



WHITE PAPER

What's the value of a pixel?

HOW BMF ACHIEVES ULTRA-HIGH RESOLUTION, ACCURACY, AND PRECISION

As the trend towards miniaturization continues to grow across a wide range of industries, manufacturing and prototyping technology must be able to achieve the high resolution, accuracy, and precision demanded by these applications. The advantages of micro-3D printing become more valuable as parts become smaller and more complex. The longer lead times and increased cost associated with traditional microfabrication methods, such as micro machining and micro injection molding, best highlight the benefits of micro-3D printing. The advantages of using 3D printing are usually in terms of reduced lead times and lower cost for prototyping or production. The same is true in micro-3D printing, but not only are you benefiting from increased speed and lower cost, you are fabricating a part that could not easily have been produced with any other method and in some cases parts that could not be produced any other way.

BMF's microArch 3D printers are built on the Projection Micro Stereolithography (PμSL) based process, as opposed to other resin 3D printing processes like Stereolithography (SLA), Digital Light Projection (DLP), or Jetting. PμSL is a technique that allows for rapid polymerization of a layer of liquid polymer using a flash of UV light at micro-scale resolution. The PμSL process differs from other DLP processes in that it incorporates high precision optics, high precision motion control and mechanical systems and software to control the pixel precisely and accurately through a top-down light source. The vat of resin moves throughout the build allowing for larger parts or arrays of parts to be built while maintaining tight tolerances and consistency over the full build area.

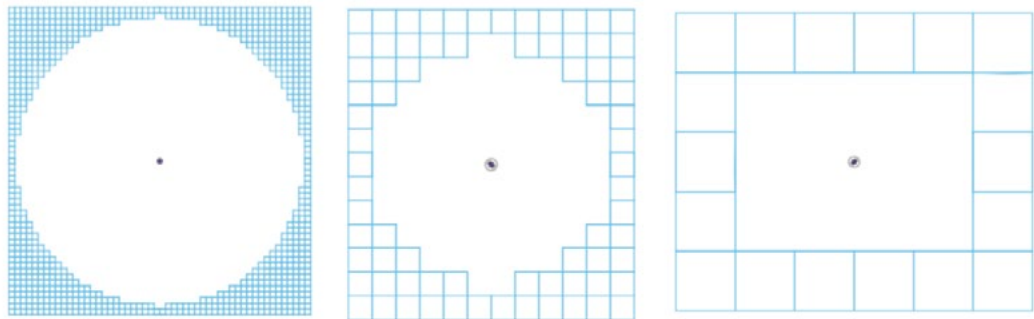
In the following sections we will discuss the basics of PμSL and how the control and building blocks of the pixels relate to the overall process. We will then discuss the differences and benefits between PμSL and other resin-based process and why this results in higher resolution, precision, and tolerances compared with other additive technologies.

What is a pixel and why does it matter?

A pixel is the basic building block of a digital image, a 2D element that makes up data from an image. A collection of pixels will combine to create the full image or set of data. The definition of a pixel is dependent on the context, and can be addressed as a square, circle, rectangle. Each pixel has a unique geometric coordinate, size, and ability to project multitudes of color. PμSL

3D Printing is a variation of DLP, in which a projector is used to cure a layer at once. With this method, pixel size defines the resolution of the printer in the XY plane. What makes the pixel so important in projection-based printing is that this is the smallest element that can be used to make up a feature. Consider, you have a house that will be made up of thousands (or more) of bricks. The brick in this case would be the pixel, the smallest building block able to be used in the building process. This brick works well when you have a large house that needs many bricks but using that same brick you are unable to build something smaller than the brick itself. The only solution in this case would be to increase the size of the part you would like to build (a larger model house) or to decrease the size of the brick itself (allowing the smaller sizes to be realized in the building process). If that same analogy is used, the process behind PμSL is shrinking the bricks (think pixels) to allow for smaller features to be realized.

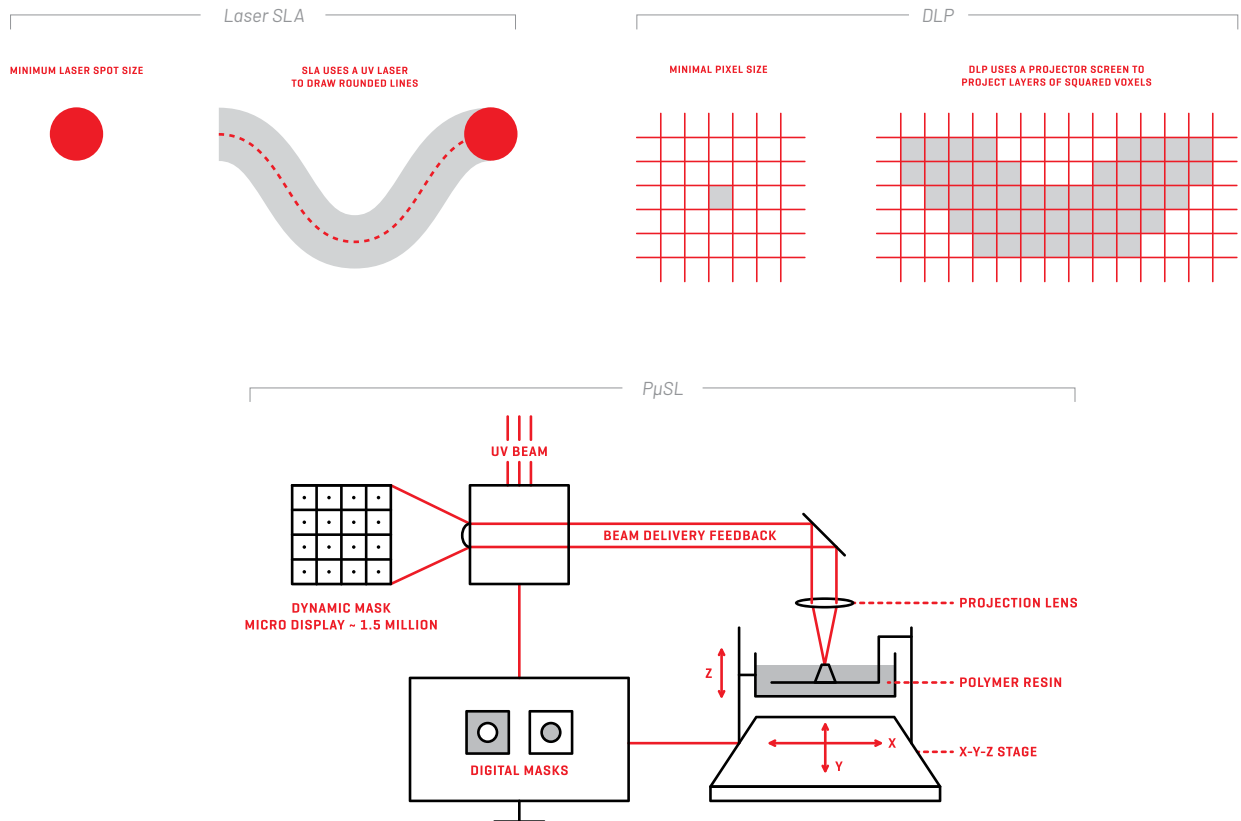
Using this concept, PμSL 3D printing incorporates advanced optics to control the pixel size down to smaller values, which directly translate to higher resolution. Controlling the pixel down to smaller sizes allows for PμSL 3D printing technology to print at a much smaller minimum feature size (think 1 pixel = 2μm square, which means 10μm minimum feature sizes are possible), while also maintaining high precision and accuracy. So, if the pixel size is 2μm, why can't a feature be 2μm? This goes back to the example of the bricks. It generally takes multiple pixels to form a feature. The 3 images below all represent a 100μm circle. It is obvious that there is a difference in the features between these three images. The difference here is that the image on the left uses 2μm pixels to approximate the feature, the one in the middle uses 10μm pixels, and the one on the right 25μm pixels.



Using this basic graphic above, we can see how important pixel size is when working with small features that require high resolution.

Now that we've defined a pixel and why it is important...

We will compare three available resin-based 3d printing techniques, SLA, DLP, and PμSL.



A resin-based laser system, known as SLA or stereolithography uses a laser to cure the resin in this process. In SLA, the laser is controlled by mirrors driven by galvanometers to aim the laser and cure the resin. The limiting factors on resolution are the laser spot size and galvanometer control of laser movement.

DLP based systems use a projector that cures an entire layer at once by flashing an image onto the resin. The resolution on the printed part is therefore set by the resolution of the projector. This means that the maximum number of pixels is set by the projector, and to increase the build size, magnification must be used, which increases pixel size and decreases resolution.

PμSL uses a variation of DLP technology to increase resolution while also maintaining the ability to print large parts and keep high tolerance on these. It is worth noting that resolution does not equal tolerance. Resolution is directly dependent on the pixel size and relates to the smallest features you can print. Tolerance relates to accuracy and precision. Accuracy is the ability to achieve the desired dimensions and precision is how close those measurements are to one another. The tolerance that is achievable is a factor of both accuracy and precision because

the parts need to be as close as possible to the desired dimension, as well as repeatable across measurements. The PμSL system developed by BMF addresses all three of these factors to create high resolution, accuracy, and tolerance machines.

Now that we have described the three technologies, we can discuss why BMF is able to achieve higher resolution than other systems. Other DLP and SLA based technologies can achieve pixel or spot sizes of sub 100μm, sometimes even as low as 50μm. Referring to the graphic earlier on pixel size, it can be shown that a larger pixel, or laser spot size, will be a limiting factor in minimum feature sizes that can be accurately created. Spacing between features will also be larger as this is related to pixel/laser spot size. With much smaller pixel sizes, BMF can achieve much higher resolution and smaller features than other printers on the market. Pixel size is not the only reason that BMF stands apart, there are additional factors that BMF uses to ensure this high level of resolution and accuracy. Another major factor in BMF's success is that the process is top down, reducing the need for support structures, which may compromise surface finish and tolerance. The chemical process itself is a hurdle to overcome in DLP, as Vat polymerization generates heat during the reaction, which will have thermal effects on the end parts. In a top-down process the vat acts as a heat sink, limiting thermal effects on tolerance. BMF also utilizes a membrane between the light source and the surface to create a defined focal plane which helps maintain tight tolerances on each layer, while also ensuring that the focal distance between the image and the material surface is precise for Z layer control. These design features along with advanced materials and software choreography ensure that our platforms can achieve performance not possible with other systems.

PμSL technology developed by BMF takes the advantages of DLP resin- based printing and addresses and overcomes the limiting factors and difficulties associated with that process. Through this variation of the technology, BMF has created a platform that allows for higher resolution, accuracy, and tolerance than other systems in the SLA or DLP 3D printing spaces.