



# Impact of different color fiber sleeves on beam hazards of 532-nm laser and vaporization efficiency

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## Abstract

The 532-nm laser has become increasingly popular for the treatment of urologic diseases. However, laser beam will pose significant hazards for the health of surgeons. In order to reduce beam hazards during surgery, we compared the beam hazards of laser fiber with black sleeves to the traditional fiber with transparent sleeves, and the vaporization efficiency. A total of 18 porcine kidney specimens were vaporized in normal saline at a room temperature under 532-nm laser delivered through a 760- $\mu\text{m}$  core diameter side firing fiber. Two groups were divided according to the color of fiber sleeves: the transparent and the black. Each group was then divided into another three subgroups by laser power: the 80 W group, the 120 W group, and the 160 W group. The beam hazard was evaluated by light intensity measured in a sector area at a distance of 0 m, 0.5 m, and 1 m from the irradiation center. The vaporization efficiency was measured by the vaporization groove depth under the working power of 80 W, 120 W, and 160 W with a working distance of 5 mm and irradiation time of 10 s. The light intensity measured in the black fiber sleeve group is significantly lower than that in the transparent one ( $P < 0.01$ ), regardless of the measuring distance (0 m, 0.5 m, and 1.0 m) and laser power (80 W, 120 W, and 160 W). No statistical difference was found on the vaporization efficiency between the groups protected by fiber sleeves of different colors (transparent/black,  $p > 0.05$ ). Compared to the traditional transparent fiber sleeves, more beam hazards will be reduced in the operative region with the protection of black fiber sleeves, especially those from the irradiation center. The vaporization efficiency is not affected by the color of fiber sleeves. Such findings may offer a completely new idea for the protection of surgeons in surgeries with 532-nm lasers.

**Keywords** Lasers · Safety · Laser therapy · Photoselective vaporization of prostate (PVP) · Efficiency

## Introduction

The 532-nm laser has become increasingly popular for the treatment of urologic diseases, like benign prostatic hyperplasia (BPH), bladder tumors, and urinary tract strictures for the past decades. However, laser beam could pose significant hazards for the health of surgeons [1].

The 532-nm laser is made of titanium, potassium, phosphate (KTP), or lithium triborate (LBO) and is within the

range of visible green light. The energy of laser beam is selectively absorbed by hemoglobin, but not water with its penetration depth of 0.8 mm and a coagulation zone limited to 1–2 mm, which leads to a more focused and effective vaporization [2–4]. It has been proved that photoselective vaporization of prostate (PVP) has a high degree of intra- and perioperative safety and is comparable to transurethral resection of the prostate (TURP) in terms of the voiding parameter improvement, with even shorter length of catheterization and hospital stay [5–9]. PVP has become an even more popular procedure around the world after the higher power laser came into use [10, 11].

Every surgeon must wear appropriate eye protection to avoid severe eye injuries during a laser surgery. We notice, however, there will be much laser light “escaping” from the fiber on its way delivered to the operating zone. We hypothesized that we could reduce such potential damages by changing the color of fiber sleeves.

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In this study, we compared the beam hazards of 532-nm laser delivered through fibers protected by black sleeves to traditional transparent sleeves, and investigated the effects on vaporization efficiency.

## Materials and methods

A total of 18 cortex specimens were isolated from fresh porcine kidneys for our study. No ethical committee approval was needed since we used cadaveric tissue. The kidney cortex was vaporized in a custom-made box where specimens were fixed with a tissue holder and all tissues were submerged in normal saline at a room temperature (Fig. 1).

A PVP-160 green light system (Realton Corp., Beijing, China) was used for emitting 532-nm laser. Laser beam was delivered through a 760- $\mu\text{m}$  core diameter side firing fiber. The fiber sleeve was specially made with its color of transparent and black. The fiber was held in a fiber holder and went into the box through a hole reserved on the side.

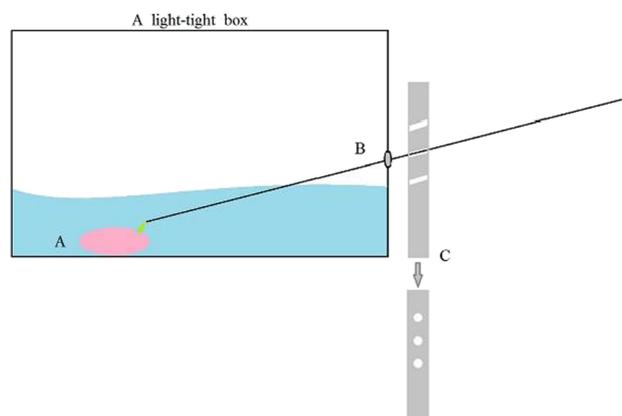
Two groups were divided according to the color of fiber sleeves: the transparent and the black. Each group was then divided into another three subgroups by laser power: the 80 W group, the 120 W group, and the 160 W group. The beam hazard was evaluated by the light intensity measured with a digital lux meter (Sanpometer® LX1010B) in a sector area at a distance of 0 m, 0.5 m, and 1 m from the irradiation center and recorded at the time of the 5th, 10th, 30th, 60th, and 120th second. The vaporization efficiency was measured by the groove depth (cortex of porcine kidney) under the laser power of 80 W, 120 W, and 160 W, with a working distance of 5 mm and irradiation time of 10 s. The specimens were then fixed in formalin, cut into thin slices, and stained. The vaporization groove depth was measured under microscope (Fig. 2).

Statistical analysis was done using the two-sample *t* test with  $p < 0.05$  considered significant.

## Results

Figure 3 shows that the light intensity measured at different distances under the laser power of 80 W, 120 W, and 160 W. When measured at a distance of 0 m, the light intensity was  $154.8 \pm 3.9$  lx and  $13.0 \pm 0.0$  lx (laser power, 80 W; transparent and black fibers, respectively;  $P < 0.01$ ),  $166.5 \pm 6.5$  lx and  $14.3 \pm 0.4$  lx (laser power, 120 W; transparent and black fibers, respectively;  $P < 0.01$ ), and  $144.8 \pm 4.4$  lx and  $14.2 \pm 0.8$  lx (laser power, 160 W; transparent and black fibers, respectively;  $P < 0.01$ ). When measured at a distance of 0.5 m, the light intensity was  $27.4 \pm 1.5$  lx and  $2.0 \pm 0.0$  lx (laser power, 80 W; transparent and black fibers, respectively;  $P < 0.01$ ),  $52.4 \pm 1.1$  lx and  $2.0 \pm 0.0$  lx (laser power, 120 W; white and black fibers, respectively;  $P < 0.01$ ), and  $83 \pm 2.3$  lx and  $2.0 \pm 0.0$  lx (laser power, 160 W; transparent and black fibers, respectively;  $P < 0.01$ ). When measured at a distance of 1.0 m, the light intensity was  $8.0 \pm 0.0$  lx and  $1.0 \pm 0.0$  lx (laser power, 80 W; transparent and black fibers, respectively;  $P < 0.01$ ),  $12.4 \pm 0.4$  lx and  $1.0 \pm 0.0$  lx (laser power, 120 W; transparent and black fibers, respectively;  $P < 0.01$ ), and  $15.6 \pm 0.8$  lx and  $1.0 \pm 0.0$  lx (laser power, 160 W; transparent and black fibers, respectively;  $P < 0.01$ ). The light intensity measured in the black fiber sleeve group is significantly lower than that in the transparent one ( $P < 0.01$ ), regardless of the measuring distance and laser power. The light intensity at the irradiation center is the strongest. When distance from the irradiation center increased, the light intensity weakened and the difference between the transparent and black fiber groups narrowed as well.

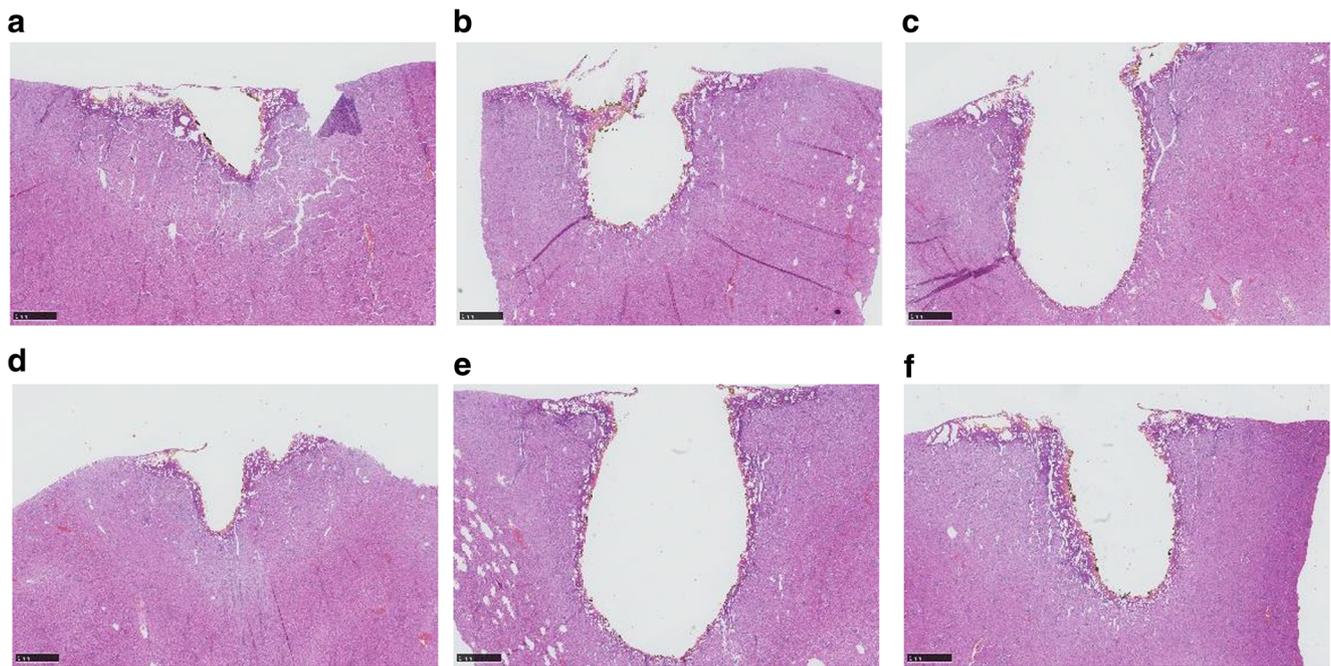
Table 1 and Fig. 4 show that when operated under the same power, the sleeve color does not have a significant effect on the vaporization efficiency ( $P > 0.05$ ). Vaporization efficiency



**Fig. 1** A custom-made device for the procedure. The kidney specimens were vaporized in a custom-made light-tight box and fixed with (A) a tissue holder. The laser fiber went into the box through the (B) hole



reserved on the side and was held in a (C) fiber holder. All procedures were done with the tissue and fiber submerged in normal saline



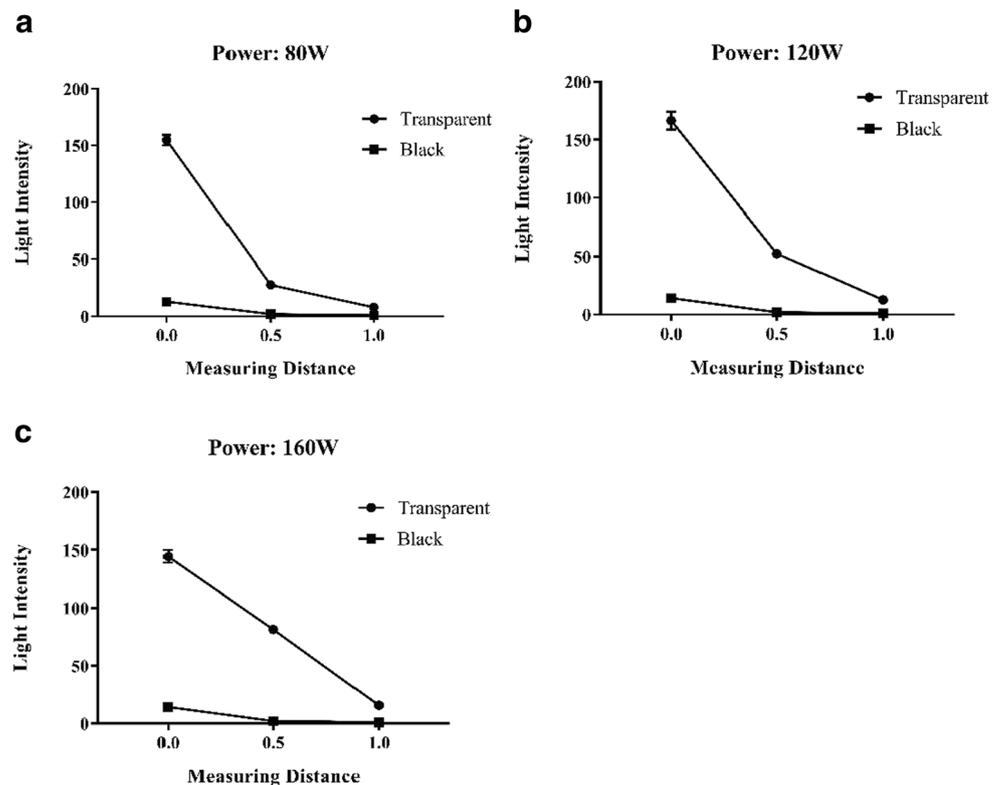
**Fig. 2** Histological images of cortex slices after vaporization. **a** 80 W (T). **b** 120 W (T). **c** 160 W (T). **d** 80 W (B). **e** 120 W (B). **f** 160 W (B). T, transparent fiber sleeve; B, black fiber sleeve

will be higher when laser power is turned from 80 to 120 W ( $P < 0.01$ ) or 160 W ( $P < 0.01$ ); however, no statistical difference was found between the 120 and 160 W groups ( $P > 0.05$ ).

## Discussion

The 532-nm laser has been more and more popular in the treatment of urologic diseases for its even better efficacy,

**Fig. 3** Light intensity measured at different distances. **a** Light intensity measured at different distances when protected by different color sleeves under the laser power of 80 W. **b** and **c** were measured under the power of 120 W and 160 W, respectively. Please check if figure captions are captured and presented correctly. There's something wrong with the caption of Fig. 1 and it should be corrected as what I comment below Fig. 1. Other figure captions are all captured and presented correctly.



**Table 1** The vaporization groove depth of each subgroup

Power	Depth (transparent; mm)	Depth (black; mm)	<i>P</i> value
80 W	3.4 ± 0.4	3.1 ± 0.3	<i>P</i> > 0.05
120 W	4.1 ± 0.5	5.8 ± 1.6	<i>P</i> > 0.05
160 W	5.8 ± 1.6	4.7 ± 1.3	<i>P</i> > 0.05

efficiency, and safety, especially for BPH. A 532-nm laser based PVP is very promising to be an alternative to TURP [2, 3, 11–13]. However, laser beam could pose significant hazards for the health of surgeons.

Ocular injury is a very serious complication arising from the use of lasers. Generally, wavelengths in the ultraviolet (200–400 nm), mid-infrared (1400–3000 nm), and far-infrared (3000–10,600 nm) regions are primarily absorbed by the anterior segment of the eye (cornea and lens) while wavelengths in visible (400–760 nm) and near-infrared (760–1400 nm) regions are mostly absorbed by the posterior segment (retina and vascular choroid) [14].

To better understand beam hazards and laser protection, one must first understand two basic concepts, which is maximum permissible exposure (MPE) and the nominal hazard zone (NHZ). MPE is the amount of laser radiation to which a person may be exposed without damage to the eye or skin. The NHZ means the space in which the level of direct, reflected, or scattered radiation exceeds the MPE and identifies the space where safety measures are required. For simplicity, it could be defined as the entire operating room [15]. Obviously, radiation must be controlled under MPE to keep one's safety. And to do that, we need to keep the radiation in NHZ to the least.

Currently, an operator's protection mainly comes from the laser protective eyewear, which could reduce laser beam going into the operator's eyes. However, there will be actually much light "escaping" from the fiber on its way delivered to the

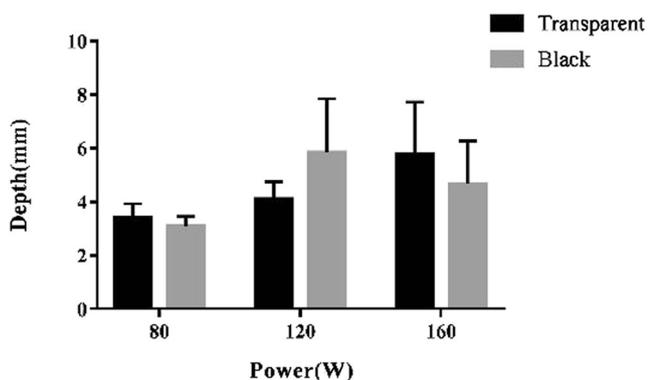
operating zone and the operating room will always be "green" during a 532-nm laser surgery. The eyewear cannot cut down the intensity mentioned above which should also be calculated in NHZ and may pose potential hazards as well. So we need to further reduce light intensity in NHZ to make radiation even lower.

In our study, we chose points 0, 0.5, and 1.0 m from the irradiation center for measurement, as the operator is usually within 1.0 m from the operating center during a laser surgery. When measured at different distances, the light intensity in the black sleeve group was significantly lower than that in the transparent sleeve group under a same laser power (80 W, 120 W, and 160 W; *P* < 0.01). The light intensity weakened when the measuring location got away from the irradiation center, and so was the difference between the transparent and black sleeve groups, however, it was still statistically significant. We consider the black sleeve could block more laser beam than the transparent one, especially beam from the irradiation center. When combined with protective eyewear, we could not only reduce beam going into the operator's eyes directly, but also reduce the total radiation in NHZ.

We estimate the vaporization efficiency with the groove depth, under the same laser power with a working distance of 5 mm and irradiation time of 10 s. The results showed that the vaporization efficiency was not affected by sleeve colors. Higher power brought higher efficiency until it reached a saturation. No statistical difference was found between the 120 and 160 W groups (*P* > 0.05), partially associated with beam divergence and limited absorption characteristics of targeting tissue, which is consistent with results in previous studies [8, 16, 17].

Laser beam from the monitor will also add the radiation during a laser surgery. In our study, we did not use an endoscope or a monitor for the purpose to simplify procedures but measured intensity of laser beam coming out of the light-tight box to estimate the intensity from the monitor, which could be a limitation.

#### Vaporization efficiency and sleeve colors



**Fig. 4** Effect of sleeve color on vaporization groove depth

#### Conclusion

Compared to the traditional transparent fiber sleeves, more beam hazards will be reduced in operative region with the protection of black fiber sleeves, especially those from the irradiation center. Vaporization efficiency is not affected by the color of fiber sleeves. Such findings may offer a completely new idea for the protection of surgeons in surgeries with 532-nm lasers.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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