

# Vectors and Points

Laser Show software operates with Frames. The software sends the Frame to the hardware controller to transform the digital Frame to an analog waveform. The output from the controller is an analog signal. The same situation as in the audio world. An audio waveform stays in digital form in the software, as a WAV, MP3 or similar format. When audio is played by a music player, the digital signal transforms to analog, and is then amplified, and we hear it by means of speakers. In laser display – we have Frames, a controller for making the analog signal, a scanner amp, and finally lasers and scanners. No doubt, there is a similarity.

The waveform, or a Frame is used as the base element. A digital wave form is divided into a sequence of Samples. A waveform is composed of a sequence of Samples. Typically, each Sample has equal duration, but a different value. A laser controller uses the Samples as the input of the DAC (Digital Analog Converter). The duration of a Sample defined by a parameter of Frame names as the “Sample Rate”. We define the Sample Rate in “Samples per second”.

We need multiple waveforms to compose a visual picture. A typical laser Frame has X and Y coordinates, and Color. The Color might be encoded in one or more channels, from 1 to 6, the same as a laser projector may be equipped with one or more lasers. For picture display, the controller operates with multiple waveforms at once, with one for X,Y, and each color channel. It is also similar to audio. There is mono, stereo, 5.1 and so on. Samples of the channels are grouped into a Point. A Point has X,Z and Color. It is the minimum required for drawing a picture.

In the software, a Point has more parameters than required for the Output. BEYOND and QuickShow software operate with X,Y,Z coordinates, 24bit RGB Color, and options that define how to use this Point. Points in the software are of a more complex construction than an Output Point that is just a group of Samples. Such a difference developed over a long period of time because of various reasons. Let`s skip history, but deal with how exactly the history has created some mix in the terms used within the laser show industry.

A Frame Point has several options. For example – a repeat counter. A simple parameter that defines how many times to repeat the Point during the Output. This simple thing can explain the difference between a Software Point and a Sample (Output Point). The Output is a continuous waveform without any options, it is just an array of numbers that represent a waveform. A Software Point may be as simple as an Output Point, but may also have options. In the general case – it is not the same and it is 1st source of confusion.

## Sample Rate

The Sample Rate defines how many Samples per second are performed by the controller. The same rate also defines the limit of the energy/brightness of one Sample. For example, we have a 1-watt laser and a 30`000 Sample per second speed. It means, each Sample will represent up to  $1 / 30`000$  watt. No more. If the Sample rate is lower, then the laser power per Sample is higher, and overall the Output looks brighter. A faster Sample rate is better for graphics because it decreases flickering, but it also decreases the brightness per Sample, per pass. The same happens with complex Frames with many Points. The

total tracing path is longer and so the laser power has to cover a bigger(longer) space, which in turn decreases the brightness of each Sample.

## Projectors and Sample Rate

A Projector is tuned for an exact Sample Rate. It is in the amp tuning. If the Sample Rate is lower, then the projector will be faster and you might see some dots in every Point location. You can see it easily - set the Sample Rate to 10K or less. If we have two Points A and B, then the Projector will be able to go to B sooner than it should be able to and wait for the next Point C. Waiting creates a visible dot because the beam does not move, and, if the Sample Rate is higher than the Projector can perform, then the beam will be unable to make its way from Point A to Point B in time. When Point C comes, the beam, will still be on the way from A to B, and it will have to make a turn to C from the middle of the way between A and B.

In fact, beam motion speed is limited by the acceleration, and that requires high current. High current creates a huge amount of heat and it will overheat/damage the scanners. You can consider it as a simple relationship between speed, time and distance. Speed is a constant and defined by the Projector. When the distance is too large or the time is too short - the trajectory of motion will be changed. So, a wrong Sample Rate on a properly designed Frame will inject some visual "details" into the picture. A large Point distance will also create effects - the beam will move as a curve instead of a straight line. This effect is used by the "point pooling" style of Frame design. It looks great, but you need to understand that it might be a problem for your scanners.

## Tears and Hot Dots

OK, now we know that scanner speed is limited and might be considered as a constant. It's time to discuss the very end of lines. Scanners have inertia and this injects some detail into motion. Lasers don't have a mechanical nature and have a much faster reaction to an input signal change. Scanners need some time to start their motion as well as to stop their motion. A waveform is made of Samples. This means, we need to add a few Samples into the same place and give time to allow the scanners to stop. By means of extra Points in the same place you can control the dynamics of motion. Multiple Points named "anchor" Points.

The most noticeable situation is the ending or beginning of a line. If the scanner does not have time to stop then the visible end of the line will be in the wrong place - either it will be placed early thus cutting the corner, or after the end of line, creating an outcrop. If we will give more time than required, then more laser energy will be accumulated at the end Point than on the line and we will see a bright Point. Such effects can be controlled by Anchor Points.

## Line Brightness Variation

Let's consider an example - a wide horizontal line that changes size. When the line has its full width,

then the laser power spreads by the whole line width. When the line width is decreased by 50%, and the laser power stays the same, the line will look brighter because the same power is used in 1/2 the width i.e. the power density of the line is increased. When the line width decreases down to 0, then all the power of the Projector will be concentrated in just one Point. This is a really dangerous situation.

A brightness variation might be good for beam shows. However, for a graphics show it might create visual problems. During Animation, a Frame may change size and but fail to keep the same brightness. So, smaller objects will look brighter than bigger objects. It is just an illustration of the logic: more points means more time; more time means more laser power and a greater power density.

## Points and Vectors explained in more detail

Let consider a line as an example: Imagine we want to draw a line in between two other Frames. To draw a line without visual distortion, the Frame should have the following:

- blank/invisible path to beginning of the line
- a few blank/black Points at the beginning to give the scanners time to fully stop
- a few visible Points to ensure that line start will be not smoothed by the scanners
- if the line is long and cannot be performed in one Sample, then we need multiple Samples/Points in the line.
- a few visible Points at the end of the line, not too many, but enough to stop the beam and
- a few black/blank Points at the end of the line for a full stop. It is important to keep the balance between visible and invisible Anchor Points. If we do not use a blank Anchor, there is a chance that the next motion will be quick and the motion to the next object will be visible for a short time, a so called "tear" after the end of the line.
- and possibly, a visible path to the next object in the Frame.

There are several styles in which to draw a Frame, but it doesn't change the nature of the problem. A scanner needs some time to accelerate, to move and to stop. A designer needs to prepare a Frame that works well.

A Vector is a type of Point with automatic Sample placement. Automatic placement means – automatically adding in Anchor Points and automatic placement of Samples on long lines, and automatic placement of Samples on corners or turns. The whole process of adding Samples to compose a line can be done by means of **two** Vector Points (or just Vectors) only.

## Vector and Point Frames

BEYOND and QuickShow dos not operate within the terms of Vector Oriented Frames or Point Oriented Frames. The Frame of BEYOND/QS can be any combination of Vectors and Points, in any order. It can be a source of confusion for LD2000 users. It is a Point option rather than Frame option.

From a technical point – a Vector is an option of a Point that enables extra processing such as Anchors, spacing, etc.

## Summary: Vectors, Points, Hardware Points (Samples)

There are 3 different things, and from time to time it creates confusion because for all 3 types, people use the same word – **Point**. You need to understand the difference. When we talk about a Projector at 30 KPPS then the talk is about Output Samples. On the other side – we have Vectors, it is a Point with extra processing. A Vector after processing may be encoded as one Sample or as big number of Samples, it all depends on the settings and exact geometry at the end of the calculation path. And finally a “Point” – might be considered as a Sample in a Frame. A Point has no extra processing except for a repeat counter, that is wrong from a theoretical standpoint, but good from a practical standpoint. Without a repeat counter, one Point becomes one Sample in the Output Stream. Points with repeats – become a number of equal Samples.

## Vector Settings

“Vector Settings” define how the software transforms Vector to Samples. Each Projector has its own Vector Settings. However, each Frame may define its own Vector Settings. It is optional - in this case the Frame is independent from the Projector Settings.

One of the consequences – if a Frame has a custom (own) Vector Setting then there is a chance that those settings will not work well on some Projectors. Hot dots, tear, and so on. The same problem may happen with Point data. A Point has no any extra processing and Anchors must present as well a separate Point or a Point with a repeat counter.

Software transforms Vectors to Samples at the end of the calculation pipe line. If you need to make it sooner, for example for applying Gradient Color Effects to a Frame, then use Effect > Filter or Image Settings. It applies Vector transformation at the place of Effect calculation.

## Time, FPS

Important detail. A Projector may have different Vector Settings, and the number of Samples depends on it. FPS is a ratio of the Sample number in the Frame and the default Sample Rate of the Projector. If the Vector Setting changes, then the Frame Duration and FPS will change too.

## Advanced Frame Editor

- Gradients and Colors at the line beginning
- Line Fading
- Curves
- The Number of points in line.

You can see such options in the Points tab of the Advanced Frame Editor.

Please keep in mind that a Point in the Advanced Frame Editor is another type of Object and has more options than a “standard” Vector or Point. One curve or one Vector will use multiple Samples even if it uses two high level “Points”.

## Projector Default Sample rate

Pretty often the default Sample rate is used to compensate for the scanner speed and projection size relationship. A bigger projection size means a bigger distance. The scanner will need to do a faster motion, and we know that a scanner has a limit of speed, or it will smooth the Frame more and more. The way to compensate for this problem is to give more time to the scanner by means of decreasing the Sample Rate. So, a bigger size means a bigger angle, and when the Projector comes to a limit, then you will have a choice - limit size, or slow down the Sample Rate.

Decreasing the Sample Rate means - the Frame play time is longer, and the total Animation time will also increase. This is a reason why a refresh based Animation can change the overall time and go out of sync. Refresh based Animations will play correctly only at the exact designed Sample Rate.

As a rule, the default Sample rate influences FPS. If the number of Samples in the Frame is constant the FPS goes down.

$$\text{FPS} = \frac{\text{the default Projector Sample Rate}}{\text{the total number of Sample Frames}}$$

This is a simplified formula, but explains the importance of the Default Sample Rate.

## Refresh Based Animations

The Idea of Refresh Based Animations is based on a sequential Output of each Frame one by one, sequentially, without gaps, and without time control. It is the opposite to a Time Based Animation. In the case of a Time Based Animation each Frame has a known start time. It leads to some other requirements, but let's skip these. The playback progress of a Refresh Based Animation defined by the number of Samples/Points in a Frame and the Sample Rate. If an Animation uses a Projector Sample Rate then this parameter exactly defines the duration. The problem is synchronization. In this case, time is also a slave parameter.

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