# Class 4. non-invasive laser therapy in clinical rehabilitation

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## ABSTRACT
Using laser light in order to induce healing of traumatized or pathological tissue is physical therapy method which is long term accepted and clinically used. The aim of this literature review is to summarize current status of research evidence of this method mainly in relation to its latest intense technological development. Recently the lasers with high intensity (Class 4) are starting to be used for biostimulation purposes. Therapeutic possibilities of these lasers and the current clinical documentation of their efficiency are discussed. **Methodology: Literature review of analysis from basic and clinical research, available in scientific databases.**

## KEYWORDS
**High intensity laser, HILT, class 4 laser, low intensity laser, LLLT, biostimulation**

*Rehabil. fyz. Lék., 20, 2013, č. 2, s. 113-119*
*(Original article in Czech language)*

## INTRODUCTION
The effects of laser radiation for the regeneration of pathologically changed or traumatized tissue, suppressing inflammation and inflammation swelling, and pain release were researched from the invention of the first laser devices in the 60s. Recent technological development enables the use of lasers with various wavelengths and intensity for the purpose of affecting their therapeutic effects. The aim of this review is to summarize the history and current state of the non-invasive laser therapy application.

## HISTORY AND DEVELOPMENT OF LASER TECHNOLOGY
The existence of stimulated electromagnetic radiation was first predicted by Albert Einstein in 1917 in article „Zur Quantentheorie der Strahlung“. However, further theories were processed in the 50s as regards the use of stimulated emission to strengthen also the light in the visible spectrum and adjacent infrared wavelength areas. Many scientific teams cooperated in practical implementation: Fundamental theoretical works within the laser devices construction include the works of Nikolaj G. Basov and Alexandra M. Prokhorov in Soviet Union from 1955, and Charles H. Townes and Arthur Schawlow in the USA from 1957, who jointly received 1964 Nobel Price for research within quantum physics. After many patent disputes, the official inventor and author of the term LASER is considered Gordon Gould, which was presented in 1959 and derives from expression Light Amplification by Stimulated Emission of Radiation [1] [2]. However, many authors consider the true laser inventor to be Theodore Maiman, who as the only one presented the first functioning ruby laser [3] [4] [5] [6] in 1960. Soon after, many laser devices were constructed with the use of various active agents for generating coherent electromagnetic radiation (additionally to solid and liquid substances, most frequently vapors of alkali metals and other gases: He-Ne, Ar, CO2, aj.), and they were very quickly used in many fields of medicine – at mostly in surgery, dermatology, and ophthalmology [4].

Jointly with the clinical use of the first high-intensity lasers in invasive medicine, the research describing the bio-stimulation effects of low intensity lasers (cold, low level laser therapy) with intensity up to 500 mW begin to emerge in the second half of the 60s. The effect was explained by the laser radiation absorption at the cell level, when the photon energy produces photochemical changes similar to the photosynthetic processes in plant cells [7] [8]. The medical use of bio-modulating effects of the low-level lasers (i.e. low-level laser therapy – LLLT) has quickly expanded from the 70s particulary in the East European countries; it earned greater popularity worldwide during the 80s, probably due to geopolitical division and insufficient literature in English language. During the period, new technologies emerged enabling the construction of significantly cheaper and smaller semi-conductive diode lasers with greater spectrum of emitted wavelengths which formed a prerequisite for wider clinical laser use in almost all areas within physical medicine [9] [4].

From the end of the 90s, lasers with performance at Watt level (high intensity laser, Class 4 laser) begin to emerge in the basic research and later in clinical rehabilitation practise. The technology enables to generate intensity commonly around 10W and more, for the purpose of producing stronger bio-modulation and analgesic effect. Despite their inclusion among class 4 lasers, the tissue damage cannot occur due to their strongly divergent character. The main contribution of this technology is a significant acceleration of the emission which enables significant increase of therapeutic dosage (J/cm2) without application time prolongation. Further effects of the high intensity laser include immediate analgesic and myo-relaxation effects in pulsed application and also adjuvant thermal effect [10] [11] [12] [13] [14]. Currently, there are two basic technologies of high intensity laser for rehabilitation purposes: Modified invasive laser (NdYAG), and diode laser with high intensity. The advantage of NdYAG devices is the possibility to emit very high intensity at kWatt level but only in extremely short pulses. Their restrictions then include the impossible continual emission, significant dimensions, and less economical operation. Diode lasers enable continual and pulsed emission, flexibility within the used wavelengths and more acceptable device dimensions. Relative disadvantage is the inability to reach extremely high peak values in pulsed emissions. [12]

## BIOLOGICAL LASER EFFECTS

The phenomena of laser bio-stimulation was first specified in 1967 by Endre Mester, Professor at Semmelweis University in Budapest who used experimental radiation on a group of mice to verify if laser radiation can produce malignant growth in tissue. This effect was not proved, however mice subjected to radiation with low intensity laser in the red spectrum of the light radiation, showed significantly faster regeneration of shaved fur compared to un-exposed group. In relation to these results Mester radiated open skin injuries and proved the effects of laser radiation by series of histological and immunological testing [10] [6]. The term laser bio-stimulation was generalized later by some authors to „laser bio-modulation“, for better specification of the stimulation and other (analgesic, inflammation prevention) effects of laser radiation in tissue [4] [7] [11] [12].

From the first description of the laser bio-stimulation in 1967 by Endre Mester, many laboratory in vitro studies and animal studies were published explaining the mechanisms and theoretic background of the LLLT effects [13] [14] [15]. Specific parts of the cellular mitochondrial chains have the ability to absorb specific wavelength of laser radiation, and the release of other signal molecules (NO, cytokinines, growth factors)

results in increased formation of ATP, increasing the level of cellular metabolism resulting in the tissue regeneration and healing [16] [17] [18] [19] [4] [15] [20]. The studies indicate that laser radiation affects also increased fibroblastic activity, collagen synthesis, and angiogenesis due to the endothelial cell proliferation in the tissue affected [21] [22] [23]. The effects on suppression of the inflammation were proven by inhibiting the in anti-inflammatory cytokinines (interleukins, etc.) in the tissue, and pain release is explained indirectly by suppressing the inflammation and swelling, and directly by stimulating the secretion of endogenous opiates – endorphins and encephalins, and reducing the distribution speed in Aδ and C nerve fibres [24] [19] [19].

## CLINICAL EVIDENCE

Clinical studies of LLLT effectiveness published during both decades at the turn of the millennium, generally conform to the findings from the laboratory experiments, however, there is a number of studies incompliant with the clinical effectiveness. This fact is, however, in accordance with the knowledge of laser light action in tissue. Low intensity laser light is mostly absorbed in the superficial tissue layers. Therefore in some cases it is difficult to reach comparable therapeutic dose during studies in-vitro and in-vivo [25]. Frequent feature of the studies with positive and negative results from this period is also very low methodological quality, incomplete description of the parameters applied, and difficult comparability of the application methods [25] [4]. Recently, the approach changes as regards this focus, and PEDro database for Evidence Based Medicine in Physiotherapy in 2010 registered almost one hundred randomized, controlled studies with acceptable methodological quality as per the scale PEDro [25]. Positive LLLT effect has been documented in particular in osteoarthritis treatment and other chronic joint disorders [26] [27] [28] [29] [30] [31], rheumatoid disorders [30] [32], tendinopathy [33] [34] [4] [35], radiculopathy [36] [37], neck spine pains [38] [39], [40] [41] [42], fibromyalgy [43], peripheral nerve disorders [44], healing wounds and scars [15] [7] [20] [45] [46] [47].

It is obvious the LLLT is a method currently very well clinically documented, however with clearly specified physical limits (in particular maximum output limiting the depth of the tissue penetration, and the limited possibility to increase the therapeutic dosage). In relation to the restrictions, recently the lasers with higher intensity are currently used. It enables to influence very deep structures and intense increase of therapeutic dosage [11] [12]. Maximum therapeutic dose in LLLT is still discussed, however does not usually exceed 16 J/cm2 [12], in high intensity laser therapy the common dosage is usually around 80-120 J/cm2. Despite the dogma of low intensity laser therapy, no inhibition effects occur with this significant increase of the therapeutic dosage. In the


contrary the results with increased therapeutic dosaging confirm increased clinical effectiveness [11] [13] [53] [12].

High intensity laser therapy is currently in the phase of dramatic development, when many clinical studies focusing on the effects are in progress. Intense basic research taking place in particular in former decades confirmed the effective mechanisms of HIL not only in surface soft tissues [54] [55] [56] but also in osseous and cartilaginous tissue [57] [58] [59] [60] [61]. Clinical studies currently published confirm the effects in symptomatic treatment of pain [53] [14] [13], low back pain [62], effects on muscular micro-circulation [63] and impingement syndrome [64]. The first results of extensive clinical studies were currently published by Navrátil [10] [11]. This author analyses the effects of diode lasers at high intensity in comparison with low intensity lasers in various chronic disorders of musculoskeletal apparatus. He describes indisputably better results in lasers with intensity over 1W, and also mentions significant treatment period reduction. These statements are confirmed by Procházka, who is the pioneer of using this technology in the Central Europe region [12] [65]. Further clinical studies confirm potential utilization of the intensity lasers in dermatological indications [66] [67] [68].

## CONCLUSION

Low intensity bio-stimulating laser therapy has been used over fifty years, its mechanisms and clinical application has been well documented. High intensity laser therapy, which has become the focus of recent years, uses the same biological mechanisms; however, due to higher intensity of laser source, it reaches higher clinical effectiveness. Clinical research confirming the statement is still only beginning, and more studies are required to verify this promising technological trend.

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