SCANNER TUNING TUTORIAL

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Let me say first of all that nearly all the techniques mentioned in this tutorial were gleaned from watching (and listening) to Bill Benner (president of Pangolin Laser Systems, Incorporated) as he tuned galvos for several different people at the various Laser Enthusiast Meetings over the past year. Bill is obviously a pro at tuning, while I am not. Nevertheless, I hope that I've captured enough of his knowledge to be able to pass it on to others.

Let me also apologize in advance for the lack of video. We've tried twice to capture the process on tape, but both times the resulting video was useless. (Washed out and blurry) However, the photos that I've added to this tutorial should make the process at little easier, especially for folks that have never tried tuning their scanners before.

Now, before we get started, a few warnings:

1) Tuning a set of scanners is a tedious, time-consuming process. Don't even think about attempting this if you're the sort of person that gets frustrated after 15 minutes of tinkering. You'll never be able to finish the job if you are an impatient person, and if you quit half-way through the process you'll probably end up with scanners that are worse off than before you started. You need to plan on having 2 to 3 hours of uninterrupted time available for your first attempt. (No, it doesn't always take that long, but it *might* take you that long on your first try.)

2) Before you start, you need to be 100% positive that you know exactly what each adjustment potentiometer (pot) on the scanner amp is for. If you are wrong, you can screw up the tuning so badly that you may not ever be able to get them right again. Print out the docs from the manufacturer and have them in your hand before you start. (I can't stress this enough. At the very least, make *sure* you know which pots control servo gain, low frequency damping, and high frequency damping. Without this information you won't be able to complete the job.)

3) Be Safe! Make sure you can't get hit with a stray beam. Wear goggles if there is a risk of stray beams. It's also a good idea to dial back the power on your laser (if it supports analog blanking), or put a pair of sunglasses or a neutral density filter in front of the scanners to reduce the brightness of the scanned image. (This also makes it easier to see changes in the pattern.)
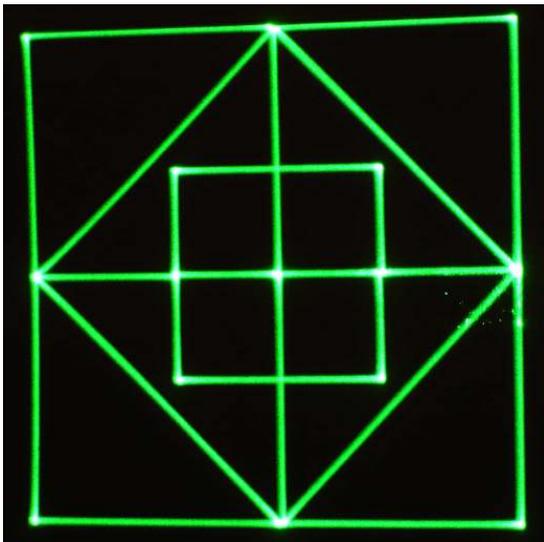
Test Patterns

Now, you'll need several different test patterns in order to tune your galvos. The most obvious one is the ILDA test pattern. There are actually 2 versions of this pattern. One (the original) is designed to be scanned at roughly 8 degrees optical scan angle. It has a circle inside a small square, with a larger square around the outside. There are some long horizontal lines at the top and 4 short horizontal lines below the square that get progressively longer. This is the pattern you want to use. (It's often labeled as the 12K test pattern, and it looks like this.)
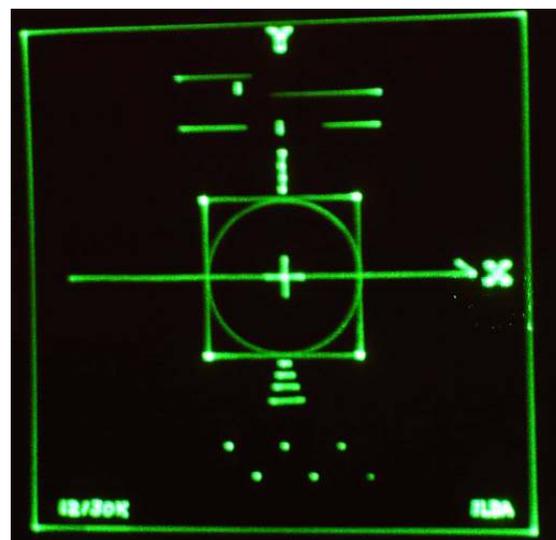
However, there is another, newer version of the ILDA test pattern that has all the same elements of the original pattern, except that way outside of the main test pattern there is another square that is *huge*. This pattern is designed to be scanned at 100% of your scanners scan angle, and while it will work, it's not as easy to use. We won't be using that version for this tutorial.

Another pattern you'll want is the Laser Media Test Pattern. This looks like a square window frame with 4 small squares inside it. There is a diamond-shape inside the square, and the corners of the inner diamond touch the sides of the outer square in the middle of each side. In the very center of the pattern there is another, smaller square. Here's a picture of what it looks like:

Finally, the last test pattern you'll need is the quadrature square wave pattern. As you can see below, it looks like a large square with bright dots at the corners.
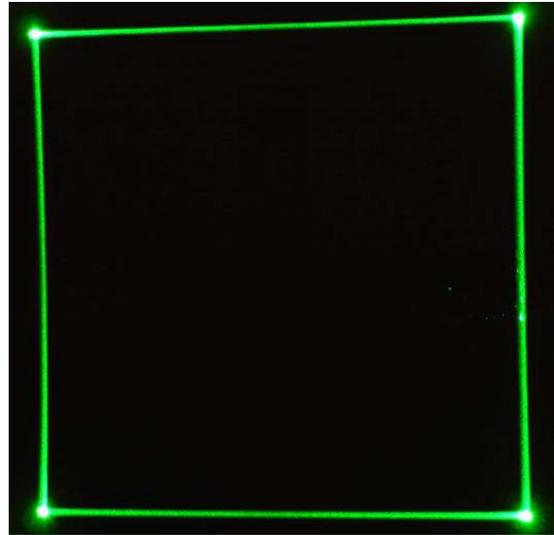
Going up the Stairs

Now a little analogy as to how tuning works. The three controls we'll be messing with are the servo gain (SG), the low frequency damping (LF), and the high frequency damping (HF). Think of these three controls as the three legs of a stool; if you remove just one leg, the stool will topple.

To adjust these three controls correctly is a bit like trying to carry a 3 legged stool up a flight of stairs. To borrow Bill's analogy, imagine that you have three guys trying to carry this heavy stool up the steps. On top of the stool is a bucket of water, which they don't want to spill. Each guy is holding one leg of the stool. As they walk up the stairs, the first two guys walk up in unison, while the third guy stands at the bottom and just lifts with his arms to keep the stool level. Eventually though, he too has to start climbing the stairs with the other two guys.

In this analogy, the two guys that go up first are servo gain and low frequency damping, while the trailing guy is high frequency damping. Going "up the stairs" means to increase the value of that setting. Try to keep this analogy in the back of your mind as we proceed.

Starting the Tuning Process

Ok. The first thing I do when I want to tune a set of scanners is to bring up the ILDA test pattern. Start with your software set to a very low scan angle – say, 5% of maximum. Set the scan speed to 30Kpps, and load the pattern.

Now slowly increase the scan angle setting in your software and watch the center circle in the test pattern. Don't worry if it's not a perfect circle, just watch it as it gets larger. Eventually you'll reach a point where increasing the scan angle setting does not make the circle any larger. STOP HERE. Back the setting down 1 or 2 percent from this point. This is where you will start tuning.

The theory behind this process is that once the circle stops increasing in size, you've reached the maximum gain for the scanners. You want to be just below this point. You should end up with at least an 8 degree scan angle here, but you may end up wider, depending on the scanners you have.

Ok, now we can tune. My preference is to dial back the scanners all the way to zero and start from scratch, mainly because this is the way I've seen Bill do it. As you get more proficient you may choose to skip this step, but I think you'll get better results if you work them down first, and then back up.

So what we want to do is to reduce the gain, LF damping, and HF damping controls all the way to zero. But you can't just start dialing the pots back.

> **IMPORTANT!**
> *Remember the 3 legged stool analogy; if you get one leg too far out of adjustment, the stool will tip and the bucket will fall! (In real life, the scanners can begin to oscillate and/or resonate, and bad things can happen to them!) So you've got to make small adjustments to keep everything balanced.*

Zeroing your Scanners

Start by decreasing the HF damping on the X amp by about ½ a turn or so. You should see the circle get larger in the X direction. You should also notice a little "undershoot" on the corner of the square that surrounds the circle. (Undershoot is when the laser traces back over the line; away from one corner and towards the other corner.)

Now reduce the LF damping a little bit (about 1 turn), and the undershoot should go away. In fact, you should start to see some overshoot. (Overshoot is when the laser traces PAST the corner, towards the outside of the pattern.) Note that the circle will get even larger when you do this.

Now reduce the servo gain until the overshoot is gone. After you've done this, the circle will be smaller, and it may be exactly where it started, or even slightly smaller than that. Congratulations, you've just walked the stool down 1 step of the stairs!

Now go back and repeat the process. As you reduce the HF damping, you should notice undershoot, and as you reduce LF damping you should notice overshoot. Dialing the gain back should bring things pretty much back to normal. Don't let either one of these two artifacts (overshoot or undershoot) get too pronounced. No more than 1/10th the length of one side of the square!

Ok - you're on your way down the steps. What you want to do is take small steps and always try to stay pretty close to having a sharp dot in the corner after each series of adjustments… Don't get too far out of adjustment, or the scanners will get away from you. Continue this for a few steps, then switch to the Y amp and do the same thing. (Try to do this evenly on both amps.)

Keep moving back and fourth, less damping, less gain, X amp, then Y amp, for many steps. At some point, you will notice that dialing back on the HF damping control doesn't have any effect on the pattern anymore. GOOD! You've worked the stool down to the point where the HF damping dude is standing at ground level.

(The HF damping pot is turned all the way down to zero.) At this point, it's easier to see what you are doing if you change test pattern. So stop for a moment and load up the quadrature square wave pattern.

You should see a large square with four dots in the corners. With this pattern, both the overshoot and undershoot are *really* easy to spot. Ok, keep dialing back on the gain and dialing back on the LF damping. One step at a time, and keep alternating between X and Y. Eventually you'll reach a point where, when you try to reduce the gain a little bit more, the whole square will collapse in that dimension. Cool! You've reached the bottom.

Increase the gain just enough so you have something that looks roughly like a square. Then work on the other amp until you reach the same point there. Good! Now you're at the very bottom and are ready to start climbing the stairs again. You should have a really rough looking square at this point.

Climbing Back up the Stairs

With the quadrature square wave pattern still displayed, start increasing servo gain. Right away you'll see that a little extra gain will give you a large overshoot.

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BE CAREFUL HERE!
Don't let the overshoot get too far! Remember: No more than 5 to 10 % of the total length of the sides of the square. If you go too far, the scanners can get out of control, and bad things will happen!

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Once you get the overshoot, increase the low frequency damping until you bring the overshoot back in line and you have a nice, crisp dot at the corner. This is important! From now on, all we want are precise dots on the corners.

See this picture:

Overshoot on X axis
Need more LF damping

Ok, now add a little more gain, and a little more LF damping… Switch to the other amp and take a few steps with it. Again, a little servo gain, followed by a little LF damping to bring the overshoot back into line.

Continue working your way up the steps like this. Eventually, you'll notice that when you add the LF damping to bring the overshoot back in line with the corner, you also get a little undershoot that runs back along the line. That means you're to the point where you need to start adding a little high frequency damping to get rid of the undershoot.
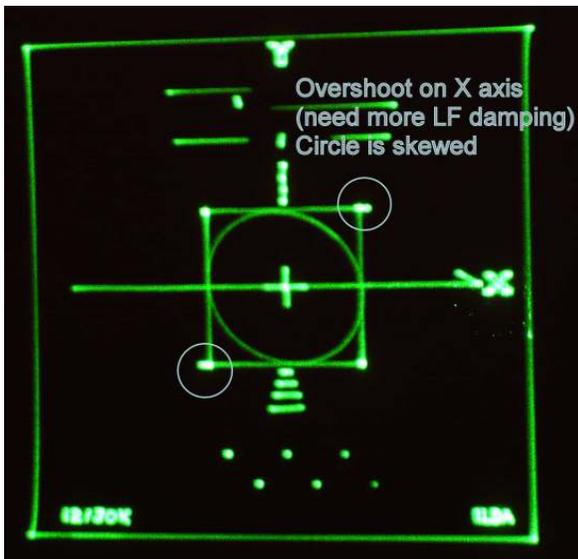

Undershoot on X
Need more HF damping

Be careful here, because it doesn't take a lot of HF damping to do the job. You want bright dots, nothing else! (It's easy to add too much HF damping, and this will cause you problems later, so be careful.)

ILDA Test Pattern

This is now a good time to switch over to the ILDA test pattern. The quadrature square wave pattern is great for large signal response, but once you get the gain up fairly high, I find it's easier to adjust things using the ILDA test pattern. So, after you've gone through 3 or 4 rounds of increasing the HF damping, switch to the ILDA test pattern and continue from there.

The center square in the ILDA test pattern behaves just like the square in the quadrature square wave pattern, except that the effects are not as easy to spot. But you can still see overshoot and undershoot in the pattern. You'll also notice the pronounced effect the damping has on the shape of the central circle.

Here is a picture showing what overshoot looks like on the ILDA test pattern:

And here is a picture of what undershoot looks like on the ILDA test pattern. Notice the extreme distortion of the circle. HF damping has a large effect on the shape of the circle.


You know you're getting very close when you've got bright dots at all the corners AND the circle is both round and just touching the sides of the square. Like this:
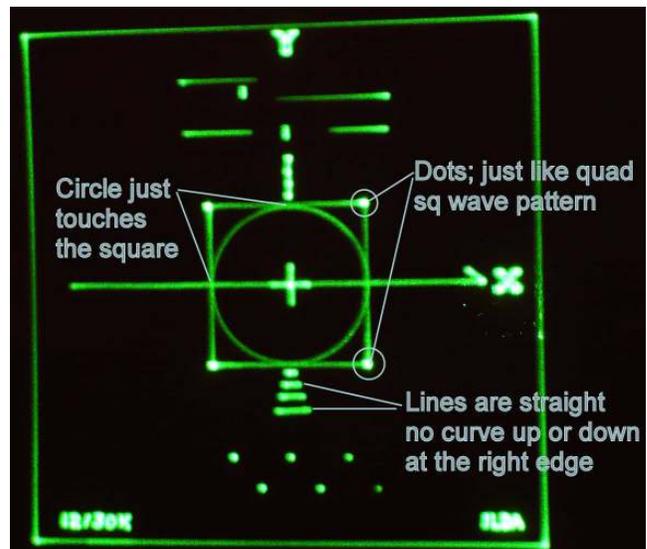
So with the ILDA test pattern up, keep adding servo gain and tweaking both LF damping and HF damping as needed to get rid of overshoots and undershoots. Watch your circle. When it's touching the square, stop. You are close, but you may not be done yet.

Laser Media Test Pattern

Now it's time to introduce a third test pattern: The Laser Media Test Pattern.
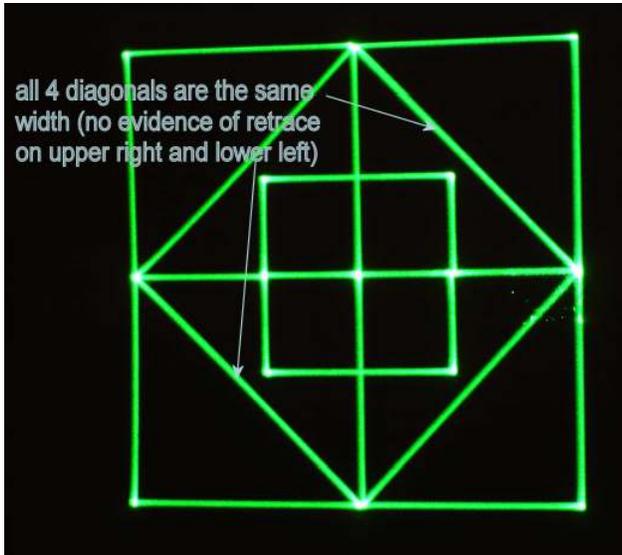
This pattern helps ensure that both scanners are running at exactly the same speed. The diagonal lines on the top right and lower left of the pattern are traced over twice. If the scanners are at the exact same speed, these lines will overlap perfectly. If once scanner is faster than the other, the lines will separate from one another, and you'll see two closely spaced lines instead of just one. If you see two lines, carefully tweak the gain DOWN on one of your scanners a little bit. (You don't know which one is off, so just pick one and dial it back a tad…) Watch the lines… If they get farther apart, then you need to go UP on the speed of the scanner you picked. If they get closer together, then you need to go up on the speed of the OTHER scanner.

Remember that increasing the servo gain (speed) will mean that you'll have to tweak the LF and HF damping again. Then go back and look at the Laser Media Test Pattern. Then check to make sure the circle is still round, and is still touching the 4 sides of the square in the ILDA test pattern. Flip back and fourth between these two patterns as you fiddle with the tuning until you find a happy medium between the two.
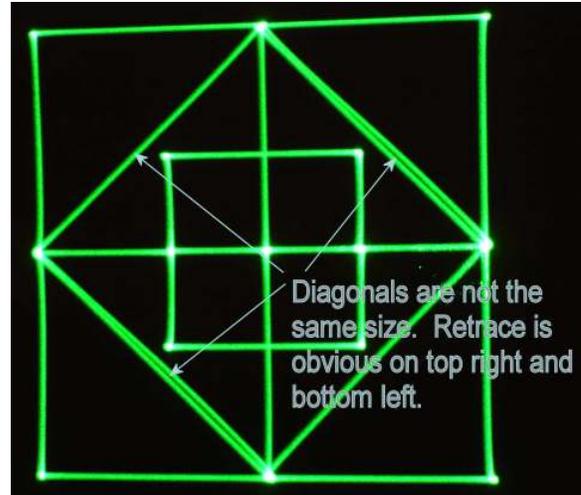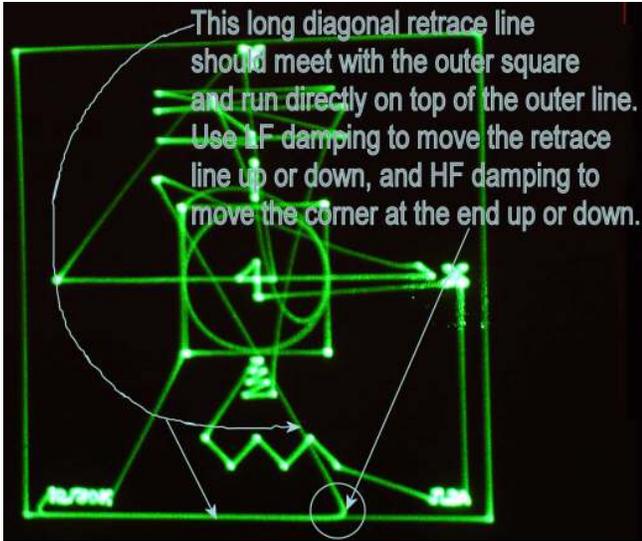

Ok – something else to check: look at the 4 lines beneath the square on the ILDA test pattern. Are they all straight, or do they curve up (or down) at the right edge? If they have a curve to them, you need to play with the damping on your Y axis scanner. Then rotate the test pattern 90 degrees in your software and look at those lines again. (They will be vertical lines now.) If they curve to the left or right at the end, then you need to adjust the damping on your X axis scanner.

What ? No Blanking ?

And finally, a great tip from Bill Benner: Turn off blanking. (Either by disconnecting the blanking lead to your laser, or by going in to your software, selecting "show blanking points", and then using the paint brush tool to make all blanked points white.) When you display the ILDA test pattern without blanking, you will see a diagonal line running from above and to the left of the center square down and to the right, where it will curve sharply to the left and merge with the bottom line on the large outer square. This diagonal line should have a reasonably hard corner where it meets the bottom line, and should then trace along the bottom with no wavy parts to it. (Nothing above or below the main bottom line.)
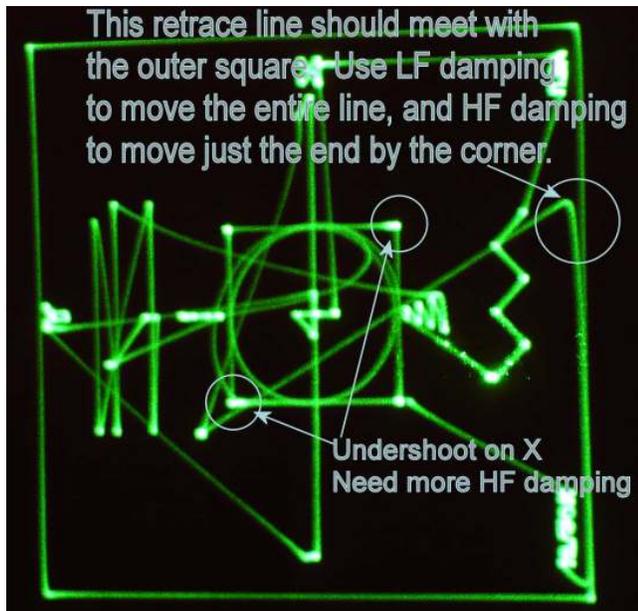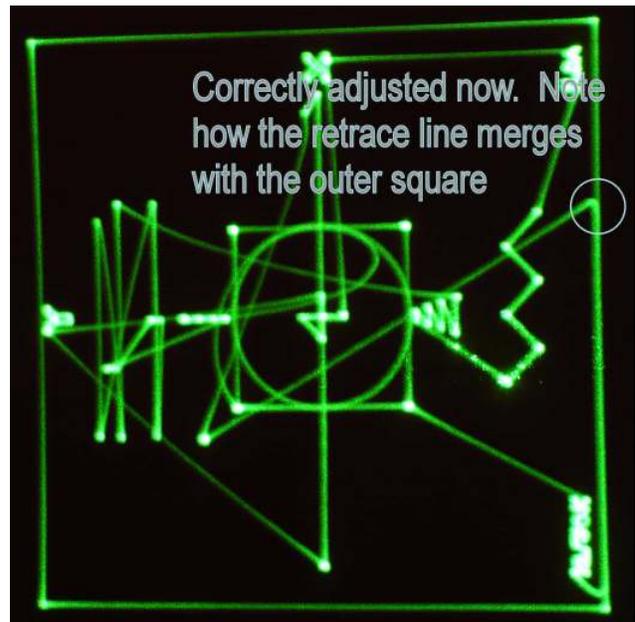
Have a look at this picture to see what I'm talking about:

This long diagonal retrace line should meet with the outer square and run directly on top of the outer line. Use LF damping to move the retrace line up or down, and HF damping to move the corner at the end up or down.

Ok, so you've tweaked the circle so it's both round and exactly touching the square. You've checked the Laser Media Test Pattern, and you have single, solid lines on the upper left and lower right diagonals. You've turned off the blanking and checked the long re-trace line to the bottom of the outer square, and it runs straight to the bottom line and traces along right on top of it. Congratulations! You've got your galvos tuned as tight as they're ever going to get. Don't touch them, and you should be good for a long time to come.

If part of this retrace line is above or below the bottom line on the square, you need to adjust the low frequency damping for your Y amp. On the other hand, if you see a wave or ripple in the line as it retraces along the bottom, that means you need to adjust your high frequency damping on your Y amp.

Also, remember that you can rotate the pattern 90 degrees in your software, and then you can check the same line again, except that this time it will be telling you about the performance of your X amp.

Correctly adjusted now. Note how the retrace line merges with the outer square

This retrace line should meet with the outer square. Use LF damping to move the entire line, and HF damping to move just the end by the corner.

Undershoot on X Need more HF damping

Now, if you've been doing all the above, and after 3 hours of twiddling you still can't get it perfect, take heart. It doesn't *need* to be perfect. If that bottom retrace line has a little wave, or runs a tad higher than the bottom line, and you can't fix it without screwing up the circle in the center square, then you may have to live with it.

Likewise, if you can't get the double lines on the Laser Media Test Pattern to go away without screwing up the circle in the square, again, you'll just have to live with it. Don't worry, your images will still look OK.

But if your circle looks like an oval, then you're not done yet. You need to tweak some more. (An oval means your speeds are way off between x and Y; the Laser Media Test Pattern will tell you this as well.) If your circle isn't

touching the square, you need to tweak some more, because BOTH scanners need more gain.

Or, if you're already maxed out on servo gain and the circle is still way inside the square, then you need to decrease your scan angle setting in your software a bit more and then re-tune. (You did make sure you had your scan speed set correctly, right?)

A Note about Scan Speed

If you tune at 30K, and then display at 40K, the circle will end up inside the square. If you tune at 40K and then display at 30K, the circle will end up outside the square. If you lower the scan speed even more, the circle might end up looking like a 12-sided polygon. That's actually what the pattern contains; 12 points that make up a rough circle that the scanners trace around 3 times.

The idea behind this polygon-circle is to send points far enough apart that the scanners never actually reach them before the next point is sent. Thus the scanners are said to be "ballistic", in that they are accelerating as fast as they possibly can. So it's always a good idea to tune at the speed you plan to display things at. (Also note that there is no true 40K standard, only 30K and 60K.) Besides, a set of scanners that can do 40K are more fun when you tune and run them at 30K, because you'll get a wider scan angle out of them. (Wider scan = larger images!)

Once you've performed this process once or twice, you may decide that you no longer need to walk the scanners all the way down to zero before you start tuning. And, indeed, most people do not do this when they tune. If you feel comfortable omitting this step, and especially if your scanners are very close to perfection already, then you can just jump right in and start tweaking. But use all three test patterns to check your results. Now that you know what to look for, the process should be easier.

Ok, that's about it. If you want more information, I suggest you have a look at the following links:

SKYWISE711

http://www.skywise711.com/lasers/scanner/scanner.html

This site has a rundown of the same basic procedure I detailed above. It's aimed at tuning the General Scanning amps for the G100, 200, and 300 series scanners, but the theory is the same. Each picture is a scan of one page of the manual.

LASER FX

http://www.laserfx.com/Backstage.LaserFX.com/Systems/Scanning1.html

http://www.laserfx.com/Backstage.LaserFX.com/Systems/Scanning3.html

The Laser FX site has a good tutorial on how to tune scanners, and also has some more information on what the test pattern is actually testing for in the second link.

PANGOLIN

http://www.pangolin.com/ILDAtest.html

http://www.pangolin.com/userhelp/scanangles.htm

http://www.pangolin.com/50K_tests/TestPatternPhotos.htm

Finally, the Pangolin website also has an article on the test pattern, along with a table (second link) to help you calculate scan angles, and finally a page (last link) showing several pictures of the overshoots on the quadtrature square wave pattern. (Look towards the bottom of the page, on the right.)

Happy tuning!