

Megapixel Technology Overview

Camera Mode on HELIOS

March 2022

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What Is Camera Mode?

Camera Mode is a toolset for Megapixel VR's HELIOS® LED Processing Platform that gives users precise control over which portions of the video frame are captured by the camera by sub-dividing the frame into equal portions known as sub-frame slices. In addition to positioning the capture window, these features have full control of the color and gain of each frame division, allowing for the features below. Note that GhostFrame is a superset of features above and beyond Camera Mode with topics covered in a separate whitepaper:

- ▶ **Chromakey background** enables real-time post-production workflows without burdening playback systems or reducing pixel capacity.
- ▶ **Blackout sub-frame slices** allow users to improve both the in-camera and in-person images.
- ▶ **Gains control** for individual sub-frame slices allows for the in-person image to be adjusted independently from what the camera sees.

Core Concepts

High Refresh Rate

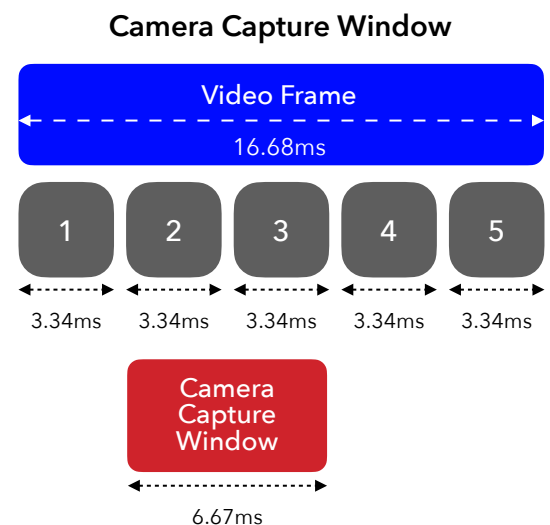
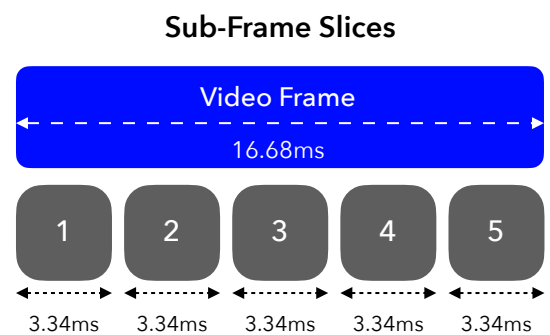
An LED tile's refresh rate may be dozens of times faster than required by the display media. Camera Mode uses these extra scan cycles to interleave image or color sub-divisions.

Sub-Frame Slices

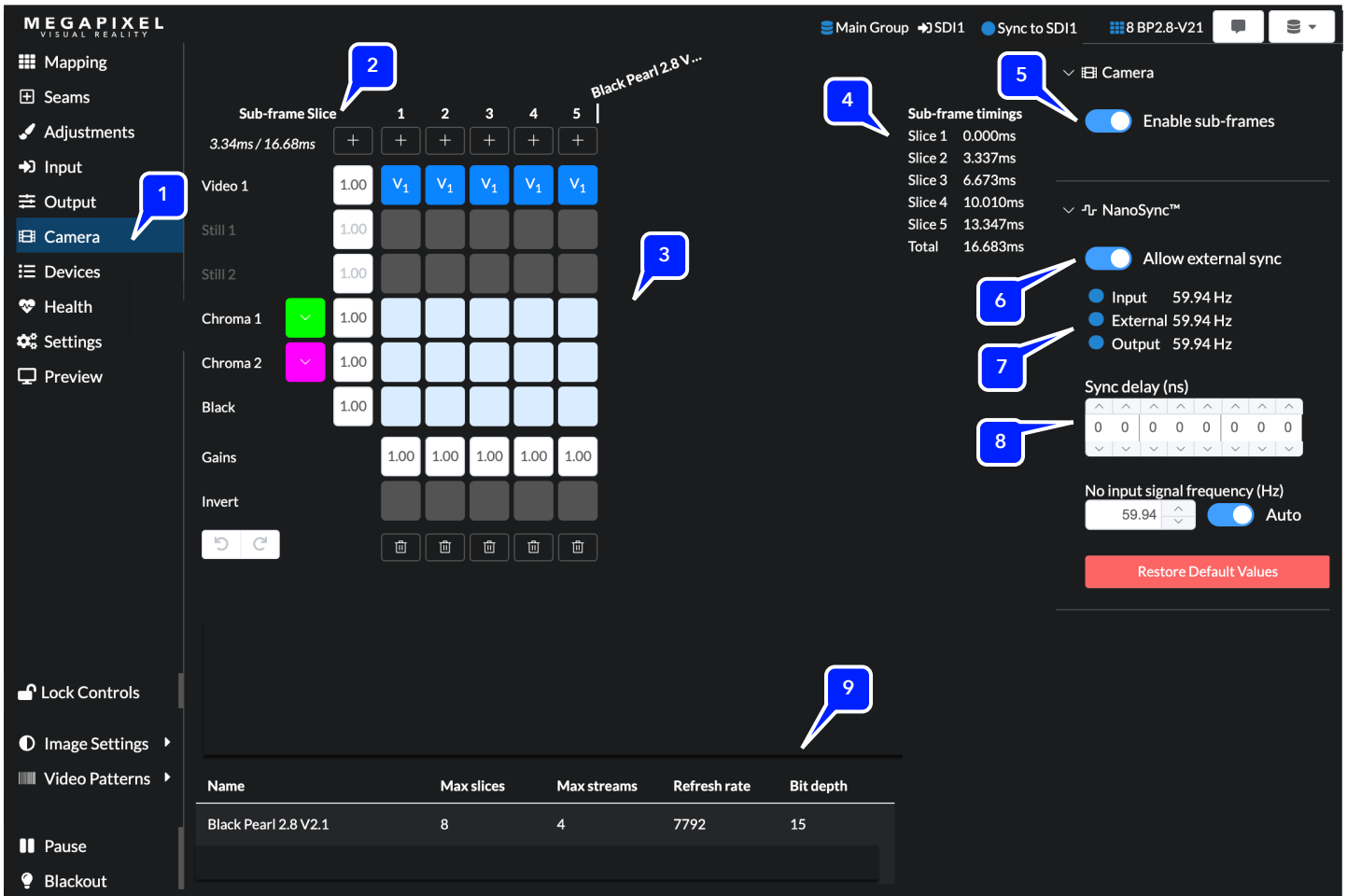
Sub-frame slices are equal-length subdivisions of the video frame. Based on the tile's refresh rate and the frame rate of the display media, HELIOS calculates the maximum number of available sub-frame slices and the time duration of each slice.

Camera Capture Window

A camera's capture window is the time required by a camera to capture a clean image, determined by the camera's sensor characteristics in conjunction with the frame rate and shutter angle.



Camera Mode Interface



- 1 Camera Page Selection
- 7 Sync Source Display
- 2 Sub-frame Slice Display
- 8 Sync Delay (ns) Dial
- 3 Sub-frame Slice Controls
- 9 Tile Data Pane
- 4 Sub-frame Timings Display
- 5 Enable Sub-Frames Toggle
- 6 Allow External Sync Toggle

1	Camera Mode Page Selection	Only visible when <i>Advanced Mode</i> is enabled in HELIOS.
2	Sub-frame Slice Display	Shows duration of each active sub-frame slice and overall frame time.
3	Sub-frame Slice Controls	<p>A. The + (plus sign) buttons add sub-frame slice templates. Templates do not become active sub-frame slices until assigned a video source or color. Active slices are numbered at the top with moving flags to indicate sub-frame slice capacity per tile.</p> <p>B. The trash can buttons delete sub-frame slices.</p> <p>C. The grid tiles assign content sub-frame slices. Select once to assign a positive image/color, a second time to invert the image/color, and a third time to unassign.</p> <ol style="list-style-type: none"> i. The <i>Video 1-4</i> buttons assign respective video feeds to sub-frame slices. ii. The <i>Still 1-2</i> buttons assign respective still-store images to sub-frame slices. iii. The <i>Chroma 1-2</i> buttons assign chroma key background color to sub-frame slices. The color button to the left opens a color picker with optional hex input. iv. The <i>Black</i> button assigns a black background color to sub-frame slices. <p>D. The <i>Gains</i> buttons display current intensity (0.00-2.00) and open a menu to adjust RGB and intensity gains. Horizontal buttons apply across a source, vertical buttons apply to single sub-frame slices. Sub-frame slices are impacted by both buttons.</p> <p>E. The <i>Invert</i> buttons invert an active sub-frame slice image. They have no function on sub-frame templates.</p>
4	Sub-Frame Timings Display	Shows number of active sub-frame slices and start time of each slice.
5	Enable Camera Mode Toggle	Enables sub-frame functions
6	Allow External Sync Toggle	<p>Selects which genlock signal is followed</p> <ul style="list-style-type: none"> ▸ <i>Input</i> for video source ▸ <i>External</i> for sync pulse generator
7	Sync Source Display	Displays the status and frequency of video source, sync pulse generator, and HELIOS output sync signals.
8	Sync Delay (ns) Dial	NanoSync adjustment allows offset from genlock signal.
9	Tile Data Pane	Displays each tile type's maximum number of sub-frames slices, maximum number of video streams, and color bit depth.

Camera Alignment

This process identifies the camera capture period, the number of sub-frame slices required for a clean image, and time-aligns the LED refresh within the video frame to best align with the capture period. This alignment process is required for every change in camera settings or media playback frame/rate frequency.

STEP 1: Configure the Sync Pulse Generator (SPG)

1. Camera, content source, and HELIOS must be connected to the same genlock source.
2. Set SPG to proper tri-level frame rate/frequency.
3. If applicable, reset any vertical phase offsets.

STEP 2: Configure the Camera

1. Set the sensor mode.
2. Set the frame rate/frequency and shutter angle.
3. Confirm the camera is locked to the SPG at the proper frame rate/frequency. If applicable, confirm the camera has no vertical phase offset.
4. Position the camera (and adjust zoom if appropriate) to ensure the full height of the LED wall is visible in frame. A confidence monitor is recommended to observe camera output.

STEP 3: Determine the camera sensor exposure time.

Table 3 provides the minimum exposure times based on common frame rates and shutter angles using the following formula:

$$\text{Exposure Time (ms)} = 1000 * 1 / ((\text{Frame Rate} * 360) / \text{Shutter Angle})$$

1. Record the exposure time for use in Step 5.

Common Exposure Times (in milliseconds)
Table 3

	8.6°	12.4°	22.5°	45°	72°	90°	144°	172.8°	180°	270°	360°
23.98 fps	0.996	1.436	2.606	5.213	8.340	10.425	16.681	20.017	20.851	31.276	41.701
24 fps	0.995	1.435	2.604	5.208	8.333	10.417	16.667	20.000	20.833	31.250	41.667
25 fps	0.956	1.378	2.500	5.000	8.000	10.000	16.000	19.200	20.000	30.000	40.000
29.97 fps	0.797	1.149	2.085	4.171	6.673	8.342	13.347	16.016	16.683	25.025	33.367
30 fps	0.796	1.148	2.083	4.167	6.667	8.333	13.333	16.000	16.667	25.000	33.333
48 fps	0.498	0.718	1.302	2.604	4.167	5.208	8.333	10.000	10.417	15.625	20.833
50 fps	0.478	0.689	1.250	2.500	4.000	5.000	8.000	9.600	10.000	15.000	20.000
59.94 fps	0.399	0.575	1.043	2.085	3.337	4.171	6.673	8.008	8.342	12.513	16.683
60 fps	0.398	0.574	1.042	2.083	3.333	4.167	6.667	8.000	8.333	12.500	16.667
120 fps	0.199	0.287	0.521	1.042	1.667	2.083	3.333	4.000	4.167	6.250	8.333

NOTE *A camera's capture window can never be smaller than the exposure time.*

These numbers are theoretical and do not account for an individual sensor's characteristics or a camera's other processing requirements.

STEP 4: Configure HELIOS

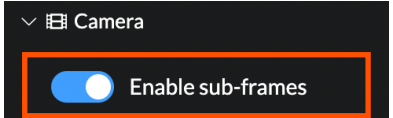
1. **Enable sub-frames**
2. Set **Allow external sync** to the active position.
3. Confirm HELIOS is locked to the SPG at the proper frame rate/frequency.
4. Confirm **Sync delay (ns)** is set to 00000000.
5. Create the maximum number of sub-frame slices for the tiles at the desired frame rate.
 - a. Press the Plus (+) button above each column to add new sub-frame slice templates.
 - b. Assign each slice a black background (a "K" will display in the slice selection) to activate it. Each column is assigned a number and a flag which will move to the right as slices are added, stopping when the tile's maximum slice capacity is reached (also displayed in HELIOS' tile data pane at the bottom of the screen.)


WARNING: Photosensitive viewers should exercise caution as the screen will pulse during configuration.

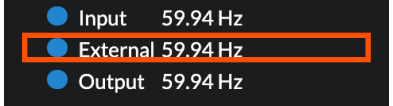
NOTE: Do not create more sub-frame slice templates than the tiles can display. This will produce inaccurate sub-frame slice times.

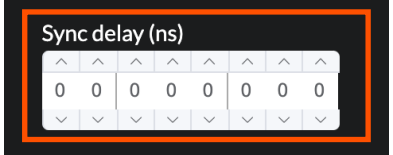
- c. Record the final sub-frame slice time to use in Step 5 and ensure all slices have content assigned or the time values will be incorrect.

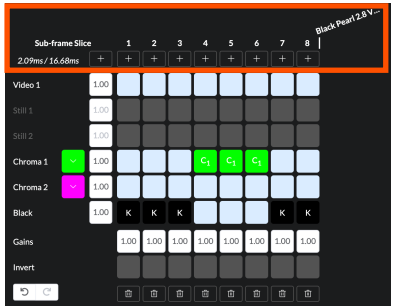
Configure HELIOS

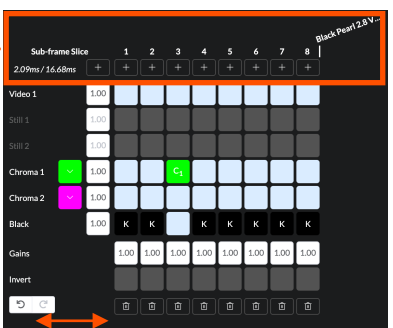
4.1. 

4.2. 

4.3. 

4.4. 

4.5.a. 

4.5.b. 

4.5.b.

Name	Max slices	Max streams	Refresh rate	Bit depth
Black Pearl 2.8 V2.1	8	4	7792	15

STEP 5: Determine the Camera Capture Window

⚠ WARNING: Running screens at low frame rates (eg 24 or 30) may cause flashing/strobing that can be uncomfortable or triggering for photosensitive or epileptic viewers.

NOTE: Identifying and aligning the camera capture window is similar to tuning an analog radio. The goal is to center on the strongest portion of the broadcast signal (the desired sub-frame slices) and eliminate interference from adjacent stations (the adjacent sub-frame slices). Using black and primary chromakey is the most efficient way to distinguish individual slices. Global and roller shutters are visually distinctive and react differently to genlock vertical phase offset changes.

1. Divide the duration of the camera exposure time from Step 3.1 by the sub-frame slice duration from Step 4.5.c to predict the minimum number of sub-frame slices required.
 - ▶ This number is most useful for global shutters.
 - ▶ Rolling shutter cameras will span multiples of the predicted value, often 2-3x.
2. Start with the first sub-frame slice, sequentially assign a chromakey to each slice, then return the slice to black. Watch the camera's output video feed (not the screen itself), and record the sub-frame slices where chroma appears to show the slices visible to the camera.

Camera Capture Window Example

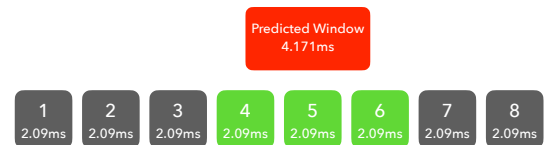
BP2V2 tile @ 60Hz = max. 8 sub-frame slices
Sub-frame slice time = 2.09ms

Global Shutter Camera with 90° shutter angle
@ 59.94 fps
Exposure time = 4.171ms

Minimum number of sub-frame slices = 2
(4.171 / 2.09 = 1.996)

Determine Camera Capture Window

Sequential color assignment to slices reveals initial window position observed in slices 4, 5 and 6. This is one more slice than predicted.

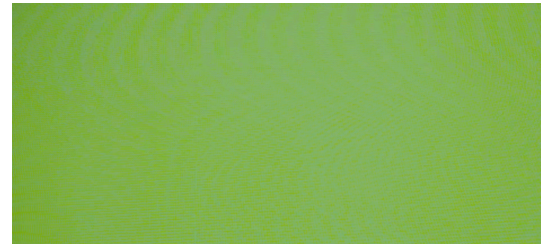


The screenshot shows a control interface for a camera. At the top, it says 'Sub-frame Slice 2.09ms / 16.68ms'. Below this is a grid with 8 columns (labeled 1-8) and several rows. The rows are: Video 1, Still 1, Still 2, Chroma 1, Chroma 2, Black, Gains, and Invert. The 'Chroma 1' row has green boxes labeled 'C1' in columns 4, 5, and 6. The 'Black' row has 'K' in columns 1, 2, 3, 7, and 8. The 'Gains' row has '1.00' in all columns. The 'Invert' row is empty. At the bottom right, there is a label 'Black Pearl 2.8V...'. The interface also includes a '+' sign in a box above the grid and a trash icon at the bottom.

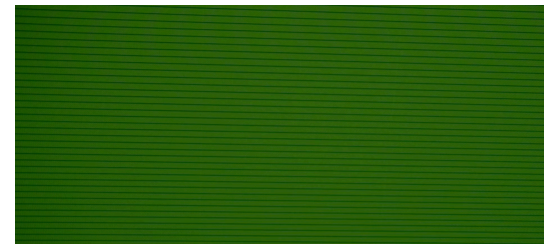
- ▶ Global Shutter - Camera-visible slices create scan lines that fill the entire screen area. The thickness and density of the scan lines increase with sub-frame slice alignment. A fully-aligned slice presents as a solid, unbroken background, while a partially-aligned slice presents as thinly spaced scan lines distributed over the screen area. If the adjacent slice is black, the lines will continue to become thinner and less dense, eventually disappearing as the phase offset is adjusted. If the adjacent slice is another color or image, the image will eventually crossfade as the offset is adjusted.
 - ▶ Rolling Shutter - Each camera-visible slice creates a solid horizontal color band that fills a portion of the screen area. Additional slices increase the thickness of the band. The band moves vertically as the phase offset is adjusted - decreasing the offset moves the bands upward on the screen (earlier in the video frame), whereas increasing the offset value moves them downward (later in the video frame).
3. Center the capture window in the fewest sub-frame slices by adjusting the vertical phase offset from the genlock signal using HELIOS' **NanoSync™**. Assign chromakey to the first clear slice before the first identified slice in the previous step. Adjust the vertical phase offset until the color lines/band first appear, then reverse direction until they disappear.

Global Shutter Color Scan Lines

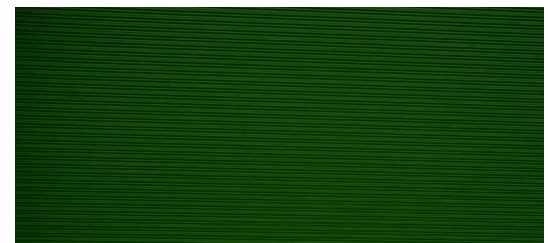
Example of fully aligned sub-frame slice



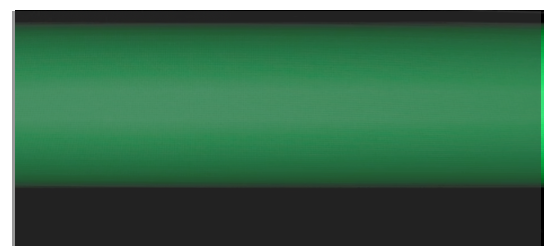
Example of partially aligned sub-frame slice



*Example of barely aligned sub-frame slice
(about to disappear)*



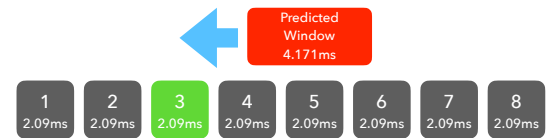
Rolling Shutter Color Scan Lines



- ▶ Use NanoSync™ to easily and accurately adjust vertical phase offset (in nanoseconds).
4. Referring to the results from Step 5b, set all sub-frame slices to black except for the one *preceding* the start of the observed capture window. If Slice 1 was the start, use the last slice.
 5. Identify the left boundary. Slowly increase the vertical phase offset value (either in seconds or lines of resolution) to move the capture window to the left (into lower-numbered slices) until color banding just begins to appear. Decrease the vertical phase offset (moving the window to right) until the frame is fully black again. Record this value (in seconds or lines of resolution).
 - ▶ Global shutter: chroma color scan lines will remain static in position but will increase or decrease in thickness and density.
 - ▶ Rolling shutter: chroma color bands will move up or down.
 6. Identify the right boundary. Cycle back through the sub-frame slices to identify the last sub-frame slice showing chroma color. Set the slice after this to chroma color. Decrease the vertical phase offset value until the color banding just begins to appear. Increase the vertical phase offset until the frame is fully black. Record this value (in seconds or lines of resolution).

Identify Left Boundary Setting

Set slice 3 to color and decrease the vertical phase offset value to move the capture window to the left in the video frame. Once color is just visible, shift back and record value.



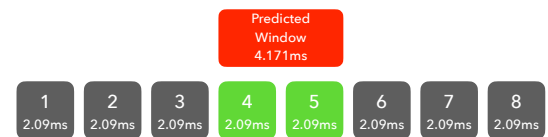
Sub-frame Slice: 1 2 3 4 5 6 7 8

2.09ms / 16.68ms

	+	+	+	+	+	+	+	+
Video 1	1.00							
Still 1	1.00							
Still 2	1.00							
Chroma 1	1.00		C ₁					
Chroma 2	1.00							
Black	1.00	K	K		K	K	K	K
Gains	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Invert								

Black Pearl 2.8 V...

Start at slice 4 to confirm the capture window within slices 4 and 5.



Sub-frame Slice: 1 2 3 4 5 6 7 8

2.09ms / 16.68ms

	+	+	+	+	+	+	+	+
Video 1	1.00							
Still 1	1.00							
Still 2	1.00							
Chroma 1	1.00			C ₁	C ₁			
Chroma 2	1.00							
Black	1.00	K	K	K		K	K	K
Gains	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Invert								

Black Pearl 2.8 V...

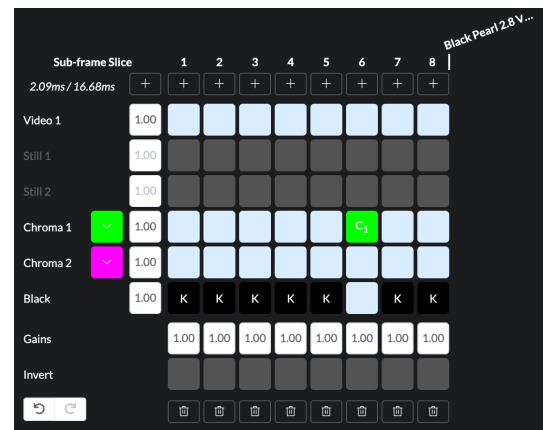
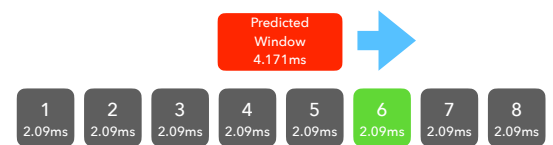
7. Center the capture window. Split the difference between the values and set the offset to that value, centering the capture window in the sub-frame slices. This confirms the number of sub-frame slices required. Centering the window helps to prevent image bleed from adjacent sub-frame slices.

STEP 6: Position Camera Capture Window in Video Frame

1. Align the camera capture window with the desired sub-frame slice(s) using the same methods in Step 5.
 - a. Set all sub-frame slices to black.
 - b. Choose the sub-frame slice where the capture window should begin.
 - c. Set the preceding slice (or final slice if aligning to Slice 1) to a chromakey. Increase the vertical phase offset to identify the left boundary and record the value.
 - d. Set the first sub-frame slice after the Camera Capture Window (known from 6.a.) to a chromakey. Decrease the vertical phase offset to identify the right boundary and record the value.
 - e. Split the difference between the values to center the Capture Window in the sub-frame slices.
2. All of the above may be accomplished using HELIOS' NanoSync™. Once the camera is aligned, you are ready to shoot.

Identify Right Boundary Setting

Set slice 6 to color and increase the vertical phase offset value to move the capture window to the right in the video frame. Once color is just visible, shift back and record value.



Notes and Strategies

Saved Configurations

HELIOS' Saved Configurations feature (via Settings) allows for the storage and recall of unique Camera Mode settings.

To record each Saved Configuration:

1. Navigate to the **Settings** page.
2. Select the **Saved Configurations** tab.
3. Select the **New button**.
4. In the pop-up window, name the configuration, select the desired settings, then select **Create Configuration**.

Recall Saved Configurations via the HELIOS interface or an external interface that supports the HTTP REST web service or the HTTP WebSocket JSON-RPC protocols. Email support@megapixelvr.com to request the HELIOS Public API documentation.

Examples include:

- ▶ Stream Deck with Bitfocus Companion Generic HTTP Request instance (Mac or PC)
- ▶ Stream Deck using the API Ninja plug-in (PC only)
- ▶ iPhone or iPad using the Actions app
- ▶ REST protocol:
HTTP POST: <http://xxx.xxx.xxx.xxx/api/v1/presets/apply>
Body: { "presetName": "saved configuration name" }
(xxx.xxx.xxx.xxx = IP address of the HELIOS)

Stream Deck

With Bitfocus Companion Generic HTTP POST



Flicker, Frequency, and Visual Balance

When using Camera Mode, unbalanced video frames exhibit noticeable in-person flicker at slower frequencies such as 24Hz and 30Hz, while none are observed at 60Hz. Simple balancing strategies to improve the in-person experience are explained below. It is crucial to balance both the temporal display and intensity of sub-frame slices.

As seen, these mitigations have a significant cost in terms of sub-frame slice capacity. While a tile operating at 30Hz usually has twice as many available slices as one at 60Hz, any advantage is negated by the visual balancing requirements.

Repetition is also significant when planning to capture multiple images in the same camera operating at a frame rate multiple. It may become mathematically impossible for the camera to capture different images.

60Hz (1:1)

Requires no visual balance

Sub-frame Slice	1	2	3	4
4.17ms / 16.68ms	+	+	+	+
Video 1	1.00	V ₁		
Video 2	1.00		V ₂	
Video 3	1.00			V ₃
Video 4	1.00			V ₄

30Hz (2:1)

Eliminates in-person flicker by repeating an identical sequence of sub-frame slices.

Sub-frame Slice	1	2	3	4	5	6	7	8
2.09ms / 16.68ms	+	+	+	+	+	+	+	+
Video 1	1.00	V ₁			V ₁			
Video 2	1.00		V ₂			V ₂		
Video 3	1.00			V ₃			V ₃	
Video 4	1.00				V ₄			V ₄

30Hz

Exhibits significant flicker, as the frame does not repeat the same sequence.

Sub-frame Slice	1	2	3	4	5	6	7	8
2.09ms / 16.68ms	+	+	+	+	+	+	+	+
Video 1	1.00	V ₁	V ₁					
Video 2	1.00			V ₂	V ₂			
Video 3	1.00					V ₃	V ₃	
Video 4	1.00							V ₄ V ₄

24Hz

A reduction from 30Hz to 24Hz requires extra sub-frame slices to mitigate the flickering effect.

Sub-frame Slice	1	2	3	4	5	6	7	8	9	10	11	12
1.39ms / 16.68ms	+	+	+	+	+	+	+	+	+	+	+	+
Video 1	1.00	V ₁			V ₁				V ₁			
Video 2	1.00		V ₂			V ₂				V ₂		
Video 3	1.00			V ₃			V ₃				V ₃	
Video 4	1.00				V ₄			V ₄				V ₄

Camera Notes

- ▶ A rolling shutter camera may have a wider capture window than is visible using the alignment methods detailed earlier. The camera sensor has reset and readout times that extend beyond the visible window. Image changes in these areas may result in a degraded image. Bookending the visible window with additional blackout frames may be necessary. Image comparisons should be performed during camera testing to verify.
- ▶ Custom shutter angles may be selected on advanced cinema cameras with granularity down to 1/10 of a degree. Precise adjustment of the capture window duration is possible by making fractional adjustments to the shutter angle rather than jumping to the next common preset.
- ▶ A single camera may capture multiple images if set to a higher multiple frame rate/frequency. Multiple sub-frame slices within the video are captured, requiring the signal to be de-interleaved with either software or hardware. If you are visually balancing frames, this may not be possible.
- ▶ Improper camera alignment will result in scan lines.

General Strategies

- ▶ An acceptable in-person (but not in-camera) image may be created with fewer sub-frame slices than the in-camera image. The intensity and color balance for the non-camera image can be independently adjusted using the sub-frame slice gains controls.
- ▶ It is easier to hide/disregard chroma sub-frame slices at lower intensities. Remember that the camera's exposure is calibrated to specific sub-frame slices, not the overall in-person image.
- ▶ Improve in-person image contrast by adding black sub-frame slices.
- ▶ Reducing the number of sub-frame slices increases the duration of each slice, which may allow a camera's capture window to fit in fewer slices.

Slice Gain Controls



About Megapixel VR

Megapixel is an innovative technology partner dedicated to delivering fast-tracked, customized, state-of-the-art LED displays and processing to the world's leading entertainment, film & TV, and architectural applications.

Our unrivaled team of engineers and designers consistently delivers the most unique and breakthrough LED solutions to market, helping our visionary clients bring their ideas to life in ways that inspire a sense of wonder and make the seemingly impossible possible. With over 200 patents and award wins from Live Design, the Emmys, and the Oscars, we endeavor to always be at the forefront of digital displays and technology for which we set the bar as the industry standard.

We provide superior product design development, manufacturing expertise, and successful deployment to deliver unsurpassed visual performance for any project and look forward making the world's next iconic projects a reality.

Visit www.megapixelvr.com for more information on HELIOS.

Megapixel Visual Reality
28316 Constellation Rd
Valencia, CA 91355



Jeremy Hochman
CEO & Innovator
20 years experience
LED Video Design & Manufacturing

Previous

- ▶ Executive Director R&D, VER
- ▶ Director of Product Management, Barco
- ▶ Founder, Element Labs (*acquired by Barco*)

Major Product Accomplishments

- ▶ All VER / Revolution Display LED systems
- ▶ Barco C-Series
- ▶ Element Labs COBRA tile
- ▶ World's first creative mapping software (RasterMAPPER)



Keith Harrison
COO
30+ years experience
LED Video Operations

Previous

- ▶ Executive Director LED, VER
- ▶ Managing Director, PSL Los Angeles
- ▶ Managing Director, Gearhouse Los Angeles

Major Project Accomplishments

- ▶ MGM Macau – Spectacular, Theater, Exterior
- ▶ Radio City Music Hall, NYC
- ▶ Coldplay "A Head Full of Dreams" Tour

Camera Alignment Worksheet

1. Configure the sync pulse generator
 - Set the proper frame rate/frequency for all devices
 - Reset any vertical phase offsets.

2. Configure the camera.
 - Set the sensor mode
 - Set the frame rate/frequency and shutter angle
 - Confirm the camera is locked to the sync pulse generator at the proper frame rate/frequency
 - Position the camera to ensure the full height of the LED wall is visible in frame.

3. Refer to Table 3 (page 15) to determine & record camera sensor exposure time: _____ (in milliseconds)

4. Configure HELIOS
 - Enable *sub-frames*.
 - Set *Allow external sync* to the active position.
 - Confirm HELIOS is locked to the sync pulse generator at the proper frame rate/frequency.
 - Confirm *Sync delay (ns)* is set to 00000000.
 - Create sub-frame slices by pressing the Plus (+) button above each column
 - Assign each template a black background
 - Record final sub-frame slice time for use in Step 5 _____
 - Ensure all slices have content assigned

5. Determine the Camera Capture Window
 - Estimate minimum number of sub-frame slices: _____ ÷ _____ = _____

Camera Sensor Exposure Time (from Step 3)
Sub-frame slice duration (from Step 4)
Min # of sub-frame slices required.
 - Sequentially assign a chromakey to each slice and return slice to black.
 - Record the sub-frame slices where chroma appears in camera's output video feed.

Slices: _____

- Adjust the vertical phase offset from the genlock signal to center the capture window.
- Assign a chromakey to the first clear slice before the first identified slice in the previous step.
- Adjust vertical phase offset until color lines/band first appear, then reverse direction until they disappear.
- Set all sub-frame slices to black except the *preceding* slice from the observed capture window, or final slice if aligning to Slice 1.
- Identify & record the left boundary: _____ (nanoseconds or lines of resolution)
- Identify & record the right boundary: _____ (nanoseconds or lines of resolution)
- Center the Capture Window: _____ — _____ = _____
Left Boundary Right Boundary Offset Value

6. Position the Camera Capture Window in the Video Frame

- Set all sub-frame slices to black.
- Choose the sub-frame slice where the capture window should begin.
- Set the preceding slice (or final slice if aligning to Slice 1) to a chromakey.
- Increase the vertical phase offset to identify the left boundary and record the value.
- Set the first sub-frame slice after the Camera Capture Window to a chromakey.
- Decrease the vertical phase offset to identify the right boundary and record the value.
- Split the difference between the values to center the Capture Window in the sub-frame slices.

$$\frac{\text{HELIOS phases line value}}{\text{\# of lines in video frame}} = \text{Inverse Value}$$

- Make the vertical phase offset adjustments via the SPG's output for HELIOS
- Record phase line number _____
- Transfer the vertical phase offset value to the camera.
 - Reset the SPG's HELIOS output vertical phase to line 1.
 - Set camera to the inverse value of HELIOS (in the opposite direction in the video frame)

$$\frac{\text{Left Boundary}}{\text{Right Boundary}} = \text{Offset Value}$$

- Set the HELIOS's NanoSync setting to this value.