系統識別號	U0026-1608201023300500
論文名稱(中文)	探討雷射光斑的大小對穿透皮膚組織後能量衰減之影響
論文名稱(英文)	The Effect of Laser Spot Size on Energy Attenuation for Skin Penetration
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系所名稱(英)	Institute of Biomedical Engineering
學年度	98
學期	2
出版年	99
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學位類別	碩士
語文別	中文
論文頁數	69 頁
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中文關鍵字	光斑大小 雷射除毛 能量衰減 穿透
中文摘要	近年來科技的進步也帶動了醫學美容發展，非侵入性且恢復期短的微整形手術更是醫學美容的趨勢，其中雷射美容就是近十幾年來最蓬勃發展的項目之一，而除毛雷射更是目前雷射應用中最常被應用的項目。但除毛雷射手術容易產生短暫性的皮膚紅腫、色素沈澱、起水泡等副作用，更嚴重的甚至引發毛囊炎，使得復原的時間拉長，治療時也較具疼痛感。縮小雷射光斑直接對單一毛囊治療，配合即時影像定位系統和雷射自動飛點掃描的技術來解決因縮小光斑而造成治療時間拉長的情況，並減少周圍皮膚組織被雷射照射到的面積，不僅可減少副作用的產生，還可以降低在治療時的疼痛感，但縮小光斑是否有除毛效果需要做進一步的驗證。 本研究的目的為探討雷射光斑的大小對穿透皮膚組織後能量衰減之影響。其特定目標為：(1)二極體雷射除毛系統設計；(2)應用動物實驗來探討雷射光斑大小對穿透皮膚組織後能量衰減之影響。本研究針對小光斑雷射除毛設計開發一套 808nm 二極體雷射系統，首先考量小光斑雷射除毛的臨床需求與功能性，利用蒙地卡羅法來模擬不同雷射光斑大小在組織間的傳播行為，然後挑選合適的二極體雷射源並分別設計二極體雷射驅動模組、訊號控制模組和光學系統，最後對整體的系統雛型校正。接著運用蘭嶼豬腹部皮膚組織來進行改變雷射光斑大小(分別為直徑 1mm、3mm 與 5mm)穿透皮膚組織後能量衰減實驗。

	其結果顯示：(1) 蒙地卡羅模擬不同光斑穿透皮膚組織(2.25mm)深度，其能量皆約為入射能量的 0.46%。(2) 二極體雷射除毛系統雛型其校正結果顯示雷射系統具有穩定的操作特性及功率輸出。(3) 假體實驗與模擬具相同的結果，光斑大小不影響能量穿透的比例。(4) 動物實驗也顯示雷射穿透皮膚組織不因光斑的大小影響穿透能量比例的改變，排除了利用小光斑雷射在皮膚組織會造成大量的能量衰減的疑慮，可作為小光斑雷射除毛系統重要的參考資料。 本系統未來可改進及持續研究的部分如下：(1) 嘗試將雷射耦合進光纖輸出，可使雷射的光能量分布較為均勻；(2) 針對毛孔擊發雷射，以組織切片觀察毛囊是否有被破壞的現象，找出可用於臨床上之規格；(3) 探討雷射擊發時毛囊位置的溫度變化分佈，了解雷射對毛囊溫度的影響。
英文摘要	In recent years, there has been a rapid growth in Aesthetic Medicine due to development of the science and technology. Using laser to achieve “non-invasive procedures” and “short convalescence” has been a major trend in the last decade in the actively developing micro-plastic surgery field. In this field, laser hair removal is one of the most popular and widely used laser applications. However, there are several side effects after a laser hair removal treatment, like skin reddening, Hypo-pigmentation, blistering, etc. In some occasions, it could cause serious side effects, such as folliculitis and extended convalescence which cause severe pain during the treatment. One way to alleviate the aforementioned side effects is to shrink the laser spot size to fire single hair follicle, and combine the real-time image positioning system and auto-controlled laser scanning system for shortens treatment time. We could thus reduce the thermal damage and pain of healthy tissue during the treatment. However, there is no previous study to evaluate the efficacy of using a smaller laser spot size on hair removal. The goal of this research is to investigate the effect of laser spot size on energy attenuation for skin penetration. The specific aims include (1) designing and developing a laser diode system for hair removal, and (2) investigating the effect of spot size laser on energy attenuation for skin penetration using animal model. To achieve the first goal, we first considered the functional requirements for a small spot size 808nm diode laser hair removal system and generated a conceptual system design. Secondly, we used Monte Carlo method to simulate light propagation in tissue with different spot size, and designed a laser source, a laser driver control module, and an optical system based on the simulations results. Finally, we calibrated the laser diode system. To achieve the second goal, the experiments for investigating the effect of laser spot size (e.g. diameter 1mm, 3mm, and 5mm) on energy attenuation for skin penetration were performed on a Lanyu pig's abdomen skin tissue. The results showed that: (1) Monte Carlo modeling indicated that the laser with different spot sizes penetrated the tissue (thickness 2.25mm) with a same energy penetration rate (about 0.46%). (2) A laser diode prototype system was developed which had stable operating characteristic and output power. (3) The results of phantom experiment were similar to MC modeling: the penetration rate was same for different laser spot sizes. (4) The results of animal experiment showed the laser spot size was not affecting the energy penetration rate of skin. The results can be an important foundation for small spot size laser hair removal system. To improve our current system, further studies are necessary which include (1) coupling the laser into the fiber for making the laser energy uniform, (2) firing laser to follicle and making the biopsy to perform histology comparisons to find out the laser system specifications for clinical treatment, and (3) investigating the variation of temperature distribution after firing laser, and verifying the efficiency of laser diode system for hair removal.