Abstract: Micromachining with Single Mode Fiber Laser for Medical Device Production, Klaus Kleine

This Thesis is based on several research and development programs to implement the use of fibre lasers in the manufacturing of medical devices like stents and pacemakers. In general, the medical device manufacturing industry has a high demand for laser micromachining applications. The content of the thesis describes laser micromachining of metallic components with single mode fibre lasers. At the started of the research work for this thesis, most laser machining processes used flash-lamp pumped solid-state lasers for those applications. Reliable laser operation and low maintenance are required to meet the yields and up-time requirements for medical devices, such as stent cutting and pacemaker welding. Many lasers for micromachining applications are configured to operate near the diffraction limited beam performance to achieve very small feature sizes. It is challenging to maintain such a laser system performance in a production environment.

The fibre laser provides a number of attractive features that could address the needs to maintain high up-time and high yields:

- A single mode fibre laser does not require mirror alignment.
- Diode pumped fibre lasers reduce maintenance due to eliminating the lamp change.
- The compact air-cooled design helps to save expensive clean room space on the production floor.

By 2000 the increases in average laser power extended the use of the fibre lasers into industrial applications such as cutting and welding.. The lasers investigated in this thesis generated 50 W to 200 W of laser power, representing the highest power levels commercially available at that time.

For the microcutting of medical implants such as stents and guide wires, kerf width and sidewall surface quality are of special interest. Developing processes capable of achieving these criteria was the primary objective of the research described in this thesis. A secondary concern is the heat affected zone created by the laser machining process. Operation conditions to minimize this effect are also discussed in this thesis.

Many microwelding applications in the electronics, telecom and medical device industry require smaller and smaller laser joining areas. The quality of a laser welded joint is very dependant on the temporal and spatial parameters of the laser beam. These parameters must be adjusted to match to the processing speed and the materials being welded. Switching continuous wave fibre lasers can achieve the parameters for processes requiring low average power. However the pulse-to-pulse stability can effect the process and has been investigated. Some welding applications require focus spot diameters in the order of 50 μm and pulse energy levels as low as 10 mJ. The fibre laser's excellent single mode beam quality provides the desired spot size and laser power density.

The research summarized in this thesis was performed to prove that fibre lasers are viable tools for micromachining. This thesis compares fibre laser machining results with those using legacy laser processes and describes ways to improve the quality of the fibre laser machining process.