LMS
Laser Diamond Marking System

Diamond Marking Principles

Emre Teoman
Dana Lee Church
Version 2.0
February 2003

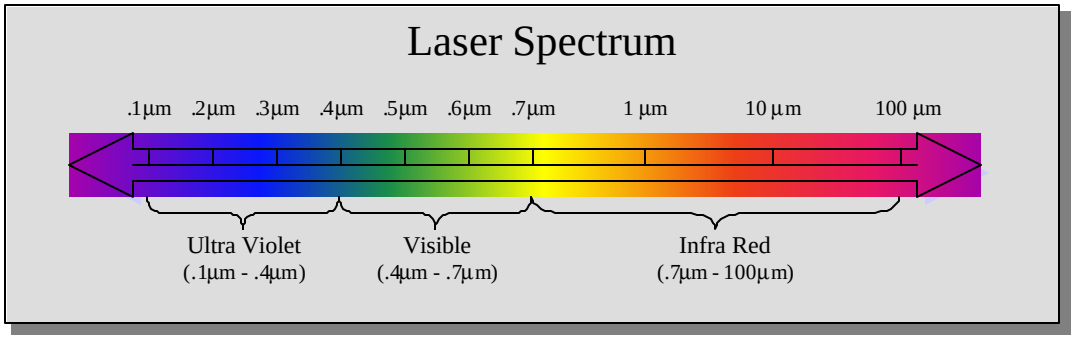
Table of Contents

1.0 Marking Diamonds with Lasers

The LMS is a laser based marking system. The system holds diamonds below a focused beam of ultraviolet light. The light has been focused so tightly that it burns a small microscopic pit onto the surface of the gem. The depth of this pit is extremely shallow (~1 or 2 microns). The color of the pit can vary from nearly transparent to totally black. The LMS creates characters by moving the diamond in X and Y axis while the laser is firing. This is much like holding a pencil still, while moving the paper below it to form characters. Marking on the girdle of a gem is the most popular use for the LMS. The diamond can be marked over the entire diameter of the gem through a series of rotations. The laser is kept in focus, like a camera, by moving the fixed lens, or objective, up and down. This motion is called Z-axis motion. In addition to moving the diamond, and the objective, the user has many other controls at his disposal. Laser energy can be varied, much like an artist varies the firmness by which he holds his brush. Laser spot size can be adjusted to achieve the effect of selecting different brush widths. In addition, the laser can be spaced to produce separate dots, or one continuous line. In a very real sense, the LMS is much like an artists pallet. The end result depends as much upon the skill of the user, as well as the sophistication of the technology.

1.1 Laser Interaction With Diamonds

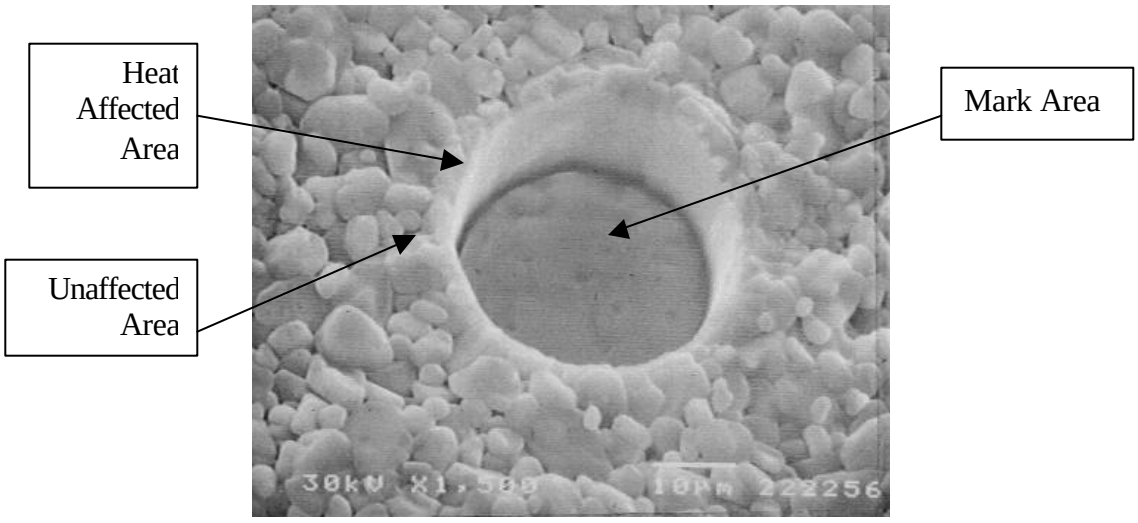
Diamonds are transparent to wavelengths well beyond those visible by the human eye. The chart below details the typical wavelength of light that can be obtained from commercially available lasers. Diamonds are transparent to laser light from .200µm in the UV to well past 10µm in the Infra Red. This transparency makes it difficult for light to be absorbed onto the surface to form a legible mark. The LMS solves this problem by emitting light in the deep UV (193nm or .193µm). At this wavelength one can mark a diamond, with little transmission of light into the body of the gem.



This lack of transmission is critical since it means that the laser can mark without the need for any other process or preparation. Other laser marking systems need to 'ink' or prepare the diamond before they begin marking. This is done to allow the light to be absorbed by the ink, and a mark formed by the heat generated by the process. The LMS doesn't need to generate this type of thermal stress to mark, and therefore presents less risk to the gem during the marking process.

1.2 **Cracking, Thermal Ablation, and Other Destructive Issues**

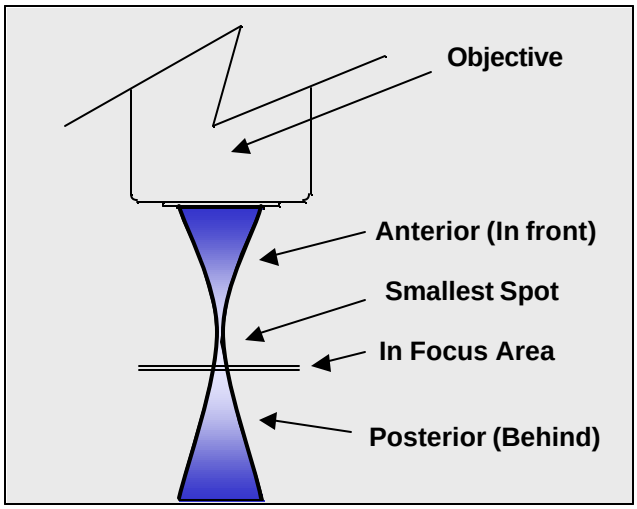
The 193nm Excimer laser ablates a mark on the diamond in a 'cold' process. This process does not appreciably affect the area around the mark. In the picture below one can see that the surrounding material shows little sign of thermal stress after exposure to laser energy.



With most other lasers the area of thermal stress is nearly as large as the mark itself. Having said this, the 193nm Excimer is not completely free from thermal effects. One must be careful in overlapping marks at the same point, near or on a fractured area. It is possible to initiate a crack, or enlarge a crack with excessive energy, and extended laser duration with some stones. In general, however, it takes quite a large amount of energy and a long dwell time for the 193nm Excimer to risk opening a crack in a diamond.

2.0 **The Laser Beam and Laser Interaction with the Diamond**

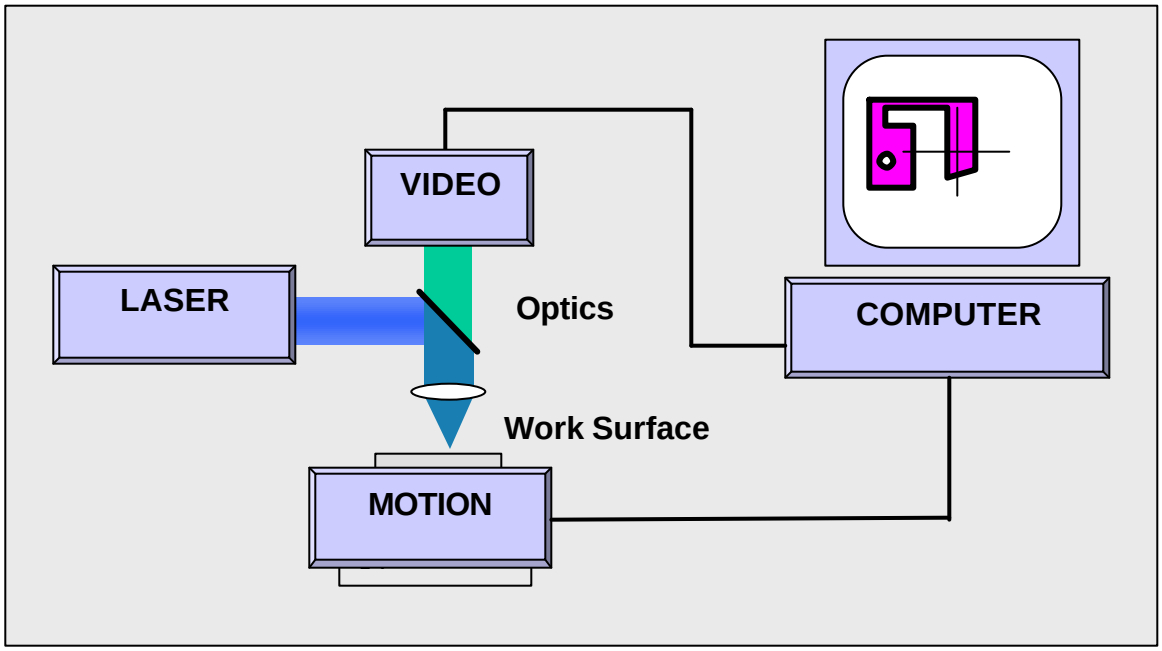
The laser beam is not a straight shaft of light as some science fiction movies would have us believe. The beam emanating from the objective of the LMS is actually a complex array of converging and diverging rays.



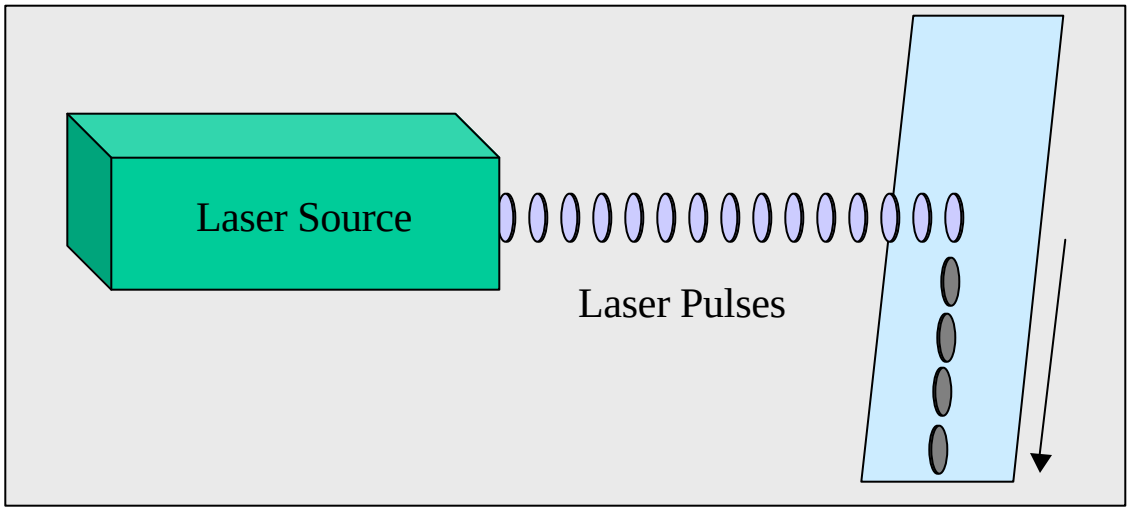
The LMS is usually configured to mark in the area just past the smallest spot, or greatest laser intensity. This is done to produce the best overall spot quality. The area that is considered to be in focus is very small, about as small as the diameter of human hair. To ensure that the laser is always in focus the objective is moved up and down on what we call the Z-stage. The marks are made by moving the diamond with the laser firing, while under the diamond.

3.0 **Diamond Marking System Design**

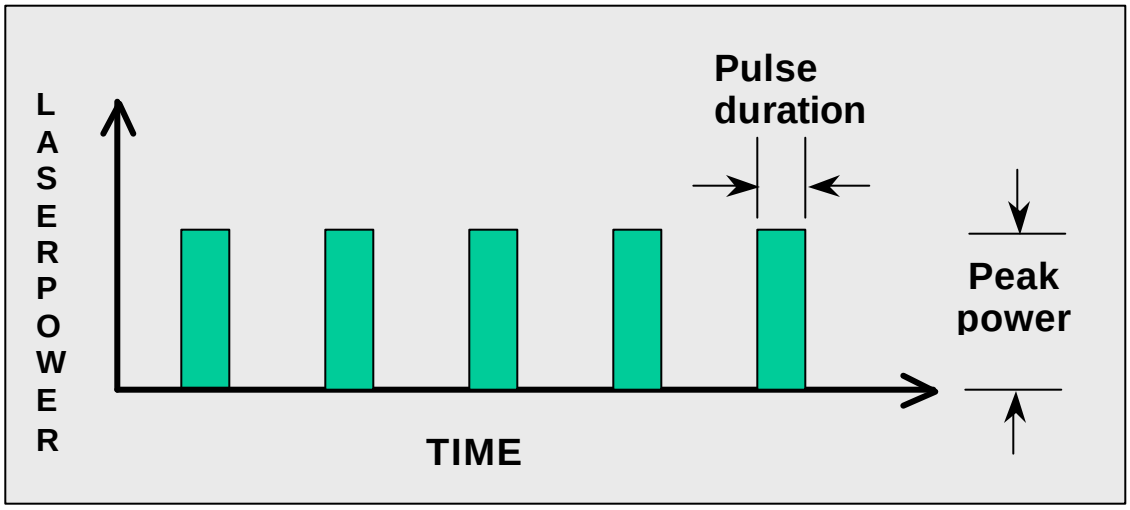
The typical diamond marking system comprises a laser, optics, a visualization system, a motion system, a part holding jig, and a structure. The numbers of possible design combinations are varied and myriad. All laser-marking systems, however, have these basic elements.



The lasers used to mark diamonds are often pulsed lasers. Pulsed lasers generate short bursts of energy, high enough to establish a mark and form carbon deposits. These pulses are emitted at regular intervals. The rate of light generation is called pulse repetition rate (PRR), or pulse repetition frequency (PRF). The higher the PRF, the higher the average energy transferred to the work surface. The strength of each individual pulse can also be adjusted. With Excimer lasers the pulse energy can be increased to provide greater marking strength. Thus, there are generally two ways to increase marking strength, greater pulse energy, or greater pulse rate.



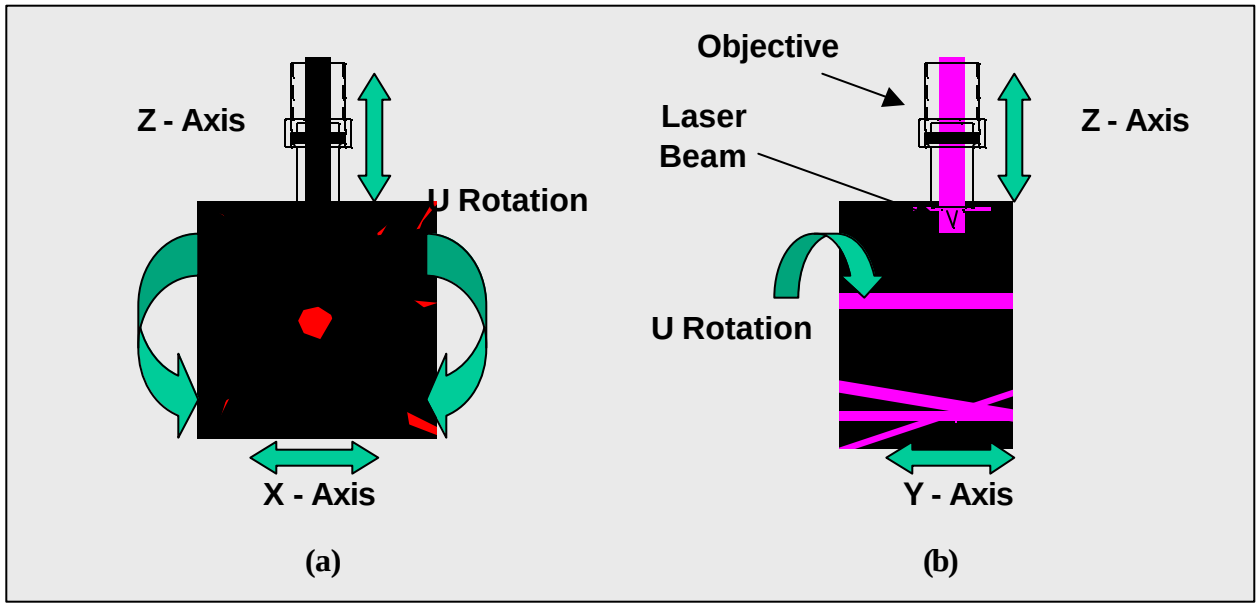
Typical Pulsed Laser Source



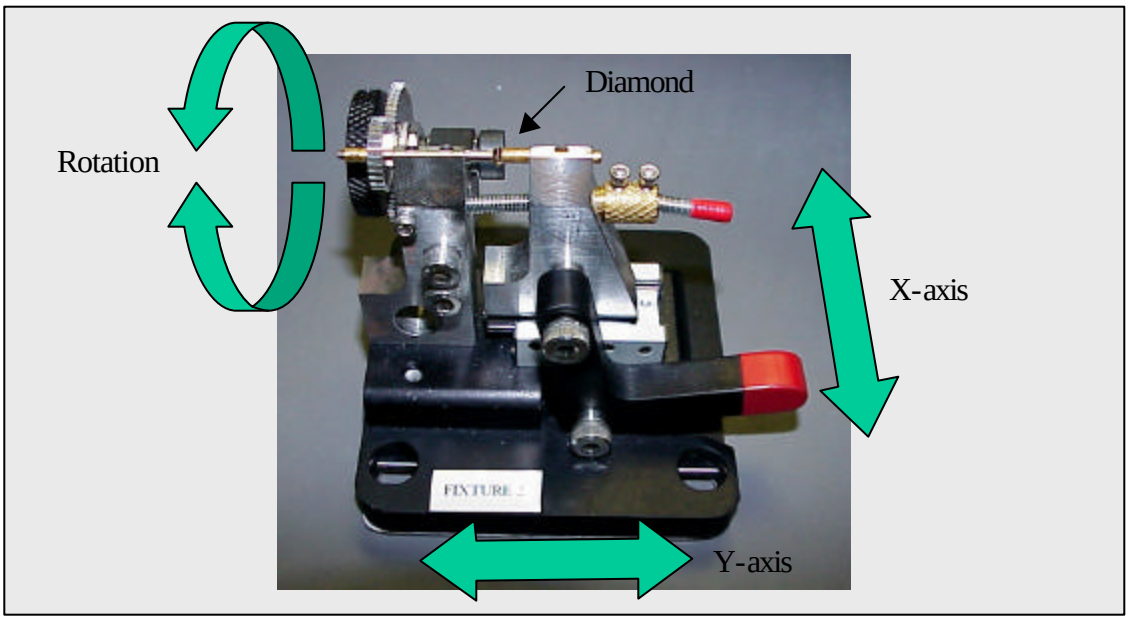
Laser Pulses and Energy Over Time

4.0 **Diamond Motion**

As stated earlier, the laser beam only moves up and down. A mark is made by moving the Diamond back and forth, as well as left and right while the laser beam is moving up and down. In addition to left, right, back, front, and up and down, the Diamond can be rotated to expose various sections of the girdle during marking.



The left and right motion is called X-axis motion. The back and forth motion is called Y-axis motion. Up and down is called Z-axis motion. Rotation is called U-axis motion.



The X and Y-axis stages are the largest and most critical to the motion system. The typical characters made are less than the width of a single human hair. The motion system must be able to move in steps over one hundred times smaller than the width of a single human hair in order to make smooth and legible marks.

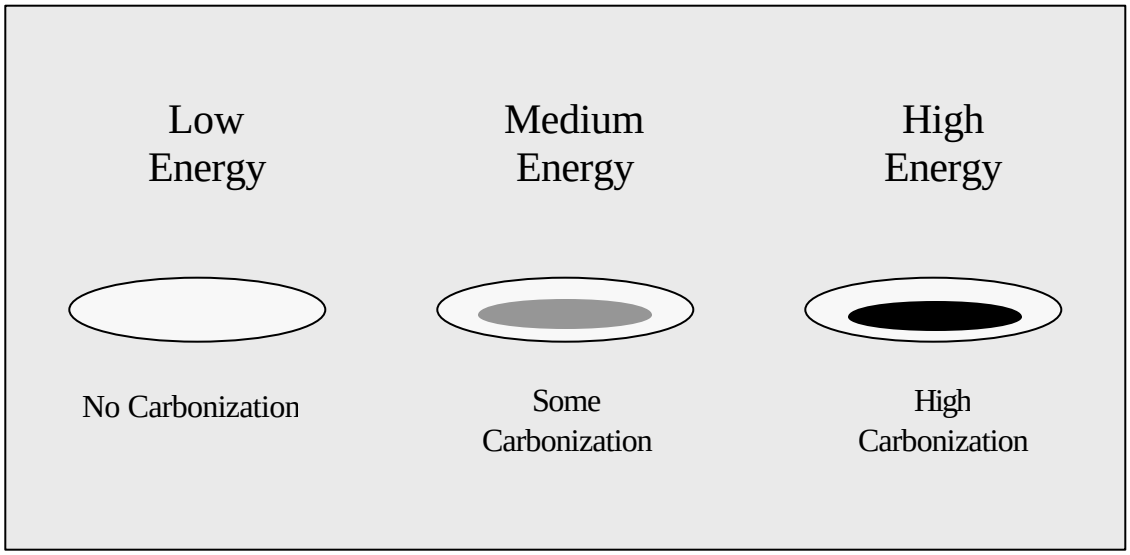
5.0 **Mark Quality and Control**

As stated earlier, marking diamonds is still more art than science. Like an artists pallet, once can control many different parameters of the LMS to achieve the desired result.

Methods of Controlling Mark Quality & Result

Type of Control	*Result on Mark Quality*
Laser Energy	Dots get darker with increased energy
Shot Spacing	Lines get darker with decreased spacing
Beam Size	Smaller and lighter marks with smaller size settings.
Repeating Mark	Mark gets darker, and a little wider
Slow Motion	Cleaner characters, better definition
Scaling	Make marks bigger and smaller
Font	Different fonts have different styles & darkness

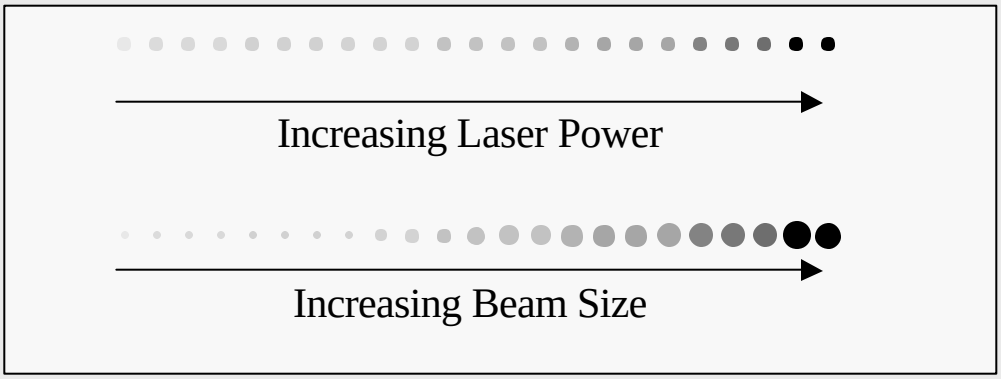
Laser energy is the primary way to increase mark darkness. With low energy the mark is nearly transparent. At higher energies the bottom of the mark begins to form carbon deposits. These deposits absorb light and make the mark look dark. Under certain circumstances the carbon can be removed. This can be accomplished by using very strong chemical treatments. Carbon can also often be removed from marks made with low energy setting.



Shot spacing will also change the look of a mark. Small spots with gaps between each spot will produce an effect similar to that of a light, fine pencil.

One can overlap dots to produce a dark, continuous line.

Beam Size will also increase spot darkness, much like power increases, however with a more dramatic increase in spot size.



Below is another example of changes in beam size affecting character quality.

Example of how beam size changes mark quality

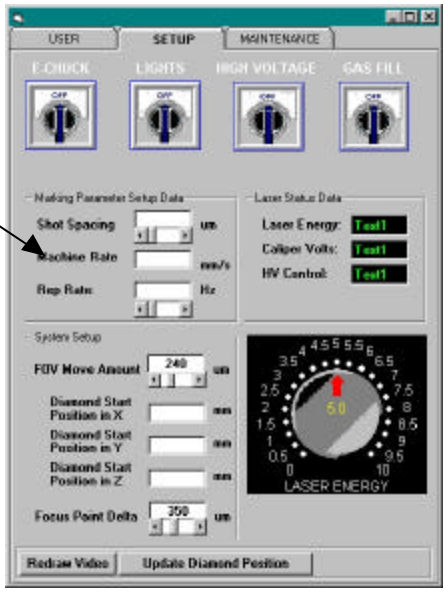
Power = 4
Beam Size = 18.5

Power = 4
Beam Size = 17.5

Because the LMS utilizes a wavelength in the deep UV one can mark over the same place repeatedly without great concern. The software for the LMS allows the user to repeat the same marks, over the same location, with great precision. By marking the diamond twice, the user can increase the darkness, and size of the mark in a fashion similar to the beam size example shown above. Repeating a mark more than twice does not appreciably increase mark darkness, or width.

Machine rate (marking speed) can be manipulated to change marking quality.

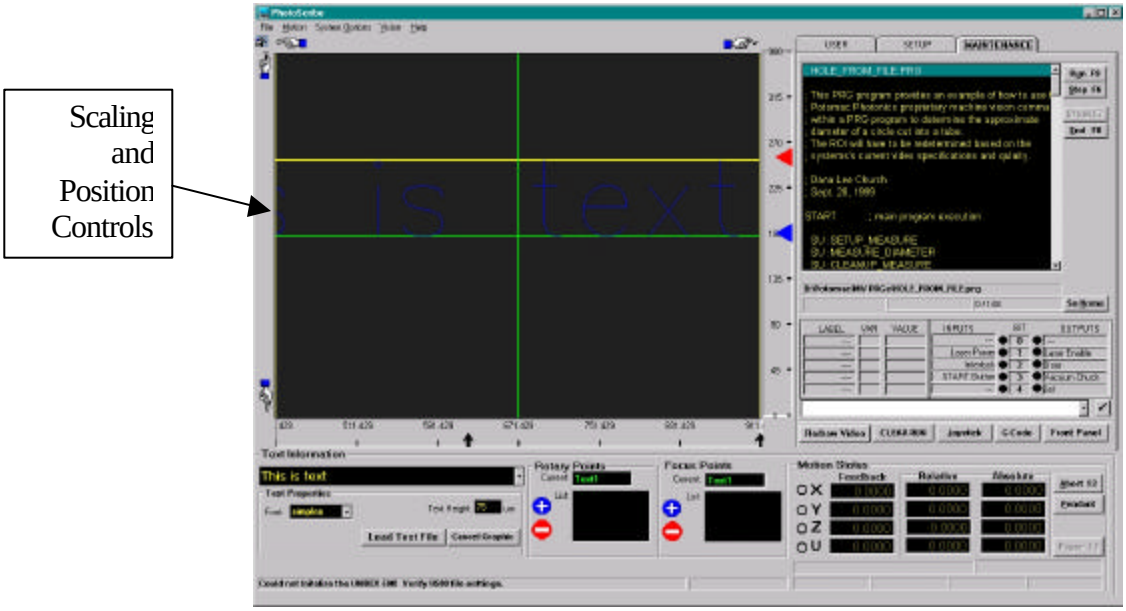
Marking Speed Control



LMS Setup Control Screen

Machine rate divided by shot spacing yields maximum pulse repetition rate (PRR). In general, by increasing machine rate one reduces the precision that the motion system can produce clean, sharp characters. Lower machine rates increase production throughput times. It is therefore the operator's judgment as to the best tradeoff between speed and quality.

One unique feature of the LMS is its ability to precisely size and position text over the live video. Once text is entered, the user can proportionally increase the size of the text string, or relocate its position relative to the gem. This is particularly helpful when thin or irregularly shaped girdles are encountered. Users typically don't create characters smaller than 30 microns, or larger than 150 microns. The system theoretically can operate over a much wider range. The text height refers to the maximum vertical features of the font. Most fonts have lower case elements which are much smaller.

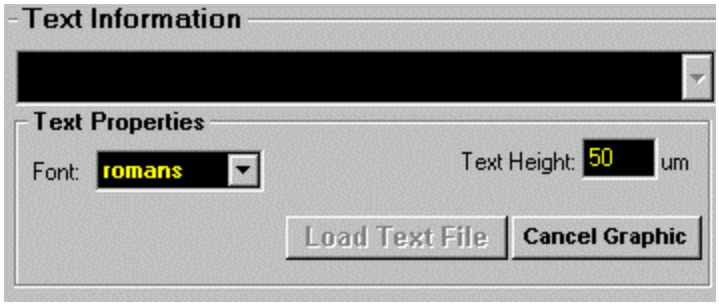


Much like a typewriter, the LMS allows the user to select from a number of fonts.

Font Style Name	*Description*
Cyrillic	Cyrillic-alphabetical
Gothice	Gothic English
Gothicg	Gothic German
Gothici	Gothic Italian
Greekc	Greek font double stroked with serifs
Greeks	Greek font single stroked with sans serifs
Italicc	Italic font double stroked with serifs
Italict	Italic triple stroked with serifs
Monotxt	Monospaced text font
Romanc	Double stroked Roman font with serifs

Romand	Double stroked Roman font with serifs for high resolution
Romans	Single stroked Roman san serif font
Romant	Triple stroked Roman font with serifs
Scriptc	Double stroked script font
Scripts	Single stroked script font
Simplex	Single stroked font
Syastro	Astronomical symbols
Symap	Mapping symbols
Symath	Math symbols
Symeteo	Meteorological symbols
Symusic	Music symbols
Txt	Default text

Fonts are selected through the text information block on the main screen. One can choose to select the text height (in microns) on this same screen.



6.0 **Summation**

As stated before, marking diamonds is more art than science. Before marking on high quality stones, it is recommended that the user practice on the glass slide fixture, or with Cubic Zirconium test gems. Glass slides carbonize much like diamonds. Glass, however, tends to crack with high energy. Cubic Zirconium gems (CZ's) are good practice stones for speed, font, shape and position, however CZ tends not to carbonize like diamonds.

The typical beginning user takes five or ten minutes to mark a 20-character inscription. Experienced users should be able to mark the same 20 characters, on a typical diamond, within one or two minutes. As one becomes comfortable with the various controls and features of the LMS speed, quality and consistency will undoubtedly improve.