submitted to the proceedings of EMLA Laser Prague 2009 - 10th International Congress of Dermatology
preprint, offered by I^{3}M, page 11

What are the technical and physical Differences between Laser and LED Phototherapy?

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Laser and LED devices are used in Phototherapy. Prices for LED and laser equipment vary from some 10 Euro (not allowed for medical use) to 100000 Euro. What are the differences? Fig. 1 shows some devices working as well with laser, and with LED. Especially the new Modulo serie (Sedatelec) and some EMRED devices allow to interchange between laser and LED modules – we would be glad to know of your respective experiences!

1. coherence

As shown in another presentation [1] laser light is produced by pure quantum physical means. This leads to the laser light being a macroscopic quantum state with lots of identical (and undistinguishable) particles in the same wavefunction Ψ. That is why these photons all have the same wavelength (= colour), the same direction (or direction distribution), the same phase. This leads to observable macroscopic quantum effects like interference. Thus, the absorbed intensity of a laser beam is often not homogeneous [2]. It might be speculated these locally inhomogeneous intensities to have some biostimulating effect [3].

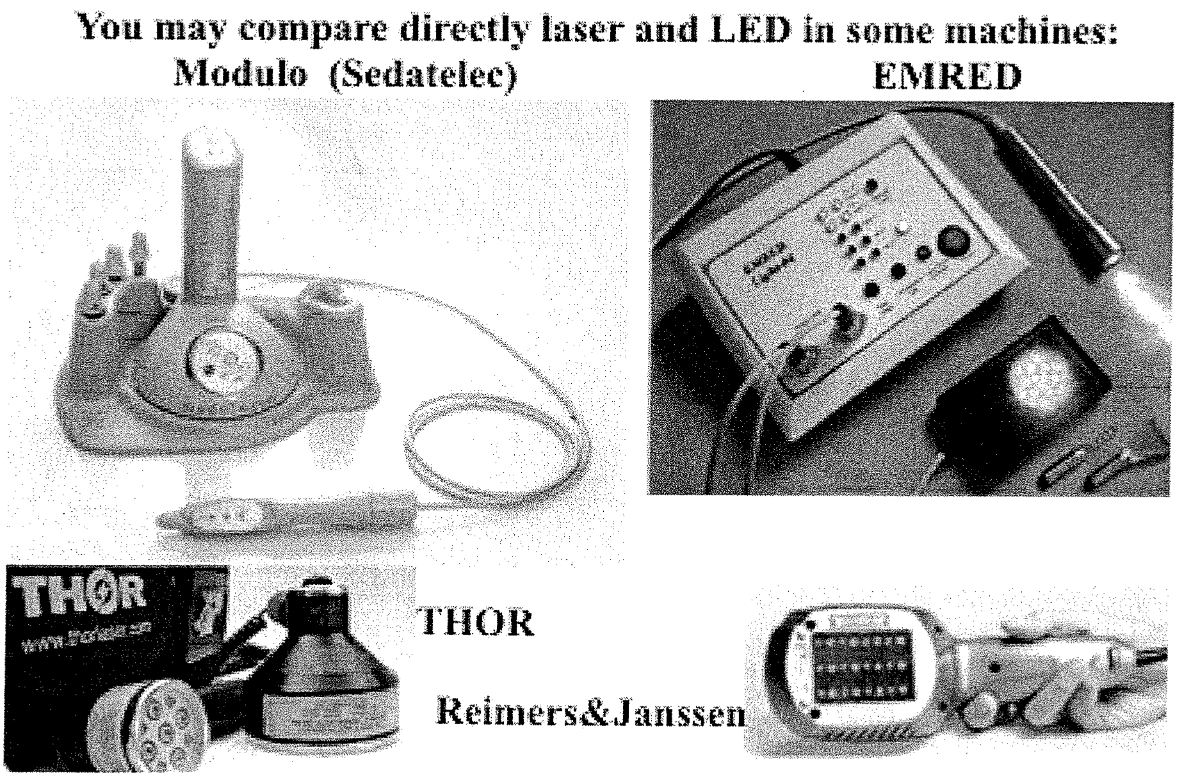

Fig. 1: Some laser / LED devices either combined, or interchangeable. The latter are proposed to perform studies on laser/LED differences. Contact through the author romberg@drromberg.de.

Why that? Stimulation might arise from environmental conditions which are not as usual. If all surrounding stays as usual we assume no stimulating action to take place. These locally strongly variing intensities are not usual, thus somė neighboring cells, or cell sub-units, might differ strongly in light absorption. This may lead to local variations in biochemical conditions that do not arise usually.

Non-laser light does not show macroscopic interference effects due to the lack of high coherence. LED light does not show these locally inhomogeneous intensities.

Upon entering tissue, scattering and absorption takes place. It can be seen by observing backscattered light that a lot of scattering events maintain coherency; at least locally. Thus, even some mm deep in tissue a considerable amount of the laser light is still coherent, at least locally. Deeper inside tissue these effects are expected to wash out, if not light-guide effects are taken into account.

The latter might arise from multiple reflections as, e.g., between bone surface, and the periosteum surfaces. As these speculative light-guide effects might go along with less absorption compared to neighboring tissue, the relative amount of coherent radiation might be enhanced inside tissue due to these effects. However, we want to emphasize the speculative character of these gedankenexperiments.

2. spectral composition

Another important difference between laser and LED light is the spectral composition of the light (fig. 2) [4]. As all photons within the coherency volume of a laser beam are indentical they all have the same wavelength = colour. In addition, depending on the quality of the laser diode and the electronics, the spread of wavelengths may be very low (<< 0.1 nm) or low (1 nm) upon time. Due to thermal effects, heating of a laser diode leads to a shift in wavelength of typically some nm.

Light emitted from LED or other light sources shoes a wavelength distribution of at least 20 nm width, often more than 100 nm. This may be more than a factor of 1000 bigger than in laser light!

Is this narrow wavelength distribution important for therapy? That seems to depend on the aimed-at therapeutic effect (we might speculate, that most often the actual biochemic effect used is not yet known. Even in future it is highly unlikely to gain knowledge of all effects to take place [5]).

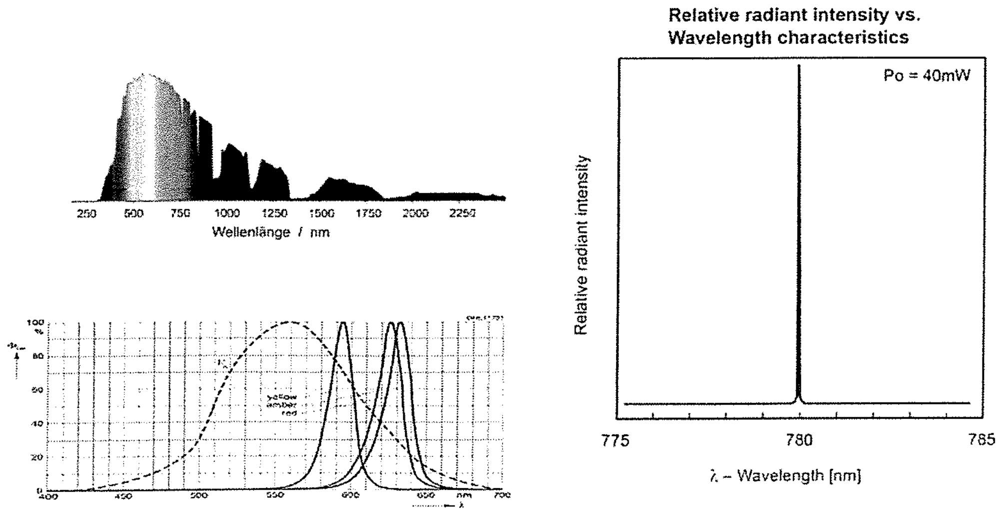

Fig. 2: Spectral distribution of sunlight, LED and laserlight [3].

If a specific absorption process is wanted, as in PDT or dedicated biochemical action [6], the percentage of the light intensity going into the desired process is high, if

1. the centers of the distributions are identical within width
2. the width of wavelength distribution of the light is smaller than the width of the aimed-at absorptive process.

The latter may be as narrow as 5 nm [7].

Whether in a specific application laser or LED light yields better healing results is not subject of this consideration – we want to show the fundamental possibilities of such differences to arise.

3. emitting area

Another difference of laser and LED light comes from the smallness of the emitting area in most lasers compared to that of LEDs. The latter emit light from big surfacec (up to 3mm × 3 mm) due to cooling reasons, whilst the former emit from areas as small as 0.001 mm × 0.1 mm [1]. Thus, laser light might be focussed much better to yield high local intensities. This is used in high power lasers, too, to produce strong local heating. In addition, this gives rice to the higher potential risk of laser light compared to LED light – even if the beam parameter and intensities would be identical. This is now taken into account in laser safety education [8] and in the respective standards for laser (IEC 60825) and LED / other light sources (IEC 62471) radiation.

4. beam geometry

Laser light may be pencil-like, diverging, or focussed (Fig. 3). LED-light is usually strongly diverging, and is emitted from a bigger area. If a laser cluster (sometimes called laser shower) is used, there is no cohereny between the different laser diodes. If the irradiated areas overlap, no big effects due to coherence are expected. If they do not overlap, locally coherence is given, but the cluster has to be moved around to yield homogenous dosage.

5. polarization

While polarization is not maintained inside tissue, it might be created upon forming locally inhomogenous intensities. Hence, regions may exist having predominantly polarized laser light. There are biochemical structures in cells that react on polarized light, allowing to propose this locally polarizing effect as effective.

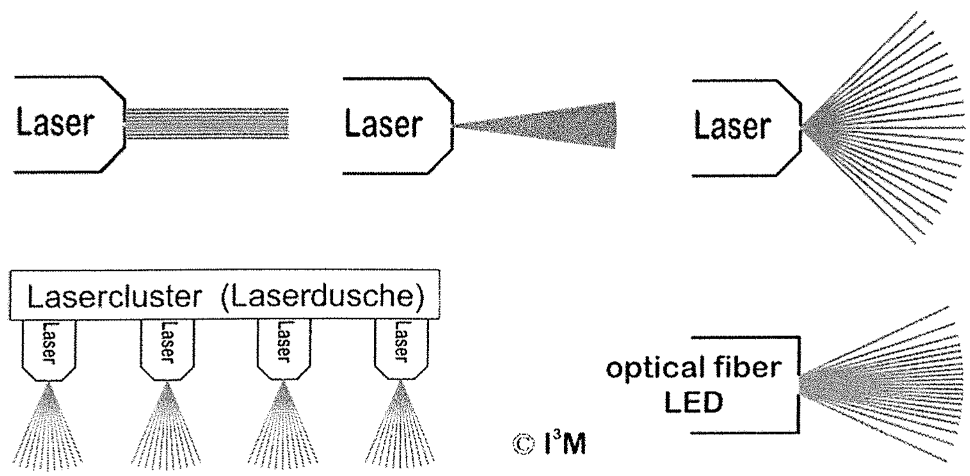

Fig. 3: scematic drawings of beam geometries [3].

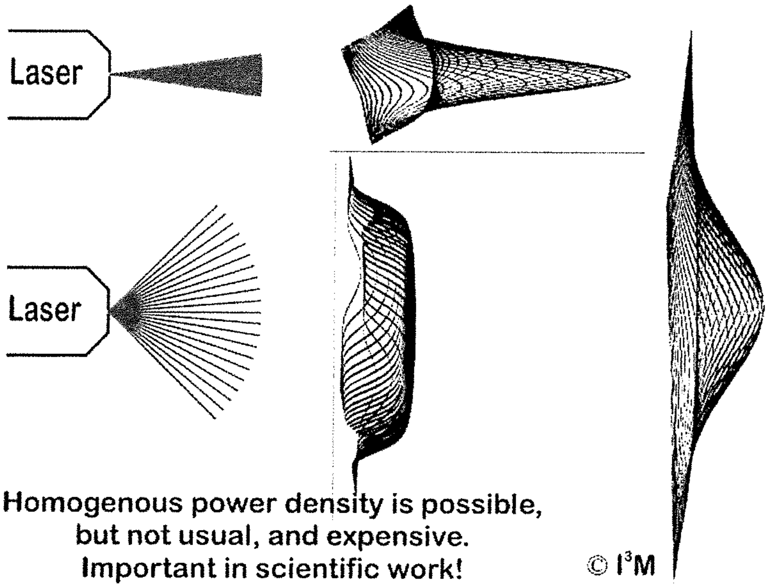

Fig. 4: More realistic intensity profile (idealized). If the beam angle is widened, the effect persists – ist widenes, too. For scientific studies flat distributions should be chosen [3].

6. How to find out?

Comparing studies using laser and LED phototherapy can yield as well big, as none, difference in therapeutical outcome. How can that be?

First it may depend on the indication looked at.

Second the beam parameter should be as identical as possible.

Third the difference might depend on the beam parameter chosen. And there are lots of parameter to look at! The author has speculated about the amount of mice needed, if a mouse model would be taken to investigate the wastness of parameter values for laser / LED phototherapy. Looking at power, power density, treatment duration, wavelength, wavelength distribution, beam diameter, beam divergence, modulation frequency and modulation techniques, etc., the amount of mice needed exeeds the mass of the earth! [4] An artist's view is shown in fig. 5 [8].

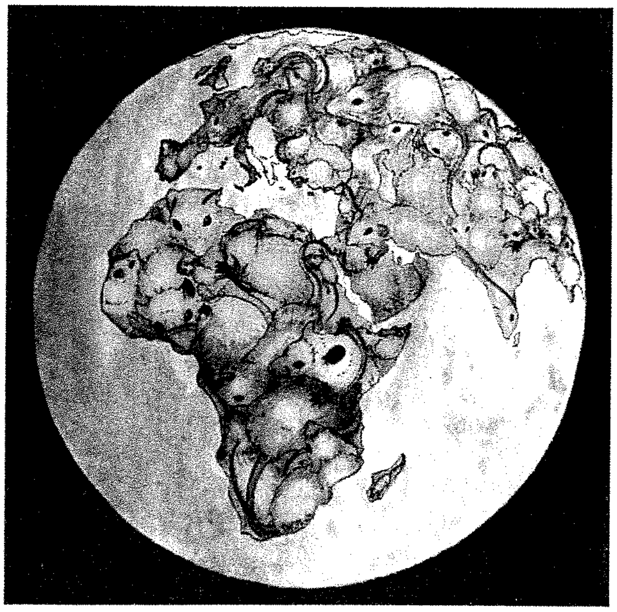

Fig. 5:
A mousy world, by
A.C. Kendall.© [8]

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[8] © A.C. KENDALL, contact through the author.