Ablation of Gastrointestinal Tumors by Nd-YAG Laser (1064 nm) Using Polymer Optical Fiber (POF) Based Endoscope

Debadyoti Ghosh
Electronics and Communication Engineering Department
Institute of Engineering and Management
Kolkata, India
debadyoti@gmail.com

Abstract—**Endoscopic diagnosis relies on the ability of the operator to visualize abnormal patterns in the image created by light reflected from the mucosal surface of the gastrointestinal tract. This paper is concerned with the endoscopic Nd: YAG laser (wavelength 1064 nm) ablation technique that has been applied for removing the gastrointestinal tumors. Near infrared (NIR) wavelengths are ideally suited for soft tissues due to their high absorption in hemoglobin. Thus NIR laser is able to ablate the target tissue very precisely & efficiently. The neodymium YAG laser at a wavelength of 1064nm produces near infrared light. The laser transmission through flexible optical fiber which can also pass easily through the tube of endoscope can be used as a tool to ablate the GI tumors. The guided laser enables an easy control. The tissues may ablate only to the direction of the fiber axis.**

Keywords- Nd:YAG laser, pulsed mode (or Q switching mode), laser pumping, polymer optical fiber.

I. INTRODUCTION

Ablation of tumor using heat is a minimally invasive surgical method to treat solid cancers. For this, special probes are used to burn cancer cells without usual surgery. Computed Tomography (CT), Ultrasound (US) or Magnetic Resonance Imaging (MRI) is used to guide and position the needle probe into the tumor. When the probe comes closer to the tumor cell, it is attached to a generator which burns the tumor. Thus image-guided ablation of tumors is an important technique used in many oncology services as an alternative to conventional surgery for those patients who are not in condition for surgery. In modern days, endoscopic laser ablation technology has become more popular which is used very successfully. High-power laser is delivered to the target area using endoscope. When coherent laser energy, interacts with tissue, it is absorbed. It depends on the wavelength of the applied laser. Each wavelength has different depth of tissue penetration. When laser energy is absorbed it is converted into heat and increases tissue temperature which destroy the cancerous cells. The entire procedure is visible endoscopically.

II. ND:YAG LASER AS A SURGICAL TOOL

Laser surgery is the surgery where instead of a scalpel laser is used to cut or damage cancerous tissue. There are many different types of lasers used in medical surgery. The most popular types of lasers used in surgery include the carbon dioxide, neodymium: YAG, pulsed dye and argon lasers.

The table.1 shows some of the continuous lasers that can be used in surgery:

TABLE.1

Laser	*Wavelength (nm)*	*Power (W)*	*Fiber Transmission*
CO_2	10600	0.5 -50	No
Nd-YAG	1064	0.5 -100	Yes
Argon	488 or 514	1 - 10	Yes
Dye	Tunable	0.05 - 5	Yes

The table.2 shows some of the pulsed lasers that can be used in surgery:

TABLE.2

Laser	*Wavelen-gth (μm)*	*Pulse durat-ion*	*Energy/ Pulse(J)*	*Fiber Transmissi on*
Nd: YAG (QS)	1.064	ns	0.1 - 1	No
Nd: YAG	1.064	μ s	0.1 - 1	Yes
Dye	0.39 - 0.44	μ s	0.01 - 0.1	Yes
Excimer	0.353	n s	0.01 - 0.1	Yes

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Gastroenterology is one of the major domains in medical surgery where Nd:YAG laser is used. The application of other lasers such as the Argon laser was also investigated, but was not associated with any significant advantages so far. The CO_2 laser is not suitable for clinical gastroenterology, since it is not transmitted through optical fibers of endoscope. Nd: YAG laser (wavelength 1064 nm) is the most important surgical laser which can be applied inside the body through endoscope. It can travel through optical fibers, which can be bent and placed into a tumor to destroy it. The Nd: YAG laser is mostly known for its large optical penetration depth (as shown in figure.1).

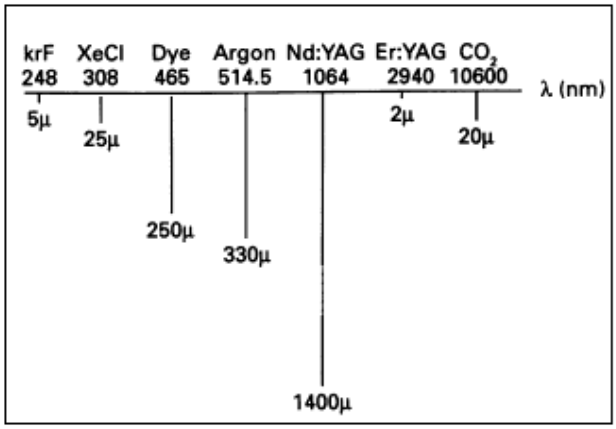

Figure 1. Penetration depths of different lasers.

III. Details of The Experiment

Neodymium yttrium aluminum garnet (Nd:YAG) is a host medium. Nd:YAG is a four-level gain medium (except for the 946-nm transition as discussed in figure.2), offering substantial laser gain. The gain bandwidth is relatively small, but it gives high gain efficiency and thus low threshold pump power.

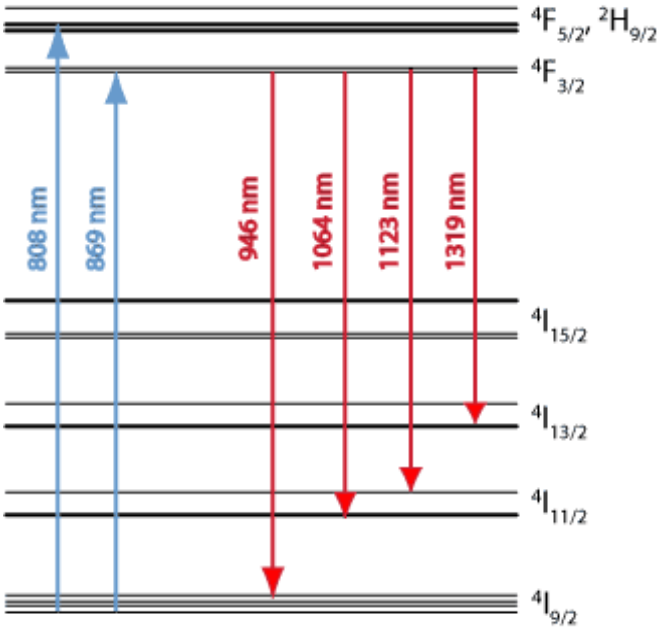

Figure 2. Energy level structure and common pump and laser transitions of the trivalent neodymium ion in Nd^{3+}: YAG.

Nd:YAG lasers typically emit light near infrared with a wavelength of 1064 nm. The Nd:YAG laser is a solid state laser where the medium is a rod of Yttrium-Aluminum-Garnet doped with Neodymium. This glass like rod is excited by pumping. The laser can be operated in both pulsed and continuous mode. Here we have used pulsed mode. This pulsed Nd:YAG laser is operated in Q-switching mode. It is an optical switch inserted in the laser cavity waiting for a maximum population inversion in the neodymium ions before it opens. Then the light wave can move through the cavity, depopulating the excited laser medium at maximum population inversion. Q switching of diode-pumped laser has been used in this experiment for generating pulses of relatively large energies. Q switching is a technique for obtaining energetic short pulses from a laser by modulating the intra-cavity losses and thus the Q factor of the laser resonator. The resulting laser light beam has been transferred to the point of use through flexible optical fiber. This technique is mainly used for the generation of nanosecond pulses of high energy as well as high power.

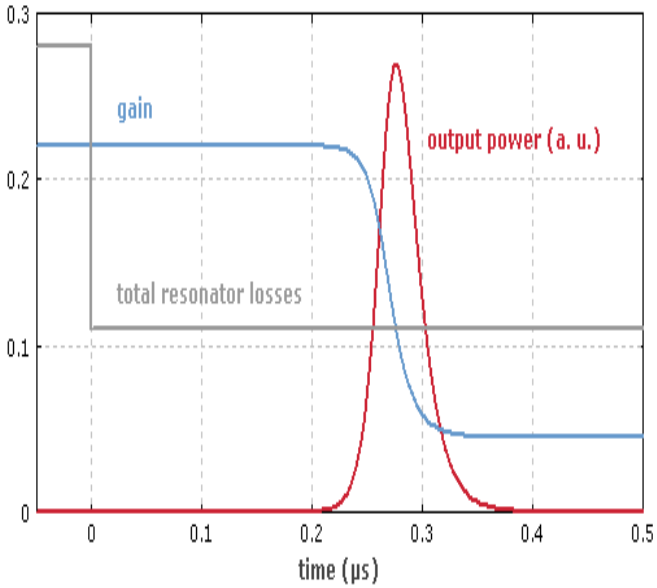

Figure 3. The Q switch is activated at t = 0. The power starts to rise exponentially at this point, but becomes high only after ≈ 0.2 μs.

IV. Polymer Optical Fiber Used

For this experiment multimode graded-index polymer optical fiber doped with a mixture of Rhodamine 6G (Rh 6G) and Rhodamine B (Rh B) dyes is used which is easily passed through the tube of endoscope. The Nd:YAG laser (1064nm) is transmitted through it and come in contact with the tumor. New developments in polymer fiber optic tips have provided with greater flexibility, decreased size, and reduced cost.

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V. RESULTS & DISCUSSION

With this arrangement we are able to couple 93% of the light from the diodes into the Nd:YAG laser rod. In this Q-switched mode, output power (of 60W to 120W) is transmitted through 600um optical fiber which is passed through the biopsy channel of the endoscope. This technique is curative in 95% of 20 cases of GI cancer.

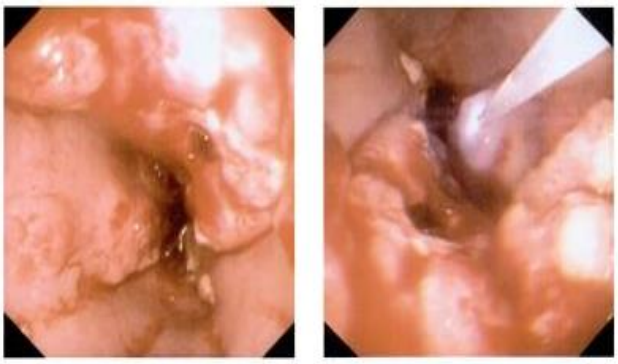

Figure 4. Nd:YAG treatment in GI tumor.

VI. CONCLUSIONS

In this paper we have shown the ablation of GI tumor using polymer optical fiber based endoscope with Nd:YAG laser that may be applied successfully. On account of the high penetration depth in tissue and the possibility of transmitting its radiation through optical fibers, the Nd:YAG laser can be applied universally. Further research works, however, may add a new feather to the endoscopic surgery in future.

REFERENCES

[1] J. E. Geusic *et al.*, "Laser oscillations in Nd-doped yttrium aluminum, yttrium gallium and gadolinium garnets", Appl. Phys. Lett. 4 (10), 182 (1964).

[2] D. Y. Shen *et al.*, "Highly efficient in-band pumped Er:YAG laser with 60 W of output at 1645 nm", Opt. Lett. 31 (6), 754 (2006).

[3] J. W. Kim *et al.*, "Fiber-laser-pumped Er:YAG lasers", IEEE Sel. Top. Quantum Electron. 15 (2), 361 (2009).

[4] Li Chaoyang *et al.*, "106.5 W high beam quality diode-side-pumped Nd:YAG laser at 1123 nm", Opt. Express 18 (8), 7923 (2010).

[5] X. Délen *et al.*, "34 W continuous wave Nd:YAG single crystal fiber laser emitting at 946 nm", Appl. Phys. B 104 (1), 1 (2011).

[6] All-Solid-State Nd:YAG Laser Operating at 1064 nm and 1319 nm under 885 nm Thermally Boosted Pumping. Ding Xin1,2, Chen Na1,2, Sheng Quan1,2, Yu Xuan-Yi3, Xu Xiao-Yan1,2, Wen Wu-Qi1,2, Zhou Rui1,2, Wang Peng1,2 and Yao Jian-Quan1,2

[7] **"**Nd:YAG Laser Procedures in Tumor Treatment". Carsten M. Philipp, MD, Ewa Rohde, MD. and H.-Peter Berlien, MD from the department of Laser Medicine, University Clinic Benjamin Franklin, Berlin, Germany.

[8] "Q switching of a diode-pumped Nd:YAG laser with GaAs", T. T. Kajava* and Alexander L. Gaeta, School of Applied and Engineering Physics, Cornell University,Ithaca, New York 14853,Received February 20, 1996.

[9] Berci G, Forde KA. History of endoscopy: what lessons have we learned from the past? Surg Endosc. 2000;14(1):5–15. [PubMed].

[10] Sivak MV. Gastrointestinal endoscopy: past and future. Gut. 2006;55(8):1061–4. [PMC free article] [PubMed].

[11] Kodama T, Tatsumi Y, Sato H, Imamura Y, Koshitani T, Abe M, Kato K, Uehira H, Horii Y, Yamane Y, Yamagishi H. Initial experience with a new peroral electronic pancreatoscope with an accessory channel. Gastrointest Endosc. 2004;59(7):895–900. [PubMed].

[12] Nichols MT, Russ PD, Chen YK. Pancreatic imaging: current and emerging technologies. Pancreas. 2006;33(3):211–20. [PubMed].

[13] Brugge WR. Endoscopic techniques to diagnose and manage biliary tumors. J Clin Oncol. 2005;23(20):4561–5. [PubMed].

[14] Iddan GMG, Glukhovsky A, Swain P. Wireless Capsule Endoscopy. Nature. 2000;405:417. [PubMed].

[15] Seibel EJ, Johnston RS, David Melville C. Optical Fibers and Sensors for Medical Diagnostics and Treatment Applications VI, Proceedings of SPIE. Vol. 6083. 2006. A full-color scanning fiber endoscope; p. 608303.

[16] Seibel EJ, Smithwick QY. Unique features of optical scanning, single fiber endoscopy. Lasers Surg Med. 2002;30(3):177–83. [PubMed].

[17] Allan W.B.(1973). Fiber Optics: Theory and practice. New York: Plenum Publishing.

[18] Allard, E.C. (1990) Fiber Optics Handbook. New York: McGraw-Hill.

[19] Cherin, A.H. (1983). An Introduction to Optical Fibers. New York: McGraw-Hill.

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