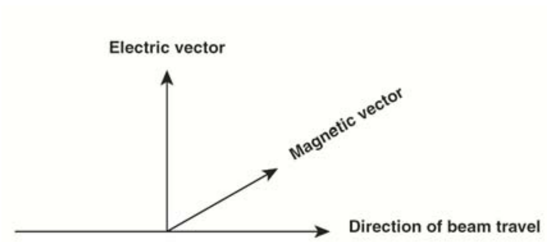
Polarization effects in metals, ceramics and acrylic

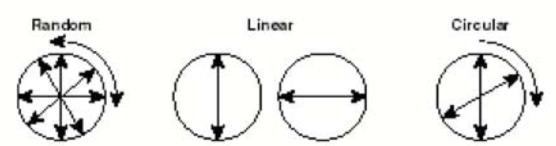
Polarization can be a complex subject area when looking at exactly how and why it affects materials processing of these materials. However, as a simple effect, it can be easily identified as cutting variations in different cut directions.

<u>What is beam polarization?</u>

Laser light is an electromagnetic wave containing both electric and magnetic components. The orientation of these components in relation to the beam's direction of travel is called polarization. Within the laser's beam, the electric vector contains the processing power. The electric vector's orientation and temporal stability (its variation over time) are key to processing metals and a number of dielectric materials.



Orientation of electric and magnetic field vectors



Schematic of types of polarization (beam directed out of the page)

In randomly polarized lasers, the beam's electric vector is rapidly changing orientation over time. Linearly polarized lasers have a fixed electric vector that extends in a fixed direction. When the beam's electric vector rotates uniformly in a circular pattern, it is said to have a circular polarization.

<u>When is "the effect" noticeable?</u>

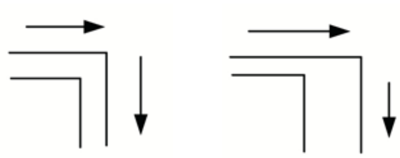
When a beam is circularly or randomly polarized, the electric vector that contains the laser power is orientated evenly in all cutting directions. Therefore, no effect can be seen. However, linear polarization means that the power (power absorption) is orientated in one fixed direction. Therefore cutting in line, at an angle and perpendicular to this direction causes variations in cutting results.

Metals

The effects of using a linear polarized beam in metals are:

· Variation in directional cut widths
· Reduced process stability
· Angled cut edges on curved cuts

Variation in orthogonal cut widths for a linear polarized beam can be up to 30%. This is a result of the beam power being absorbed differently when the polarization is in line and perpendicular to the direction of travel.



Schematic of the effect of polarization, in terms of cut width and length of arrow indicating cut speed. Direction of linear polarization indicated in parenthesis.

Circular/ Random *Linear (←→)*

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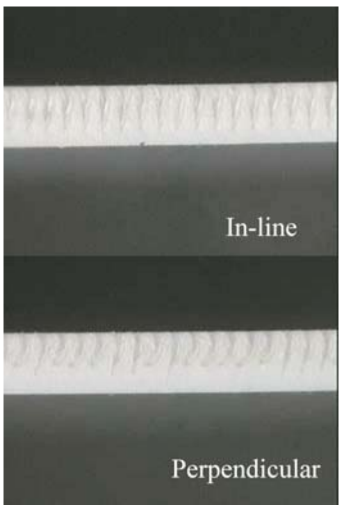
This difference in cut widths reduces pattern resolution and increases dimensional tolerances. In addition to this the stability of the process is reduced as changing a cut width tends to upset the cutting action. More generally, as a result of enhanced absorption the in-line direction of cutting is the fastest.

When cutting a circle out, at some point the cut path becomes angled to the directional of polarization, this causes an interesting outcome.

At this point the cut edge geometry changes from being square to tapered outward at the base of the cut. The result is that the topside of the cut is a circle, however the underside is an ellipse. The angle of this taper is around 5 degrees, so the effect becomes more pronounced the thicker the material. Under 0.04"thickness this effect is fairly minimal.

Ceramics

The dielectric nature of ceramic produces polarization sensitivity. The key result is a difference in scribe depth when processing in-line and perpendicular to the direction of polarization.



The pictures highlight the difference. Processing with the polarization perpendicular to the scribe direction causes a reduction in scribe depth and the tendency to produce the "hook" defect. Circular polarization offers mid ground - not as much penetration as parallel but consistency in all directions without showing the hook defect.

Acrylic

When discussing polarization, this is a surprise material, however when cutting past a certain thickness does show direction dependency.

The effect is similar to the tapered edge produced in metal cutting. The effect in acrylic is a result of material waveguiding the laser. Multiple reflections of the beam within the cut width cause the polarization of the beam to be a factor. This is only seen when cutting material thicker than 0.4" thick, again, the top surface is a perfect circle but the underside is an ellipse.

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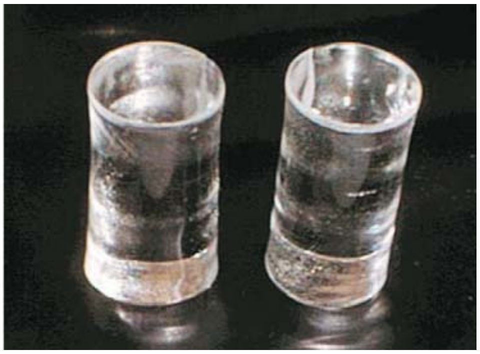

1" thick acrylic, left with linear, right with circular.
Note the sloped edges on the linear samples.
The ellipticity of the top compared to the bottom was 1:1.15.

Getting a circular or randomly polarized beam

The majority of lasers emit linearly polarised light, therefore, must somehow be converted to circular. This is achieved by reflecting the beam at angle of 45 degrees to what is named a ¼ waveplate reflector. The mechanism of how this works is a phenomenon known as birefringence. These can be easily obtained from optics supplier. At this point it is worth noting that Synrads range of dual tube lasers exhibit properties similar to random polarization, and therefore in many cases do not need to be circularly polarized.

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