med.* 19 324–330
[6] Pozner J N and Goldberg D J 2000 *Dermatol Surg* 26 733–746
[7] Konovalov A N and Ul’yanov V A 2012 *Applied Optics* 51 3900-3906
[8] Kortunov V N, Dmitriev A K, Konovalov A N and Ul’yanov V A 2010 *Photodiagnosis and Photodynamic Therapy* 7 522