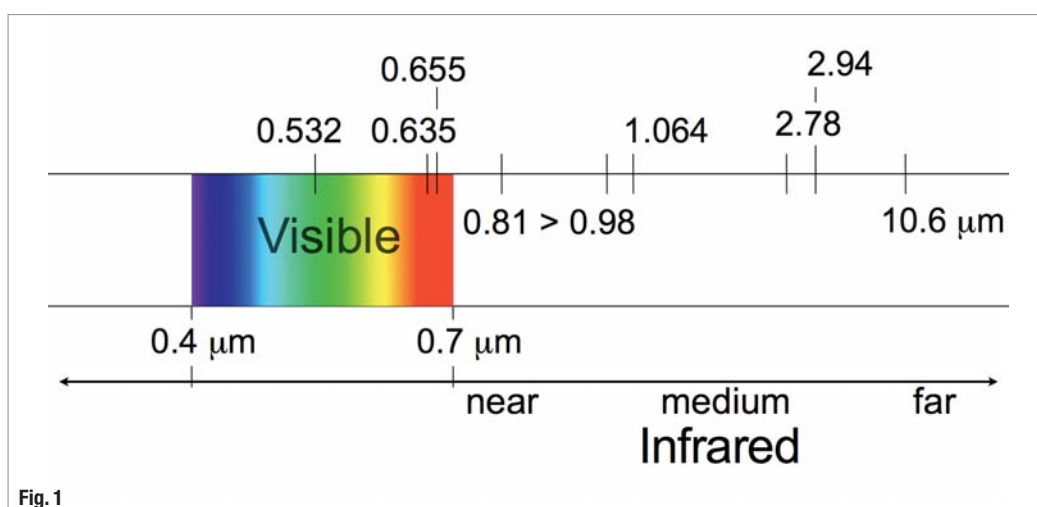


# Laser in endodontics (Part I)

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**Fig. 1** Lasers and the electromagnetic spectrum of light.



**Fig. 1**

The main goals of endodontic treatment are the effective cleaning of the root-canal system. Traditional endodontic techniques use mechanical instruments, as well as ultrasound and chemical irrigation to shape, clean and completely decontaminate the endodontic system.

The complexity of the root-canal system is well known. Numerous lateral canals, of various dimensions and with multiple morphologies, branch off from the principal canals. A recent study found complex anatomical structures in 75% of the teeth analysed. The study also found residual infected pulp after the completion of chemo-mechanical preparation, both in the lateral canals and in the apical structures of vital and necrotic teeth associated with peri-radicular inflammation.<sup>1</sup>

The effectiveness of the debridement, cleaning and decontamination of the intra-radicular space is limited, given the anatomical complexity and the inability of common irrigants to penetrate into the lateral canals and the apical ramifications. Therefore, it appears advisable to search for new materials, techniques and technologies that can improve the cleaning and decontamination of these anatomical areas.

The use of lasers in endodontics has been studied since the early 1970s, and lasers have been more widely used since the 1990s.<sup>2-7</sup> In this regard, Part I of this article will describe the evolution of laser techniques and technologies. The second part, which will be published in *roots* 2/2011, will present the state-of-the-art effectiveness of these instruments in the cleaning and decontamination of the endodontic system and take a look at the future, presenting recent preliminary studies on new methods of utilising laser energy.

## Lasers in endodontics

Laser technology was introduced to endodontics with the goal of improving the results obtained with traditional procedures through the use of light energy by increasing cleaning ability and the removal of debris and the smear layer from the root canals and also improving the decontamination of the endodontic system.

Different wavelengths have been shown to be effective in significantly reducing bacteria in infected canals and studies have confirmed these results *in vitro*.<sup>8</sup> Further studies have demonstrated the

efficiency of lasers in combination with commonly used irrigants, such as 17% EDTA, 10% citric acid and 5.25% sodium hypochlorite.<sup>9</sup> The action of the chelating substances facilitates the penetration of laser light, which can penetrate into the dentinal walls up to 1 mm in depth and have a stronger decontaminating effect than chemical agents.<sup>8,9</sup> Other studies have investigated the ability of certain wavelengths to activate the irrigating solutions within the canal. This technique, which is termed *laser-activated irrigation*, has been shown to be statistically more effective in removing debris and the smear layer in root canals compared with traditional techniques and ultrasound.<sup>10-12</sup> A recent study by DiVito *et al.* demonstrated that the use of the Erbium laser at subablative energy density using a radial and stripped tip in combination with EDTA irrigation results in effective debris and smear layer removal without any thermal damage to the organic dentinal structure.<sup>13</sup>

### Electromagnetic spectrum of light and laser classification

Lasers are classified according to their location on the electromagnetic spectrum of light. They can be visible and invisible, near, medium and far infrared laser. Owing to optical physics, the function of the various lasers in clinical use differs (Fig. 1). In the visible spectrum of light, the green light laser (KTP, a neodymium duplicate of 532 nm) was introduced in dentistry in recent years. There have been few studies concerning this wavelength. Its delivery through a flexible optical fibre of 200  $\mu$  allows its use in endodontics for canal decontamination and has shown positive results.<sup>14,15</sup>

Near infrared lasers (from 803 nm to 1,340 nm) were the first to be used for root decontamination. In particular, the Nd:YAG (1,064 nm), introduced at the beginning of the 1990s, delivers laser energy through an optical fibre.<sup>5</sup> The medium infrared lasers, the Erbium (2,780 nm and 2,940 nm) laser family, also produced at the beginning of the 1990s, have been equipped with flexible, fine tips only since the beginning of this century and have been used and studied in endodontic applications. The far infrared laser CO<sub>2</sub> (10,600 nm) was the first to be used in endodontics for decontamination and apical dentine melting in retrograde surgery. It is no longer used in this field with the exception of vital pulp therapy (pulpotomy and pulp coagulation). The lasers considered here for endodontic applications are the near infrared laser—diode (810, 940, 980 and 1,064 nm) and Nd:YAG (1,064 nm)—and the medium infrared lasers—Erbium, Chromium:YSGG (Er,Cr:YSGG; 2,780 nm) and Erbium:YAG (2,940 nm). A brief introduction to the basic physics of laser–tissue interaction is essential for understanding the use of lasers in endodontics.

### Scientific basis for the use of lasers in endodontics

#### Laser–tissue interaction

The interaction of light on a target follows the rules of optical physics. Light can be reflected, absorbed, diffused or transmitted.

Reflection is the phenomenon of a beam of laser light hitting a target and being reflected for lack of affinity. It is therefore obligatory to wear protective eyewear to avoid accidental damage to the eyes.

Absorption is the phenomenon of the energy incident on tissue with affinity being absorbed and thereby exerting its biological effects.

Diffusion is the phenomenon of the incident light penetrating to a depth in a non-uniform manner with respect to the point of interaction, creating biological effects at a distance from the surface.

Transmission is the phenomenon of the laser beam being able to pass through tissue without affinity and having no effect.

The interaction of laser light and tissue occurs when there is optical affinity between them. This interaction is specific and selective based on absorption and diffusion. The less affinity, the more light will be reflected or transmitted (Fig. 2).

#### Effects of laser light on tissue

The interaction of the laser beam on target tissue, via absorption or diffusion, creates biological effects responsible for therapeutic aspects that can be summarised as:

- photo-thermal effects;
- photomechanical effects (this includes photo-acoustic effects); and
- photochemical effects.

Fig. 2 Laser–tissue interaction.

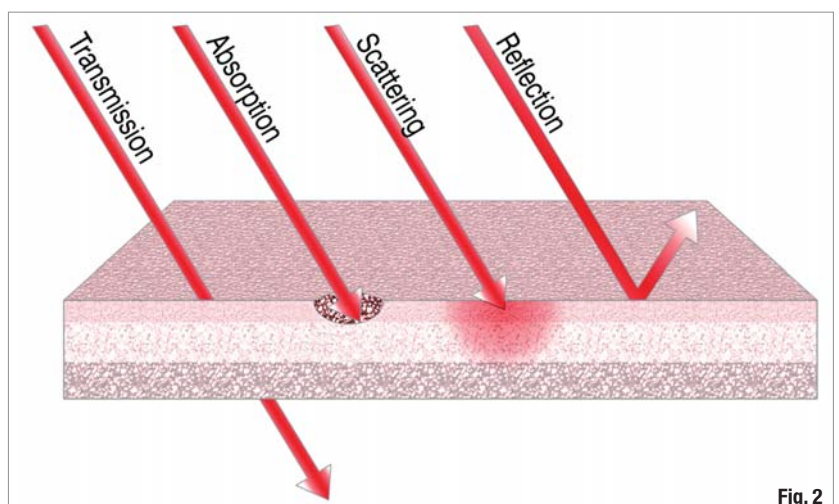


Fig. 2

P	power (in W)
E	energy (in J)
R	pulse repetition rate (in Hz)
Pd	power density or density of power (in W/cm <sup>2</sup> )
F	fluence or density of energy (in J/cm <sup>2</sup> )
P(W)	average power = E x R
PP(W)	peak power = E; length of single pulse (in seconds)

**Table I**

**Table I** Laser light emission parameters.

The diode laser (from 810nm to 1,064nm) and the Nd:YAG (1,064nm) belong to the near infrared region of the electromagnetic spectrum of light. They interact primarily with soft tissue by diffusion (scattering). The Nd:YAG laser has a greater depth of penetration in soft tissues (up to 5mm), while the diode laser is more superficial (up to 3mm). Their beam is selectively absorbed by haemoglobin, oxyhaemoglobin and melanin, and has photo-thermal effects on tissue. Therefore, their use in dentistry is limited to the vaporisation and incision of soft tissue. They are also used for dental whitening with a laser beam, by thermal activation of the reagent. In endodontics, they currently represent the best system for decontamination, owing to their ability to penetrate the dentinal walls (up to 750µ with the 810nm diode laser; up to 1 mm with the Nd:YAG)<sup>8</sup> and for the affinity of these wavelengths with bacteria, destroying them through photo-thermal effects.<sup>16</sup>

The Erbium lasers (2,780 nm and 2,940 nm) belong to the medium infrared region and their beam is pri-

marily absorbed superficially by soft tissue between 100 and 300µ and up to 400µ by the dentinal walls.<sup>8,17</sup>

The chromophore target is water, which is why their use in dentistry extends from soft to hard tissue. Owing to the water content of the mucosa, gingiva, dentine and carious tissue, Erbium lasers vaporise and affect these tissues thermally. The explosion of the water molecules generates a photomechanical effect that contributes to the ablative and cleaning process (Fig. 3).<sup>18-20</sup>

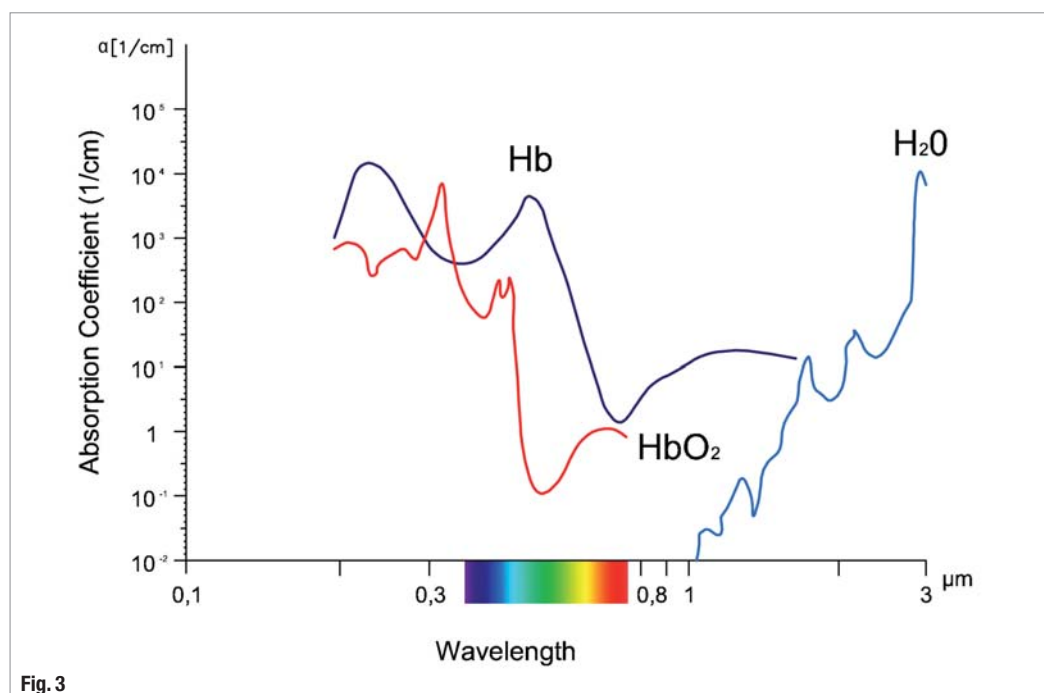
*Parameters that influence the emission of laser energy*

Laser energy is emitted in different ways with various instruments. In diode lasers, the energy is emitted in a continuous wave (CW mode). A mechanical interruption of the energy emission is possible (properly called 'gated' or 'chopped' and improperly called 'pulsed'), allowing for better control of thermal emission. The pulse duration and intervals are in milliseconds or microseconds (time on/off).

The Nd:YAG laser and the Erbium family emit laser energy in a pulsed mode (also called free-running pulse), so that each pulse (or impulse) has a beginning time, increase and an end time, referred to as a Gaussian progression. Between pulses, the tissue has time to cool (thermal relaxation time), allowing for better control of thermal effects (Fig. 4).

The Erbium lasers also work with an integrated water spray, which has the double function of both cleaning and cooling. In the pulse mode, a string of

**Fig. 3** Coefficients of tissue absorption.



**Fig. 3**

pulses is emitted with a different pulse repetition rate (improperly called 'frequency') referred to as the Hertz rate (generally from 2 to 50 pulses) per second. The higher emission repetition rate acts in a similar way to the CW mode, while the lower repetition rate allows for a longer time for thermal relaxation. The emission frequency (pulse repetition rate) influences the average power emitted, according to the formula shown in Table I.

Another important parameter to consider is the 'shape' of the pulse, which describes the efficiency and the dispersion of the ablative energy in the form of thermal energy. The length of the pulse, from microseconds to milliseconds, is responsible for the principal thermal effects. Shorter pulses, from a few microseconds (< 100) to nanoseconds, are responsible for photomechanical effects. The length of the pulse affects the peak power of each single pulse, according to the formula in Table I. Dental lasers available on the market today are free-running pulsed lasers, the Nd:YAG with pulses of 100 to 200  $\mu$ s and the Erbium lasers with pulses of 50 to 1,000  $\mu$ s. Furthermore, diode lasers emit energy in CW that can be mechanically interrupted to allow the emission of energy with pulse duration of milliseconds or microseconds depending on the laser model.

#### Effects of laser light on bacteria and dentinal walls

In endodontics, lasers use the photo-thermal and photomechanical effects resulting from the interaction of different wavelengths and different parameters on the target tissues. These are dentine, the smear layer, debris, residual pulp and bacteria in all their various aggregate forms.

Using different outputs, all the wavelengths destroy the cell wall due to their photo-thermal effect. Because of the structural characteristics of the different cell walls, gram-negative bacteria are more easily destroyed with less energy and radiation than gram-positive bacteria.<sup>16</sup> The near infrared lasers are not absorbed by hard dentinal tissues and have no ablative effect on dentinal surfaces. The thermal effect of the radiation penetrates up to 1 mm into the dentinal walls, allowing for a decontaminating effect on deeper dentine layers.<sup>8</sup> The medium infrared lasers are well absorbed by the water content of the dentinal walls and consequently have a superficial ablative and decontaminating effect on the root-canal surface.<sup>8,16</sup>

The thermal effect of the lasers, utilised for its bactericidal effect, must be controlled to avoid damage to the dentinal walls. Laser irradiation at the correct parameters vaporises the smear layer and the organic dentinal structure (collagen fibres) with characteris-

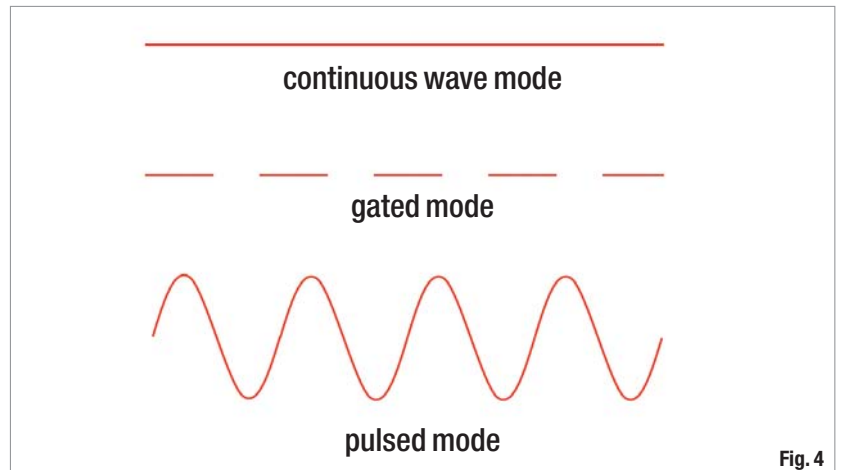


Fig. 4

tics of superficial fusion. Only the Erbium lasers have a superficial ablative effect on the dentine, which appears more prevalent in the intertubular areas richer in water than in the more calcified peri-tubular areas. When incorrect parameters or modes of use are employed, thermal damage is evident with extensive areas of melting, recrystallisation of the mineral matrix (bubble), and superficial microfractures concomitant with internal and external radicular carbonisation.

Fig. 4 Methods of laser light emission.

With a very short pulse length (less than 150  $\mu$ s), the Erbium laser reaches peak power using very low energy (less than 50 mJ). The use of minimally ablative energy minimises the undesirable ablative and thermal effects on dentinal walls while the peak power offers the advantage of the phenomena of water molecule excitation (target chromophore) and the successive creation of the photomechanical and photoacoustic effects (shock waves) of the irrigant solutions introduced in the root canal on the dentinal walls. These effects are extremely efficient in cleaning the smear layer from the dentinal walls, in removing the bacterial biofilm and in the canal decontamination, and will be discussed in Part II.<sup>10-13</sup>

*Editorial note: A complete list of references is available from the publisher.*

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