FOLIA MEDICA CRACOVIENSIA
Vol. LIII, 2, 2013: 23–34
PL ISSN 0015-5616

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GREEN FIBER LASERS IN UROLOGY

Abstract: We performed morphometric, scanning electron microscope and chemical studies of the working ends of KTP-green light laser fibers used in urology. The type and degree of damage depended on the amount of laser work. We proposed fiber recycling technology.

Key words: Green laser, KTP laser fibers, destruction.

INTRODUCTION

Currently, three types of lasers are used in urology: neodymium-yag laser (Nd: YAG), holmium laser (Ho:YAG) and KTP-green light laser (potassium-titanium-phosphorus, Nd: YAG frequency-doubled laser).

KTP lasers are also referred to as green light lasers. It is a Nd: YAG laser with a frequency doubling crystal. It is made of titanium, potassium, phosphate (KTP) with a wavelength of 532 nm which is in the range of visible light. The name of the laser comes from the color of the laser beam that is formed by passing a Nd: YAG laser beam through a KTP crystal. Green light is much more absorbed by living tissue than Nd: YAG light, it is not absorbed by water, but it is strongly absorbed by hemoglobin [1, 2].

The essence of each type of laser is light absorption by specific substances, thus releasing energy. A wavelength of 532 nm is best absorbed by dark pigments: hemoglobin in blood and melanin in the skin.

These properties make KTP lasers ideal for removal of vascular lesions or changes that contain dark pigment. The high absorption of KTP laser radiation in melanin allows for elimination of hyperpigmentation in different locations. This laser penetrates relatively easily in shallow blood vessels on the face and limbs. Absorbed by hemoglobin green laser beam causes micro damage and thus creates inflammation in the vessel and in adjacent tissues. This phenomenon at 40 W leads to closure of the vessel via coagulation.

Full power 80–120 W triggers vaporization of tissue [3, 4]. Green light laser surgery was pioneered by Malek from the Mayo Clinic [5, 6]. In Poland, the first operation using Green Light Laser was performed by Lipiński *et al.* and Jeromin *et al.* in 2003 [1, 2, 5].

Laser methods allow us to significantly reduce the risk during and after prostate surgery and post-resection syndromes [7, 8]. Kwinta *et al.*, using a KTP laser for routine prostate surgery did not record a single case of blood transfusion [9, 10], contrary to conventional operations [11].

The values of green laser energy per operation ranged from 17 000 to 352 000 J, and treatment time from 25 to 155 minutes. This was related primarily to the size of the prostate in cm^3 and its morphology. The gland with a predominance of collagen fibers that do not contain hemoglobin vaporizes less easily and slowly.

KTP lasers are also used in the process of photo-rejuvenation. Absorption of radiation in micro vessels releases heat into the adjacent tissues, especially those located in the deeper layers. This leads to overheating and an increase in collagen synthesis. We observe skin smoothing, elimination of wrinkles, removal of stains. The method of laser photo-rejuvenation is classified as non-invasive treatment.

Optical fibers are an integral part of lasers being responsible for the proper transmission of the beam from the generator to the surgical site. Optical fibers with their ends are the weakest link in the transmission of the laser beam energy. Fiber optics are constructed in such a way that the inner part of the light conductor is wrapped in a protective outer “armor”. At the end of the fiber there is a mirror changing the direction of the light and emitting the laser beam on the outside. It is an operating bundle (Fig. 1).

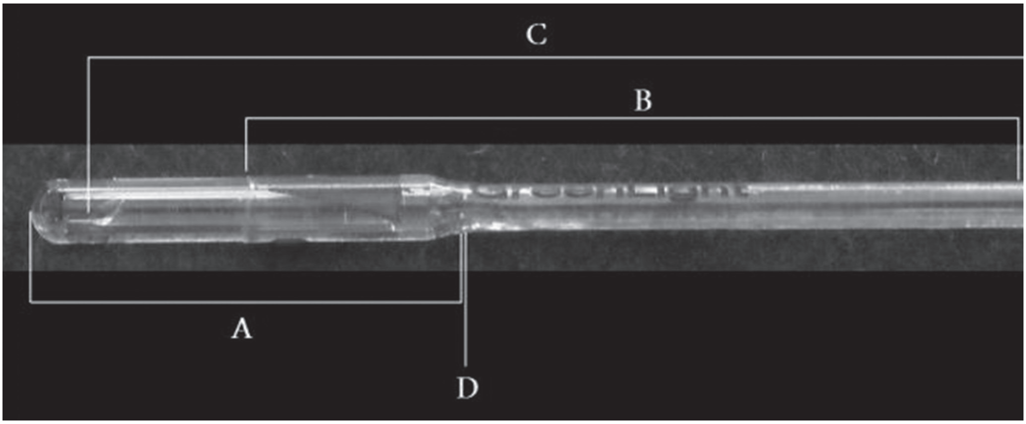

Fig. 1. Fragment of KTP laser fiber tips.

A — laser fiber tip in the middle is a cylindrical casing with a mirror embedded in the resin; B —manufacturer’s label; C — fibers embedded in the interior mirror reflecting the laser beam; D — connection site.

The aim of the present study was to investigate optical fibers and estimate damage to KTP laser fibers, as well as changes on fiber tips depending on duration of laser work and energy used. Attempts were made to find a relationship between the size of the degraded laser tip, fiber degradation and maximum laser working time.

The experimental section of the study consisted of two main parts: examinations of the KTP laser tips and their assessment after urological procedures.

METHODS AND MATERIALS

The experimental material was properly prepared for visual inspection (with the naked eye), examination under a digital microscope, after taking photos with a camera and scanning electron microscope. Microscopic images were used for measuring the shape of "craters" formed in fibers as a result of laser light interaction.

Scans of the craters and their surroundings were obtained and optical fiber reuse was proposed.

Material for testing consisted of 16 laser fibers. KTP laser is equipped with special, sterile, disposable (magnetic card operated) optical fibers. A mirror reflecting laser light beams at an angle of 70° is embedded in the cylindrical fiber tips. In this way the laser beam is diffracted and dispersed in the operating field.

A total of 16 fibers were tested. Operation time was determined for 12 fibers whereas in the case of four fibers operation time remained undefined.

Fibers were provided by the St. John Grande Hospital of The Merciful Brothers' Order in Krakow, where photoselective vaporization of the prostate (PVP) had been performed since June 2006.

RESULTS

Parameters A and B of the fibers shown in Photo 1 i.e. shape of fiber ends differ between samples (Table 1, Fig. 2).

Fiber dimensions shown in Photo 1.

Measurements of the "crater", which is formed by laser light in the optical fiber according to the diagram shown in Photo 1.

Parameters C, D (Photo 2) as well as E and F show variations of the crater formed due to work of this element (Table 2, Fig. 3, 4).

Measurements are summarized in Table 2 and depicted in Fig. 3–6.

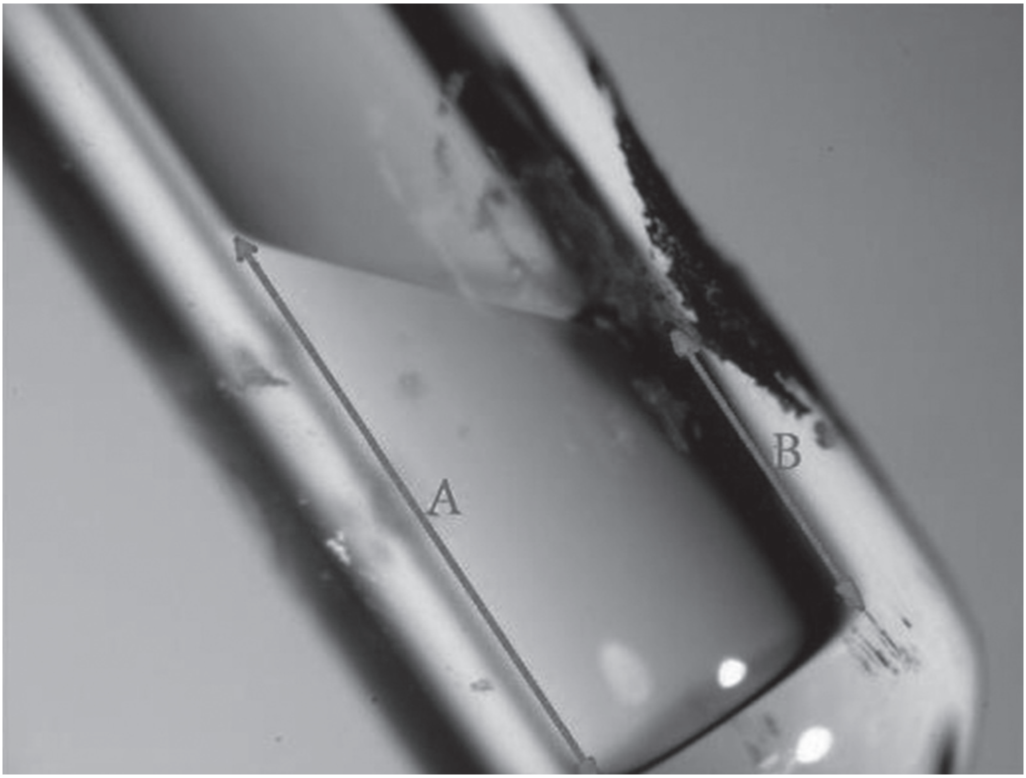

Photo 1. Magnified image of the fiber end with the mirror (Angled); A, B — dimensions of the fiber tip given in Table 1.

Table 1

Fiber dimensions shown in Photo 1.

Parameters A and B (µm)			Parameters A and B (µm)		
Blank — no data			Blank — no data		
Sample No.	A	B	Sample No.	A	B
1	1706	472	9	1579	668
2	1534	560	10	2018	1054
3			11	1989	1987
4			12		
5			13		
6	1682	601	14	1474	581
7	1587	673	15	1593	794
8	1619	676	16	1561	746

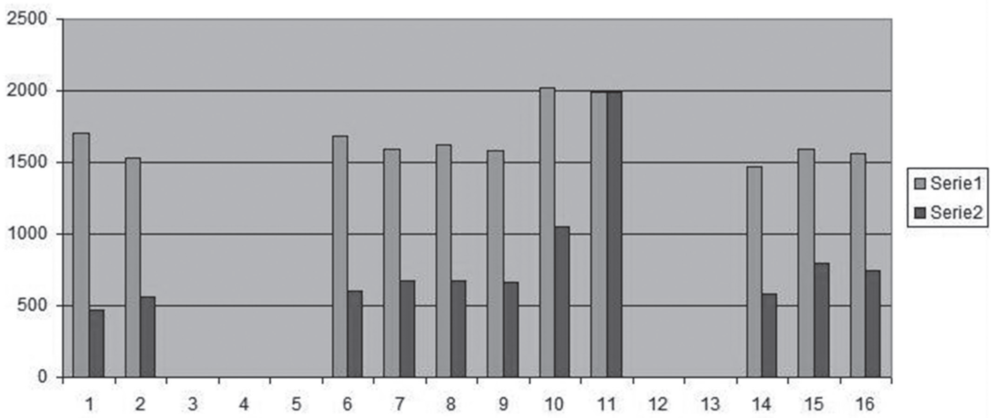

Fig. 2. Size parameters A, B (μm) — see Photo 1 (1–16 fibers) Series 1 — dimension A, Series 2 — dimension B.

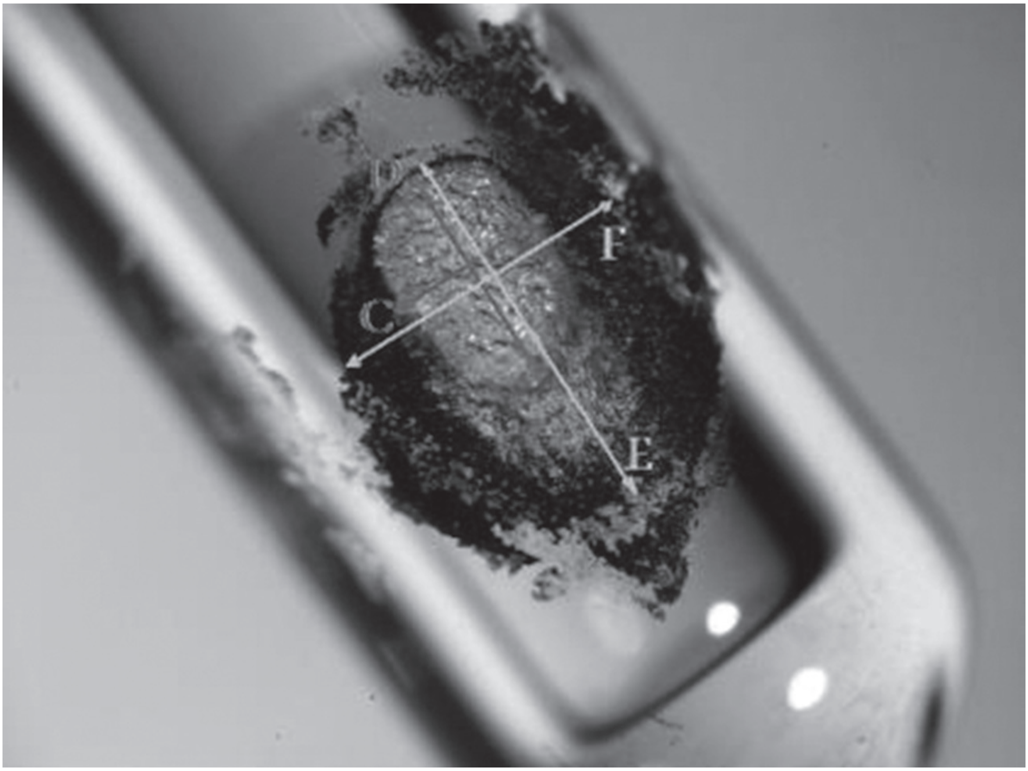

Photo 2. “Crater” in one of the fibers. Measurements of “crater” axes. Axes C, D — smaller inner part of the “crater”; E, F — greater external part of the “crater”. Digital microscope.

Table 2

Size of “craters” in the test fiber (μm) (Blanks — fiber mirrors are destroyed)				
	axis			
Sample No.	crater pcs.	internal	crater-part.	outside
	C axis	D axis	E axis	F axis
1	623	385	1500	1078
2	737	549	1448	1322
3				
4				
5				
6	671	419	2779	1759
7	806	453	2050	1751
8	646	530	1197	1128
9	626	486	2109	1488
10	872	874	1223	1061
11	807	515	1285	1057
12				
13				
14	743	497	1919	1424
15	676	460	1615	1865
16	665	458	2256	1255

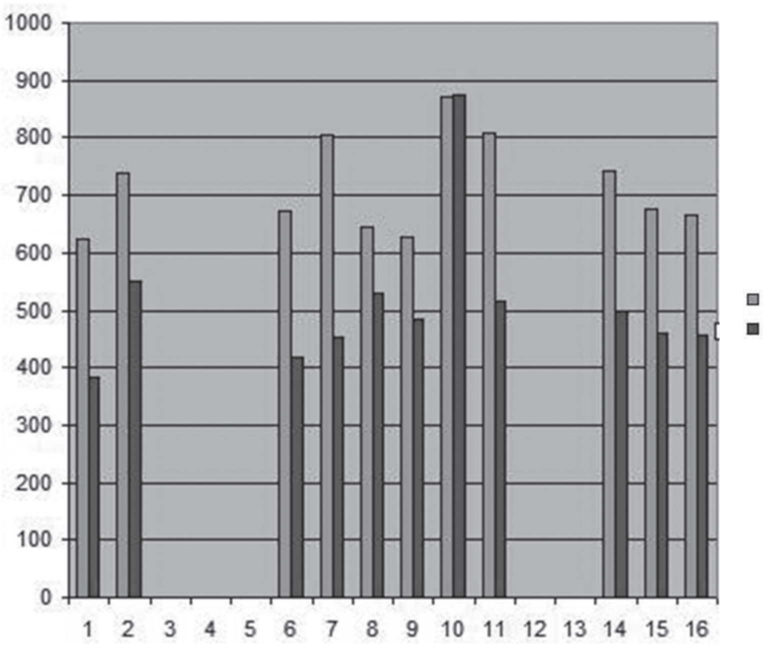

Fig. 3. Parameters C and D (μm) — see the lower part of Photo 2 “craters” test fiber (1–16). Blue column — type C, maroon column — D dimension.

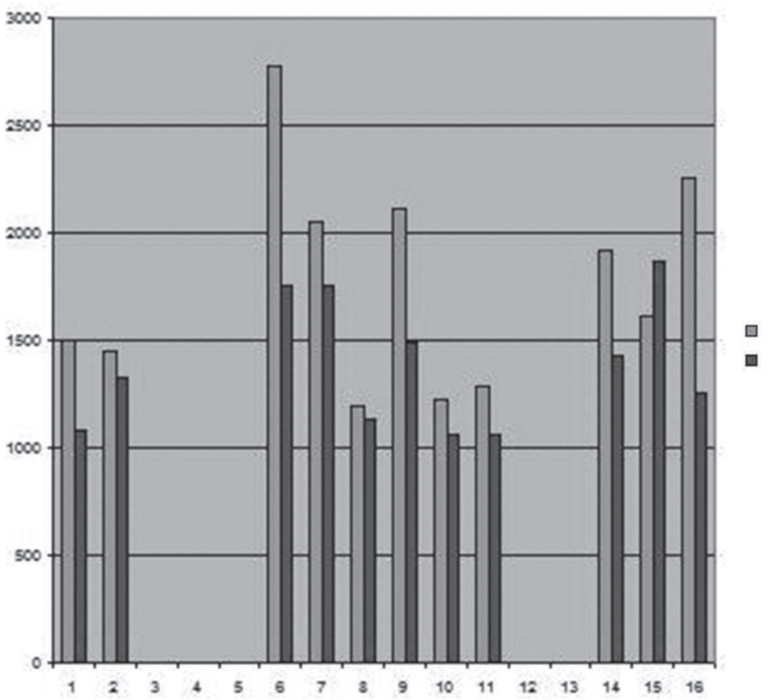

Fig. 4. Parameters E and F (µm) — see the upper part of Photo 2 "craters" test fiber (1–16). Blue column — size E, column maroon — dimension F.

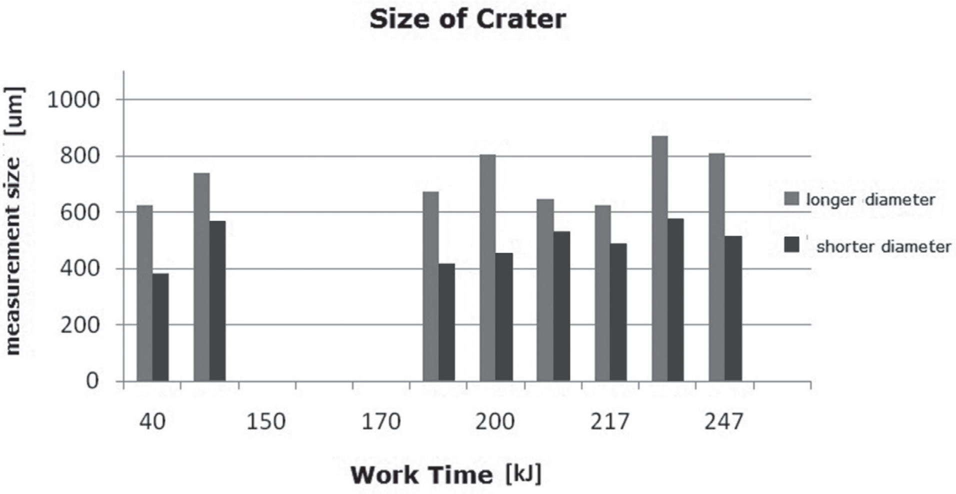

Fig. 5. The graph showing the size of the bottom of the "crater" (µm) in the analyzed fiber depending on the operation of the laser (KJ). Longer diameter —diameter C, shorter diameter — diameter D (see Photo 2).

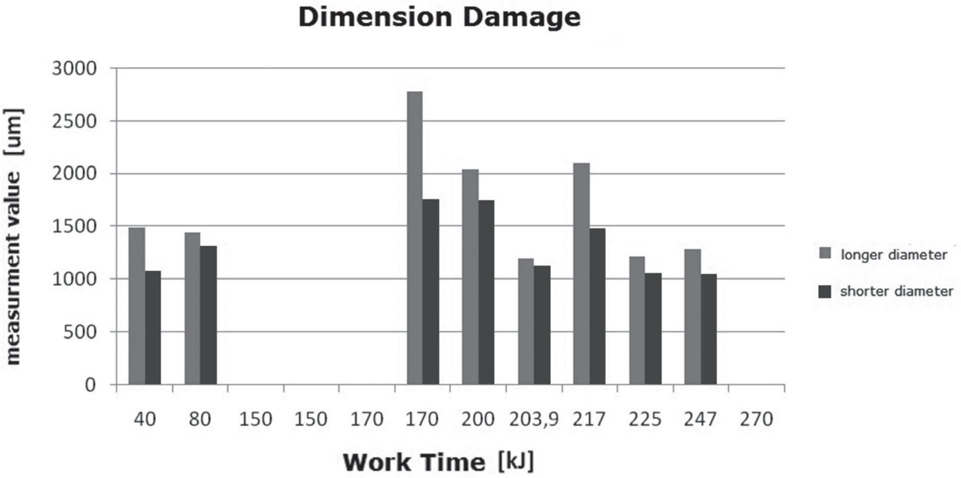

Fig. 6. Size of the "crater" top (µm) in the analyzed fiber depending on the operation of the laser (KJ). Longer diameter — diameter E, shorter diameter — diameter F (see Photo 2).

MORPHOLOGY OF "CRATERS"

Both measurements and microscopic findings confirmed the relationship between the degree of fiber tip destruction and laser working time calculated in KJ. The destruction did not go hand in hand with the size of the crater, but rather with the degree of build-up on the tip (Photos 3–6).There was no relationship between the layer of coal deposited on the crater with its surroundings and laser working time. It seems that apart from working time and the amount of the emitted energy, the type of operation and degree of intraoperative bleeding, partly coagulated by the laser beam, has a significant effect on the degree of damage to the tip. Coagulated blood is the main factor contributing to the formation of carbon shell around the "crater".

Electron microscopic findings show that the laser beam causes the melting of the plastic fiber. The melting occurring in the interior of the crater results in profound changes in the structure of the polymer in fibers working for a shorter time (Photo 7A) with the melting reaching the surface of the mirror (Photo 7B).

Chemical analysis of the surface of the "craters" using an EDS shows that it is covered with various materials (Photo 7), which apart from oxygen contain Na, S, P, C, and other elements (Fig. 7). They are derivative substances resulting from the transformation of tissues and tissue fluids under the influence of laser light. The phase identification is impossible at this stage of the study due to a small amount of test material.

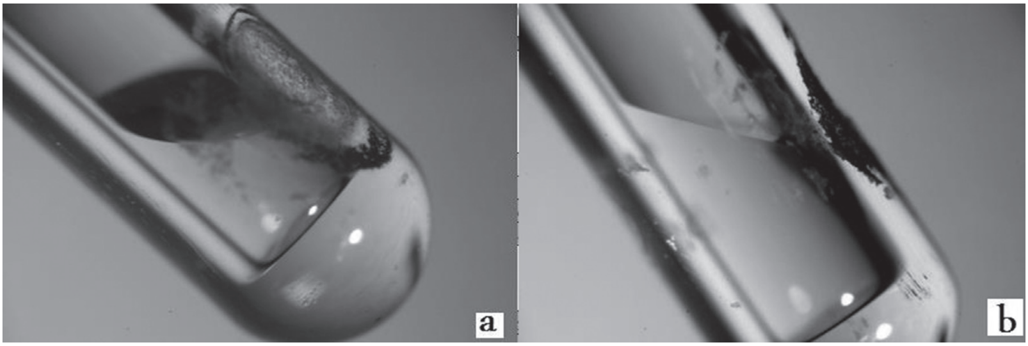

Photo 3. Fiber (Sample 1) — 40 KJ laser work. (a) Crater visible in the lateral section; (b) 10 × magnification

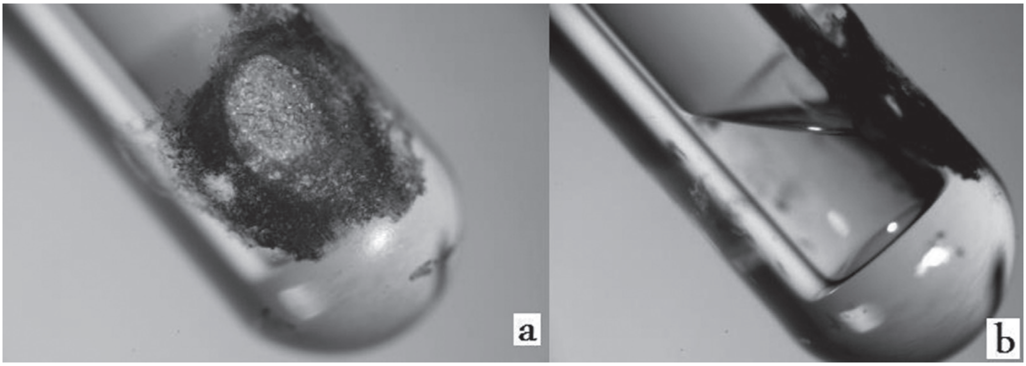

Photo 4. Fiber (Sample 2) — work 80 KJ. (a) Laser crater in frontal and lateral section; (b) 10 × magnification

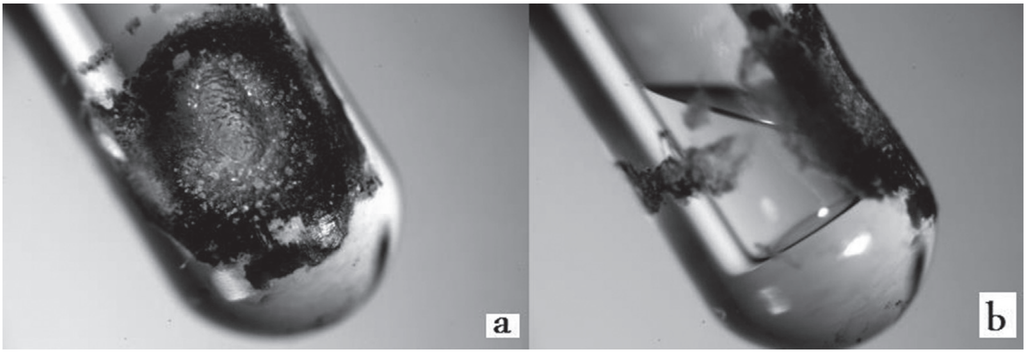

Photo 5. Fiber (Sample 6) — 170 kJ laser operation. (a) Crater visible in frontal and lateral section; (b) 10 × magnification.

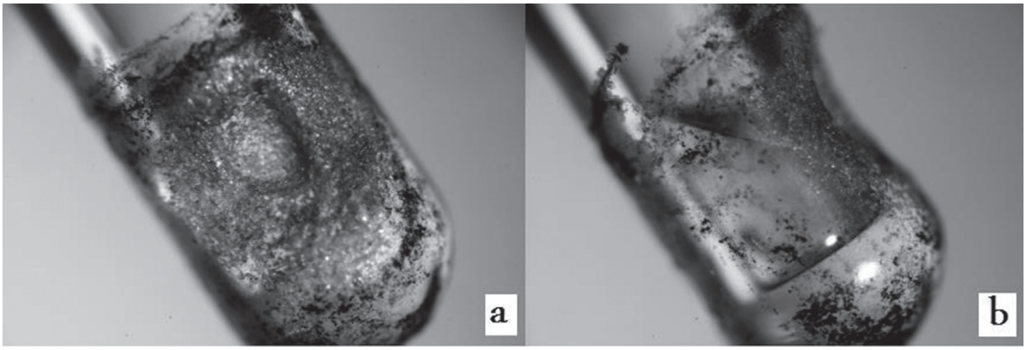

Photo 6. Fiber (Sample 9) — 217 kJ laser operation. (a) Crater visible in frontal and lateral section; (b) 10 × magnification.

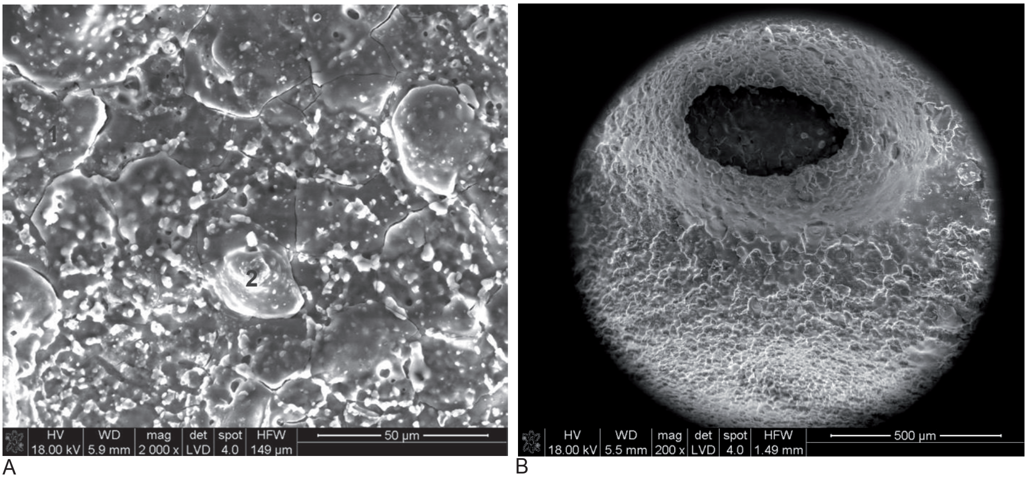

Photo 7. Microscopic images of destroyed polymer fiber ends. A — molten surface morphology of the fiber in the “outgoing” laser beam. 40 KJ laser work; B — melting of the polymer to the surface of the mirror in the optical fiber working for 225 KJ.

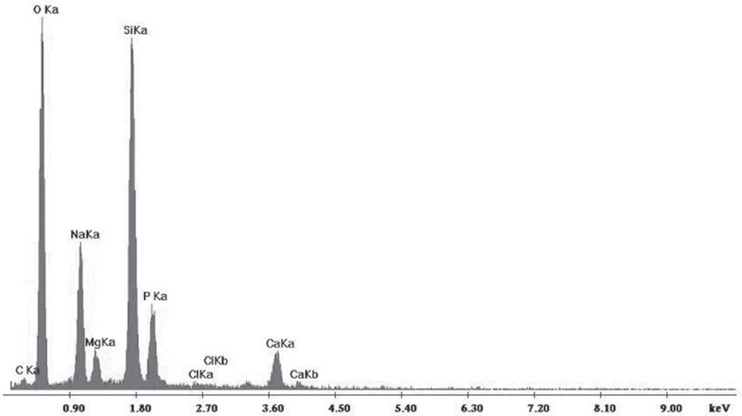

Fig. 7. EDS spectrum of substances covering the “crater” area in sample 16.

ATTEMPTS TO RENOVATE OPTICAL FIBER

Due to high costs of optical fibers an attempt was made to renovate them. The outer “shell” of the fiber was cut in order to rotate it around its long axis and slide the intact part of the shell over the mirror. Unfortunately, despite many attempts, the procedure failed.

DISCUSSION

In Poland Green Light Laser KTP was first used for prostate surgery in 2003, but only in some hospitals [1, 2, 7]. The operations of prostate glands in St. John Grande Hospital of The Merciful Brothers’ Order in Krakow have been performed since 2006 [6, 11]. The introduction of new surgical technologies and their evaluation is possible due to scientific collaboration with a technical university i.e. AGH — University of Science and Technology in Krakow.

The study confirmed the strong relationship between the degree of destruction of the fiber tips and laser work defined in KJ. Our results are consistent with the results of Malek *et al.* [12] and Różański *et al.* [13]. Laboratory findings confirmed the clinical observations that direct contact of tissues and blood with the operating fiber leads to rapid fiber wear. The destructed and broken plastic casing of the mirror causes aberration and scatter of the laser beam. It can be dangerous because accidental vaporization of healthy tissues may occur. It is also important for the safety of both the patient and the medical staff. Our results confirm the experience of other health centers that fiber conducting laser light from laser to ailing tissues is the most used up part of the system [14]. For this reason damaged fibers with a big crater-shape defect of the mirror have to be changed for patient safety even during the operation.

CONCLUSIONS

1. KTP laser fibers wear out during work.
2. Damage to the plastic casing forms a crater on the mirror fiber.
3. Optimally, optical fibers should not be in direct contact with tissue and blood.
4. For cost reasons, it is essential especially in the beginning of the operation, although it may be difficult because of anatomical conditions.
5. If the plastic shell covering the mirror melts and there is beam aberration, the fiber should be replaced for safety reasons.

ACKNOWLEDGMENTS

The study was supported by a grant from the AGH no 11.11.140.319.

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