Course: **High Temperature Processes**

Professor: **Dubenskaya Maria**

Laboratory session

on

Practical Work: Laser Engraving /Cutting

Laser Beam Properties

Ecole Centrale de Lyon, France

Master of Science in Mechanical Engineering and Advanced Technologies

Programme

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1. ABSTRACT

This comprehensive lab report delves into the intricate realm of laser technology, with a primary focus on the VLS 3.5—a 50W CO2 laser system renowned for its versatility. The study encompasses practical applications such as engraving and cutting various materials, offering a blend of theoretical calculations and hands-on exploration. Calculations involving Gaussian beams, minimum radius, and focalization provide quantitative insights into laser behavior, while practical insights into raster engraving processes and the operational specifics of the VLS 3.5 contribute to a holistic understanding of laser applications. The report seeks to elevate our comprehension of laser phenomena and underscore the tangible implications of these insights.

2. INTRODUCTION

Laser beams, characterized by their coherence and focused intensity, play a pivotal role in modern optics and photonics. The acronym "LASER" itself encapsulates the essence of these devices – Light Amplification by Stimulated Emission of Radiation. Unlike conventional light sources, lasers emit monochromatic and collimated light, making them indispensable in various scientific, medical, and industrial applications.

Within the realm of laser beams, Gaussian beams stand out for their unique intensity profile, resembling a bell-shaped curve. These beams, known for their well-defined spatial and spectral characteristics, find widespread use in applications ranging from laser imaging to precise material processing. Understanding the properties and behavior of Gaussian beams is fundamental to harnessing their potential in diverse technological arenas.

A notable application of laser technology is raster engraving, a process that involves controlled material removal by scanning a laser beam across a surface in a systematic pattern. This technique is particularly valuable in industries where intricate designs and detailed patterns are paramount, such as in the fabrication of electronic components or artistic engraving. Raster engraving offers unparalleled precision, enabling the creation of intricate and customized designs on various materials.

In this lab report, we delve into the intricacies of laser beams, with a specific focus on Gaussian beams and their characteristics. Additionally, we explore the practical application of laser technology through raster engraving, aiming to comprehend the underlying principles and methodologies governing this precise material processing technique. Through experimental analysis and theoretical considerations, our objective is to deepen our understanding of these optical phenomena and their implications across a spectrum of technological applications.

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3. EQUIPMENT DESCRIPTION:

The VLS 3.5, equipped with a 50W CO2 laser with a wavelength of 10.6µm, emerges as a user-friendly and versatile tool for material processing. The integration of special optics facilitates precise focusing on the workpiece, while the numerically controlled table, spanning 60 x 40 cm, ensures adaptability to material height. This equipment stands out for its capability to engrave and cut non-metallic, chlorine-free materials, ranging from traditional engraving materials to glass, wood, and plastics, making it instrumental in scientific, medical, and industrial applications.

4. BEAM CALCULATIONS

Calculation of the minimum radius

Using the divergence formula, we know that $w_0 = \frac{\lambda}{\pi\theta}$ therefore,

$$w_0 = \frac{\lambda}{\pi\theta} = \frac{10.6 \text{ x } 10^{-6}}{0.0025\pi} = 1.3496 = \mathbf{1.35 \text{ x} 10^{-3}}$$

Calculation of the Rayleigh length Z_R

$$Z_R = \frac{\pi w_0^2}{\lambda}$$

$$Z_R = \frac{\pi(1.35 \text{ x } 10^{-3})^2}{10.6 \text{ x } 10^{-6}}$$

$$Z_R = 0.54014$$

$$\mathbf{Z_R = 0.54}$$

Calculation of the beam radius w on the mirror.

To calculate the beam radius on the mirror, we know that the distance is L/2 = we use the formula:

$$w(z) = w_0 = \sqrt{1 + \left(\frac{\lambda z}{\pi w_0^2}\right)}$$

$$w(L/2) = w_0 = \sqrt{1 + \left(\frac{\lambda \left(\frac{L}{2}\right)}{\pi w_0^2}\right)}$$

$$= \mathbf{1.548 \ x \ 10^{-3}}$$

Focalization

The Gaussian beam is focused by a spherical mirror and the determination of how the Gaussian beam is transformed at the focal plane if the beam diameter, w'_0 at the focal point is described by the following relationship.

$$\frac{w'_0}{w_0} = \frac{1}{\sqrt{\left[\left(\frac{Z_R}{f}\right)^2 + \left(1 - \frac{Z_R}{f}\right)^2\right]}}$$

Gaussian beam is focused by a spherical mirror with a focal length of 2 inch = 50.8 mm. To determine the laser spot after focalization we the above formula therefore,

$$w'_0 = w_0 \frac{1}{\sqrt{\left[\left(\frac{Z_R}{f}\right)^2 + \left(1 - \frac{Z_R}{f}\right)^2\right]}}$$

$$= \mathbf{9.412 \ x \ 10^{-5}}$$

5. RASTER ENGRAVING

In laser machining processes, there are three distinct methods for bringing the laser beam onto the workpiece: raster engraving, vector marking and vector cutting.
Raster: is a process in which the laser beam generates an image using bi-directional, horizontal raster lines. The laser automatically engraves fills and bitmaps in raster.

ENGRAVING A PHOTO ON WOOD

We engraved the photos on the wood as stated below:

1. In Photograv software, we opened the files in *.jpg/bmp format.
2. We selected the material to be laser engraved.
3. We resized our images and set the resolution to 600 DPI.
4. Next, we pressed the "Interactive Mode" button to see on the screen how the engraving would be done on the selected material.
5. We also performed manual post-processing by converting the images to grayscale.
6. We finalized the processing step.
7. After finalizing the processing, we saved the photo for laser engraving.
8. We then opened the processed file in Inkscape and drew a frame for laser cutting, specifying a red line (R:255, G:0, B:0) with a thickness of 0.01mm.
9. The file was registered in PDF format.
10. Finally, from Acrobat Reader, we sent the file to the VLS 3.5 laser.

VLS 3.5 SETTINGS

Viewing And Tools

- We opened the UCP software, and the visualization window appeared. Here, we checked the state of our files: cutting lines should appear in red, engraving areas in black and grey, vectors in blue.
- Using the "Pointer" tool, we moved the laser pointer to define where the machine will work.
- The "Move" tool facilitated the movement of the drawing.
- We duplicated and multiplied the number of drawings.
- We estimated the working time.

MATERIALS

- We chose a material.
- We entered its thickness.
- To finish, we clicked on "Apply" and then on "OK"; the UCP software window closed.
- In the next window, we clicked on "Print."

Engraved Picture

6. RESULTS & DISCUSSION

The calculated values serve as numerical benchmarks that elucidate the nuanced behavior of laser beams. The minimum radius ($\mathbf{1.\ 35\ x10^{-3}}$) underscores the precision inherent in the laser system, a critical factor in applications requiring accuracy. The Rayleigh length $\mathbf{(Z_R = 0.54)}$ and beam radius ($\mathbf{1.548\,x\,10^{-3}}$) on the mirror provide spatial insights, crucial for understanding how the laser distributes its energy. Delving into Gaussian beam transformation at the focal plane reveals the intricate relationship between initial beam diameter and transformation characteristics after focalization ($\mathbf{9.\ 412\ x\ 10^{-5}}$). The discussion merges theoretical considerations with practical implications, bridging the gap between numerical insights and real-world applications.

7. CONCLUSION

In conclusion, this report navigates the multifaceted landscape of laser technology, showcasing VLS 3.5 as an exemplary tool. The calculated values serve as foundational benchmarks, providing a deeper understanding of laser behavior. The VLS 3.5, with its adaptability and precision, emerges as a versatile asset in material processing. This report, by intricately connecting theory and practice, contributes to the ongoing discourse on laser phenomena and their tangible applications across diverse material processing scenarios. The numerical insights garnered from calculations provide a roadmap for optimizing laser processes, further cementing the significance of VLS 3.5 in the ever-evolving landscape of laser technology.