Micromachining setup using femtosecond pulses

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Abstract

A laser scanning system using femtosecond laser for micromachining has been implemented. This system can be used as writing or cutting purpose. Femtosecond pulses with low energy are able to remove hard material without thermal damage. This ability can be explored to cut several materials with high degree of control. Consequently, a very small object can be sculpted and we can call this as micromaching. Here, a micromachining has been demonstrated by making stents for medical application. These stents, consisting in a small and complex tubular structure, can be introduced inside the heat vessel to open it. This is a special method that can be used for the rapid manufacturing of microcomponents.

Introduction

A micromachining setup using ultrashort laser pulses is described here. Micromachining using laser beam is a new interesting growing area due to it technological application. The increasing interest for light and movable electronic systems, sensors, and small digital devices, drives the technological research toward integrated devices with small dimensions. A laser beam has been successfully used as cutting tools due to the possibility of the laser beam being focussed in a small spot size. Nevertheless, CW or long pulse laser, traditionally used as cutting tools, sometimes not allows obtaining a precise cutting finish due to the thermal effects. Nowadays, with the technological development, there are several commercial laser systems that can delivery high intensity femtosecond pulses with high repetition rate. Femtosecond pulses with low energy are able to remove hard material without thermal damage. This ability can be used to cut several materials with high degree of control. Consequently, a very small object can be sculpted and we can call this as micromaching. Also, the femtosecond laser has several new applications beyond cutting tool. A controllable reproducible modification of dielectrics within the bulk of material by focused ultrashort laser pulses provides the opportunity for writing three-dimensional (3D) photonic structures of transparent dielectrics, microlenses, etc [1]. Here we have developed a laser scanning system that can be used to control a femtosecond laser beam propagation. This laser beam can be focussed and used to write or cut any type of figure shape. Special effort is directed to make possible cut small and tiny piece of metals, i. e., micromachining.

Materials and Methods

The femtosecond laser used in this experiment is a commercial chirped pulse amplified CPA 2001 system from Clark MRX Inc. This system cans delivery pulses up to 0.8mJ with 150fs at 775nm at 1KHz repetition rate.

The laser scanning system is based on two galvanometers, with two metallic mirrors, that can deflect a focussed laser beam in two orthogonal directions, x and y. Also, we have a step motor that can be used to rotate a cylindrical target, if necessary. For small object, high degree of accuracy and stability are necessary. The whole fabrication process is divided into two main steps: first, one determined patterning is made readable for the writing system, in our case a standard bitmap draw. Second, the laser prints this draw with the servo mechanical devices assisted by the computer. Special care should be taking to match the desired size of figure into the target. Lens with different focal length should be used. To control these servo mechanical devices, one PC computer with AD/DA converter card was used. Using a LabView program, we have developed codes to read and print any figure with the laser. There are different process strategies for writing or for cutting. For example, we have to work with the compromise between laser intensity, scan speed and laser repetition rate to obtain the best compromise between the time consuming and finish quality.

The ability of the femtosecond laser pulse not produce thermal damage can be explored to cut several materials with high degree of control. Consequently, a very small object can be sculpted and we can call this as micromaching. Here, a micromachining has been demonstrated by making stents for medical application. Stents are small and complex tubular structures that can be introduced inside a clogged heart vessel to keep it open. These tiny tubular structures can be introduced inside a vessel and be expanded several times with a balloon.

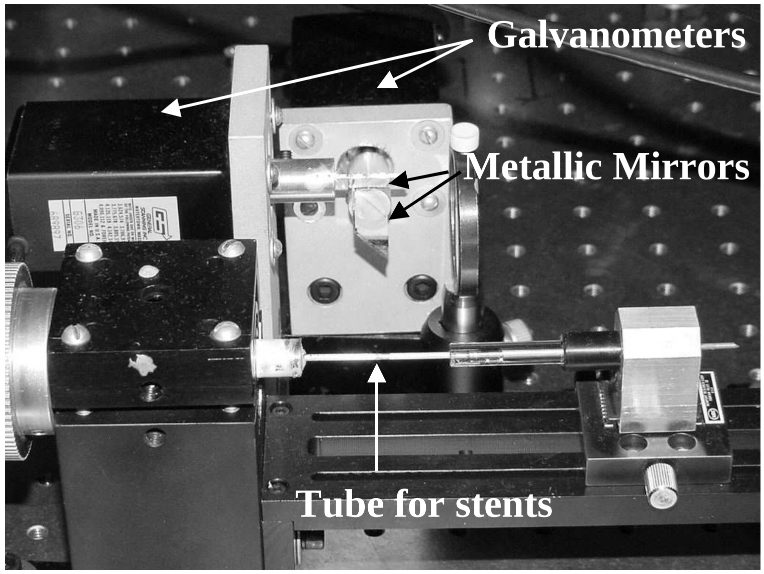

Figure 1: Picture of the writing system. Here, we can see: two galvanometer with metallic mirrors, a support controlled by a step motor and a tube to make the stents.

Results and Discussions

Several tests have been performed to demonstrate a reliability of the laser scanning system. In the beginning, we have plotted letters and simple figures with "big" size using only the two galvanometers (*x* and *y* directions). These tests allow evaluating the quality of the electronics, the mechanical components and the response to the computer control. The galvanometers have a characteristic response time that should be matched with the electronic control and the laser repetition rate. The linear scan speed should be not to fast to avoid dots in a trace due to repetition rate of the laser (1KHz). As we can see in the fig. 2, the laser scanning system could plot a draw with high quality.

Figure 2: Writing test in a sheet of iron steel.

We also have tested our laser scanning system as cutting tool. In this development of micromaching ability, we have worked with production of a small stent [2]. These stents have about 1.5 mm diameter, 10 mm long with 100 μm thick walls (fig. 3).

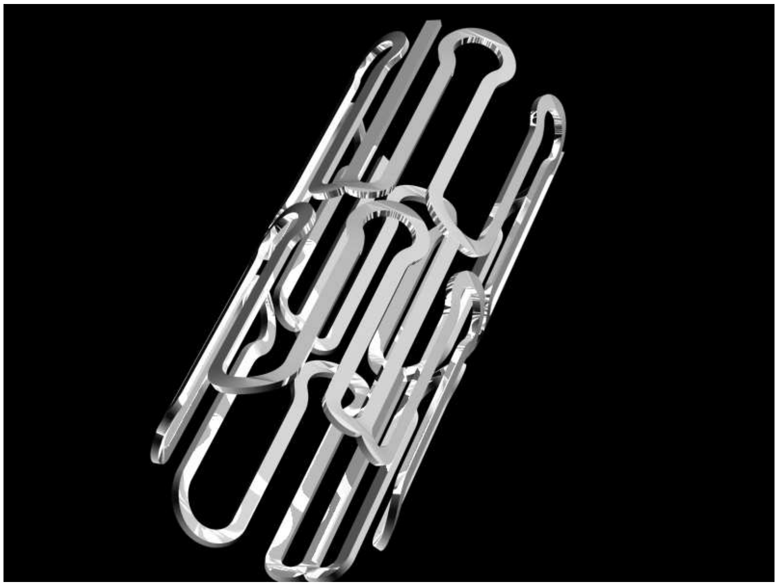

Figure 3: Picture of a type of stent.

To make this stents, we have to use a tiny metallic tube where we have to sculpt the shape of the fig. 3. We have used one galvanometer to move the beam in horizontal direction (*x*-direction) and a step motor to rotate the tube (*y*-direction). The effects of pulse energy, repetition rates and *x-y* translation speed in the cutting should be evaluated. For low energy pulse, low translation speed should be used. A metallic insert is used to avoid the trespassing of the laser beam into other side of the tube walls. Here we have obtained good cutting quality working with pulses with about 0.2 mJ focused by f=10 cm long lens and about 1mm/min of linear speed. The cutting size was about 50 μm. This big spot size is probably due to transversal multimode property of the laser beam. The total time to obtain one stent stills long, about an hour. Further investment has to be done to improve the speed of the fabrication process.

Conclusions

In summary, a laser scanning system using femtosecond laser for micromachining has been implemented and tested. This system has been used as writing and cutting tool. Micromachining has been demonstrated making stents for medical application. This is a new promising method for manufacturing of microcomponents

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