Christian Greig, IPG PHOTONICS
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Transcript Part IV

[Can you mention why beam quality is important?]

Oh. Beam quality is really important. Let's talk about the fundamental YAG. Typically a resonator is about a meter long. The longer the resonator, the better beam you can get, but it also becomes more finicky because of the longer rail length. You've usually got a high reflector and a partial reflector that makes your resonator, and you've usually got a Delran or Teflon housing that's gonna hold your gain medium. In that case it's YAG- yttrium aluminum garnet. So you've got something about the size of a chapstick-it's a very large bulk medium, and then I've got end or side pumping going on with either diode bars or lamps.

Now we talked about that 1 or 2% wall plug efficiency? The reason is I'm hitting it with a flashlamp so I've got this large spectrum of light going in trying to get one wavelength out, so the coupling efficiency is poor. If you use a fiber laser you've got these single stripe emitter diodes that are about 960 nanometers, and I'm trying to get one micron out, so it's already very close.

Let's get back to the resonator for a second. So I've got two mirrors, I've got the cavity where I have my lamp and so forth, I've got my bulk media and flowing water will take all that heat out that's not being converted properly. Then I've got usually a Q-switch on there that allows me to release the pulse after it's gone a certain amount of trips. So the problem with that is with that Teflon block and the water, what you've got is a clear flow rod- it's glass- and what it allows me to do is get a nice laminar flow over that bulk media. The problem is, as I pump it harder there is more and more heat and with that flow a thermal gradient takes place. It's cool on the outside from the water, but it's very hot in the center of that, and what happens is the beam starts to spread by internal lensing.

With a fiber laser, you've got about a 7.5 micron core. With that 7.5 micron core there's no thermal gradient that takes place. It's a very long medium that's very fine in diameter. With no thermal lensing taking place, the beam product when it runs through its dynamic range – in this case we go from 105% (power) down to 10%- so a 6 kilowatt laser, I can run it all the way down to 600 watts and I get the same beam product out which is very important. I'm just selecting a power, speed and frequency and so forth based on the process and I'm not actually tweaking my laser based on the need for that particular day or hour even if I'm job shopping. That's important.

Now here's what happens. On that rail what you normally have just after the key switch, prior to the partial reflector where the beam's going to come out, you'll usually see a lot of laser integrators or a lot of laser manufacturers block will have a block there with a set of knurled knobs, and these knurled knobs will have different diameter orifices in them- 1 mm, 1.5 mm, 2 mm. So let's say I've got a 6 mm raw beam coming out; I'll select the appropriate aperture to take out all of these multimodal or interference patterns that are appearing. So what happens is I've got poor efficiency going into the YAG to start with- bad wavelength match-, then I've got a number of trips trying to select out my laser energy, and then I take that 6 mm beam and get rid of the bulk of that energy because it's not useful. So I've got, you know, 1.5 mm of clean beam coming out, let's call it. But I've still got side modes because there's still a little multimodal going on there, and going through an aperture you're going to create a pattern anyway. So now I've got poor efficiency, selecting out energy, so now I've got really poor efficiency.

What I want is the cleanest beam I can have, which takes all the energy of the beam and puts it into the useful part of the beam. So if I've got one nice Gaussian distribution, that's gonna be (my aim). But with a multimode or traditional YAG or YLF, there's all these side lobes, what they'll do is - there's not enough energy there to say "Process the material I want," but there's usually enough energy in there to interact with the material. If I'm doing like a single silicon crystal, what'll happen is that'll cause what's called a heat affected zone and that'll interact with the material. So now it'll cause peelback if there's any chips or any laminations on there. It's gonna cause heat affect and heat affect is going to cause the single crystal to go to some sort of amorphous or some other nondesirable type of silicon for processing. They usually have to grind that off or work it out with shielding gases.

With a fiber laser, because it's coming through a 7.5 micron, 10 micron core, what I've actually done is I've constrained it now so it's truly a single mode laser. There are no side-nodes because they can't exist inside the fiber. Now all of that energy that was wasted and dumped by the aperture in the old method is being turned into usable energy. Again, I can use less energy, I can select a lower power – instead of a kilowatt I can use 750 watts. So I can select a smaller laser, a better price point. But it also allows me to produce a smaller spot on target. When you use the laser with the side lobes they'll actually be imaged on the part. You can see a series of concentric rings- like if you throw a rock into a pond and see the wavelengths coming out. Same idea- and you want to get rid of those.

Lastly, the most important part from my processing stand point, again, for cutting applications, with that YAG there's another reason they're putting in that aperture. They have what's called an astigmatism in the beam. Astigmatism is referred to as a cat's eye. Instead of a nice round spot, so if I move in x and y I have even energy density, I'll have something shaped more like a cat's eye. So in this axis I've got more time on target. It's narrower, so I have higher energy in one axis than in this axis.

A good example is if you cut a circle you'd see slitting in one application and you'd see a wide… and it may not do slitting. So I have to increase my power so the lower powered axis can still cut. Then I'm overcutting the other axis. It also changes the geometry and the shape of the part. It's no longer round – it's thinner on this axis because the beam is so wide and it's wider on these two ends so I have an elliptical cut out.

This uses a Q-switch. It's basically a piece of quartz, in this case, where we're striking it with a frequency. It changes the lattice structure which basically makes an optical switch. We then take that small seed pulse and put it through a two-stage linear amplifier and then we amplify it up to the power we need. Even though it's 20 Watts average power we're getting gains of something like 7.4 kiloWattts. So it's peak energy that only exists for about 100 nanoseconds in time. What's nice about that is two-fold: one is you get a lot of energy to do work and ablate the material but it's only on target for a short period of time so there's not a lot of heat being applied to the part. This is a problem for a lot of processes, especially thin metals and plastics.

That laser then comes through a delivery fiber, which is armor clad just for the safety of the fiber itself (it's safety interlocked), an optical isolator, which typically consists of a polarizer and a quarter wave plate, and then we've got a collimator which is going to give us a nice collimated parallel beam coming out. That beam is then launched into a galvo head over here, which is a series of galvanometers, two here in this case- two mirrors coated for the appropriate wavelength- in this case one micron, and then a focusing lens.

This is a 163 mm lens, which is going to give a roughly four inch by four inch mark field, and spot size is around 28-40 microns. So based on that energy density…. If you look over here at this software, what they're doing is actually delineating the mark field of this particular galvo and lens arrangement. So as I select a different lens, a different file will launch. What we've done here is selected different parameters; in this case, they call them pens in this software, this is telling me the power of the laser, how hard I'm pumping the diodes, the speed- how fast I'm traversing along the part, and the frequency- how fast I'm turning the laser on and off to get those pulses. Low frequency means I get more trips (through the laser) and more trips through the laser means I get higher peak power. High frequency means I get more pulses in a period of time, but there's less time for them to get that gain going through the medium so I get lower peak power but better average power.

So once I select that pen, I can create some feature, a 2-D barcode, which seem to be the biggest thing for marking, for traceability and so forth. 2-D barcodes seem to be the biggest flavor because they have redundancy. If I lose one line in a standard barcode I lose all the information. This one here is called ECC200. It's used by aerospace and medical and it actually has redundancy of about 35%. If I lose part of that mark through wear and tear in the field I can actually still recover all the information. It may actually include from 50 to about 500 characters.

So we're gonna mark this as "on-target;" what we're using here is a pointer so you can actually see where the process is going to take place. Now you watch the mark take place. It's not actually engraving, but rather heating the material. Based on time on target and energy, fluence, we can get different colors out of the material. It's an oxide formation, so as the light goes through that oxide you get different colors. We're talking about a material maybe a few angstroms in height, so there's nothing that would cause wear and tear on other parts. Oh, ok, there's the part, it's done; that took 62 seconds. If I was to do that same mark as just an engraving… there. It's more impressive to the camera, and a lot faster. That one took four seconds, and that can be optimized by spot size and so forth.