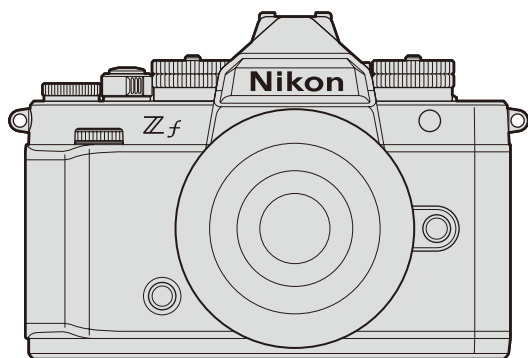


Nikon



Z f Professional Technical Guide —Pixel Shift Edition—

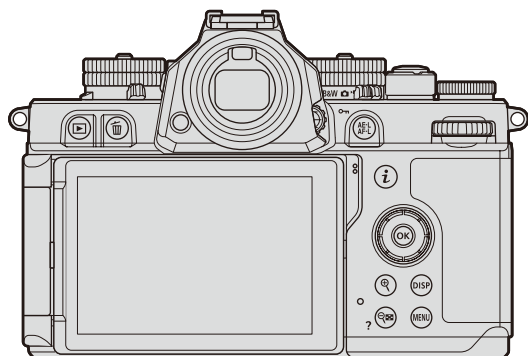


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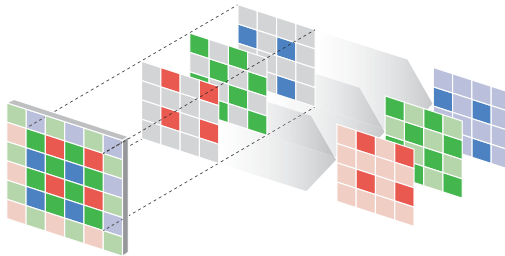
Pixel Shift

What Is “Pixel Shift”?

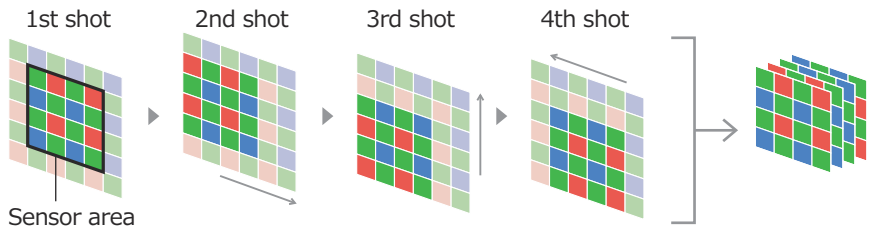
Pixel shift allows you to take multiple pictures while shifting the camera's image sensor by a single pixel or less and to merge them to generate a higher-resolution image than that which can be obtained through normal single-frame shooting.

How Pixel Shift Works

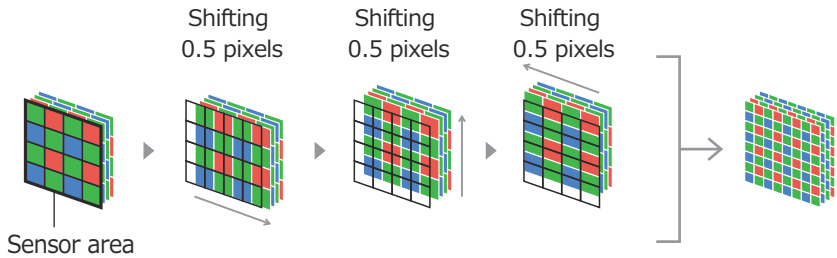
The Bayer image sensor installed in general cameras including Nikon cameras can only capture one type of color information (R, G, or B) per pixel. When displaying in RGB, the remaining colors must be interpolated from the surrounding pixels. In the following example, color information is captured in the ratio of R:1, G:2, and B:1, and each RGB channel captures the color information of the remaining pixels through the interpolation process.



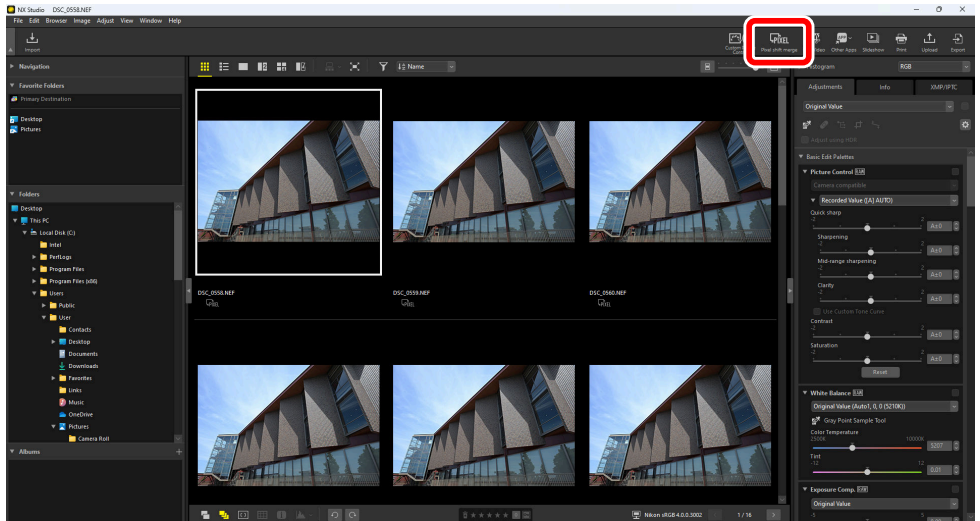
In pixel shift shooting, taking multiple pictures while shifting the image sensor by one pixel unit allows G or B to be captured at the pixel location where R was captured. Since RGB can be overlapped without interpolation, *moiré*, and color fringing caused by the interpolation process can be reduced, improving color reproducibility in the details.



The image sensor can also be shifted by units smaller than a single pixel. Since the camera captures more detailed information, higher-resolution images than those captured by shifting one pixel unit can be generated. Nikon cameras can shift the image sensor by 0.5 pixels.



Pictures taken with the pixel shift shooting function can be merged into a single, high-resolution image with Nikon's NX Studio software. Noise can also be averaged and reduced by merging multiple images.



 **Images and Illustrations**

The images and illustrations in this document are for expository purposes only.

The Pixel Shift Workflow

Pictures taken using pixel shift cannot be merged within the camera. NX Studio allows you to generate high-resolution images by merging pictures taken with pixel shift.



Step 1: Shoot with a camera that supports pixel shift

Take pictures using pixel shift to generate images for merging ([book 20](#)).

Step 2: Merge pictures taken using pixel shift with NX Studio

Merge pictures taken by the camera using pixel shift with NX Studio. Use NX Studio to view and edit pictures and videos shot with Nikon digital cameras ([book 24](#)). Use the latest version of the software to merge pictures taken using pixel shift. NX Studio can be downloaded from the Nikon Download Center (<https://downloadcenter.nikonimglib.com/>).

Step 3: Adjust merged pixel shift images with NX Studio or third-party software

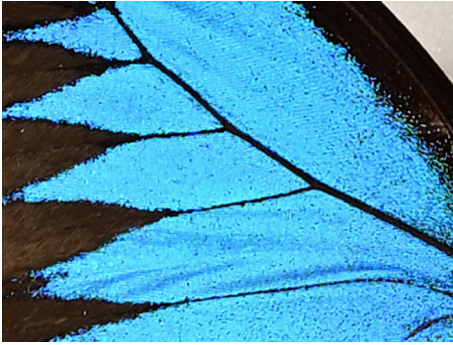
Adjust merged pixel shift images with NX Studio or third-party image processing software. The brightness, contrast and other factors of merged pixel shift images can be adjusted with NX Studio ([book 31](#)).

The Benefits of Pixel Shift

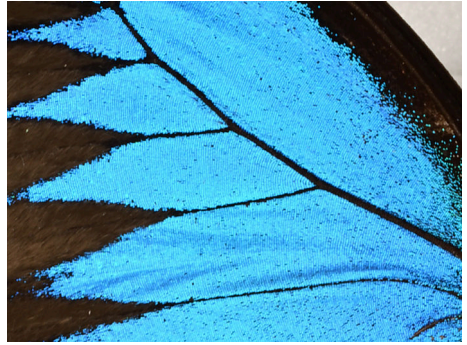
Here are the benefits of pixel shift.

Reducing *Moiré* and Color Fringing

Pixel shift can reduce *moiré* and color fringing because it does not interpolate between pixels.



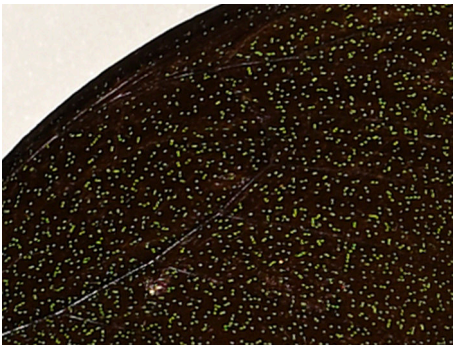
Single frame image



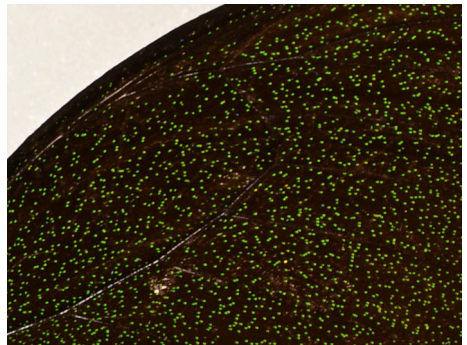
Merged pixel shift image

Improving Color Reproduction of Details

Pixel shift does not interpolate between pixels regardless of whether it merges 4, 8, 16, or 32 pictures, so color reproduction of details can be improved when compared to single frame shooting.



Single frame image



Merged pixel shift image

Improving Resolution

By using pixel shift, more detailed information can be captured, resulting in high-resolution and high-definition images.



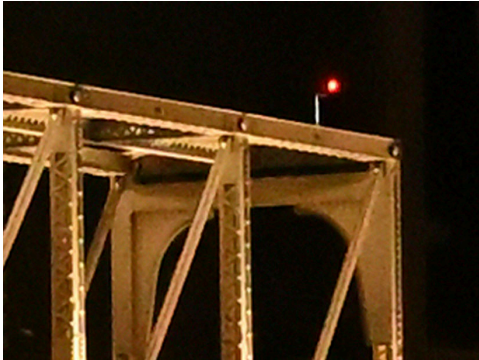
Single frame image



Merged pixel shift image

Reducing Noise

Noise can be noticeably reduced by merging 8 or 32 pictures with NX Studio.



Single frame image



Merged pixel shift image

Scenes Where Pixel Shift Is Effective

Here are some examples where pixel shift is effective and how to take advantage of it.

When You Want Images with a Larger Size or Higher Definition

Pixel shift is effective when you want images with a larger size or higher definition. The resulting image has four times the number of pixels of the original and it can be generated in a larger size. When 16 or 32 pictures taken using pixel shift are merged into a single image, the resulting height and width are double those of the original pictures. For example, images taken at 6048×4032 pixels can be merged to generate an image of $12,096 \times 8064$ pixels.



© Taylor Gray



Single frame image



Merged pixel shift image with quadruple the number of pixels

When You Want High Quality Images with the Same Size as Single Frame Shooting

Pixel shift is effective even when a large image is not needed. "Oversampling," in which higher-resolution data is taken and then resized to a smaller size, can generate a high-definition and high-quality image at a high resolution while having the same image size as single frame shooting. The file size of the generated image is not significantly different from that of an image of the same image size without oversampling and is recommended from an archive perspective.

- If 32 pictures are merged to make a generated image and oversampled to be the same image size with the merged image of 4 or 8 pictures, the resulting image will produce a higher image quality than those counterparts.



© Taylor Gray



Single frame image



Merged pixel shift image from 8 shots



Merged pixel shift image from 32 shots, resized to a single frame image size

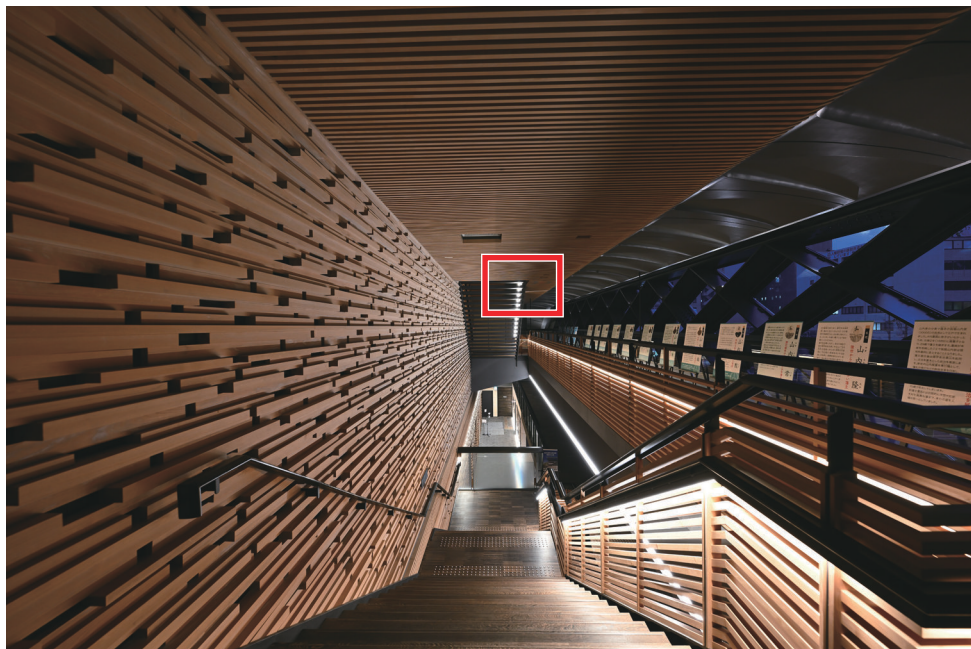


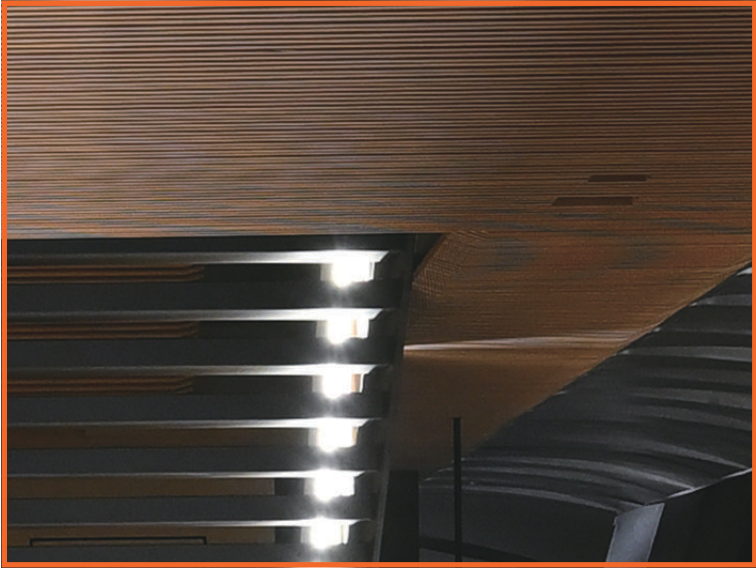
Merged pixel shift image from 32 shots

When You Shoot Subjects that Cause *Moiré*

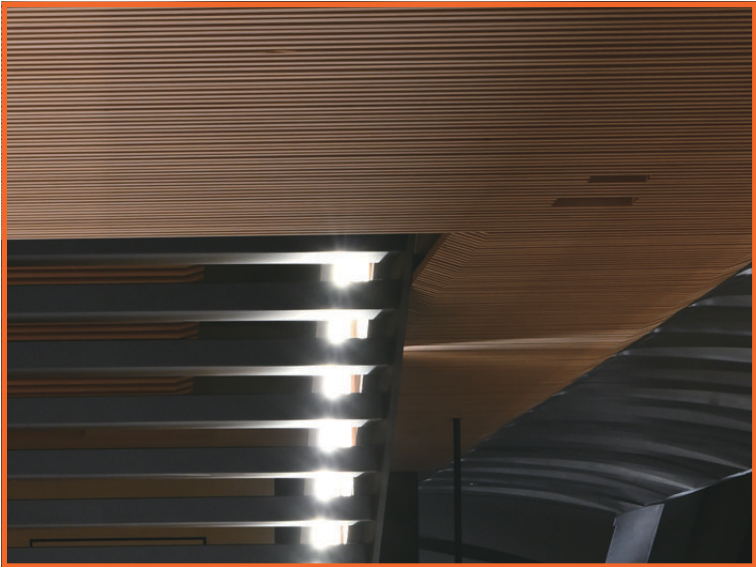
Moiré occurs due to the relationship between the fineness (frequency) of a subject's structure, its colors, and the performance of the camera. It is difficult to eliminate *moiré* from pictures after shooting, so it is important to prevent it during shooting. Pixel shift is effective when shooting subjects with repeated fine structures, such as textiles, building roofs, or tile walls.

- Regardless of the [Number of shots] setting (4, 8, 16, or 32 pictures), *moiré* may be less noticeable compared to single frame shooting.





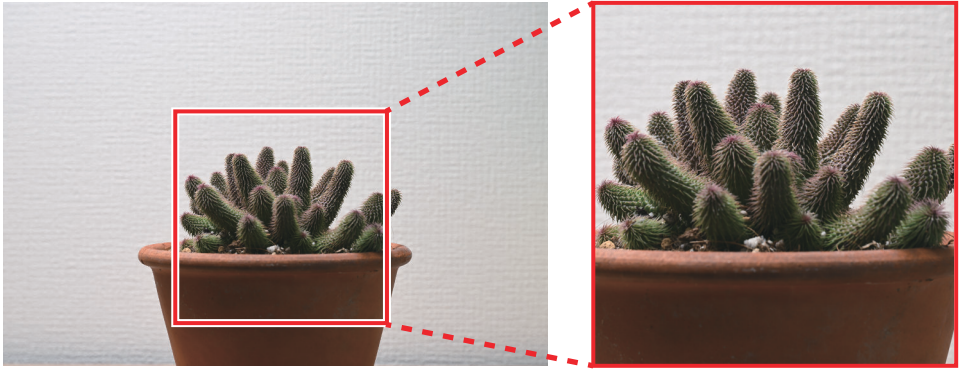
Single frame image



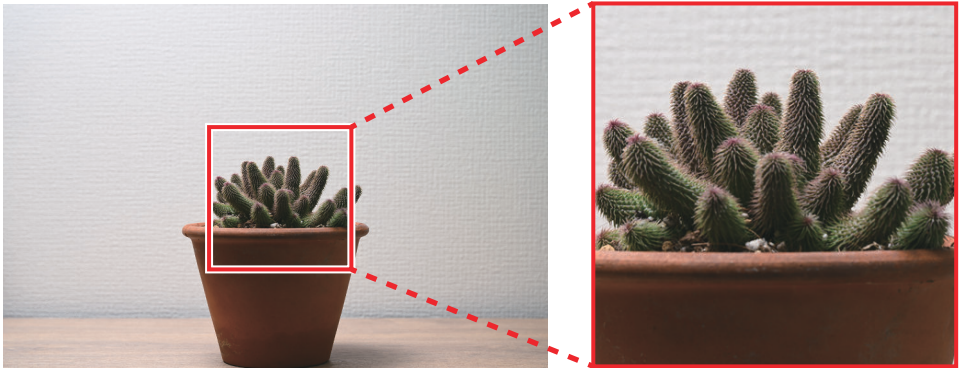
Merged pixel shift image

When You Need a Deeper Depth of Field or a Wider Angle of View

Pixel shift is effective when you want to increase the area in focus or to include a wider area in the picture. It can generate images with approximately four times the resolution of a single frame shot. Therefore, it is possible to shoot away from the subject while maintaining the equivalent resolution of a single frame shot. A longer distance from the subject may lead to lower magnification and a change in perspective, but can also provide a deeper depth of field and a wider angle of view.



Single frame, 70mm, f/8, 1/2 s









Merged pixel shift image shot at a focal length of 70 mm, aperture of f/5.6, and shutter speed of $\frac{1}{4}$ s

As shown above, pixel shift provides a better image quality and a deeper depth of field than a single frame shot, even with a wider angle of view, a larger aperture value, and faster shutter speed achieved. This allows you to take pictures with extra space and with a wider aperture than usual. It also reduces the time and effort required for post-processing depth composition.

Tip: The Number of Pictures Taken during Pixel Shift Shooting

In pixel shift shooting, you can select the number of pictures taken from 4, 8, 16, or 32. This provides several advantages during a pixel shift merge, depending on the number of pictures taken. More advantages can be gained as more pictures are taken.

Number of shots	Advantages	
4	<p data-bbox="244 376 992 432">Reducing <i>moiré</i> and color fringing, improving color reproduction of details and resolution.</p> <div data-bbox="244 464 1031 756"></div> <p data-bbox="348 764 530 788">Single frame image</p> <p data-bbox="656 764 1020 788">Merged pixel shift image from 4 shots</p>	
8	<p data-bbox="244 826 1014 882">Reducing <i>moiré</i>, color fringing, and noise, improving color reproduction of details and resolution.</p> <div data-bbox="244 914 1031 1206"></div> <p data-bbox="258 1214 620 1238">Merged pixel shift image from 4 shots</p> <p data-bbox="656 1214 1020 1238">Merged pixel shift image from 8 shots</p>	

Number of shots	Advantages	
16	<p data-bbox="244 188 992 245">Reducing <i>moiré</i> and color fringing, improving color reproduction of details and resolution, doubling the image size.</p>  <p data-bbox="255 576 622 600">Merged pixel shift image from 4 shots</p>	 <p data-bbox="656 576 1023 600">Merged pixel shift image from 16 shots</p>
32 pictures	<p data-bbox="244 635 1014 692">Reducing <i>moiré</i>, color fringing, and noise, improving color reproduction of details and resolution, doubling the image size.</p>  <p data-bbox="255 1023 622 1046">Merged pixel shift image from 16 shots</p>	 <p data-bbox="656 1023 1023 1046">Merged pixel shift image from 32 shots</p>

The number of images generated, as merged pixel shift images can be selected if more than 4 shots are taken. For example, when shooting 32 shots, 32 shots be merged into 1 image, and multiple merged images can be generated (such as 2 images each from 16 shots, 4 images from 8, and 8 images from 4). Even if a merged image is disrupted due to blurring of the subject in some shots, the desired merge result may be generated by changing the number of images to be generated ([📖 28](#)). It is recommended to always take 32 shots unless there is a particular reason, such as shortening the shooting time or saving storage device capacity.

Notes on Pixel Shift

Pixel shift is a technique that takes multiple pictures of the same subject while gradually changing in-camera settings and merges them into an image. Therefore, if some changes occur with the subject during pixel shift shooting, the pictures cannot be successfully merged. It is recommended to use pixel shift only when shooting a completely static subject with the camera fixed on a tripod or similar device.

Conditions Unsuitable for Pixel Shift Merge

The desired merge results may not be generated if any of the following conditions occur during pixel shift shooting:

- **When the subject moves:** Moving subjects (people, animals, etc.) are not suitable for pixel shift merge.
 - Even if shooting a completely static subject such as a building, if there is something moving within the angle of view, the merge of that area may not work.
 - The desired merge result may not be generated if the subject looks like it is moving due to atmospheric fluctuations (heat haze, mirages, etc.) when shooting landscapes.
- **When the camera moves:** Be sure to fix the camera on a tripod or similar device. Even when the camera is fixed on a tripod, it may be shaken by wind or vibrations caused by people or cars passing by.
- **When the brightness of the subject changes:** Changes in the brightness of the subject due to changes in weather conditions, sunrise and sunset, flickering lighting, etc. will affect the merge result.

Shooting Time

It is difficult to control external factors such as light, atmosphere, and ground during shooting. The longer the shooting time, the more susceptible the camera is to external factors, so it is recommended to set the camera to complete shooting in as short a time as possible.

Tip: Raise the ISO Sensitivity to Shorten the Shooting Time

Even if the ISO sensitivity is set to a low value, a high-resolution image may not be available due to external factors depending on the shooting time. In these cases, it is recommended to raise the ISO sensitivity and shorten the shooting time. For example, when shooting with 32 pictures, better results are expected by shooting at ISO 500 and a shutter speed of 4 seconds than at ISO 64 and a shutter speed of 30 seconds.

Pixel Shift Shooting

Before Pixel Shift Shooting

Note the following before starting pixel shift shooting.

Choose a Static Subject

As mentioned in "Notes on Pixel Shift" ([book 19](#)), choose a static object as the subject. Examples of subjects suitable for pixel shift merge include:

- Buildings
- Objects
- Specimens and taxidermy mounts
- Landscapes

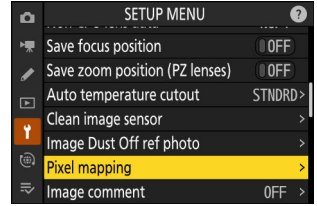
Fix the Camera

Be sure to fix the camera on a tripod or with a camera arm so that it will not move during pixel shift shooting. Choose a location where the tripod is not subject to vibrations from the ground or wind.



Perform Pixel Mapping

If unexpected bright spots appear in a shot taken during pixel shift shooting, performing a pixel shift merge may cause them to be more noticeable. We recommend using **[Pixel mapping]** in the setup menu before shooting.



Set Functions That Can Be Used with Pixel Shift Shooting

The following camera features can be used in combination with pixel shift shooting. Configure the settings before shooting begins.

Tone Mode [HLG]

You can select **[HLG]** for **[Tone mode]** in the photo shooting menu to take NEF (RAW) pictures that can be saved as HEIF copies with a wide dynamic range.

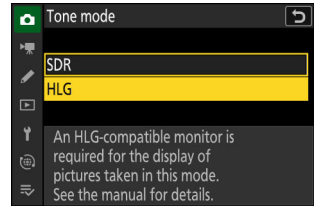
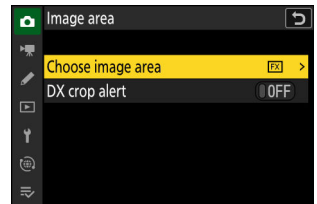


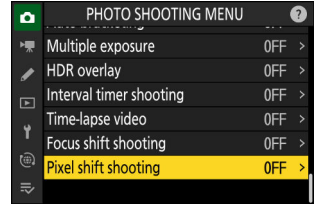
Image Area

Image areas can be selected using **[Image area]** in the photo shooting menu. Image areas other than **[FX (36 x 24)]** can also be set for pixel shift shooting.



Pixel Shift Shooting Settings

Set the camera for pixel shift shooting in **[Pixel shift shooting]** in the photo shooting menu.

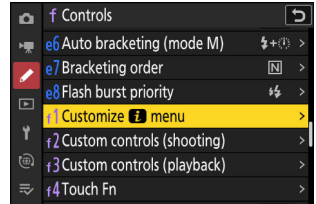


Option	Description
[Pixel shift shooting mode]	<ul style="list-style-type: none">• [On (series)]: Take multiple series of pixel shift pictures. To end pixel shift photography, select [Pixel shift shooting mode] again and choose [Off].• [On (single photo)]: End pixel shift photography after recording a single series.• [Off]: End pixel shift photography.
[Number of shots]	<p>Choose the number of shots taken each time the shutter-release button is pressed.</p> <ul style="list-style-type: none">• Long series require more time to record but produce better-quality results when merged into a single image.• Unless there is a particular reason, 32 shots is recommended.
[Delay]	<p>Choose the delay between the shutter-release button being pressed all the way down and the start of pixel shift photography.</p>
[Interval until next shot]	<p>Choose the interval between shots, in seconds.</p>

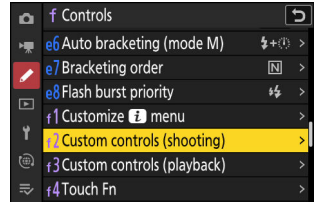
Tip: Functions and Settings Useful for Creating Shortcuts for Pixel Shift Shooting

Here are recommended functions and settings useful for creating shortcuts for pixel shift shooting.

- **Assigning [Pixel shift shooting] to the **i** menu:** Assign [**Pixel shift shooting**] using Custom Setting f1 [**Customize **i** menu**] to promptly move to the [**Pixel shift shooting**] settings display.



- **Assigning [Pixel shift shooting] to a custom control:** [**Pixel shift shooting**] can be assigned to a control using Custom Setting f2 [**Custom controls (shooting)**].
 - Rotate the main command dial while pressing the assigned control to change the [**Pixel shift shooting mode**] setting.
 - Rotate the sub-command dial while pressing the assigned control to change the [**Number of shots**] setting.



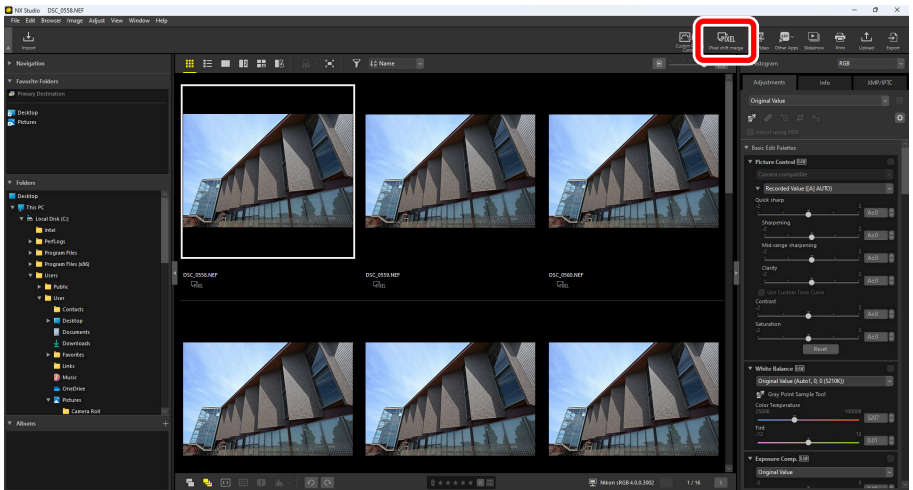
Merge Pictures Taken Using Pixel Shift

Merge Pictures Taken Using Pixel Shift with NX Studio

Merge pictures taken using pixel shift with NX Studio. The software will detect the pixel shift sequence of the selected picture and the pictures in the sequence can be merged into a single file.

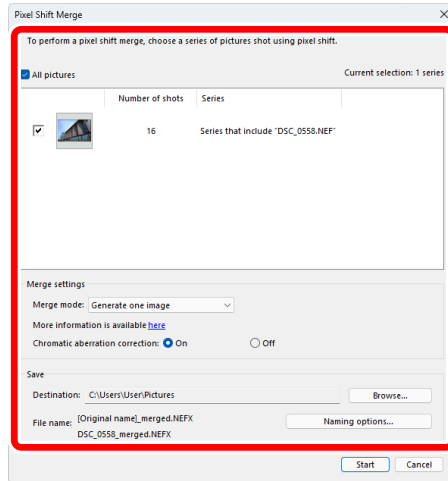
Using Pixel Shift Merge

- 1 Display the folder containing the pixel shift sequence, and click [**Pixel shift merge**] in the toolbar.

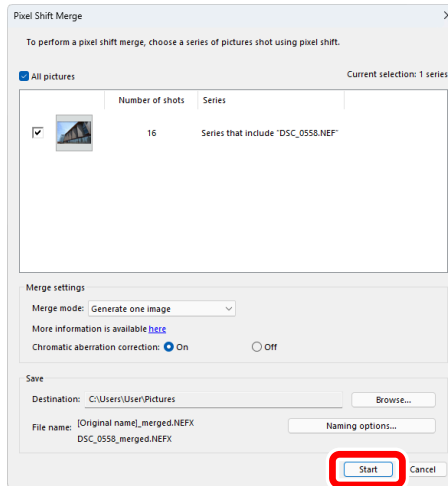


- The [**Pixel Shift Merge**] dialog will be displayed where you can choose a series of pictures taken with the camera using [**Pixel shift shooting**].

- 2 In the **[Pixel Shift Merge]** dialog, adjust settings such as "Merge mode" (number of generated images) and "Chromatic aberration correction" ([📖 26](#)).

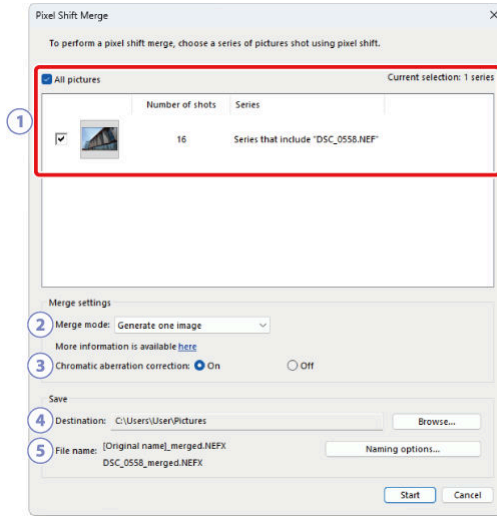


- 3 Click **[Start]** to save merged pixel shift images in the selected destination folder.



Pixel Shift Merge Setting Options

Set options in the [Pixel Shift Merge] dialog as follows:



Option	Description
① Pixel shift sequence	Select the sequence to merge. If there are multiple sequences in the view area, they can be selected and merged at the same time.
② [Merge mode]	Select the number of images to generate after merging. The number of images depends on the number of pictures to be merged (book 27).
③ [Chromatic aberration correction]	Select [On] to reduce lateral color aberrations.
④ [Destination]	Choose the destination folder for the generated images.
⑤ [File name]	Name the generated files. Click [Naming options] to select how files are named with prefix and suffix.

Number of Images Generated

- The number of generated images that can be selected varies as follows according to the number of pictures to be merged:

No. of original pictures	No. of generated images	Details
4	1	One merge to generate 1 image from 4 pictures.
8	1	One merge to generate 1 image from 8 pictures.
	2	Two merges to generate 2 images from 4 pictures.
16	1	One merge to generate 1 image from 16 pictures. <ul style="list-style-type: none">• The resulting height and width are double those of the original pictures.
	4	Four merges to generate 4 images from 4 pictures.
32	1	One merge to generate 1 image from 32 pictures. <ul style="list-style-type: none">• The resulting height and width are double those of the original pictures.
	2	Two merges to generate 2 images from 16 pictures. <ul style="list-style-type: none">• The resulting height and width are double those of the original pictures.
	4	Four merges to generate 4 images from 8 pictures.
	8	Eight merges to generate 8 images from 4 pictures.

- When multiple sequences of pictures taken using pixel shift are selected at the same time, it is only possible to generate a number of images that are available to all selected sequences. For example, if a sequence of 8 pictures and a sequence of 16 pictures are selected at the same time, only 1 image can be generated; if a sequence of 8 pictures and a sequence of 32 pictures are selected at the same time, you can select whether 1 or 2 images will be generated.

Tip: Time Required for Merging

The read/write speed of the hardware greatly affects the processing time of a pixel shift merge. A fast read/write storage device such as an SSD is recommended.

Tip: When the Merged Image Is Partially Disrupted

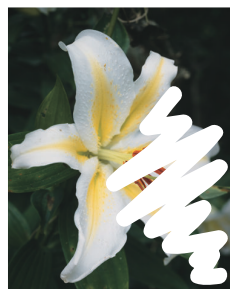
If the camera, the subjects, or the light source moves during a pixel shift shooting, the merged image may be partially disrupted. The following figure shows how 32 pictures are merged into a single image.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32



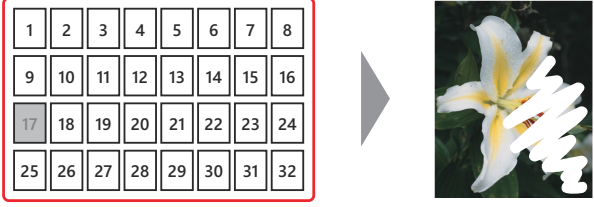
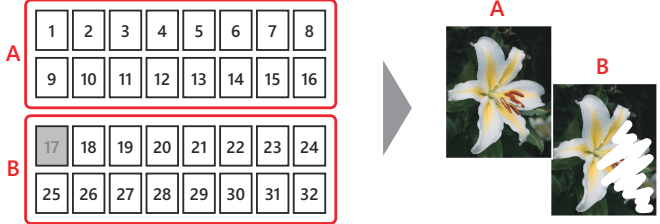
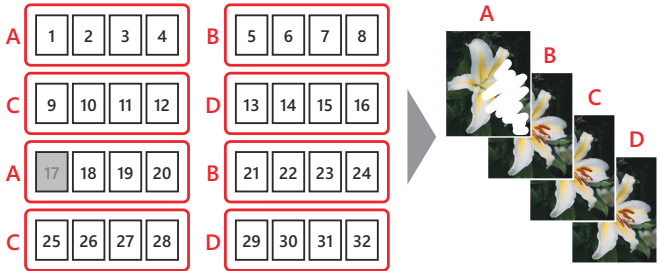
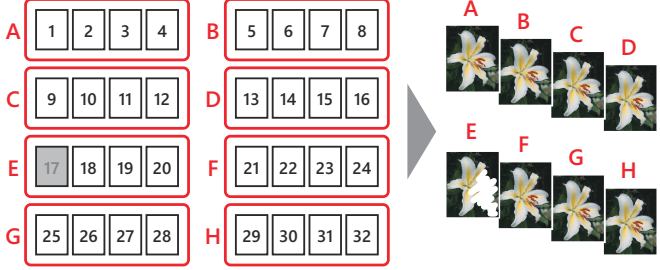
If a merge includes pictures disrupted, the resulting image will be partially disrupted.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32



An example of a disrupted merged image caused by a moving subject during the 17th picture.

In these cases, we recommend changing the number of merged images to be generated. Increasing the number of generated images may change the image quality of the merged image, but the merged image can be generated with pictures that do not include the cause of the disruption. Set the number of generated images with **[Merge mode]** in NX Studio when performing a pixel shift merge. The number of generated images can only be selected if 32, 16, or 8 was selected for **[Pixel shift shooting]** > **[Number of shots]** in the photo shooting menu. The relationship between each picture taken with number of shots set to 32 and the resulting merged images is as follows:

No. of generated images	The relationship between pictures taken and the merged images to be generated
1	
2	
4	
8	

When generating a single image, the merged image is disrupted because all the pictures are used, including those that were disrupted. Generating two images, on the other hand, causes the first merged image to be generated using the first to 16th pictures and the second merged image to be

generated using the 17th to 32nd pictures, so the first merged image, which does not include the 17th disrupted picture, will not be disrupted. The desired result is more likely to be achieved by generating a single image that produces the highest image quality first, and if disruption occurs, by increasing the number of generated images in the order of 2 images, 4 images, and 8 images. It is also recommended to always take 32 shots unless there is a particular reason not to.

- When 32 pictures are taken and 4 images are generated, each image is made of 8 pictures, and note the discontinuity of the combination of the 8 picture components to be merged. Consequently, a better result may be obtained by choosing to generate 1 image merging 8 pictures when 8 consecutive pictures are taken in the shortest possible time. Specifically in situations where the brightness changes quickly (sunrise, sunset, etc.), it is recommended to set the number of shots to 8.
-

Take Advantage of Pictures Taken Using Pixel Shift

Adjust/Export the Images with NX Studio

Pixel shift images merged with NX Studio can be adjusted in the adjustments/info palette [Adjustments] pane. Exported (converted) images can be adjusted or processed with third-party image editing software.

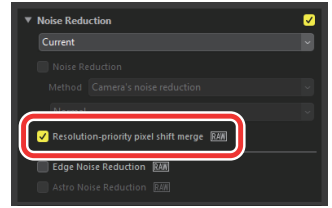
Adjust Merged Pixel Shift Images

Adjust images using tools in the [Adjustments] pane. Adjust settings such as [Picture Control], [Exposure Comp.], and [White Balance] as necessary. The tools that can be used to adjust merged pixel shift images are the same as ones for normal RAW (NEF/NRW) images. For detailed instructions on how to use NX Studio, see the documentation provided with the software or online help.

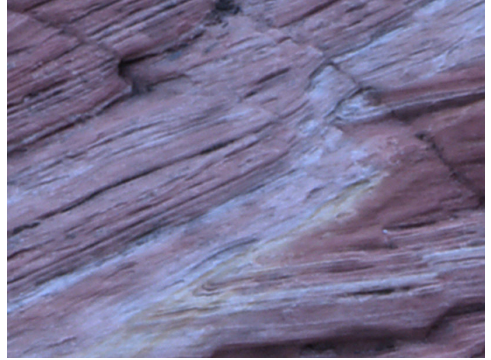


Noise Reduction

With the **[Noise Reduction]** item, you can set the amount of processing to reduce noise in the merged images. For merged pixel shift images, select **[Resolution-priority pixel shift merge]** to completely disable **[Noise Reduction]**. Since noise reduction is not performed, noise remains in the image, but the resolution of the image is maintained.



[Resolution-priority pixel shift merge] is off
(the default setting)



[Resolution-priority pixel shift merge] is on

Tip: Noise Reduction

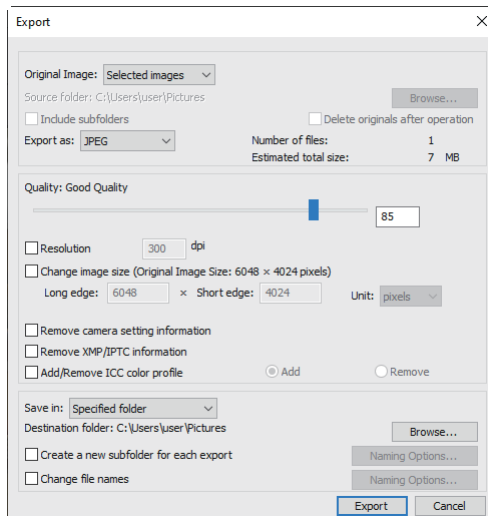
[Noise reduction] is not available for HEIF pictures. To process **[Resolution-priority pixel shift merge]**, select **[SDR]** for **[Tone mode]** in the photo shooting menu in the camera before taking pictures.

Export Merged Pixel Shift Images

Click **[Export]** in the toolbar to export merged pixel shift images in JPEG, HEIF, or TIFF format.

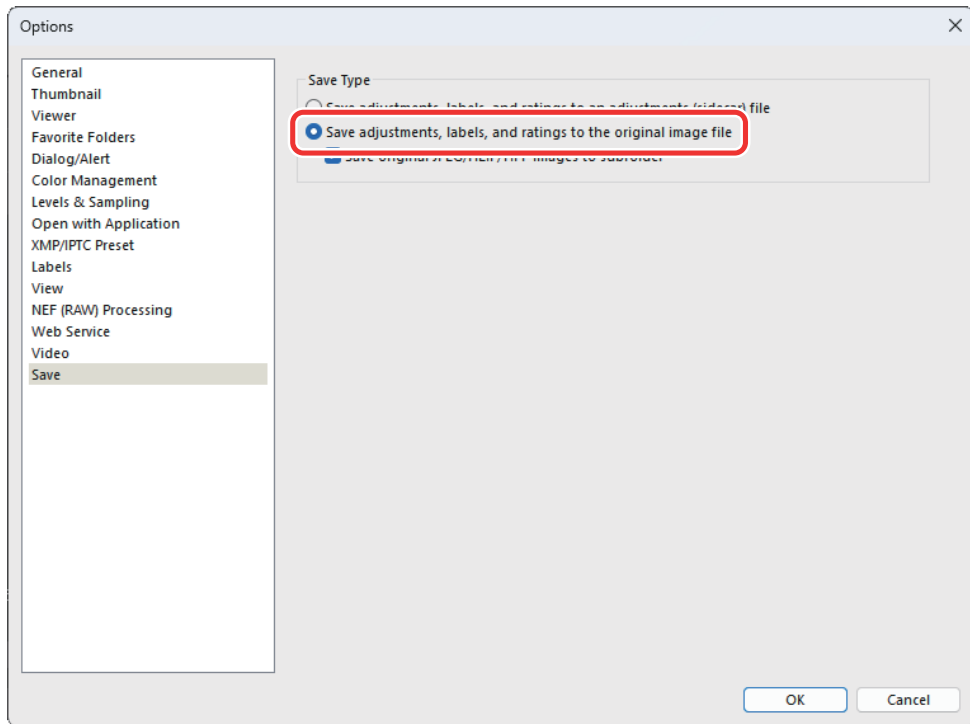


Choose a format, adjust image quality, size, and other settings, and click **[Export]** to export the files to the selected destination folder.



Tip: Using Third-Party Image Editing Software That Supports the NEFX Format

When using third-party image editing software that supports images in the NEFX (merged pixel shift) format (extension: .nefx), save the image using **[Save]** or **[Save As]** in the **[File]** menu. In these cases, select **[Save adjustments, labels, and ratings to the original image file]** in the **[Save]** category of the options dialog before saving the image.



Using Third-Party Software

Exported image files can be further processed and edited using third-party image editing software. Use image editing software that supports images in NEFX (merged pixel shift) format (extension: .nefx) to open a merged pixel shift image as is without converting it to JPEG or TIFF format.

Software Manufacturers Providing Image Editing Software That Supports the NEFX Format

The following software manufacturers provide image editing software that supports the NEFX format. For detailed information on the software, visit the respective manufacturer's website.

Software manufacturer	URL
Adobe	https://www.adobe.com/products/photoshop-lightroom.html
Capture One	http://www.captureone.com/

- Nikon does not recommend or guarantee operation of above software.
- NEFX is supported in Adobe Camera Raw version 15.5 or later.
- NEFX is supported in Capture One version 16.3.4 or later.

Adobe

CAPTURE  ONE



Appendix

Recommended Settings

Here are recommended settings for pixel shift shooting and merging images.

Camera

“Pixel Shift Shooting” in the Photo Shooting Menu [\(22\)](#)

Option	Settings	Description
[Pixel shift shooting mode]	[On (series)]	Take multiple series of pixel shift pictures.
[Number of shots]	32 pictures	Merging 32 pictures generates the highest quality images. There will also be more options for the number of images to be generated than other settings. You will be able to choose the number of generated images according to your purpose, such as generating 2 merged images from 16 pictures each or 4 merged images from 8 pictures each (27) .
[Delay]	2-5 seconds	Reduce blur caused by camera shake when the shutter-release button is pressed.
[Interval until next shot]	0 seconds	Minimize shooting time.

i Menu and Custom Control Assignments

Assign [Pixel shift shooting] to the **i** menu or a custom control to promptly configure the settings for pixel shift shooting [\(23\)](#). To support focus operation, it is recommended to assign [Zoom on/off] to a lens Fn button or a custom control on the camera.

NX Studio

“Pixel Shift Merge” (📖 26)

Option	Settings	Description
[Merge mode]	[Generate one image]	By merging all the pictures in series, a merged image with the highest image quality is generated (📖 26).
[Chromatic aberration correction]	[On]	Perform accurate lateral color aberration corrections suitable for pixel shift shooting.

“Noise Reduction” (📖 32)

Option	Settings	Description
[Noise Reduction]	[Resolution-priority pixel shift merge]	<p>Emphasize fine colors and details. Recommended when shooting at low sensitivities from ISO 64 to ISO 500.</p> <ul style="list-style-type: none">• The same effect can be achieved with third-party software by disabling the noise reduction function. Noise may remain in the image, but fine colors and details can be emphasized. It is recommended to select this option when shooting 32 or 8 pictures because, in these cases, noise is less noticeable than in normal RAW (NEF/NRW) images.

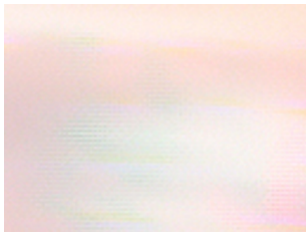
Other

The longer the shooting time, the more susceptible the camera is to external factors, and it may not be able to produce the desired result. Better results can be achieved by raising the ISO sensitivity and shortening the shooting time ([📖 19](#)).

Troubleshooting

Solutions to common issues are listed below.

Merged Images Show Disruption Such as Banding, Uneven Colors, Mosaic Patterns, or Other Distortions



Example of uneven colors
(When the subject moved)



Example of mosaic patterns
(When the camera moved)



Example of bandings
(When the brightness changed)

- Change the number of images to be generated in pixel shift merge and re-examine the combination of pictures to be merged ([📖 27](#)).
- The pictures may not have been taken properly. Check the subject and shooting environment and to try again ([📖 20](#)).

Bright Spots Appear on the Merged Image

- Perform pixel mapping before shooting ([📖 21](#)).
- The image can be retouched with NX Studio. For more information, see NX Studio online help.

Nikon