# Potential Applications of Lasers in Ophthalmology*

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Shortly after Maiman successfully produced the first working model of the ruby laser in 1960, lasers were employed in the field of ophthalmology. Ophthalmology may, therefore, logically lay claim to having introduced this ingenious device as a therapeutic modality into the medical armamentarium. Actually, the discipline of ophthalmology has for almost a century experimented with the idea of using high intensity visible light for the treatment of retinal pathology. This idea became practical with the epochal work of Meyer-Schwickerath (1959) and Littmann (1957) who developed the well-known Zeiss light coagulator. The laser, therefore, may be considered simply another energy source in light coagulation, a light source which, in some instances, may be found superior to the xenon arc and, in other instances, inferior.

The rapid progress of laser development requires constant reevaluation of its usefulness in the field of medicine and, in particular, the field of ophthalmology.

From the great number of existing lasers today, whether gaseous, liquid or solid state, only five are probably of ophthalmological interest at present. In regard to pulsed lasers, i.e., those emitting light within millisecond ranges, the ruby and neodymium lasers must be looked at critically, while in the CW (continuous wave), the He-Ne (helium-neon) and argon gas lasers are of importance. Special attention should be given to the YAG-Nd (neodymium-doped, yttrium-aluminum-garnet) laser for reasons outlined below.

The advantages, disadvantages, as well as the potentials of these lasers, will now briefly be discussed and compared with the xenon arc as a light source (Fig. 1).

## Ruby Laser (694.3 nm)

At present only the ruby laser has been used clinically on a more or less routine basis and here only in the normal pulsed mode, i.e., a pulse duration approximately 200 $\mu$sec to a few milliseconds. Extremely short exposure times of nanosecond ($10^{-9}$ sec) or even picosecond ranges ($10^{-12}$ sec) can physically be achieved; however, they have no place clinically and may be extremely hazardous for the ocular fundus. At these very short exposure times high energies are delivered so fast that effects other than those caused by heat generation take place. For instance, shock waves may be produced which may cause explosion-like disruptions of biological structures with intraocular hemorrhages and retinal detachment.

The principal advantage of the ruby laser clinically is the emitted monochromatic dark red light. This spectral quality prevents photophobia, and the short exposure time allows for ocular treatment without anesthesia in most cases and treatment of areas close to the macula

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with less of a hazard. Some of the disadvantages, however, have to do with the same two factors which are also classed as advantages. The red light of the ruby laser is not suitable for vascular lesions of the ocular fundus, since the red blood vessels, aneurysms or vascular tumors reflect the light to a great extent where absorption is needed for effective treatment. In addition, the very short exposure times make it necessary for the intended intensity of the exposure beam to be preset. Once the triggering button is pushed, all the energy impinging on the eye will interact with the exposed ocular structures without further adjustments being made during this exposure time. This fact was responsible for severe overexposures with subretinal, intraretinal, and even preretinal hemorrhages when lasers were first used clinically in ophthalmology. Even today this complicating factor may still be a considerable one where the operator is inexperienced. Another disadvantage of the laser burn is that sharply demarcated coagulation spots produced by lasers are at times less desirable clinically than those with a wider reactive zone, decreasing in intensity toward the periphery of the lesion (Geeraets et al., 1965; Geeraets, 1965).

### Neodymium Laser (1060 nm)

A theoretical advantage of this laser lies in the fact that the beam is invisible to the eye. Exposure times correspond to those of the ruby laser. Clinically its great disadvantage in ophthalmology is the high absorption of its beam energy within the ocular media (Geeraets and Berry, 1968). The total amount of energy necessary to produce a chorioretinal lesion comparable to that produced by a ruby laser is five to ten times as great as the energy required with the ruby laser (Geeraets, 1967).

Investigations on the effect of neodymium and ruby lasers on nonpigmented and pigmented experimental retinal or choroidal tumors indicated that both light sources failed to completely destroy the tumor masses. Tumor cells continued to show undisturbed growth in cell cultures after maximum exposures to these laser light sources (Unpublished data), and most of the cells appeared also histologically unaltered in morphology. This latter observation was also described by Chan, Guerry, and Geeraets (1963) following treatment with the xenon arc as a light source. High intensity exposures with the neodymium laser or fast repetition of such exposures have led to cataract formation and to extensive biomicroscopically visible vitreous clouding and electrophoretically-demonstrable protein changes in the vitreous (Geeraets, 1966; Berry, Lederman and Geeraets, 1968).

### He-Ne Laser (632.8 nm)

This laser, which emits a bright red colored light beam, belongs to the CW gas lasers. Its emission appears more intense to the human eye than does the deep red light of the ruby laser. Its greatest advantage lies in the greater variability of possible exposure times. For the production of chorioretinal lesions, exposure times may be chosen from millisecond ranges up to any desired length, thus combining positive features of the ruby laser and the xenon arc. For long exposure times, however, it would be preferable or necessary in most instances to administer retrobulbar anesthesia.

At present, the greatest disadvantage of this laser is the great length and weight of the instrument required to obtain adequate power output if one wishes to achieve the great range of exposure times. Experimentally this has been solved by delicately counterbalancing the instrument. The use of fiber optics, though decreasing the power output, may reduce this disadvantage.

### Argon Laser (Major Output at Wave Lengths 488 nm and 515 nm)

This laser emits numerous wave lengths from the ultraviolet region to the blue-green spectrum with the

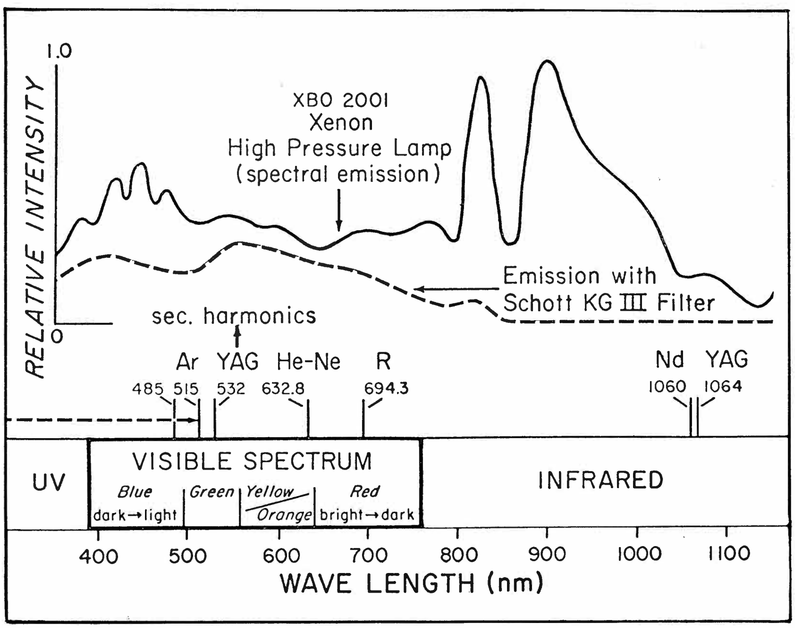


Fig. 1—Spectral position of light emitted from various laser sources in comparison with emission characteristics of a xenon high pressure light source.

latter as the most intense emissions. From a theoretical point of view, this laser has a number of advantages. The transmission of these wave lengths through the ocular media is almost 95°, and they fall in the region of peak absorption by the retinal pigment epithelium and hemoglobin (Geeraets et al., 1962). The output energy of this laser is greater than that of the He-Ne laser, which means that the exposure times can be chosen by the surgeon to fit the optimal needs of a given situation. As of now the greatest disadvantages of this laser for clinical ophthalmological use are its bulkiness and the high purchase price. Experimentally this laser has given promising results. Exposures are best done under retrobulbar anesthesia unless very short exposure times (ms ranges) are used.

### YAG-Nd Laser (1064 nm)

Though the primary wave length of this solid-state laser is very close to that of the neodymium laser, the YAG-Nd laser seems to be capable, experimentally, of having sufficient energy if its second harmonic is used, i.e., frequency doubling. This can be achieved by passing the primary laser beam through a barium-sodium-niobate crystal ($B_2NaNb_5O_{15}$). In this way the wave length obtained is 532 nm. The exit energy at the 532 nm wave length seems, experimentally, to be sufficiently great to give a flexibility in exposure time selection even greater than that described for the He-Ne and argon lasers. This laser seems to be unique in this respect, since it can be pulsed or used in Q-switched fashion similar to the ruby and neodymium lasers as well as on a CW mode similar to most gas lasers.

Its dimensions and weight are significantly less than those of the two gas lasers mentioned above. The emitted wave length of green color would theoretically be somewhat less advantageous than that of the argon laser (about 12% of the light incident on the cornea is absorbed by the hemoglobin [Geeraets et al., 1962]). However, the other features described lead one to believe that this more recent laser development may present a light source possibly of some potential for use in clinical ophthalmology.

### Xenon High Pressure Light Coagulator (Zeiss—Spectral Range 350-1100 nm)

This instrument has had universal clinical acceptance with its usefulness documented by the successful treatment of thousands of patients all over the world (Meyer-Schwickerath, 1959; Guerry, 1968). Its greatest advantage is that of adjustable exposure time. The standard commercially available instrument allows the operator to select exposure times by push-button operation while making it possible to observe the area under treatment as the actual exposure takes place. This permits the operator to terminate the exposure at any time he deems advisable. An optional accessory is a built-in shutter, which allows exposure times down to 20 msec. In most cases retrobulbar anesthesia is advisable. This factor is really not a disadvantage as has been claimed by some advocates of the ruby laser, for it allows one more easily to manipulate the globe by forceps. This feature is of particular value where the extreme temporal periphery is to be treated or where the globe to be treated is relatively enophthalmic.

A disadvantage claimed by some is that a portion of the emitted spectrum is in the near infrared. Though this spectral range has as high an absorption rate by the ocular media as does the neodymium wave length, one should realize that, in the latter instance, this is the only wave length emitted, while in the xenon light coagulator the greatest spectral portion lies in the visible range with a high transmission through the ocular media up to 95% (Geeraets et al., 1960, 1962). When properly used, i.e., not too rapid exposure and avoidance of overexposures, this coagulator apparently gives rise to no ill effects attributable to these spectral emission characteristics, a general observation based on more than ten years of experience since its introduction into clinical ophthalmology. If one wishes to eliminate these theoretical disadvantages, a Schott KG III heat-absorbing filter can be inserted within the optical pathway of this coagulator. This eliminates the near infrared beyond 900 nm almost entirely from the exit beam. In some instances, where lesions close to the macula must be treated, shorter exposure times than those obtainable with the Zeiss coagulator would be of advantage. Experimentally this has been achieved by pulsing the xenon high pressure lamp via a capacitor bank (Ham et al., 1963). These short pulses simulate the exposure times of the ruby laser. Broad-base interference filters used with this coagulator also provide a means of comparing the effects of various spectral regions.

## Conclusion

The continuing evaluation of laser instrumentation is of particular interest to the ophthalmologist. Several lasers now exhibit potential properties which may result in superior clinical instruments in the future.

An important feature of almost all existing lasers, as related to ophthalmology, is the potential hazard of accidental exposure of the eye. This aspect of the laser is certainly as important as its clinical application, and it should be the responsibility of ophthalmologists to work actively to provide recommendations for safety standards and criteria for ocular protection in every field of laser application.

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