



NEW WAVE
R E S E A R C H

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**LASER MACHINING
OF SEMICONDUCTOR, LCD
AND MICROELECTRONIC DEVICES**

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Introduction

The following pages present various examples of applications using a microscope-mounted laser system to cut, trim and ablate materials commonly found in semiconductors, LCDs and microelectronic devices. These examples describe the use of the New Wave Research QuikLaze™ microelectronics machining laser system using different wavelengths on various materials.

QuikLaze is a compact Nd:YAG laser system that mounts on an optical microscope. It is designed primarily for trimming and cutting most of the materials used in the construction of semiconductor and other microelectronic devices. The system features multiple wavelength energies (infrared, green and/or ultraviolet). This makes it possible to more closely match the laser energy used to the material being removed. A variable aperture and energy attenuator allow precise control of laser energy.

Following the descriptions of the application examples, there is a summary chart defining the preferred wavelengths for a variety of materials. A section titled, “Laser Cutting Parameters,” follows the wavelength chart. It provides a summary of recommended wavelengths, energy levels and microscope magnification levels for the cutting, trimming, and ablating applications described in the report.

The settings shown in the “Laser Cutting Parameters” section should be viewed as a starting point for similar applications. Test cuts are required to determine the optimum laser settings for every different cutting and trimming application. So, use the “Laser Cutting Parameters” section as a guide.

Example 1:

LASER REPAIR OF LCD (LIQUID CRYSTAL DEVICE) MATERIALS.

ITO (Indium Tin oxide) is used commonly in LCD displays as a conductive material. Sometimes, shorts occur between parallel lines. Infrared energy is used to remove these shorts.

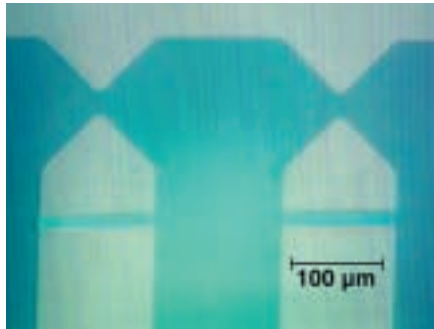


Figure 1
ITO Line Cut on LCD

Laser cut parameters:

Cut size: 15 x 110 μm
IR wavelength @ 20 Hz
Medium energy ~ 50%
50X NIR (Near InfraRed) objective

Chrome is used near the outside of an LCD display as a signal conductor and also for ESD protection during manufacturing. Either infrared or green laser energy can be used to remove shorts between chrome lines, or to cut the ESD protection lines prior to final assembly of the LCD.

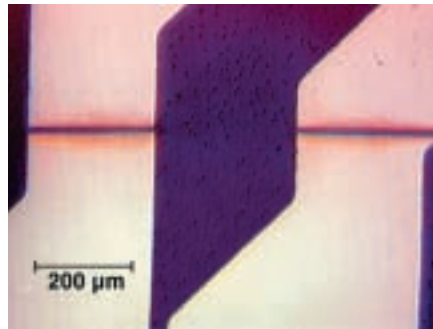


Figure 2
Chrome Line Cut on LCD

Laser cut parameters:

Cut size: 15 x 220 μm
IR wavelength @ 20 Hz
Medium energy ~ 50%
50X NIR objective lens

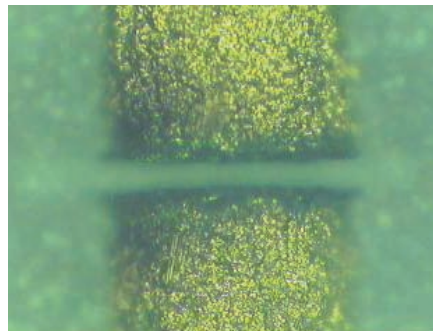
Example 2:

CUTTING A GOLD LINE ON A CERAMIC MCM MODULE.

Gold circuit lines on ceramic MCM modules are cut to disable/enable certain parts of the device.

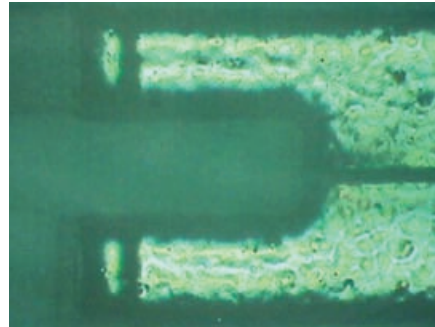
Laser cut parameters:

Cut size: 20 x 300 μm; 15 μm deep
(20 x 40 μm laser beam)
Green wavelength @ 20 Hz
High energy ~ 80%
50X objective lens



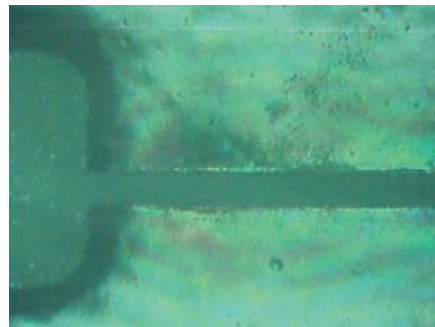
Example 3:
RESISTOR TRIMMING.

Certain semiconductor devices contain resistors designed to be trimmed to a specific value, depending on variations of other parameters in the circuit. In this example, a thick-film resistor was trimmed using IR wavelength energy.



Laser cut parameters:

Cut size: 30 x 4,000 μm
(30 x 100 μm laser beam)
IR wavelength @ 20 Hz
High energy ~ 60%
20X NIR objective lens

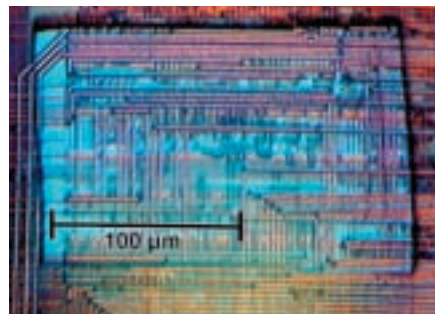


Example 4:
POLYIMIDE REMOVAL.

A semiconductor device with a polyimide top layer passivation must have an area of polyimide removed to facilitate FIB edits (adding a metal line) or to allow E-beam probing. In this example, an area of polyimide was removed using UV (355 nm) wavelength energy.

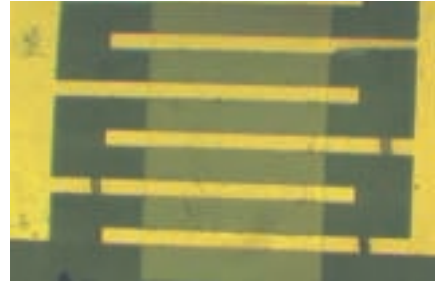
Laser cut parameters:

Cut size: 130 x 200 μm , 3 μm
deep (40 x 40 μm laser beam)
UV wavelength @ 20 Hz
Very low energy ~ 15%
50X NUV (Near UltraViolet)
objective lens



Example 5:
CAPACITOR TRIMMING.

High-frequency devices often have capacitors that are trimmed to finely tune the device to a certain frequency. In this example, a gold capacitor on a ceramic substrate was trimmed using green wavelength energy.



Laser cut parameters:

Cut size: 25 x 60 μm
Green wavelength @ 20 Hz
Medium energy ~ 60%
20X objective lens

Example 6:
FLEX CIRCUIT MICRO-MACHINING.

Flex circuits are commonly found in disk drives, keyboards, microprocessors used in lap top computers and printers. In the following example, Kapton was removed from a portion of a flex circuit for failure analysis (left figure). UV (355 nm) energy was used to remove the polyimide covering the copper circuit. With the copper circuit exposed, green laser energy was used to make the cut (right figure).

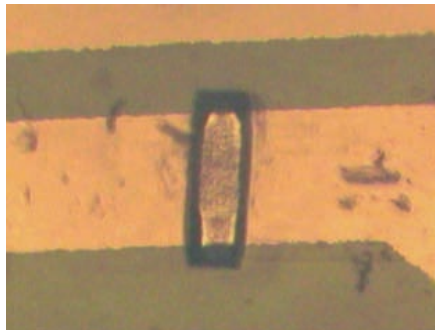


Figure 1
Kapton removed.

Laser cut parameters:

Cut size: 20 x 100 μm ; 20 μm
deep (20 x 40 μm laser beam)
UV wavelength @ 20 Hz
High energy ~ 80%
50X NUV objective lens

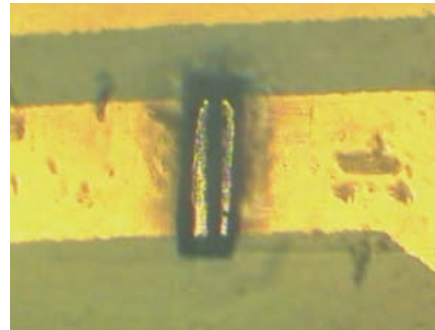


Figure 2
Copper line cut after Kapton removal.

Laser cut parameters:

Cut size: 20 x 100 μm polyimide
(20 x 40 μm aperture)
Cut size: 15 μm x 100 μm copper
(15 x 40 μm laser beam)
Green wavelength @ 20 Hz
High energy ~ 80%
50X NUV objective lens

NOTES:

1.

A Mitutoyo FS60 YC microscope with a UV (355 nm) transmitting tube lens was used in all of the above examples. NIR (Near InfraRed) or NUV (Near UltraViolet) objective lenses were used to make the cuts. The maximum aperture size, (and laser cut) was 50 x 50 μm with a 50X objective lens. When making cuts larger than 50 x 50 μm using a 50X lens, the microscope stage was translated and the laser beam was “scanned” over the area where the cuts were made. The maximum cut size with a 20X objective lens was 125 x 125 μm .

2.

The laser system used to make the cuts described in the above examples was the New Wave Research QuikLaze TriLite™, a three-wavelength, Nd:YAG laser. The three available wavelengths in this system are 1064 nm (infrared), 532 nm (green) and 355 nm (ultraviolet). A QuikLaze laser head is shown mounted on a Mitutoyo FS60 YC microscope in the photograph below.



LASER WAVELENGTHS FOR OPTIMUM MATERIAL REMOVAL

Success in laser trimming, cutting and ablation is usually determined by the choice of wavelength. Different materials react differently to various wavelengths. Effective removal of metals depends on how much energy is absorbed and how much is reflected. The more energy absorbed, the easier the metal will vaporize and be removed.

In general, metals absorb shorter-wavelength energy better. For example, gold is 1% absorbing at 1064 nm, 40% absorbing at 532 nm, and 45% absorbing at 355 nm. However, there are limits to the effectiveness of shorter wavelengths determined by the microscope optics used. In the foregoing examples, the Mitutoyo microscope transmitted about 45% of the 1064 nm laser energy, 35% of the 532 nm energy, and only about 17% of the 355 nm energy. In the gold example cited above, even though gold is more absorbing at 355 nm than at 532 nm, the microscope transmission of laser energy at 532 nm usually makes it the preferred wavelength for cutting gold.

Aluminum can be cut using either 1064 or 532 nm. The absorption is relatively constant from about 1,100 nm to about 400 nm with a slight increase in absorption around 1 μm .

A different process removes organic material, such as polyimide. UV energy is able to break the chemical bonds between the carbon-carbon, carbon-oxygen, and carbon-silicon atoms. These bonds break with sufficient energy in the range of 339-445 nm. The third harmonic of an Nd:YAG laser is 355 nm. It is an excellent wavelength for breaking the atomic bonds of the polyimide molecule.

The following table shows the preferred wavelength for vaporizing or ablating various materials commonly found in semiconductor and microelectronic devices.

Recommended Wavelengths for Various Materials

	Infrared (1064nm)	Green (532nm)	UV (355nm or 266 nm)
<i>Metal/Conductors</i>	Aluminum	Aluminum	
	ITO	ITO	
	Chrome	Chrome	
		Ni-Chrome	
		Ti-Tungsten	
		Copper	
		Gold	
<i>Insulators</i>			Polyimide
			Teflon
		Silicon Nitride	Silicon Nitride
		Silicon Dioxide	Kapton
<i>Semiconductors</i>		Polysilicon	Polysilicon
<i>Color Filter Materials</i>	Red	Green	Blue

LASER CUTTING PARAMETERS

The table below presents a summary of recommended laser settings for the applications described in this report. The settings are for a New Wave Research QuikLaze laser system. These settings should be viewed as a starting point from which a finely tuned cutting process can be defined for a specific application. When tuning the cutting process, a non-critical area of the device should be selected for practice.

After the technique has been determined, the laser parameters can be saved as a Laser Micro using PCLaze, the laser control software package that is supplied with every QuikLaze system. PCLaze runs under Windows95 and WindowsNT. It requires a PC with a Pentium (or equivalent) CPU, at least 16 MB of RAM, and one available RS232 serial port. For further information on QuikLaze and PCLaze, see the information below or contact New Wave Research.

Recommended Laser Settings for Various laser Machining Operations

Sample Material	Cut Size	Microscope Lens	Wavelength	Energy Setting	Energy Range	No. of Shots
LCD repair: remove ITO short	15 x 110 μm	50X NIR	1064 nm	500	High	50
LCD repair: remove chrome short	15 x 220 μm	50X NIR	1064 nm	500	High	100
MCM module: cut gold line	20 x 300 μm 15 μm deep	50X	532 nm	800	High	1200
Thick film resistor	30 x 4000 μm	20X	1064 nm	600	High	2000
Semiconductor device: Polyimide removal	130 x 200 μm 3 μm deep	50X NUV	355 nm	300	Low	2000
Trim gold capacitor	25 x 60 μm	20X	532 nm	600	High	3000
Flex circuit: remove Kapton	20 x 100 μm 20 μm deep	50X NUV	355 nm	800	High	1500
Flex circuit: cut copper line	15 x 100 μm	50X NUV	532 nm	800	High	1000

EQUIPMENT

QuikLaze

QuikLaze is a frequency-doubled and -tripled pulsed Nd:YAG laser. The laser can fire a single shot or continuously at a rate of up to 20 or 40 pulses per second, depending on the model. The laser has an energy control feature allowing control from 2% to 100% of maximum energy. Switch-selectable wavelengths of 1064 nm, 532 nm and/or 355 nm are available in various models. An RS232 interface is available for controlling the laser from a Windows95- or NT-based PC running PCLaze.

PCLaze

PCLaze provides users with a convenient method to control laser functions using a PC running Windows95 or WindowsNT through an RS232 serial port. PCLaze features a graphical user interface (GUI) that allows users to control laser cut size, laser energy level, wavelength (on multi-wavelength models) and laser firing. In addition to the GUI, PCLaze allows laser parameters to be saved as Laser Macros. They can be stored on disk and recalled later for similar laser cutting tasks. This greatly reduces the learning curve and increases user productivity. PCLaze also supports DDE for communicating with other Windows-based programs.

Microscope Optics

All cuts described in this paper were made using a Mitutoyo FS60 microscope. The zoom mechanism was replaced with a UV transmitting, fixed 1X tube lens. All UV (355 nm) cuts were made using a 50X NUV Mitutoyo objective lens. The FS60YC microscope and the 50X NIR lens were used for the IR cuts. Both the NIR and NUV lenses transmit green (532nm) energy.

The most common objective lenses used for laser cutting procedures are the Mitutoyo 20X, 50X and 100X objectives. The 80X lens, available only in the visible wavelength range, is also a suitable cutting objective for green laser energy. The higher the objective lens magnification, the greater the cutting power (energy density). Energy density increases as the square of the change in magnification. That is, when changing from a 50X to a 100X cutting objective, the energy density, or fluence, increases by a factor of four. This is important in choosing an energy level setting. The energy level must be significantly reduced when increasing objective magnification to maintain the same cutting results.

The 50X lens allows a minimum cut size of approximately 2 x 2 μm . The maximum cut size with the 50X lens using the Mitutoyo microscope is approximately 50 x 50 μm . The maximum and minimum cut size using the 100X objective lens are approximately one-half of that attainable with the 50X lens. Cut sizes using a 20X objective increase over those using a 50X objective by a factor of 2.5. Larger cuts are obtained by translating the sample across the beam using the microscope X-Y stage.

Summary

Successful laser cutting on microelectronic and LCD devices is wavelength dependent. Different wavelengths and different techniques are required with various materials. Use of multiple wavelengths on the same device are often required to obtain the desired results. UV is the preferred wavelength for organic materials. Most metals are cut best with green wavelength energy. Normally, infrared is used to cut ITO and chrome found on LCD devices.

Comments or questions about using
New Wave Research laser systems for your
applications are welcome. Please contact us in the
manner most convenient for you using the contact
information provided below.



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