Cutting with a 10 Watt Endurance Laser

by John Walker

This article covers some through-cut testing I did with a 10 Watt laser, compliments of George Fomitchev, CEO of Endurance Lasers.

A quick safety disclaimer: You can burn your eye out, kid! I am not a pro by any stretch of my imagination. Please verify what I'm saying here to avoid potential equipment damage, the needless wasting of materials, and, most importantly, to prevent injury to yourself and others.

Notice of Addendumb

Raised Bed: With sincere thanks to someone I've never previously spoken with in the Endurance Laser Facebook group, a Mr. Chris M. Kirby, I now have a better cutting experience to tell of. Some of you are going to laugh as this should've been a no-brainer for me, but I'm referring to a raised bed onto which you will place the stock to be cut. (In my own defense, I have been cutting with my CNC where one doesn't dare NOT clamp stock to the table! Old habits...) When you look at my original photos, below, you'll notice flaring/burning on the back side, with some even working their way up through the cut to the top. Per Chris's suggestion, all I did was prop up the stock (I went an inch [2.54 cm] or so) above my wasteboard and then cut. It made a WORLD of difference, so I've added a series of "good/bad" pics near the very bottom of this article for you to compare. Thanks a million, Chris.

Metric Conversions: Again with thanks to another in that same FB group, one Allie Sinclair - and for my other maker brothers and sisters across the pond and elsewhere - I have (said warmly and jokingly) taken it upon myself to do your homework for you by converting my Imperial units (which nearly the entire planet used to use) and adding Metric. I don't think in Metric, so kindly inform me if I've made any errors in convention, rounding, etc. Thanks.

Now, back to your regularly scheduled article...

I Wish Someone Would Just Tell Me the Settings!

I not only said that myself, but have seen it expressed several times in the forums. Wouldn't it be great to just down/upload knowledge? Nah. What would be the fun in that?

I actually did try to do provide this, somewhat, but only after doing some preliminary writing to try to ensure that we have a common frame of reference. Of course, you can just jump to the good part for now, and then back up if you later arrive at something that doesn't make sense.

Definitions

Throughout this article, I'm going to be using some terms that were unfamiliar to me until just a short while ago, so maybe they will be to you, too. I'll try to explain them to whatever degree I think I now understand them, but apologize in advance if I fail to do a good job.

Divergence. In the Hardware section which follows, I'll be discussing diode laser lens types, and one of the things I'll mention is beam "divergence." The best way I can think of to describe this is to ask you to think of a laser's beam as an hour glass. The top and bottom parts are where the laser's beam is widest but out of focus, while the narrowest space between them (where the sand passes through) is where the laser's beam is in focus (its **focal point**). The beam's divergence, then, refers to the degree of width that the out-of-focus area is at a distance away from the focal point. It's simply how far it diverges in width from where it's in focus at its narrowest.

Focal length is the distance between where the laser's light leaves the lens at its widest to the spot where it converges, i.e., where it's in focus. Using the hour glass example, it's the distance from the wide top of the hour glass to the smallest point where the sand passes through in the middle. Different types of lenses have different focal lengths, making each desirable (or not) for a particular application.

Air Assist refers to a means of delivering a concentrated air stream to the focal point of the laser to improve the laser's ability to cut by blowing away smoke and already-charred bits, thus exposing fresh material. In my case, I'm using an aquarium air pump with a hose and nozzle to deliver 60 liters of air per minute.

The Hardware

If you haven't read my last article, I had an Endurance laser mounted onto a Shapeoko 3 XXL CNC Router. This gives me quite a large area (roughly 32" x 32" or 81 cm x 81 cm) on which to do my cutting/engraving. Because there's no way I can currently afford a faster-cutting, stand-alone CO2 laser with a bed of similar size, my current set-up for works well for me. I get to do other tasks while watching over my shoulder as the laser engraves and cuts one large piece of stock into several small ones, almost like having an employee. And there's little effort required to switch between laser and router with my current mount.

The lens which came with my Endurance, and the one I used for these tests, is a "3-element lens." It has a 3-inch (7.6 cm) focal length and minimal divergence, meaning that it'll maintain a decently perpendicular cut through thicker materials. The down side of a 3-Element is that it only transmits about 70% of the laser's full power; the more glass surfaces, the less light gets through. So, in my case, the 10 Watt is effectively reduced to a 7.

Another type of lens is called a "G2," which is 95% efficient, so will cut and engrave faster. But its greater divergence makes it less desirable for cutting thicker materials, because the walls of the cut will be less perpendicular to the material's surfaces.

The lens I hope to get is the "G7," which is a marriage of the positive features of the other two. It transmits roughly 88% of the laser's power with minimal divergence; a really nice compromise.

The Software

Fortunately, I had purchased a license for LightBurn (laser cutting software) along with my first laser, a 3.8 Watt from JTech, so didn't have to learn a new program. It's a great app, and I highly recommend it. I tried a couple of others, both free and paid, but they seemed unnecessarily clunky.

While I will refer in this article to the settings I used in Lightburn, a working knowledge of that specific program is unnecessary to grasp what I'm trying to present here. Basically, I'll be referencing travel speed (in either inches or cm per minute), and intensity (expressed as a percentage of the laser's full power); parameters which are essential to cutting regardless of the app used.

What I also make mention of here that may not be pertinent to you, depending upon whether your hardware has an automated Z axis, are LightBurn's "Relative Z" settings, which specify the number of passes (if more than one is required to through-cut), and the amount of descent executed with each pass. More on this later.

In a later article, I'll be covering some additional LightBurn settings for raster (photo) engraving. If you haven't tried LightBurn yet, why not give it a look? They offer a fully functional free trial, after which a fair license is pretty cheap to buy. You can find it here: https://lightburnsoftware.com/

Materials I Used

Hoping to make shopping easiest for everyone in the States, I stuck with offerings from the Big Box stores, namely Home Depot, Lowe's, and Hobby Lobby. There's a great sawyer some drive away from me where I could get practically everything else that grows in my rain forest, but I still don't have a jointer, planer, or thickness sander, so have to settle with the mundane for now. Maybe you'll have such a source, or a local lumber yard, too.

The materials I used in these tests are:

- 1/4" (actual: .200" or 5 mm) Luan 5-Ply (stop laughing)
- 1/4" (6.4 mm) Solid Poplar
- 1/8" (3.2 mm) Baltic Birch Ply
- 1/8" (actual: .135" or 3.4 mm) Balsa Wood
- 1/8" (3.2 mm) Bass Wood

I could've gotten some Red Oak, too, but assumed it would've been too tough to through-cut.

My Notations Explained

I recorded (scribbled) my settings onto the stock, so here are examples of what you'll see in the pictures, along with their explanations. More on this under "The Math" in the next section.

10/100 on the top row would indicate that the laser traveled at 10 inches per minute (25.4 cm/min) at 100% percent laser power. (I convert the best cut to Metric in the tables.)

3 x .042 says that the laser made three passes along the cut path, descending in the Z-axis by .042 per pass. Ideally, the one value multiplied by the other should equal the thickness of the material, give or take, but I occasionally played "what if," and ran the laser around one more time without altering the depth just to see if it would make a difference. (I don't think it really mattered.)

AA=.25, though not always noted, speaks to the height of the air assist nozzle above the material, in this case 1/4". Later, I determined that, as long as I stayed within an inch (2.54 cm) of the surface, varying the height seemed to make little difference. So, in the tables of settings, below, I simply declared that Air Assist was used.

Red Rectangles: Look carefully at the photos and you'll see red rectangles. These represent the cuts which I thought turned out best, regardless of the number of passes.

The Math

So, did I just guess at my numbers? Well, I'm kind of embarrassed to admit that, at first, I did. (I HATE math!) But what could I do but guess? This was all new to me and, besides, no one would just tell me the stinkin' numbers! So, I said fie on the math, at first. But, after trying to wing it a couple of times, it quickly became apparent that I was gonna have to use my gourd.

Understanding the relationship between speed and power is a prerequisite to getting good cuts. Move the laser too quickly and you might not make a scratch. Too slowly, and you might torch your workshop! The same is true for the laser's power. Too little power, and all you'll have is a bright flashlight. Too much, and your drink coaster will resemble a meteor.

Not all cuttings are created equal. As with everything we do as makers, quality plays a roll. Just because we *can* quickly power our way through a material doesn't mean that we should. Heck, we can get through stuff a lot quicker with Oxy/Acetylene, right? But time isn't money if the end result ain't purdy enough to sell, and making it so, Number One, could be a lot tougher than it sounds if don't develop a "feel" for this. I'm not saying I have, but I'm a lot closer than I was before I started this test.

My goal, then, was to cut through these materials at the speed of light while still getting the best quality obtainable. The task was somewhat simplified by my electing to run with 100% power throughout the test, while attempting to improve the quality of the cut by increasing or decreasing the speed. I realized no advantage in using less power as one might need to do with less stout materials.

For your reference, the squares I cut were 1" x 1" (2.5 cm x 2.5 cm).

Bonus Math

This is for those of you who might be wondering how I arrive at my passes and depth-per-cut values.

Let's consider something simple to begin. We'll start with a material of common thickness, say 1/4" (6.4 mm). Assuming that your super-duper laser can cut through this in one pass at 100 inches (254 cm) per minute and 100% power, you would naturally set your cut depth to 1/4" (6.4 mm). It would then follow that 2 passes would require a depth of 1/8" (3.2 mm), 4 passes, 1/16" (1.6 mm), and so on. Piece of cake, right?

But, what if you don't know how deeply your laser will cut at a given speed and power? Surely, we diode owners need multiple passes, even at 100%, to cut through 1/4" (6.4 mm) of any wood. So this is what I do:

I use my vast experience (cough) to guess at my initial speed and power settings (I'm often WAY too optimistic), and then run the laser once around the track over the desired material. I then carefully cram a finely graduated 6" (15 cm) rule into that crack to get an idea of how deep it is. (I'm sure there's a more proper tool to gauge the depth of such a fine fissure, but I probably can't afford one.) Next, I take my trusty calculator and divide the material's thickness by that number, which gives me the number of passes required at that depth. It's often not the RIGHT number, but it gets me closer than a complete guess.

That's it, really. Cut, measure, repeat. If you find that your current speed is too slow, evidenced by much charring, you'll have to crank it up, which means it won't cut as deeply per pass, which means that you'll have to increase the number of passes by which to divide your thickness, and then adjust the depth per pass accordingly.

Got that?

The Good Part

So, here's the skinny on each of the materials with pics and tables of what I found to be the optimal settings to through cut.

When you look at the back sides, you'll see many pieces which nearly cut all the way through but didn't, and might think that to be a bad thing. In my view, the uncut fragments can serve as tabs - especially handy on small pieces when using air assist which might send the little buggers flying. After the sheet finishes, these pieces can either easily be cut free with a razor or simply popped out.

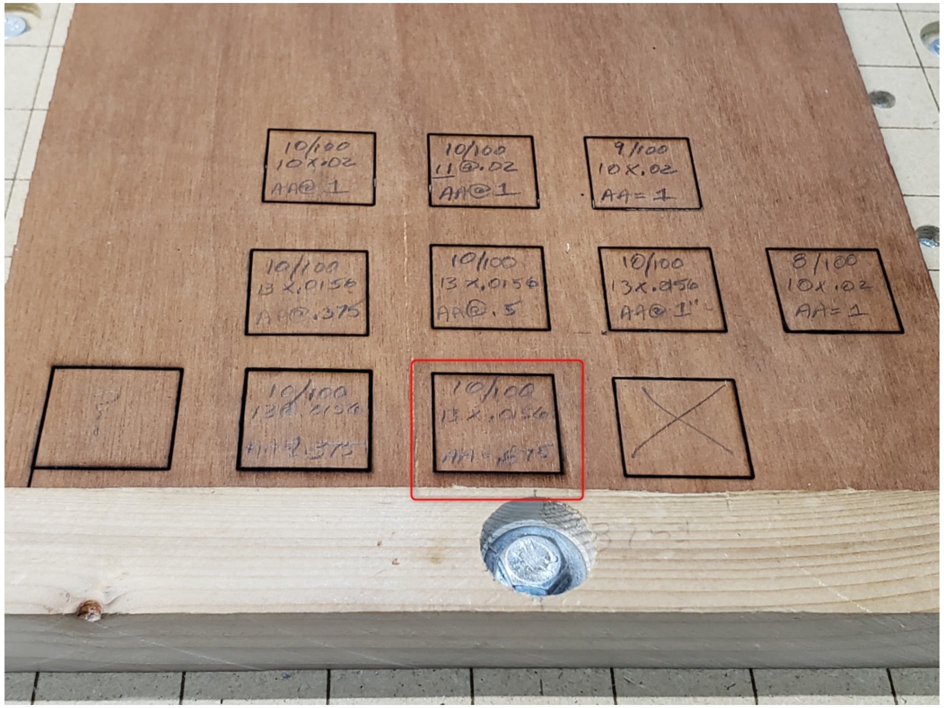
1/4" Luan Plywood (actual: .200" or 5 mm)

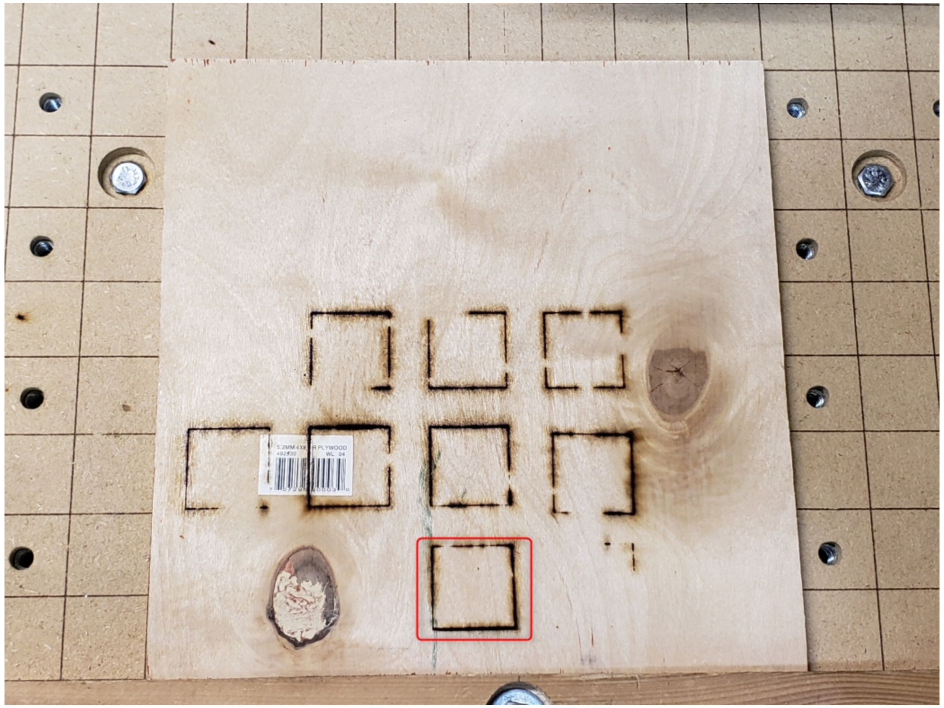
Why on earth would I try this? Luan is notorious for having undesirable voids and/or fillers. Still, there was a time when I didn't know how it would cut, so now think it might be helpful to others who are also curious.

I'm certain that the laser is capable of cutting through this with fewer passes than I used, but it was quite a challenge for the 3-Element lens. But, at some point, we have to decide when to call it quits, so I did when 13 passes seemed to do a decent job. If you look carefully at the back, you'll see that some of the places that didn't cut through would line up with a straight edge. That was because there were stripes of filler that ran from one edge of my sample to the other within the hidden, middle layer. Still, the fact that it could cut through 1/4" (6.4 mm) of anything was impressive. (Just wait 'til we get to the Poplar in the next section.)

One more thing. The stuff I bought looked like 3-layer ply, but it is actually five, with the outer two being extremely thin veneer. So, if you plan to rush things by scorching your way through this, there's a good chance that you'll sand through the veneer in an attempt to remove the flaring.

FRONT **BACK**



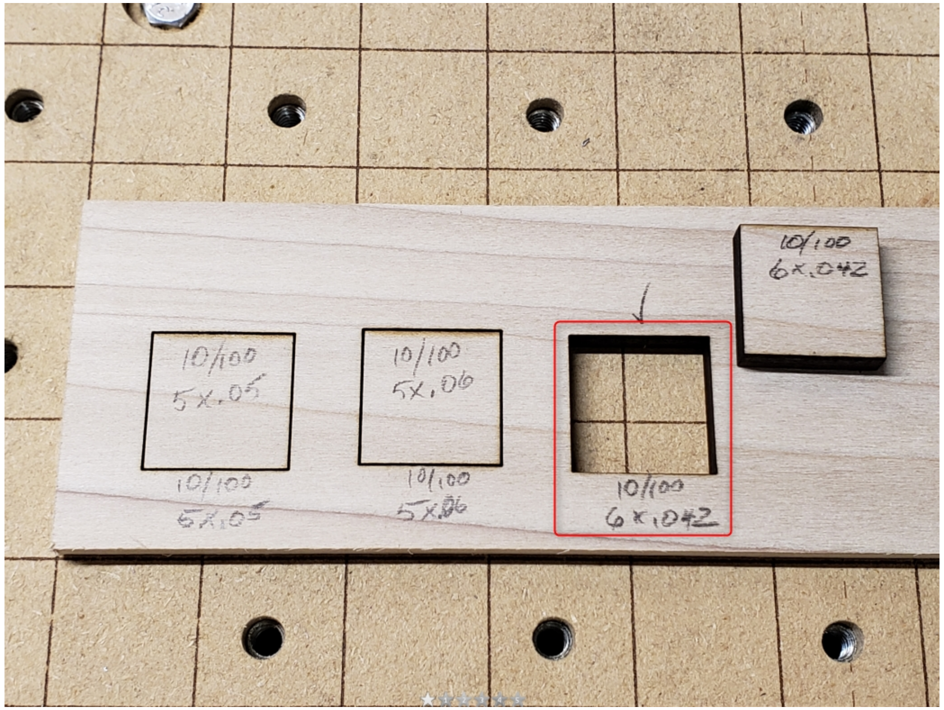


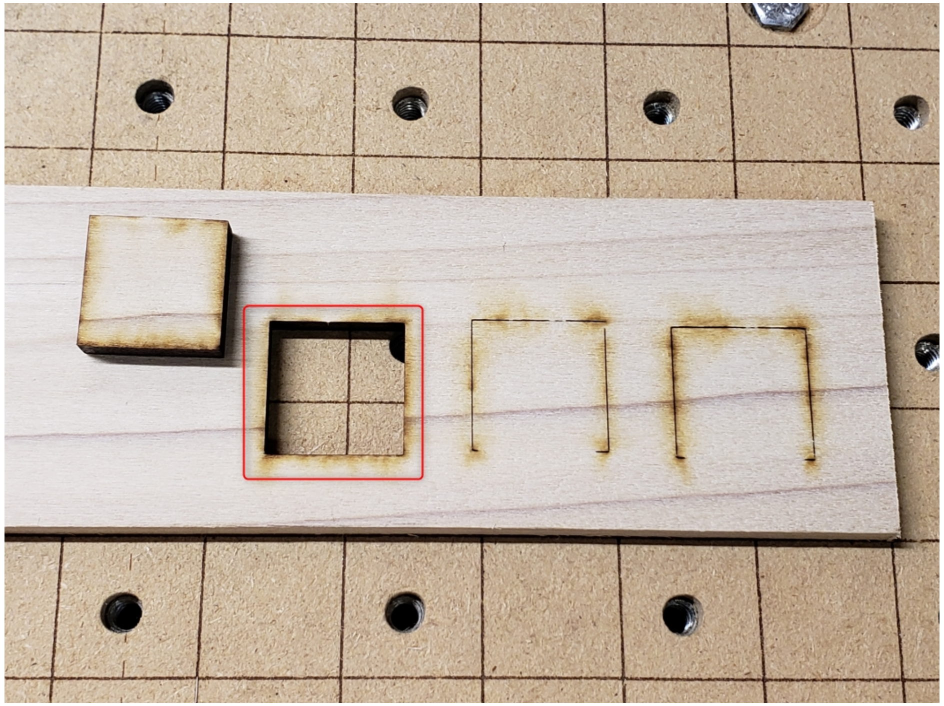
Optimal Settings to Laser Cut Through 1/4" (actual: .200" or 5 mm) Luan Plywood	
Speed in Inches (cm) Per Minute	10 (25.4)
Power as a Percent of Full	100
Passes	13
Depth Per Pass in Inches (mm)	.016 (.406)
Air Assist	Yes
Notes:	

1/4" (6.4 mm) Solid Poplar

Now we're talking! I couldn't believe this cut so well. The edges are nicely browned but with very little charring, and sanding away what little flaring there is won't hurt a bit, as it might with the Luan. You may scoff at having to go six passes, but, depending upon your needs, the ability to cut this at all could be a Godsend. Now I'm wishing I had bought some of that Red Oak.

FRONT **BACK**





Optimal Settings to Laser Cut Through 1/4" (6.4 mm) Solid Poplar	
Speed in Inches (cm) Per Minute	10 (25.4)
Power as a Percent of Full	100
Passes	6
Depth Per Pass in Inches (mm)	.042 (1.07)
Air Assist	Yes
Notes:	

1/8" (3.2 mm) Baltic Birch Plywood

Here's a good example of the speed and power relationship. If you look at the back of the two highlighted cuts, you'll see that the flaring looks about the same. Now, if you'll look at the numbers on the front, you'll see that you can either go with a speed of 4 over 2 passes, or a speed of 10 over 6 with pretty much the same result. So how do we decide which to choose?

First, considering that each square is 1" (2.54 cm) on a side, one pass around = 4" (10.2 cm).

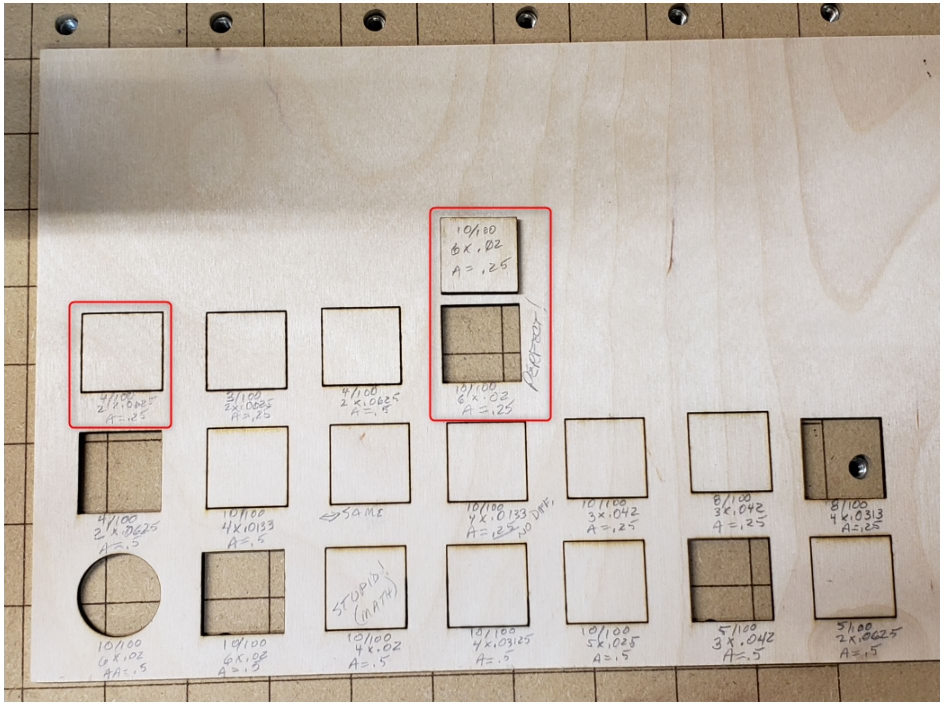
For the first example, then, 2 passes gives us 8" (20.3 cm) total to cut. At a rate of 2 inches/min (5 cm/min), then, it would take 4 minutes.

In the second example of 6 passes, we would have a total of 24" (61 cm) to cut. But, at a rate of 10 inches/min (25.4 cm/min), this one would only take 2.4 minutes.

So, you're looking at a factor of 5 for wear 'n' tear vs. being able to produce nearly twice as many parts in the same amount of time. It would depend upon your profit margins, of course, but I'd likely favor the greater production potential.

It would be nice if this formula was universal for all woods, wouldn't it? No such luck, as we'll see in our next, Balsa, example.

FRONT



BACK

Optimal Settings to Laser Cut Through 1/8" (3.2 mm) Baltic Birch Plywood	
Speed in Inches (cm) Per Minute	4 (10)
Power as a Percent of Full	100
Passes	2
Depth Per Pass in Inches (mm)	.063 (1.6)
Air Assist	Yes
Notes:	

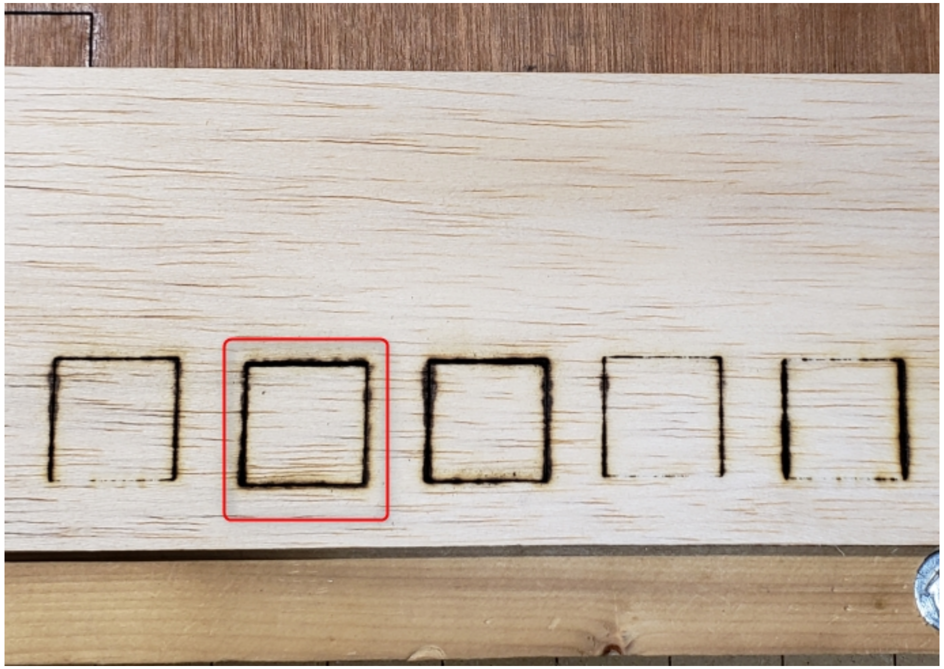
1/8" (3.2 mm) Balsa Wood (actual: .135" or 3.4 mm)

Because Balsa is so soft, I had to cut it quickly at 100% power or it would just burn. Because I wanted to remain consistent with the power settings throughout these comparative tests, and because I wanted to cut everything as quickly as possible, I didn't try cutting this with a less than 100% power setting. If I ever need to actually use this material on a project, I'll definitely devote more time to tweaking.

Of all the woods I tested, here, I think Balsa is the best candidate for what I mentioned earlier about not cutting quite all the way through. Not only would the "tabs" keep this aircraft-light wood from taking off, but there'd be less of a burned look on the back. Take a gander at the 2nd cut from the right on the Back view. It has the least blackening and would easily be freed from the whole with a few light strokes from a sharp blade. If you don't mind the cutting, this might be your winner.

FRONT

BACK



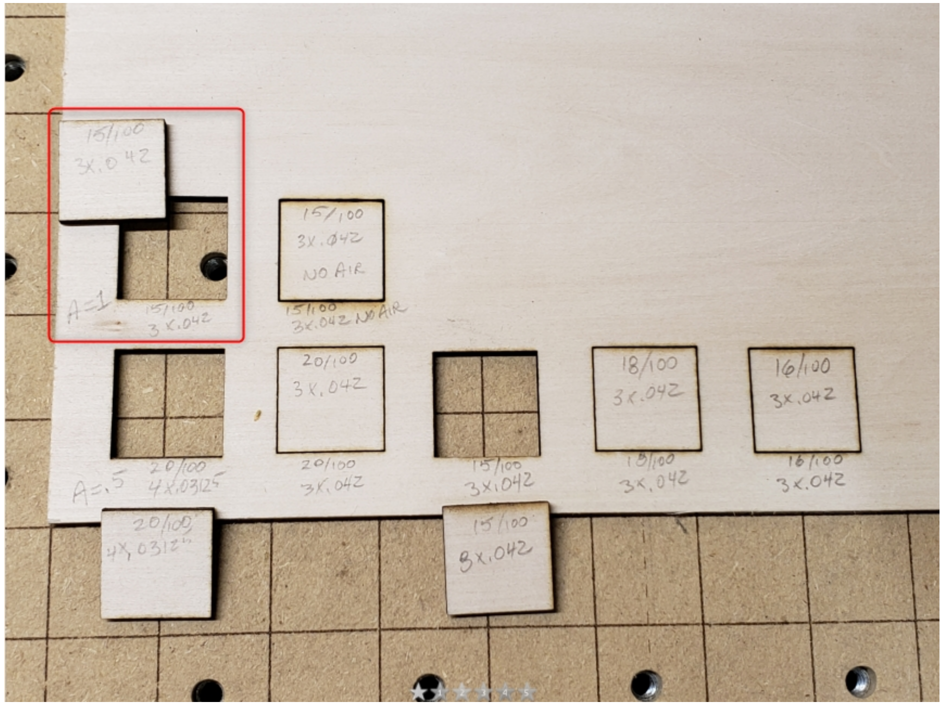
Optimal Settings to Laser Cut Through 1/8" (3.2 mm) Balsa Wood	
Speed in Inches (cm) Per Minute	20 (51)
Power as a Percent of Full	100
Passes	4
Depth Per Pass in Inches (mm)	.035 (.9)
Air Assist	Yes

Notes:	

1/8" (3.2 mm) Bass Wood

I drew my red rectangle around this one because the laser had cut through it without my having to do anything after the fact. Using a blade to release pieces from the stock works fine, but I'd rather not add an extra step if I don't have to. After moving the stock around a bit while writing this article, I discovered that the pieces I thought I would have to cut loose wound up freeing themselves with very little encouragement from my fat fingers. So, in retrospect, I would like to nominate the cut that's 2nd from the left in the bottom row on the front. It's the piece marked "20/100, 3 x .042." Note how light the cut is on the front, and how little flaring there is on the back.

FRONT



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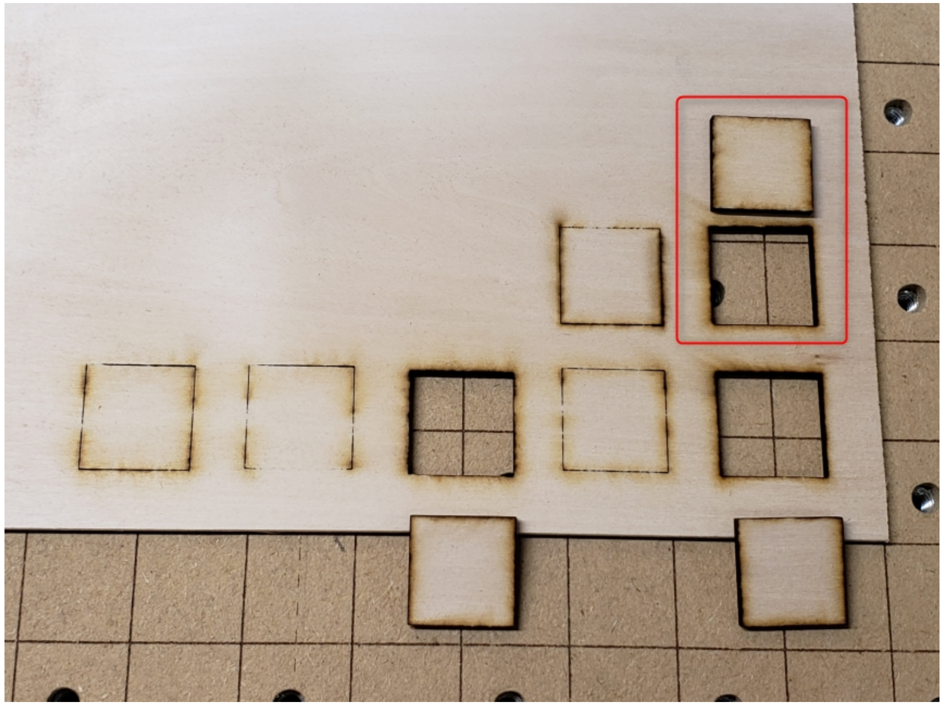

Optimal Settings to Laser Cut Through 1/8" (3.2 mm) Bass Wood	
Speed in Inches (cm) Per Minute	20 (5)
Power as a Percent of Full	100
Passes	3
Depth Per Pass in Inches (mm)	.035 (.9)
Air Assist	Yes
Notes:	

The Conclusive Beginning

A very popular question in product reviews and forums is, "How many passes does it take (X-Brand Laser) to cut through (some material)?" I gather, then, that some of us equate "fewer passes" with "better laser." But, provided that I did my math correctly, the Baltic Birch test shows that the number of passes needed to cut through a material isn't the only criterion we need to consider, as we can actually cut through a material substantially quicker with MORE passes. And, as the Balsa Wood test indicates, cranking up the power in order to cut with fewer passes can ruin the look of the cut.

You can likely read a dozen+ articles on the subject of "best settings," with each presenting different results and opinions. This is understandable because we're dealing with a somewhat subjective science, especially when cutting organic materials. I don't expect my findings to do much more, perhaps, than to save someone some time by giving him or her a little better guess at a starting point for success.

P.S. Raised Cutting Bed Improvements

As promised in the "addendumb" at this article's beginning, here are a series of pics, each showing good vs. bad cuts for the labeled material. (Jeez... I laser cut like I cook!) To duplicate these results and avoid the scorched stuff I was producing, simply raise the stock off of the bed to cut.