Mechanically Drilled Controlled Depth Micro Vias an Alternative to Laser Drilling

Robert Lupfer Jr.
DDI
Milpitas, Ca.

Abstract
As the requirements for controlled depth micro-vias become ever increasing in today's market place the best feasible solution appears to be laser drilling. However laser drilling can be problematic when approaching dielectric thicknesses over 3 mils. FR4 is a composite of epoxy and fiberglass with the fiberglass portion being most problematic for the laser. Since the fiberglass is a weave the laser will have to be adjusted to drill through the knuckle of the glass intersect and hit the capture pad. This is achievable however lateral ablation of the epoxy can occur. This phenomenon can lead to uneven plating and potential reliability issues as can be seen in Figure 1.

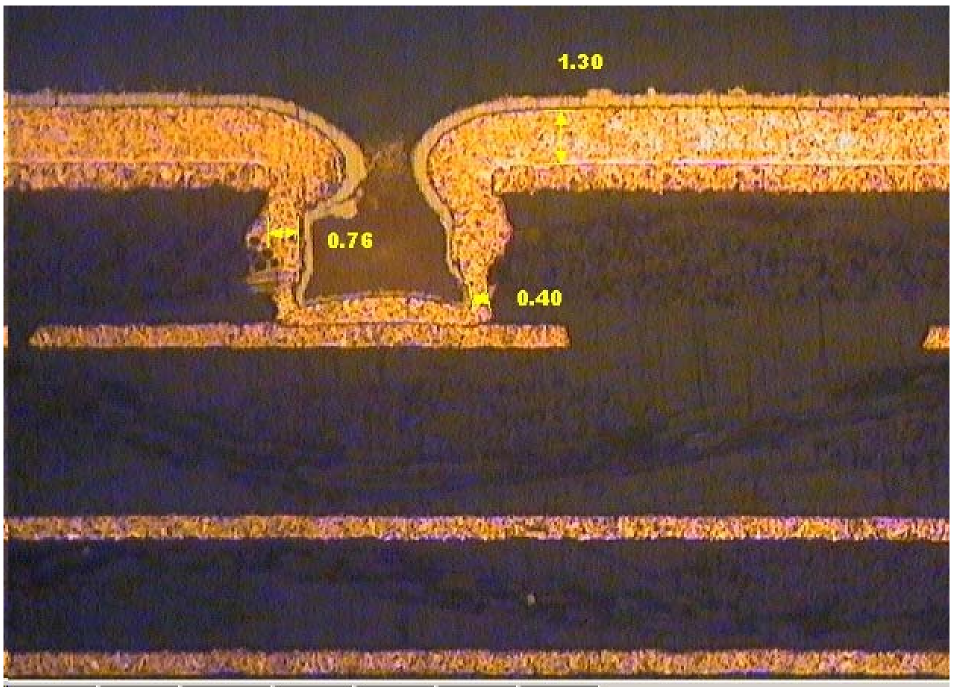

Figure 1

The very nature and shape of the laser drilled hole limits the aspect ratio that can be plated on a consistent basis. The productivity of laser drilling however is unparalleled in the mechanical drilling arena. Laser drilling can produce holes any where from 500-1000 holes per minute.

Let's take a look at mechanical drill holes now. Typically mechanically drilled controlled depth holes are done utilizing 3 methods of detection. The first is a direct electrical connection between the copper on the top of the panel connected to the drill machine ground and the tip of the drill bit. The second method is a capacitive sensing system that does not require a hard connection between the top of the panel and the drill machine. The third is the pressure foot flag method that uses the pressure foot as the indicator of depth. Of the 3 methods available the first 2 are the most consistent on maintaining depth to the target pad.

The X, Y and Z positioning systems also vary in mechanical drilling. The lead screw system is very common; however the linear drive machines are becoming more common in the market place. I am fortunate to have all of the above systems at my disposal for testing. The highest productivity in mechanical drilling is accomplished using a capacitive sensing system using linear drives. 5 mil micro vias 5 mils deep are produced at a rate of 500 hits per minute. 8 mil x 8mils can be produced at a rate of 400 hits per minute. Below in Figure 2 is an example of the benefits of mechanical drilling controlled depth micro vias.

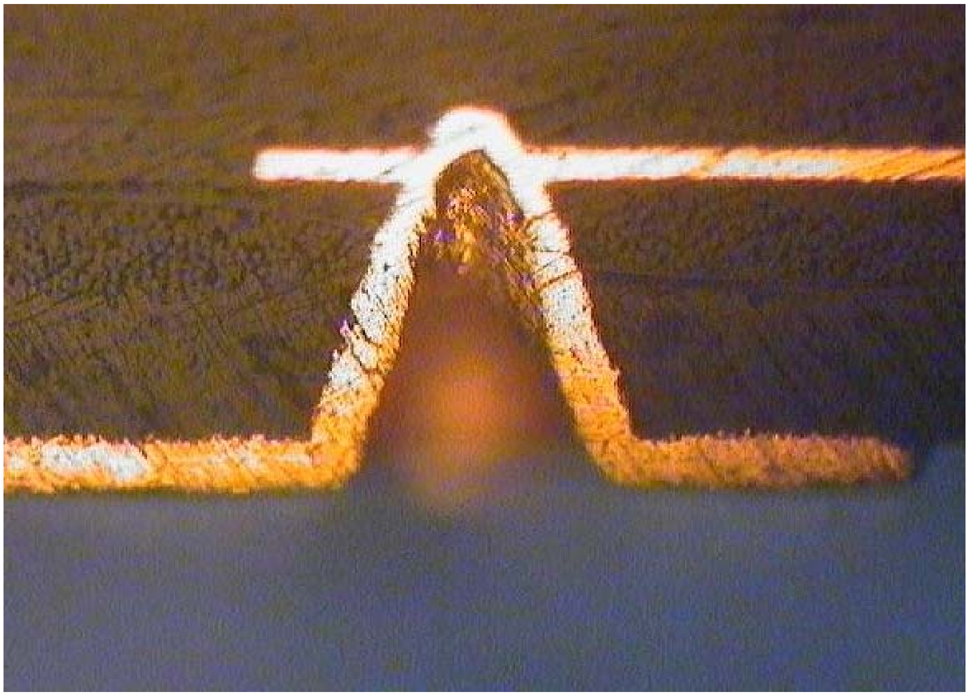

Figure 2

The composite nature of FR4 is irrelavlent when mechanically drilling as can be seen here. Plating is more consistent and reliability issues are minimized. The concave formation of the hole using tapered bits minimizes the entrapment of air bubbles in the holes.

Introduction

This paper will describe the methodology used in producing micro vias using laser technology. Along with this description examples of laser drilled micro via formations will be shown and discussed. Subsequently mechanically drilled micro via methodology will be discussed along with appropriate examples. The emphasis of this paper is focused on the process variables employed in the mechanical drilling of micro vias as a viable option to laser drilling. Potential benefits of mechanical drilling will also be explored.

Laser drilling micro vias

The typical process and sequence in the process for laser drilling micro vias varies depending on the board requirements. However a registration step is always required. There is one specific reason this is required other than the obvious standard registration requirements of any PC board. That specific reason is the laser must hit the capture pad on the target layer. If the laser misses the capture pad during ablation it may cause a fissure adjacent to the capture pad that may be very difficult to plate. This phenomenon is demonstrated in figure 3.

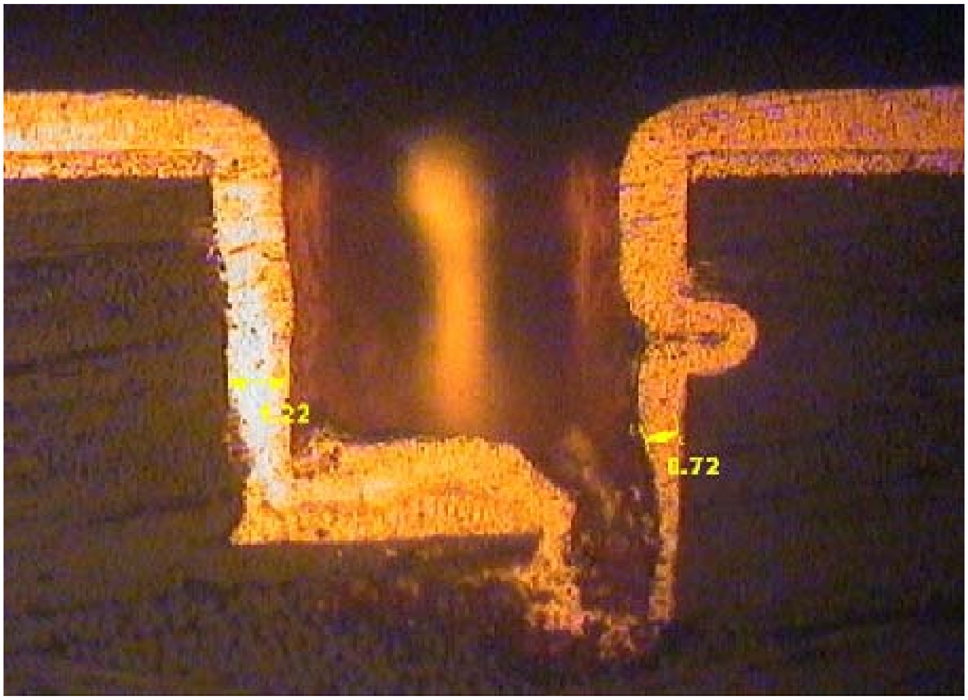

Figure 3

Depending on the board requirements the set-up for registration may use either a skived fiducial on the target layer or a drilled hole from a previous operation. If the product to be laser drilled contains through holes some consideration should be made to assure the through holes and the laser drilled micro vias match each other. Most laser systems commercially available are equipped with a vision system and software to allow modification of the drill program in order to align, scale or step depending on the needs of the end user. The laser beam itself has a multitude of settings to allow the user to create the micro via required. Adjustments include the use of spiraling, trepanning and various energy settings to achieve the desired results. The desired result typically would be a taper hole landing squarely on the target pad. See figure 4.

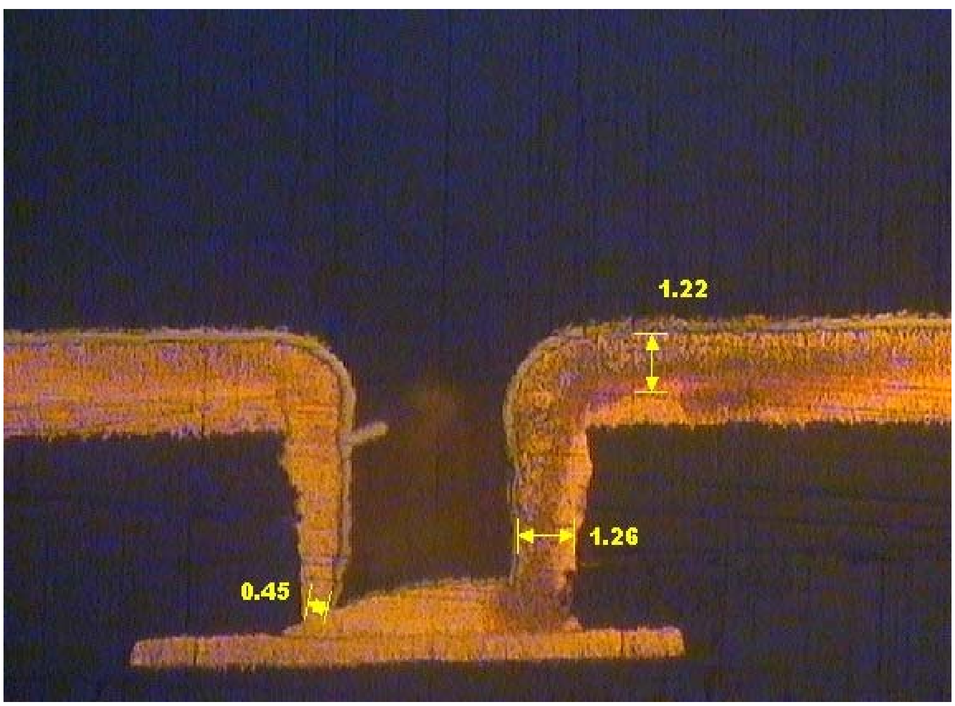

Figure 4

Aspect ratio is also a concern when laser drilling micro vias. This is not so much a concern for the laser drilling process itself; it is more of a concern for subsequent metallization and plating processes. Most printed circuit board shops would probably agree with me when I say the preferred controlled depth micro via aspect ratio is .5 to 1. Although this is a preferred aspect ratio, technology is demanding higher and higher aspect ratios. It is not uncommon to see aspect ratios of 1 to 1. Here is an example of a perfectly formed and plated micro via using laser drilling with an aspect ratio of .5 to 1. Figure 5

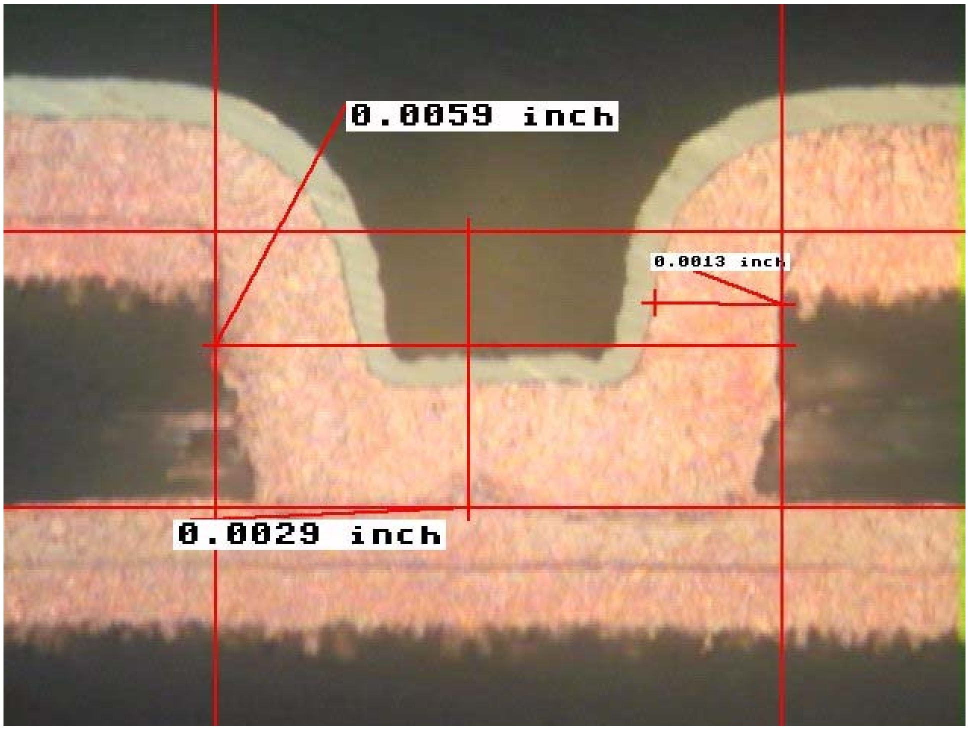

Figure 5

Mechanically drilled micro vias
There are many variables to consider when setting up to mechanically control depth drill micro vias. Registration is always a concern for the mechanical process. However the registration technique is consistent with the standard methods used in setting up any mechanical drill. This is usually done using x-ray optimization, x-ray verification or cross section. Once the registration is optimized consideration must be made on the tool type, method of depth control and entry material.

Tool type: I have found that using specially designed tapered tools produce a very consistent and receptive shape for subsequent metalization and copper plating. The V shape reduces the occurrence of trapped bubbles in the plating processes. Figure 6 is an example of a taper tool that creates that V shape.

Figure 6

This particular image of a tapered tool has a single flute with a slight flat area at the tip. This type of tool will produce a blind hole as seen in figure 7.

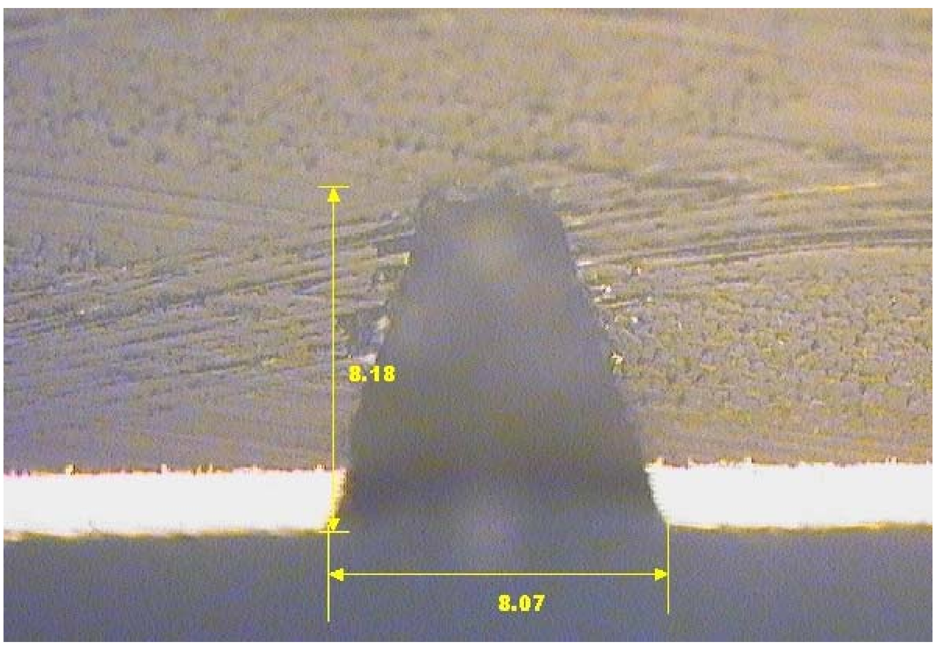

Figure 7

With this geometry an aspect ratio of 1:1 can be maintained up to the tool size of .0118". The tool life of this tool penetrating to a depth of .008" is 5000 hits. At a cost of approximately $5.00 per tool the cost per hole is $0.0001. There are many tool options available commercially as well as custom designed tools. The focus of this paper will be on this tool specifically.

Depth detection: The method of depth detection varies depending on machine type. One type of depth control system uses a hard electrical sensing system that requires a hard connection from the top of the panel to the metal table. In most cases this is accomplished using either pneumatic side clamps or a dedicated specialty clamp built into the drill machine. The way the system works is the panel is one side of the circuit connected to ground and the tip of the drill is the other side of the circuit, when the two meet the z axis encoder or scale measures the distance to travel. This system is very accurate. The tolerance is stated at +or- .0005". However there can be additional tolerance added if conductive entry material is used. The manufacturing tolerance of the entry material would need to be added to the machine tolerance to get the total depth tolerance. Typically a .007" sheet of aluminum entry would hold a tolerance of +or- .0007". This added to the machine tolerance would put the total depth control tolerance at +or- .0012". On the other hand if non-conductive entry material is used the stated tolerance of the machine would hold true for the depth control tolerance. The next method of detection is a capacitive method of detection where no electrical connection is required from the panel to the table. The way this works is as the tip of the drill bit touches a conductive surface the capacitance of the signal being sent out changes and this triggers Z axis measurement system to start counting. This system is also very accurate. The tolerance is stated at +or- .0005". Once again there can be additional tolerance added if conductive entry material is used and once again if non-conductive entry material is used the stated tolerance of the machine would hold true for the depth control. The third method is the flag controlled depth method. This is a method where the relationship between the pressure foot and the tip of the drill is determined in the tool laser station and is retained in memory. When the drill cycles the depth is measured from the point where the pressure foot stops and the relative position of the drill tip as measured in the laser station. This method is prone to produce depths with tolerances of + or - .001". This tolerance can be compounded by the type of entry material used and the cleanliness of the work surface. Any manufacturing tolerance of the entry material would be applied to the machine tolerance to arrive at the total tolerance of depth control. If given a choice of depth control methods I prefer the capacitance method. This is primarily due to the tight depth control tolerance and the fact that no external connection to the panel is required. The minimum mass required for the capacitance system to work is an area of about 1 square foot of metal surface.

Entry material: The type of entry material to be used can cause problems and solve problems depending upon the selection. Consideration for the depth control system being used as well as the tool type being used. In addition the entry material reduces the formation of burrs while producing good hole wall quality. As I had stated earlier in the depth detection description, metal based entry materials will add additional tolerance to the process. In addition to the tolerance issue metal entry material will sometimes stick to the tip of the tool and cause false depth detection. Bearing this in mind the use of non-conductive entry material is preferred. When the drill bit pierces the non-conductive entry material it actually cleans the tip of the tool and prevents false detection due to metallic residues on the drill bit. However when using the taper bit drill care must be taken to minimize impacting the single flute design with entry material. The flute on this tool is only .040" long so the total depth of your entry material and the target depth of the micro via should be taken into consideration. I have tried several types of entry material such as .017" phenolic, .012" phenolic, .012" pressboard and various other types of entry targeting a via depth of .008" with very marginal results. In all cases the nonconductive entry materials left a considerable amount of debris behind in the micro vias. The best entry material I was able to get good results with was a .006" paper product. There was no debris left behind with virtually no burring. This is also demonstrated in figure 7. The choice of entry material is probably one of the most important decisions to make when drilling micro vias mechanically.

Table mechanics: Various different methods are used in positioning the spindle in the proper location in order to make the drill stroke. The most predominant is the lead screw system using linear scales for positional accuracy. Other options include linear drive systems with linear scales. These are available in X, Y and Z axis. The benefit of this type of system is the increased speed of operation. In comparison with drilling using the same spindle speed, in-feed rate, retract rate, depth and quick drill settings a linear drive system will drill approximately 20-35% faster than a lead screw system.

Process benefits: Mechanically drilling micro vias does have some significant benefits over laser drilling micro vias.

1. The most obvious is the use of the conventional drilling platform when the demand for micro vias drilling requirements in the factory is low.
2. The single set up when drilling micro vias and through holes at the same time.
3. The perfect registration between the micro vias and the through holes.
4. The concave shape of the micro via for subsequent metalization and plating processes.
5. Low cost model per hole.
6. Deeper holes to potentially eliminate multiple lamination cycles.
7. Reduce drill time when employing linear drive systems.
8. No capture pad fissure problems due to registration.
9. Expensive service contracts for laser maintenance eliminated.

Summary

In conclusion laser drill is here to stay and has the versatility to be adapted to many board requirements. However there is some inconsistency in the shape of the vias produced due to the constant adjustments that need to be made for different glass styles, different copper weights and different material types. Many times the shape is less than optimum for subsequent metallization and plating processes. This can be seen in figure 8.

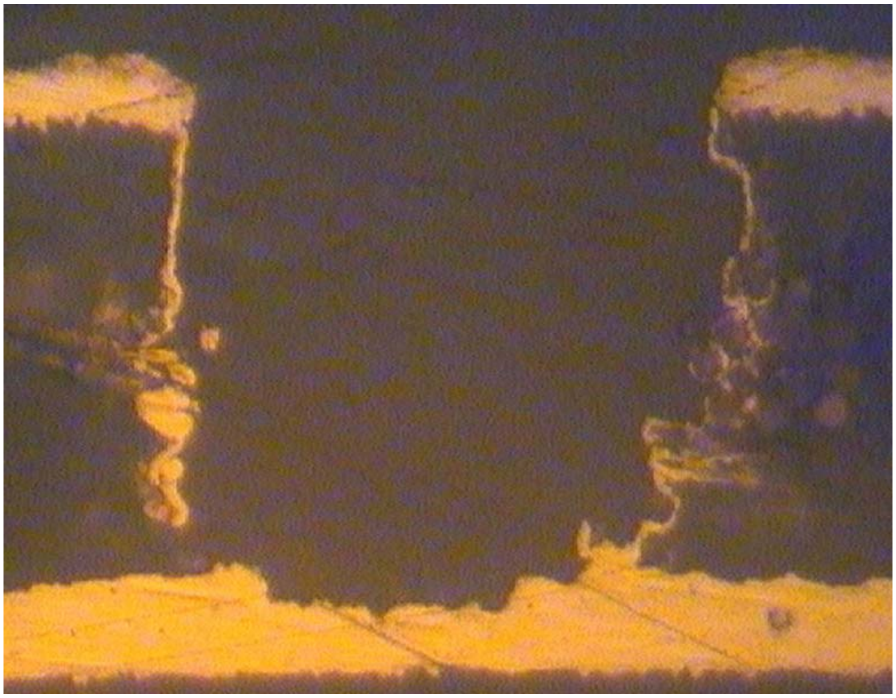

Figure 8

Mechanical drilling on the other hand will produce the same shape via every time. With the newer generation of mechanical drills tighter controls on depth produce very consistent hole wall quality and repeatable depth. This is demonstrated in figure 9. The speed of the new linear drive systems are starting to get close to the speed of laser drilling systems.

Figure 9

If your company is thinking about buying equipment to drill micro vias, consider this. Laser drilling platforms are generally 1 station. This means you can only produce 1 side of a panel at a time. Mechanical drilling with control depth can be a multiple station platform. So for the same cost you can buy a 6 station machine instead of a 1 station machine So even if the laser speed is 2 times faster than mechanical drilling, a 6 station mechanical drill can produce 3 times the work in the same amount of time.

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