DESY summerstudent program 2008

Laser Ablation

Christoph Wilms

Supervisor: Dr.Alke Meents

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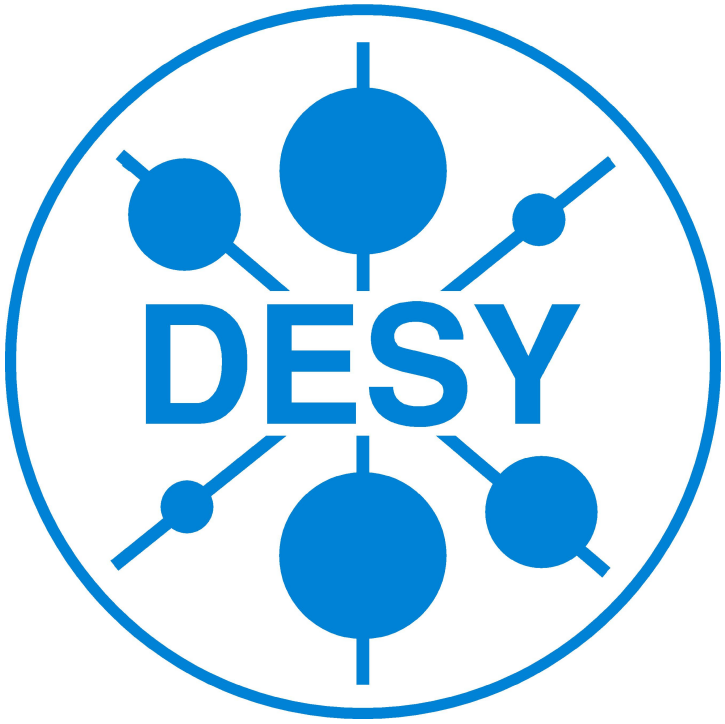

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1 Motivation

My Project was motivated by the fact, that it is hard to find a company, which is able to produce a special design of a diamond crystal. Whether the quality of the product is not good enough or the prices are too high. Furthermore DESY has the possibilities to do Laser ablation due to the fact that the pump Laser (Titanium Sapphire) of Flash has enough power for this kind of operation.

2 Introduction to Lasers

The term "laser" is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers are based on the mechanism, that Atoms can absorb or emit Energy via Photons. The Energy is given by

$$E = h\nu, \tag{2.1}$$

where h is the Planck Constant. An excited Atom can either way go back into ground state via Spontaneous emission or by an induced emission. These mechanisms are illustrated in Figure 1. A Laser uses the principle of induced Emission to create coherent monochromatic

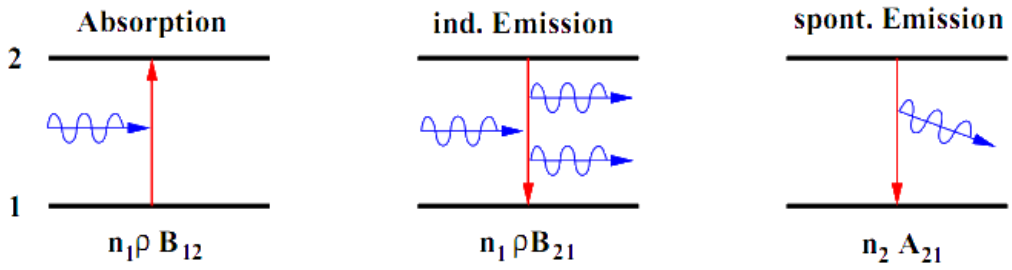

Figure 1: Sketch of the emission and absorption process[1]

light of high intensity. Coherence is a property of waves that enables stationary interference. Taking the Maxwell-Boltzmann-Distribution into account, it is clear that the ground state has a higher population than the excited state in thermal equilibrium. If the induced emission process is supposed to be dominant then it is necessary that the excited state has a higher population. This situation is called population inversion. To create such a situation it is necessary to apply energy to the system, e.g. by electron collision or by optical excitation.
A Laser consists mainly of three parts, a lasing medium that allows the induced transitions due to the population inversion, a pumpsource which supplies the required energy and a resonator, which reflects the emitted light, so that the process of induced transitions can be activated.
The simplest case is a two-level-system with population number n_1 and n_2 and the Einstein Coefficients A_{21}, B_{21} and B_{12}, which represent the transition probability. The Number $\dot{N}$ of

absorbed or emitted Photons per Volume unit and time can be calculated via

$$\dot{N}_A = n_1 \rho(\nu) B_{12} \quad \text{absorption} \tag{2.2}$$

$$\dot{N}_{IE} = n_2 \rho(\nu) B_{21} \quad \text{induced emission} \tag{2.3}$$

$$\dot{N}_E = n_2 A_{12} \quad \text{spontaneous emission.} \tag{2.4}$$

whereas $\rho(\nu)$ is the density of the radiation field. A Laser, which works on the principle of a two-level-system can not be realized, because it is not possible to create a population inversion.
The name of the Titanium-Sapphire Laser refers to the used crystal of sapphire (Al_2O_3) that is doped with titanium ions, that makes up the lasing medium. Titanium-Sapphire lasers are usually pumped by another laser like argon-ion lasers. The wavelength output of a Titanium-Sapphire laser is tuneable from 650 to 1100 nanometers, but it operates most efficiently at wavelengths around 800 nanometers.

2.1 Laser ablation

The main principle of Laser ablation is the conversion of optical into thermal energy via electronic excitation. If the energy of the Laser is high enough, the chemical bondings of the material can be destroyed, so that the material vaporizes and may be ejected from the material.
By this process it is possible to create small holes on the surface of the material and if this technique is applied often enough, it is possible to shape the crystal if moved properly.
The structure of the hole, especially the depth, created by the laser radiation depends on the optical properties of the material and the wavelength of the laser.

3 My work

My work on this project was mainly to set up a machine that can move a probe in three dimensions. I also had to write a program which controls these three motors, so that it is possible to give the probe a defined shape.
At first I had to assemble the connecting plugs, which connect the motor with the motor control unit. Therefor it is necessary to know the pin assignment of the motor control unit. With this knowledge the cables can be connected to the connecting plugs via brazing.
The motors can be controlled with a computer. In Figure 2 is a drawing which shows the principle of controlling a motor by a computer. The VME-Crate is the connection between control terminal and motor. Online is an interface for Linux, which can communicate with a VME-Crate, so that it is possible to control motors, shutters and various other beamline components. Online is able to handle perl scripts (perl is a programming language).

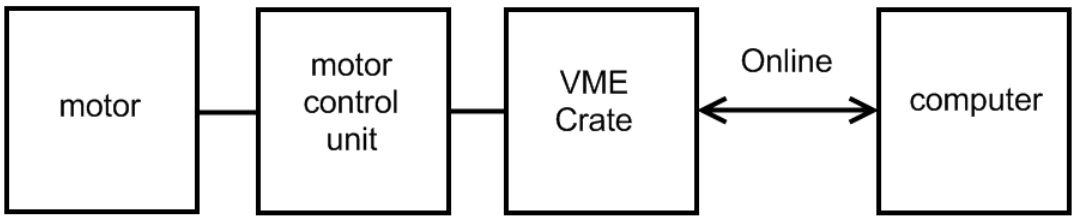

Figure 2: Drawing of the communication principle

For this Project it was necessary to develop a program which uses a simple form of data input. Therefor I have chosen a black and white picture; a black pixel is equal to a spot, which is supposed to be lasered, whereas a white pixel is not supposed to be lasered. With the help of this technique it is easy to write a program, which "'reads"' a picture pixel by pixel and moves the probe to the position, which should be removed. After the program has red a whole picture it loads the next picture, which represents a new layer, so that it is possible to create three dimensional structures. To improve the quality of the produced shape it is necessary to place a shutter in the beam, so that the beam can be switched off, while the probe moves.
The used motors are stepped motors, that means one step is the smallest distance such a motor can move. For the x- and y-axes one step is equal to a distance of 27,5nm and one step in the z-direction corresponds to a distance of 5,5nm (but this is just an abstract value, in reality the accuracy is in the micrometer range). The laser beam has a diameter of 10μm. Therefor it is important to translate the pixels into the correct amount of steps.
During the process of laser ablation a thin layer of carbon is produced on the surface. This layer can be removed with an acid afterwards.

4 My results

Because the Laser has been upgraded during my project, I didn't have the possibility to use it for laser ablation. So I will present some intermediate data.

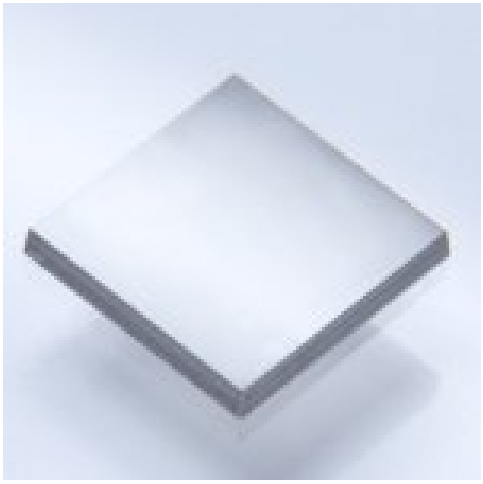

Figure 3: A picture of a comparable diamond crystal with other dimensions (2.6 x 2.6 x 0.5 mm)[2]

The basic material is an artificial diamond crystal (2 x 3 x 1.5 mm) (cf. Figure 3). Based on these Informations my program uses pictures where one pixel is equal to one micrometer. With the help of the module IMAGER[1] for perl I have created a three dimensional shape based on the object illustrated in Figure 4. In Figure 5 are some of these pictures illustrated, it is obvious that it is necessary to laser the crystal from both sides, top and bottom, because it has a structure on both sides.

[1] `http://imager.perl.org/`

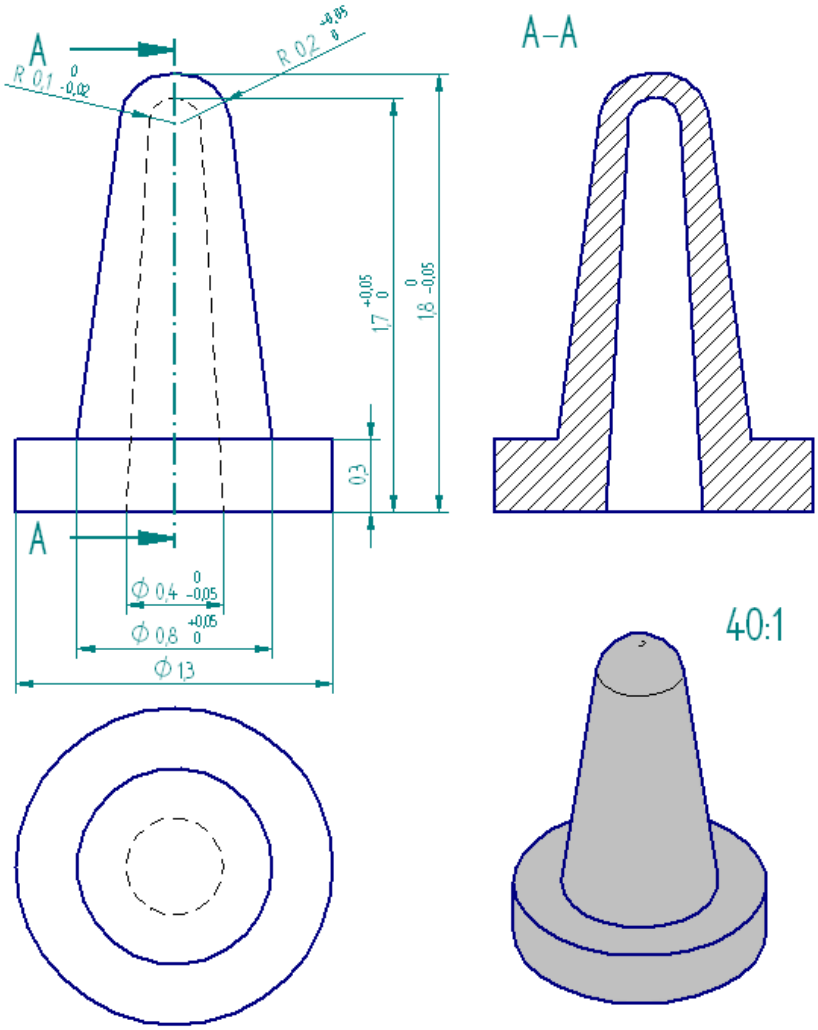

Figure 4: Sketch of planned shape of the diamond crystal

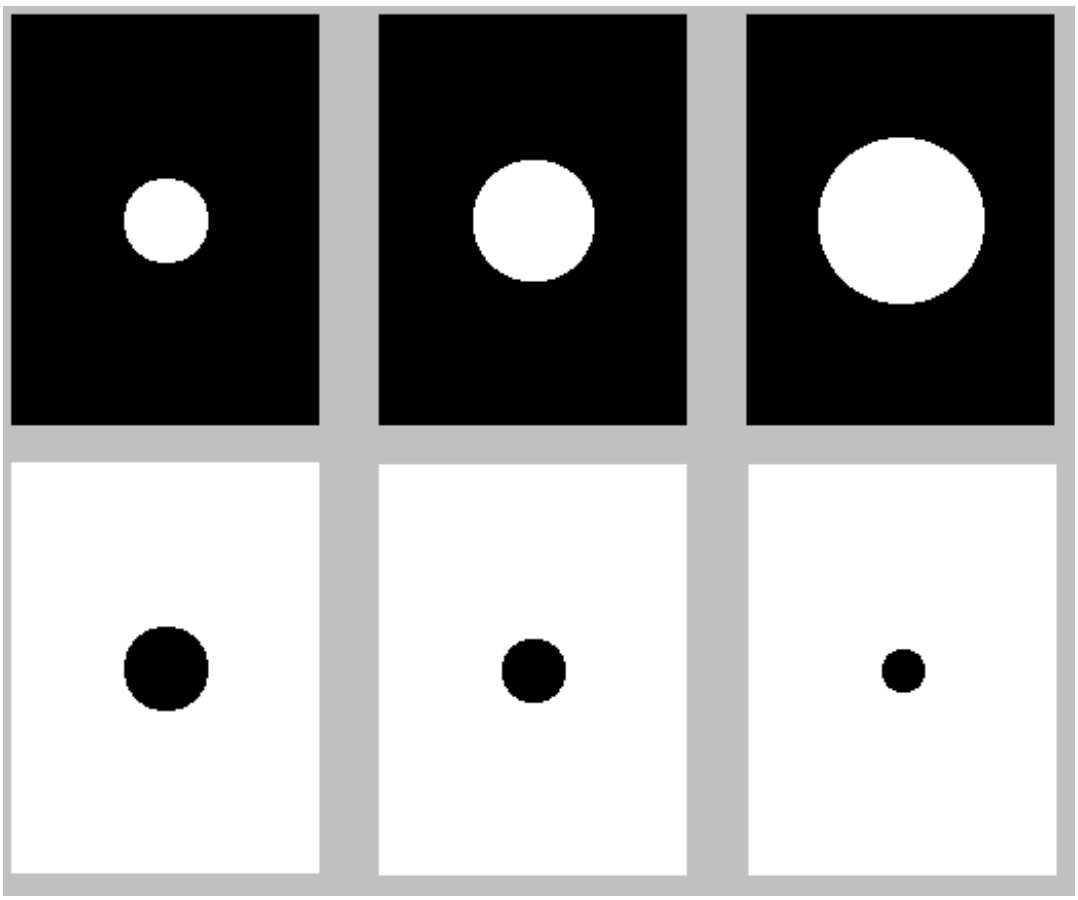

Figure 5: Pictures created by my program

References

[1] http://praktikum.physik.uni-dortmund.de/neu/images/provisorisch/v61.pdf

[2] http://193.120.252.126/cvd/uploaded_files/iiiaplte.jpg

September 11, 2008