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Microjet Penetrator - medical use of laser induced shock waves and bubbles[1]

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The laser-driven microjet penetrator system accelerates liquids drug and delivers them without a needle, which is shown to overcome the weaknesses of existing piston-driven jet injectors. The system consists of two back-to-back chambers separated by a rubber membrane, one containing "driving" water behind another of the liquid drug to be delivered. The laser pulse is sent once, and a bubble forms in the water chamber, which puts elastic strain on the membrane, causing the drug to be forcefully ejected from a miniature nozzle in a narrow jet of 150 micron in diameter. The impacting jet pressure is higher than the skin tensile strength and thus causes the jet to penetrate into the targeted depth underneath the skin. Multiple pulses of the laser increase the desired dosage. The experiments are performed with commercially available Nd:YAG and Er:YAG lasers for clinical applications in laser dermatology and dentistry. The difference in bubble behavior within the water chamber comes from pulse duration and wavelength. For Nd:YAG laser, the pulse duration is very short relative to the bubble lifetime making the bubble behavior close to that of a cavitation bubble (inertial), while in Er:YAG case the high absorption in water and the longer pulse duration change the initial behavior of the bubble making it close to a vapor bubble (thermal). The contraction and subsequent rebound for both cases were seen typical of cavitation bubble. The laser-induced microjet penetrators generate velocities which are sufficient for delivery of drug into a guinea-pig skin for both laser beams of different pulse duration and wavelength. We estimate the typical velocity within 30-80 m/s range and the breakup length to be larger than 1 mm, thus making it a contamination-free medical procedure. Hydrodynamic theory confirms the nozzle exit jet velocity obtained by the microjet system. A significant increase in the delivered dose of drugs is achieved with multiple pulses of a 2.9μm Er:YAG laser at 250μs pulse duration. At this wavelength, the beam is best absorbable by water. Further, to increase the bubble size, a sapphire based fiber tip is entered into a water chamber as a beam is gathered at the bottom of this fiber tip's conical end, which is polished at an angle graduated from 30° over the full core diameter. The power density at the exit of the conical fiber tip is increased in comparison with the direct radiation at water. The water superheats and thus a larger bubble forms right at the tip. The bubble is typically an elongated (stretched) shape in case of a direct laser irradiation in water, but when light is irradiated through a conical fiber tip, the resulting bubble is an enlarged spherical bubble which is several times larger in its volume when compared to the direct beam radiation in water. In this talk, a review of our recent research effort in achieving high-throughput injection of drug via the microjet penetrator is given with its potential medical applications.

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