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A Brief History of the Nd:YAG Laser

John C. Fisher

The successful operation of the first working laser by Theodore Maiman¹ in 1960 was like the key to a locked chest full of other types of laser, just waiting to be discovered. Only six years later, working prototypes of gas, liquid, solid, and semiconductor lasers had been constructed by several groups of investigators, spurred on by Maiman's achievement. By the end of that decade, hundreds of materials had been found capable of laser action.

In December of 1961, Elias Snitzer² reported achieving laser action in barium crown glass doped with neodymium ions. His work undoubtedly stimulated Geusic, Marcos, and Van Uitert³ to pursue the development of the Nd:YAG laser, which they announced in 1964, together with laser action in other neodymium-doped garnets.

All of these scientists, of course, were the ultimate intellectual beneficiaries of the legacy of Albert Einstein,⁴ whose 76-year lifespan ended in 1955, just five years too soon for him to see the fulfillment of his inspired prediction, in 1917, of the possibility of stimulated emission of radiation. However, he did survive long enough to witness the construction of the first masers by Gordon, Zeiger, and Townes⁵ in the United States, and by Bassov and Prokhorov⁶ in the Soviet Union, in the year 1954.

The early medical experimenters who saw potential value in lasers as surgical tools began their trials, often haphazard and unscientific, not long after Maiman's first firing of the ruby laser. Perhaps prophetically, G. Meyer-Schwickerath⁷ in Germany had reported the first surgical use of light in 1954, the year of the maser, to prevent retinal separation.

Bessis and his associates⁸ in France in 1962 described the use of the ruby laser to irradiate the constituents of living cells. In that same year, Koester, Snitzer et al.⁹ wrote of experimental retinal coagulation by ruby laser. In 1965, Minton, Zelen, and Ketcham¹⁰ described the use of ruby and pulsed Nd:glass laser lasers on the Cloudman S-91 mouse melanoma. In 1971, James Fidler¹¹ in Cincinnati reported his use of a 100-W Nd:YAG laser with a Nath fiber to incise canine livers, and in that same year, Musigang and Katsaros¹² in West Germany used a 25-W Nd:YAG laser to study its effects on excised tissues.

The first clinically significant application of the Nd:YAG laser to surgery was Peter Kiefhaber's¹³ use of it in West Germany to control massive gastrointestinal bleeding in humans. In 1978, Alfons Hofstetter and Karlheinz Rothenberger¹⁴ tried coagulation of tumors of the bladder wall, transmitting the laser beam through an optical fiber inserted via the urethra. In 1979, L. Toty et al.¹⁵ in France reported the endoscopic treatment of tracheobronchial lesions by the Nd:YAG laser. In the hands of Jean-Francois Dumon and his colleagues¹⁶ in Marseille, by 1983 the Nd:YAG laser had become the preferred modality for palliative treatment of obstructing malignant tumors of the airway.

In 1973, in Paris, Daniele Aron-Rosa¹⁷ had begun her long search for an ultrashort-pulsed laser to do intraocular surgery, which culminated in 1980 in the use of a mode-locked, picosecond-pulsed Nd:YAG laser to cut vitreous strands. Concurrently, Franz Fankhauser¹⁸ in Bern was developing the ophthalmic applica-

tions of the Q-switched, nanosecond-pulsed Nd:YAG laser in collaboration with the firm Lasag, A.G. of Thun, Switzerland. By 1978 he had performed iridectomies in 102 eyes, using the multimode Lasag Microrupter 1 laser. At this writing, short-pulsed Nd:YAG lasers have become standard tools of the ophthalmologist, performing posterior capsulotomies and other precise intraocular procedures that are difficult or impossible to do by means of the argon-ion laser or other modalities.

In 1984, in Cincinnati, Stephen Joffe and his associates¹⁹ introduced sapphire tips for quartz optical fibers to the United States, following a collaborative development with Norio Daikuzono and his associates in Japan. These shaped waveguides, attached to the standard quartz fibers used for transmission of Nd:YAG laser beams, are placed in contact with the surgical target, and permit precise cutting of soft tissue with excellent first-pass hemostasis of transected vessels, but without the extensive thermal damage characteristic of Nd:YAG beams delivered by noncontacting fibers. I was a scientific reviewer of Joffe's paper for the journal *Medical Instrumentation*, and I was impressed by the elegant simplicity of this concept, which has opened the whole field of thoracic and abdominal surgery to the Nd:YAG laser, formerly thought to be useless for precise cutting and vaporization.

Today the Nd:YAG laser has become a standard instrument in general laser surgery, complementing the CO₂, which originally dominated the field. Its applications extend to bronchology, gastroenterology, dermatology, gynecology, ophthalmology, neurosurgery, urology, and vascular surgery. There is probably no part of the human body that cannot be surgically treated in an effective manner by the Nd:YAG laser in one form or another.

With the use of nonlinear optical materials, such as potassium titanyl phosphate and others, it may be possible in the near future to build a frequency-quadrupled Nd:YAG laser to produce a wavelength of 266 nm for the precise surgery now being done experimentally with various excimer lasers. Perhaps the most important applications of all will be in the field of biostimulation, where Abergel and his associates²⁰ have demonstrated the ability of rays at 1064 nm to lyse collagen in keloids. Uses of this kind may

well overshadow the purely surgical applications of the Nd:YAG laser in the next decade.

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