Removing Noise

As described in the **Sampling** section, under-sampling is almost always the cause of noise in your renders. Simply increasing the overall amount of sampling will reduce the amount of noise, but it will also cause many parts of your image to be over-sampled and your render times to increase. Targeting the various types of rays to the correct part of your image is critical for optimization, sending more of the wrong kind of ray will not increase the quality of your render. The goal, when setting your sampling parameters, is to balance Speed with Quality. For more information about the specific parameters described below, see **The Sampling Tab** and the **Extra Image Planes Tab**.

In general, when attempting to remove the noise in your render, it is good practice to start by adding the following image planes:

Direct Lighting (per component)

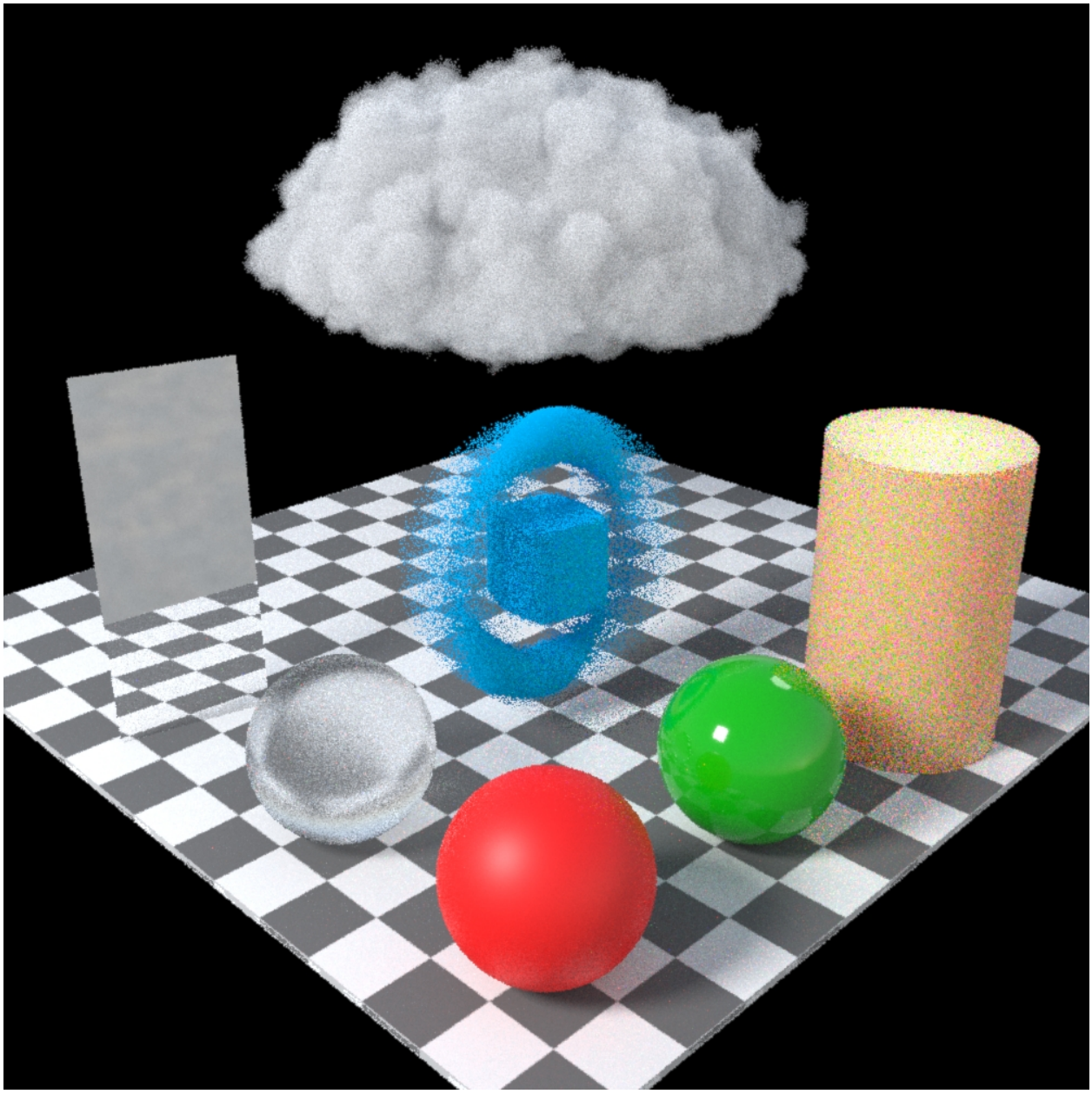
Indirect Lighting (per component)

Direct Samples

Indirect Samples

These will allow you to analyze different parts of your scene one at a time.

The following render is an example of a scene with multiple material types and motion blur. All sampling values on the Mantra Node are set to the defaults except for Pixel Samples, which are 1x1. On the limits tab, Diffuse Limit has been set to 2, Volume Limit has been set to 2 and SSS limit has been set to 1.

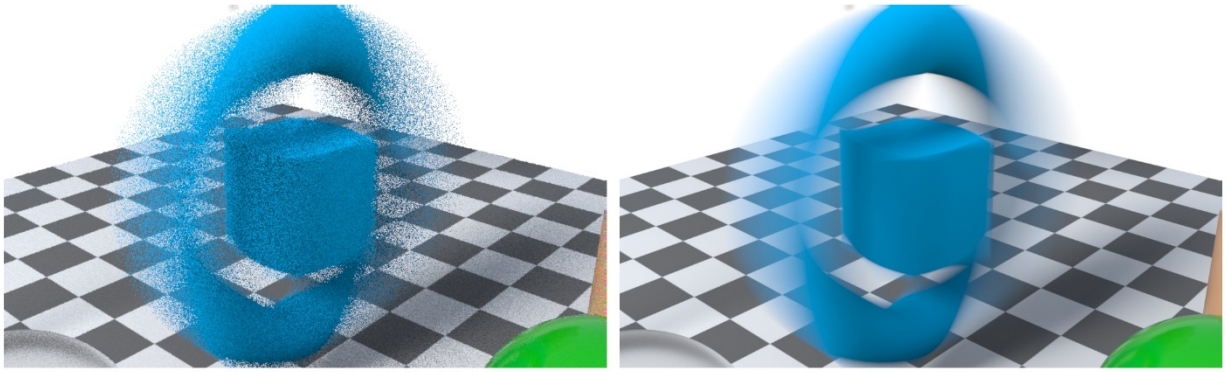


For each Example below, we will adjust only the parameters that are mentioned in the descriptions accompanying each noise type.

Motion Blur

When “Allow Motion Blur” is enabled on the Mantra node, fast moving objects can cause your image to become noisy. This noise is essentially a type of aliasing that occurs when an object must be sampled across time as well as space. See the chapter on Motion Blur, for a more in depth explanation of how mantra samples objects in motion and how certain objects may be optimized for heavily motion blurred scenes.

Increasing **Pixel Samples**, also described as Primary Rays, is the only way to remove this type of noise.



Pixel Samples 1x1 Pixel Samples 9x9

Increasing Pixel Samples will act as a multiplier for all other types of rays (see **Sampling Tab**). In the example above, you can see that increasing the pixel samples has also removed most of the other types of noise in this scene. For this reason, it is a good idea to remove Motion Blur as a first step as it may solve other types of noise in your scene at the same time.

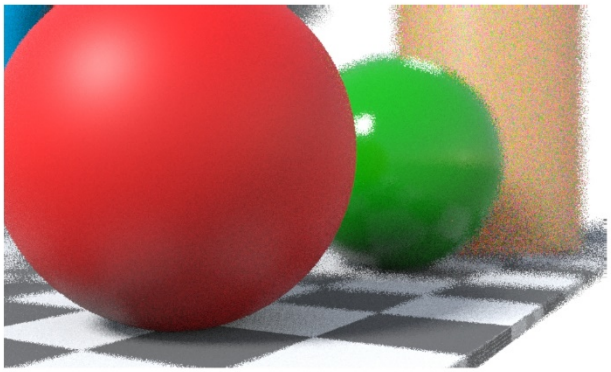
To identify this type of noise, it can be useful to check the Alpha Channel for noise at the ends of objects. If overlapping objects make this impossible, turn off "Allow Motion Blur" and check the noise levels versus the non-motion blurred scene.

Pixel Samples 1x1 Pixel Samples 9x9

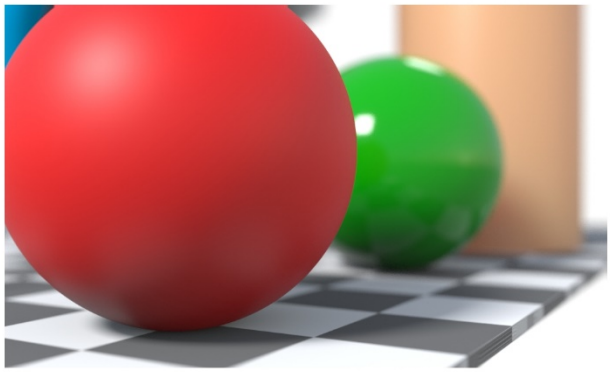
Depth of Field

When "Enable Depth of Field" is checked on the Mantra Node, objects which are distant from the camera's "Focus Distance" can become noisy. This is especially evident in bright highlights and the edges of objects.

Increasing **Pixel Samples** is the only way to remove this type of noise.



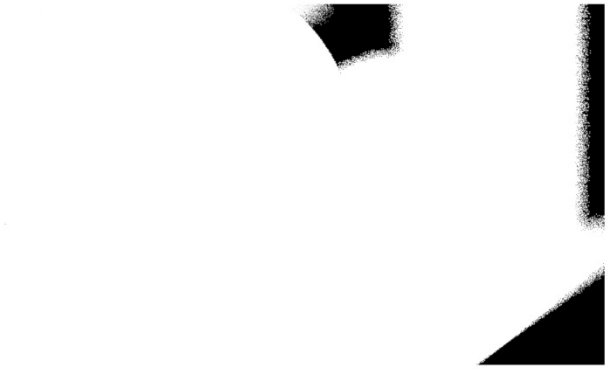
Pixel Samples 1x1



Pixel Samples 9x9

As with Motion Blur, removing noise from images with Depth of Field may have the side effect of removing other types of noise as well. Consider removing this type of noise first before attempting to remove noise from other sources. However, always check the “in focus” areas of your image for any of the other noise types as some extra attention may be required in these areas.

To identify this type of noise, it can be useful to check the Alpha Channel for noise at the edges of objects or along the motion path. If overlapping objects make this impossible, turn off “Enable Depth of Field” and check the amount of noise in the image without Depth of Field blurring.



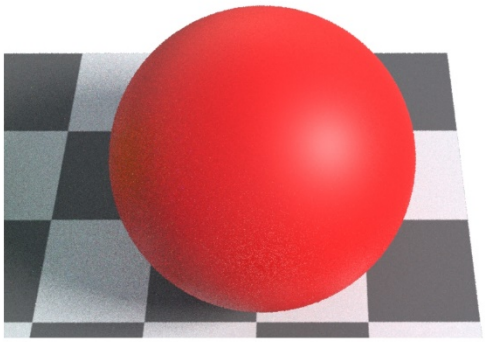
Pixel Samples 1x1

Pixel Samples 9x9

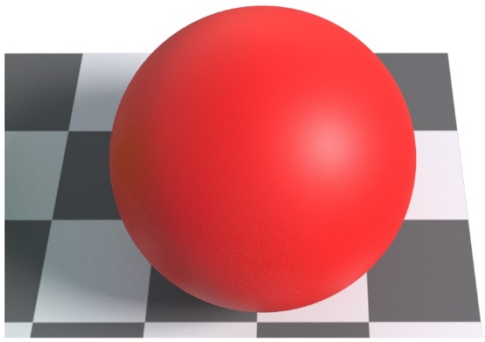
Edge Aliasing

Without enough Primary Rays, the edges of objects can appear jagged and rough. This can be especially evident in high-contrast areas or within high-frequency patterns.

Increasing **Pixel Samples** is the only way to remove this type of noise.



Pixel Samples 1x1



Pixel Samples 3x3

In the above example, notice how the edges of the sphere and plane appear jagged in the image on the left.

To identify this type of noise, it can be useful to check the Alpha Channel for noise at the edges of objects or along the motion path.

Pixel Samples 1x1

Pixel Samples 3x3

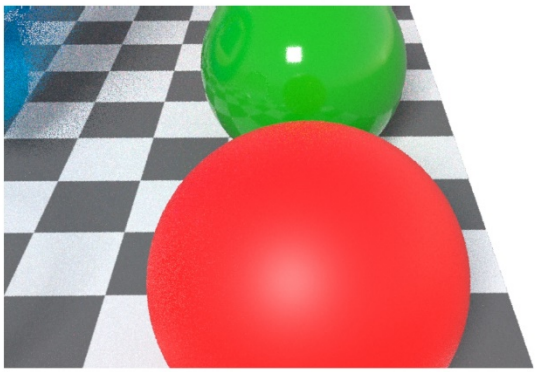
For many scenes, setting pixel samples to 3x3 will be sufficient to remove this type of noise. For images with high frequency patterns generated by a shader, it may be necessary to increase these values to get a fully anti-aliased image. If possible, it may be more efficient to handle filtering in the shader, rather that using the brute force approach of increasing pixel samples.

DIRECT ILLUMINATION

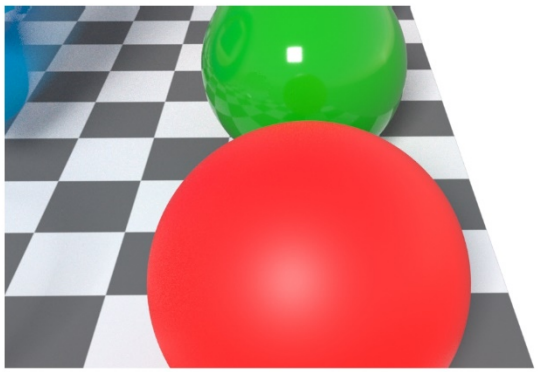
Direct Reflections

Direct Reflections refer to the reflection of light sources directly from the surface of an object. These reflections can exhibit a speckled noise pattern especially in materials with small amounts of roughness in combination with Area Lights or Environment Lights.

The best way to remove this type of noise is to increase the **Sampling amount on the Light** which is causing the noise. Increasing Pixel Samples will also help remove the noise, but will cause an increase in all other types of rays. It can often be a good idea to start with the default Pixel Sample value of 3x3 because it will also remove any distracting Edge Aliasing from your image.



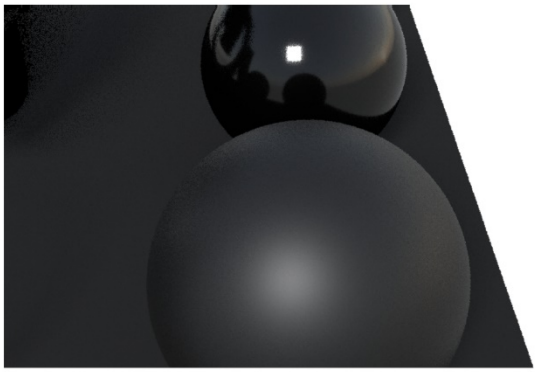
Pixel Samples 1x1
Env Light Sampling Quality 1
Area Light Sampling Quality 1



Pixel Samples 3x3
Env Light Sampling Quality 3
Area Light Sampling Quality 3

Increasing light samples will act like a multiplier on the number of Direct Rays in your scene so it is not a good idea to simply increase samples to extremely high values for all lights. Increasing **Direct rays** (Min and Max Ray Samples) will help remove this type of noise. This means that you must balance the need to clean up noise from a specific light, against cleaning up Direct Sources of noise throughout your image.

To identify this type of noise, enable the “Direct Reflect” image layer, this will allow you to examine the contributions to Direct Reflections without interference from other sources of noise in your scene.

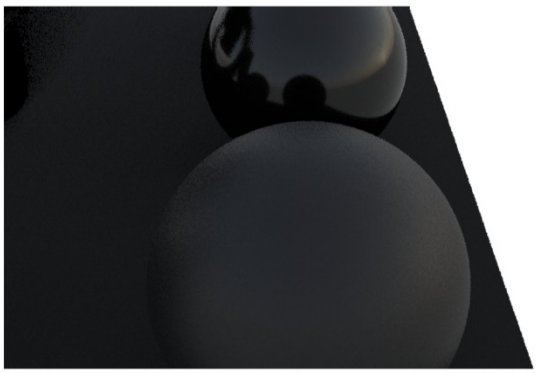


Pixel Samples 1x1
Env Light Sampling Quality 1
Area Light Sampling Quality 1

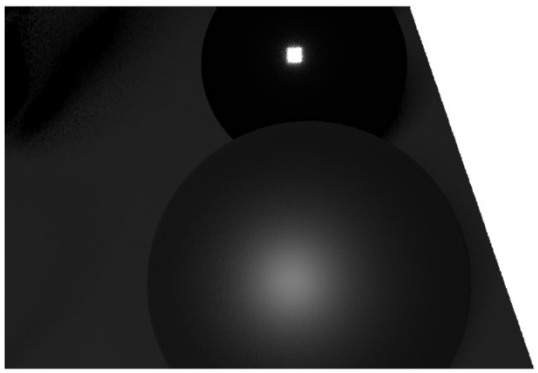
Pixel Samples 3x3
Env Light Sampling Quality 3
Area Light Sampling Quality 3

In the above images, the Direct Reflection noise is much clearer since it no longer mixed in with all other sources of noise.

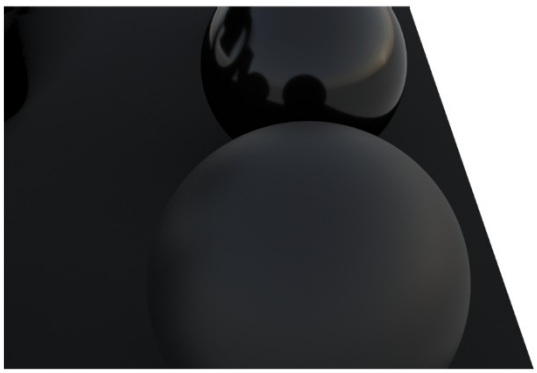
For complex scenes with many lights, it can be useful to export the “Direct Reflect” layer using the “Per Light” option. This will allow you to isolate the specific lights that are causing noise in your scene, allowing you to increase sampling only on the offending light sources.



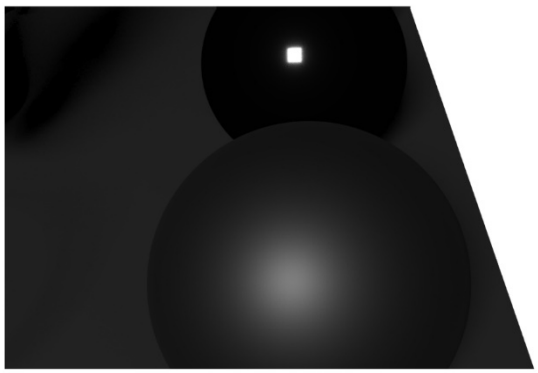
Env Light Sampling Quality 1



Area Light Sampling Quality 1



Environment Light Sampling Quality 3



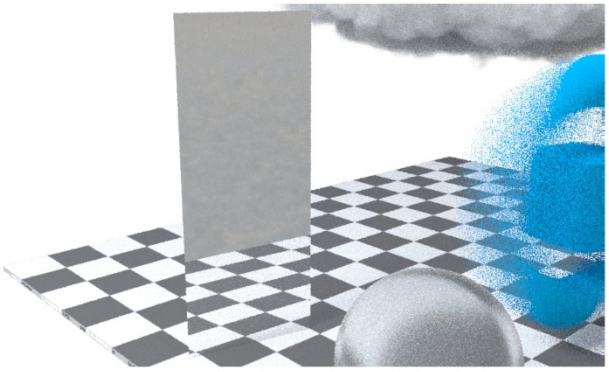
Area Light Sampling Quality 3

Direct Refractions

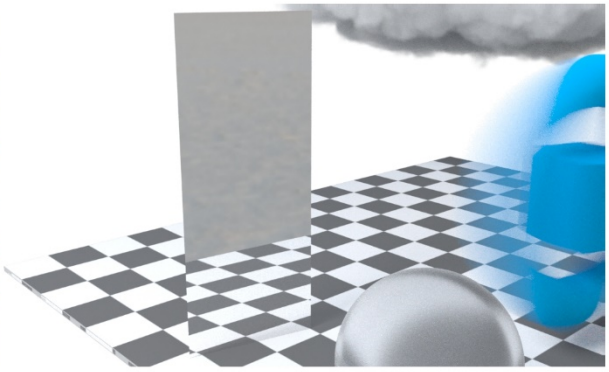
Direct Refractions are caused by the refraction of light sources through a single surface (A grid for instance) These refractions can exhibit a speckled noise pattern especially in materials with small amounts of roughness in combination with Area Lights or Environment Lights.

(Remember that any refractions through more than one surface will be considered an Indirect Refraction.)

The best way to remove this type of noise is to increase the **Sampling amount on the Light** which is causing the noise. Increasing Pixel samples will also help remove the noise, but will cause an increase in all other types of rays, causing areas of the image without noise to become over-sampled.



Pixel Samples 1x1
Env Light Sampling Quality 1

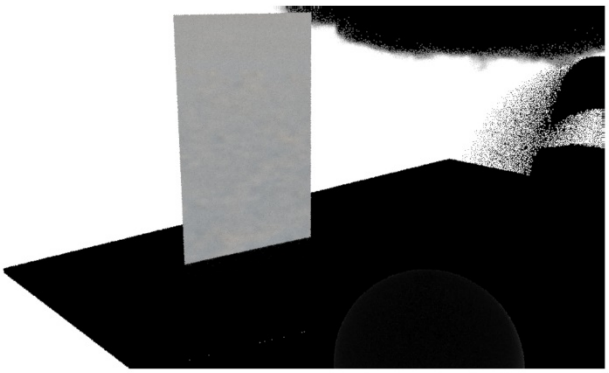


Pixel Samples 3x3
Env Light Sampling Quality 1

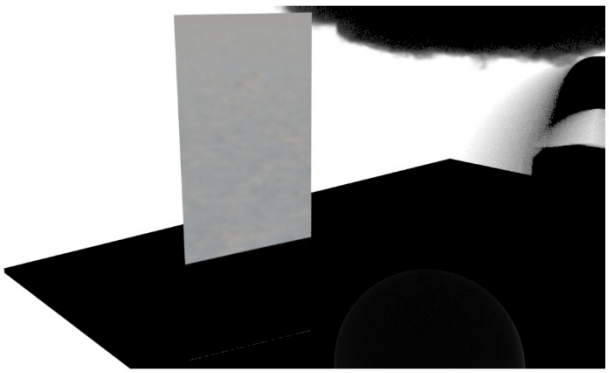
In the above example, increasing the Pixel Samples to 3x3 removes all the Direct Refraction noise and so the Sampling Quality on the Environment Light did not need to be adjusted. This is another good reason to approach the removal of noise in stages. For this case, Removing Edge Aliasing has effectively resolved the Direct Refraction noise as well.

Increasing light samples will act like a multiplier on the number of Direct Rays in your scene so it is not a good idea to simply increase samples to extremely high values for all lights. Also, increasing **Direct rays** (Min and Max Ray Samples) will also help clean up this type of noise. This means that you must balance the need to clean up noise from a specific light, against cleaning up Direct Sources of noise throughout your image.

To identify this type of noise, enable the “Direct Refract” image layer, this will allow you to examine the contributions to Direct Refractions without interference from other sources of noise in your scene.



Pixel Samples 1x1
Env Light Sampling Quality 1



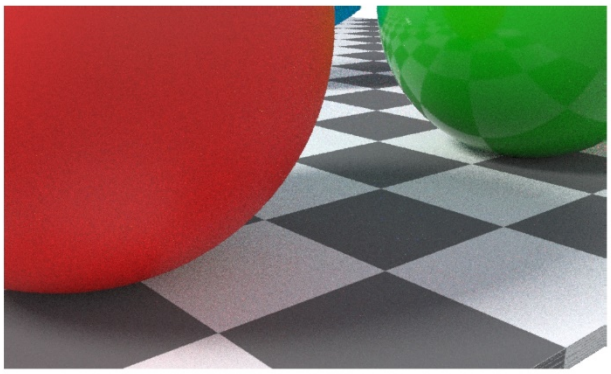
Pixel Samples 3x3
Env Light Sampling Quality 1

For complex scenes with many lights, it can be useful to export the “Direct Refract” layer using the “Per Light” option. This will allow you to isolate the specific lights that are causing noise in your scene, allowing you to increase sampling only on the offending light sources

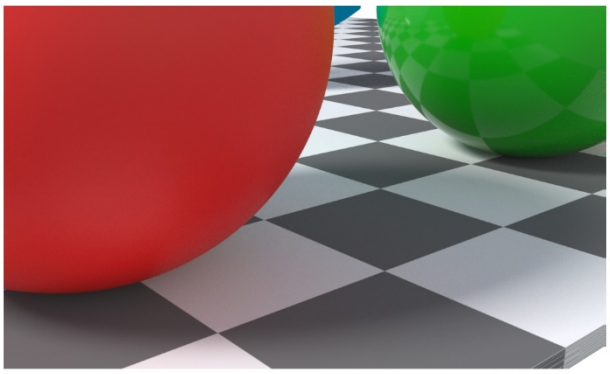
Direct Shadows

Direct Shadows, which occur when a point in your scene does not have a direct path to a light source, can exhibit a speckled or rough noise pattern. This is especially evident in soft shadows cast from large area lights.

The best way to remove this type of noise is to increase **the Sampling amount on the light** which is causing the noise. Increasing Pixel samples will also help remove the noise, but will cause an increase in all other types of rays, causing areas of the image without noise to become over-sampled.



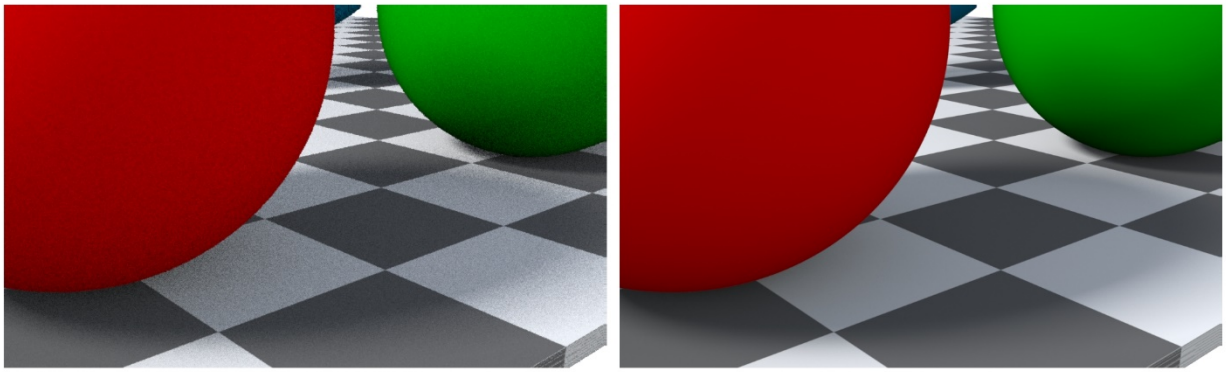
Pixel Samples 1x1
Env Light Sampling Quality 1
Area Light Sampling Quality 1



Pixel Samples 3x3
Env Light Sampling Quality 5
Area Light Sampling Quality 3

Increasing light samples will act like a multiplier on the number of direct rays in your scene so it is not a good idea to simply increase samples to extremely high values for all lights. Also, increasing **Direct rays** (Min and Max Ray Samples) will also help clean up this type of noise. This means that you must balance the need to clean up noise from a specific light, against cleaning up Direct Sources of noise throughout your image.

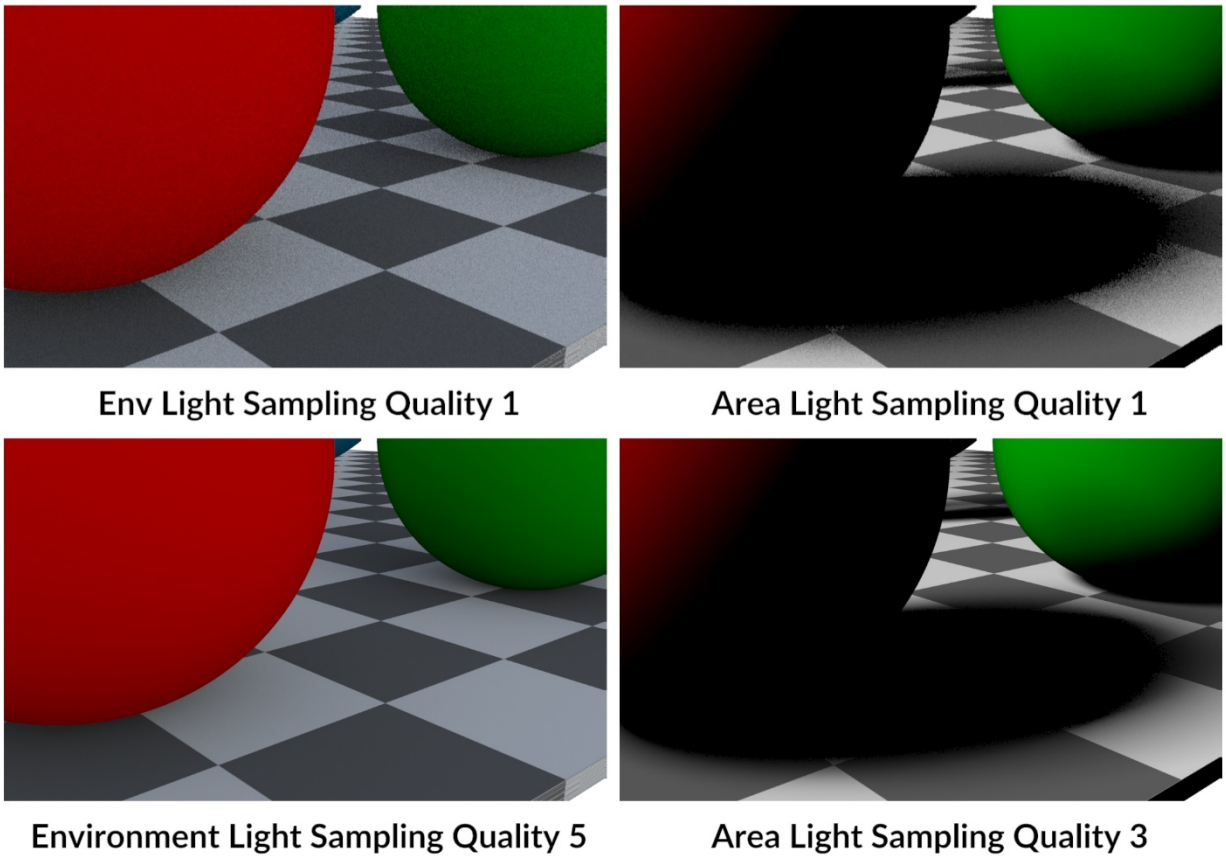
To identify this type of noise, enable the “Direct Diffuse” image layer, this will allow you to examine the shadows caused by direct lighting without interference from indirect sources of shadow.



Pixel Samples 1x1
Env Light Sampling Quality 1
Area Light Sampling Quality 1

Pixel Samples 3x3
Env Light Sampling Quality 5
Area Light Sampling Quality 3

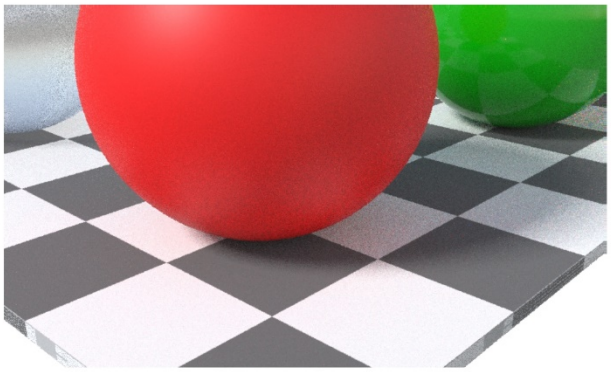
In the above example, identifying which light is responsible for the noise is difficult, especially since environment lights have the effect of “filling in” shadows. It can be useful in these cases to export the “Direct Diffuse” layer using the “Per Light” option. This will allow you isolate the specific lights that are causing noise in your scene, allowing you to increase sampling only on the offending light sources.



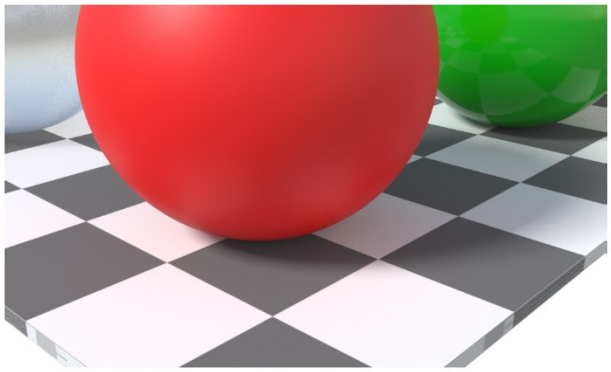
In the examples above, it is much more obvious which light is causing the various types of noise. This is especially evident on the edges of the shadows cast by the area light. In this case, you can see that the Area light required fewer samples to remove the noise than the Environment light. In complex scenes, this kind of close examination of per-light noise can help prevent significantly over-sampling your scene.

Indirect Illumination

Indirect Diffuse



Pixel Samples 1x1
Diffuse Quality 1

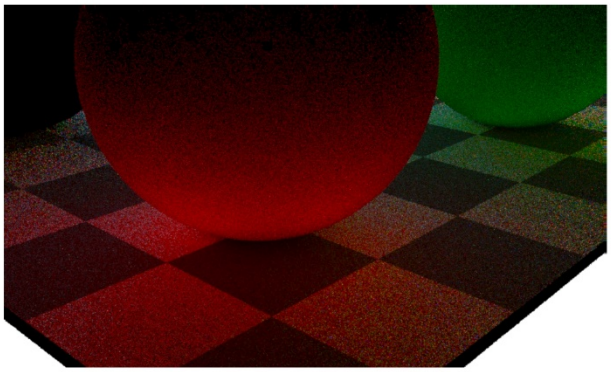


Pixel Samples 3x3
Diffuse Quality 3

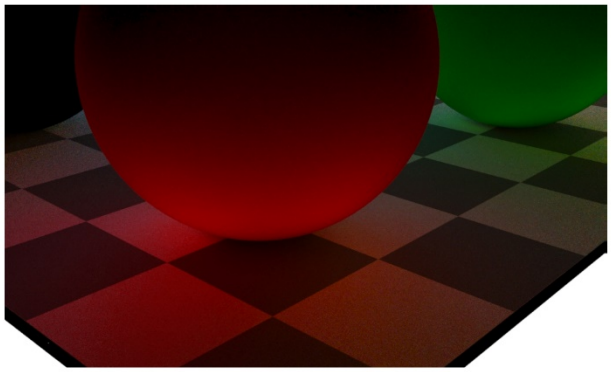
Indirect Diffuse, which is the light contribution from other objects in a scene, can be a significant source of noise. This can be especially evident in scenes with physically accurate light sources which are also very near other objects (Light sconces or inset lights, for instance.) and only contribute a small amount to direct lighting.

The best way to remove this type of noise is to increase the number of indirect samples that are being sent. You can achieve this by adjusting the **Diffuse Quality** parameter on the Mantra node. Increasing Pixel samples will also help remove the noise, but will cause an increase in all other types of rays, causing areas of the image without noise to become over-sampled.

To identify this type of noise, enable the “Indirect Diffuse” image layer, this will allow you to examine the light contributions to this layer without interference from other types of noise.



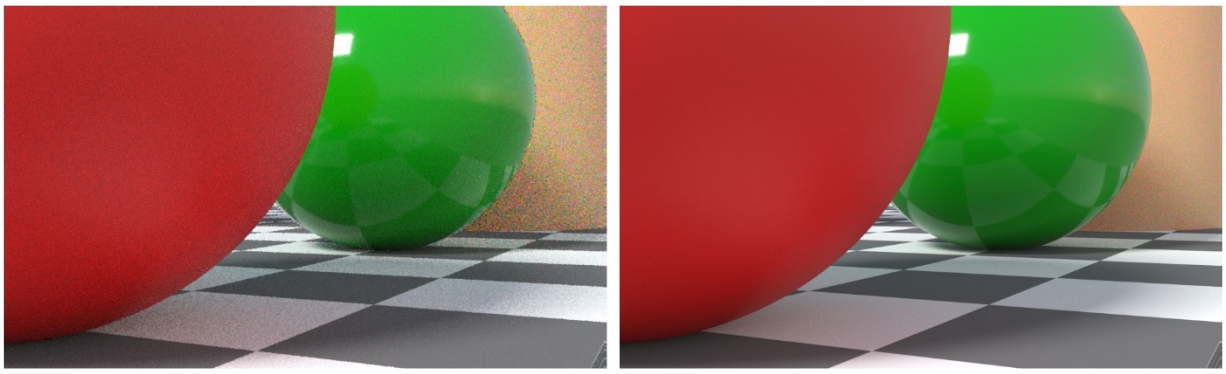
Pixel Samples 1x1
Diffuse Quality 1



Pixel Samples 3x3
Diffuse Quality 3

Keep in mind that you do not have to completely remove noise from this component to have a clean image, indirect noise is often imperceptible when it has been combined with direct lighting information. Always refer to the Combined Color image plane to see how your sampling is affecting the fidelity of the final image.

Indirect Reflections



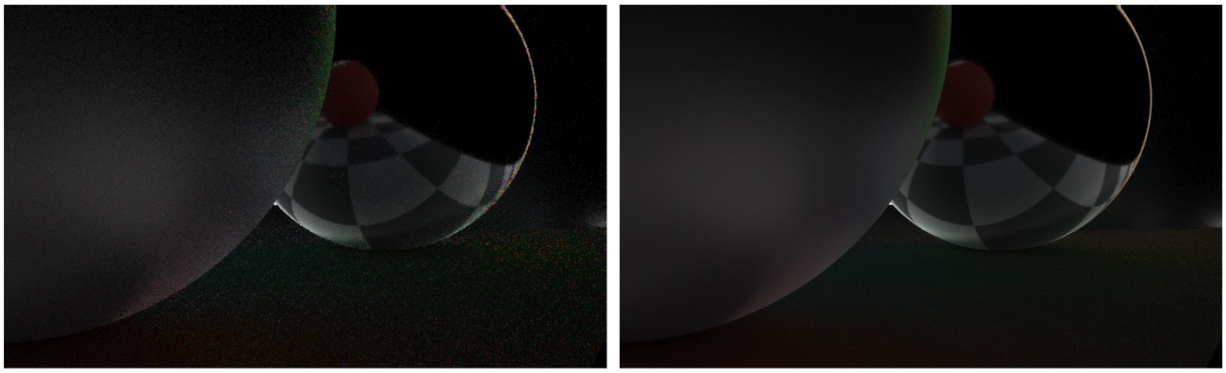
Pixel Samples 1x1
Reflection Quality 1

Pixel Samples 3x3
Reflection Quality 2

Indirect Reflections, which are the reflections of other objects, can be responsible for much of the noise in your scene. This can be particularly evident in scenes with very bright glossy reflections in combination with other objects with rough reflections.

The best way to remove this type of noise is to increase the number of indirect samples that are being sent. You can achieve this by adjusting the **Reflection Quality** parameter on the Mantra node. Increasing Pixel samples will also help remove the noise, but will cause an increase in all other types of rays, causing areas of the image without noise to become over-sampled.

To identify this type of noise, enable the “Indirect Reflect” image layer, this will allow you to examine the amount of noise caused by indirect reflections without interference from other types of noise.

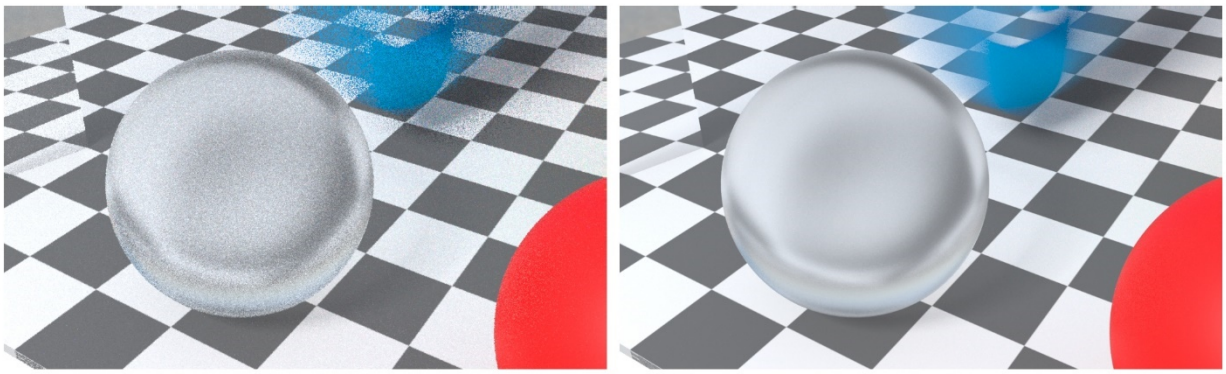


Pixel Samples 1x1
Reflection Quality 1

Pixel Samples 3x3
Reflection Quality 2

Keep in mind that you do not have to completely remove noise from this component to have a clean image, indirect noise is often imperceptible when it has been combined with direct lighting information. However, unlike indirect diffuse noise, indirect reflections can be responsible for most of the color of a final pixel. (An object with a mirror-like finish, for example) Always refer to the Combined Color image plane to see how your sampling is affecting the fidelity of the final image.

Indirect Refractions



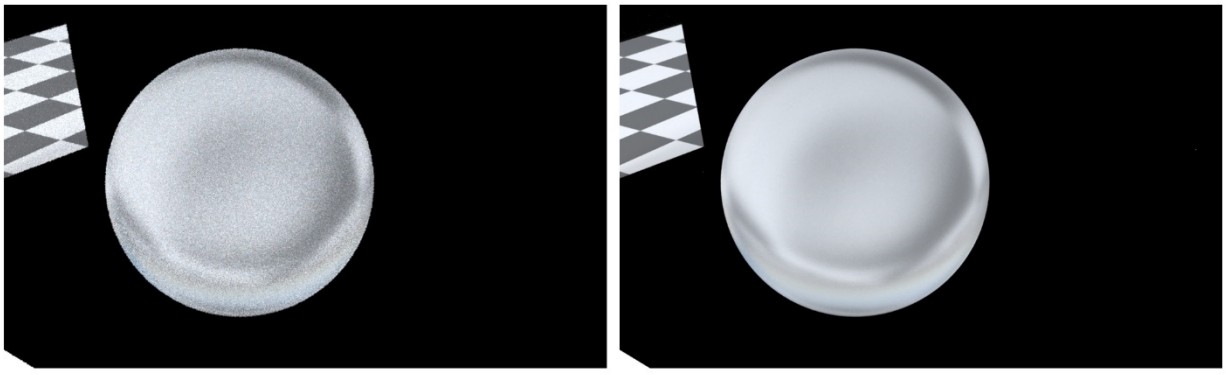
Pixel Samples 1x1
Refraction Quality 1

Pixel Samples 3x3
Refraction Quality 6

Indirect Refractions, which are the refractions of other objects and surfaces in your scene, can be significant sources of noise in your scene. This is especially true when rendering refractive objects with a high roughness value.

The best way to remove this type of noise is to increase the number of indirect samples that are being sent. You can achieve this by adjusting the **Refraction Quality** parameter on the Mantra node. Increasing Pixel samples will also help remove the noise, but will cause an increase in all other types of rays, causing areas of the image without noise to become over-sampled.

To identify this type of noise, enable the “Indirect Refract” image layer, this will allow you to examine the amount of noise caused by indirect refractions without interference from other types of noise.

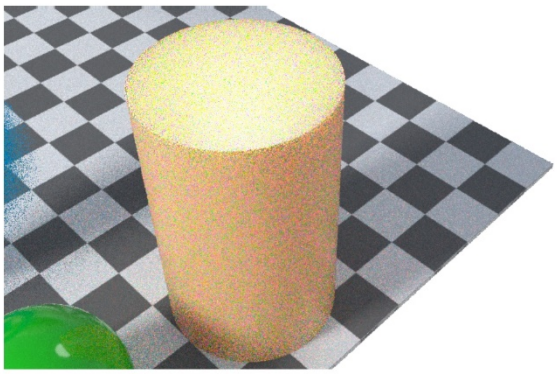


Pixel Samples 1x1
Refraction Quality 1

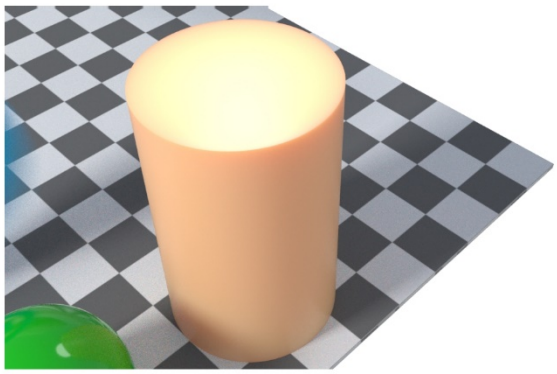
Pixel Samples 3x3
Refraction Quality 6

Keep in mind that you do not have to completely remove noise from this component to have a clean image, indirect noise is often imperceptible when it has been combined with direct lighting information. However, unlike indirect diffuse noise, indirect refractions can be responsible for most of the color of a final pixel. (A glass of water, for instance.) Always refer to the Combined Color image plane to see how your sampling is affecting the fidelity of the final image.

Subsurface Scattering



Pixel Samples 1x1
SSS Quality 1

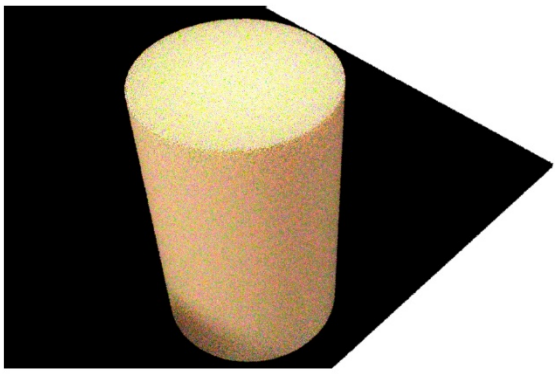


Pixel Samples 3x3
SSS Quality 45

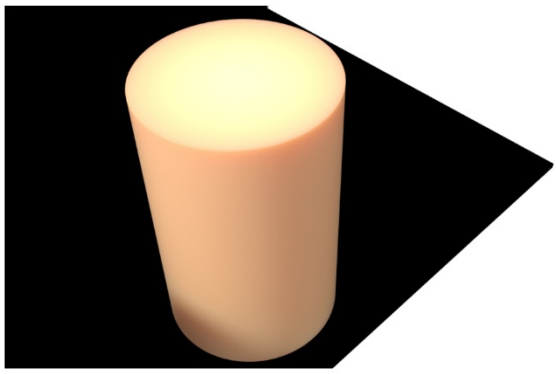
Subsurface Scattering refers to a type of indirect light caused by light scattering inside the surface of an object before exiting. Typically, this effect is seen in materials like candle wax or human skin. Objects with Sub Surface Scattering enabled can contribute a significant amount of noise in your scene.

To remove this type of noise, increase the SSS Quality parameter on the Mantra node. Increasing Pixel samples will also help remove the noise, but will cause an increase in all other types of rays, causing areas of the image without noise to become over-sampled.

To identify this type of noise, enable the “Indirect SSS” image layer, this will allow you to examine the amount of noise caused by indirect reflections without interference from other types of noise



Pixel Samples 1x1
SSS Quality 1



Pixel Samples 3x3
SSS Quality 45

Keep in mind that you do not have to completely remove noise from this component to have a clean image, SSS noise is often imperceptible when combined with other lighting components. However, in some materials the SSS component may be responsible for much of the final pixel color, in those cases a significant increase in the number of rays sent may be necessary. Additionally, because Subsurface Scattering is highly depending on the viewing angle, it may be a good idea to test your sampling settings across multiple frames if your camera or object is animated. Always refer to the Combined Color image plane to see how your sampling is affecting the fidelity of the final image.

VOLUMES

Pixel Samples 1x1
Stochastic Sampling 4

Pixel Samples 3x3
Max Ray Samples 36
Stochastic Sampling 9

Volumes require a different sampling strategy than surfaces, rays “march” through each object and accumulate values across multiple depth samples. This added complexity can make rendering volumes costly. Like surfaces, it is best to approach the removal of noise in a series of stages based on the type of noise present.

Direct Volumes

Direct Volumetric lighting, refers to volumes that have receive their lighting only directly from light sources.

When rendering volumes, there can be more than one type of noise present per component - noise from under-sampling the transparent parts of an object and noise from under-sampling the lights.

To begin, increasing Stochastic Samples will dramatically reduce noise without causing a large increase in render times. This will be most notable in semi-transparent areas, usually in the soft edges of the volumetric object. At some point, increasing Stochastic Samples will no longer have a significant effect on noise. If this occurs, and noise remains in this component, begin increasing Max Ray Samples slowly until the remaining noise is removed.

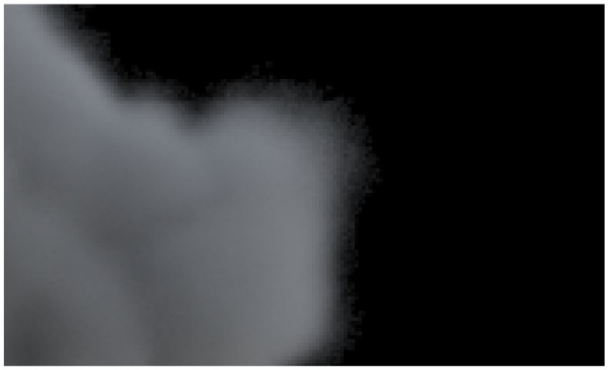
To identify these types of noise, enable the “Direct Volume” image layer, this will allow you to examine the amount of noise in this component without interference from types of noise.

Pixel Samples 1x1
Stochastic Sampling 4

Pixel Samples 3x3
Max Ray Samples 36
Stochastic Sampling 9

As with all noise types, increasing Pixel samples will help reduce this type of noise. This can be particularly expensive when rendering volumes, so it is best to avoid this if possible. However, the default setting of 3x3 pixel samples is often a good starting place.

If you plan to composite your volumetric images with a separate background image, be sure to occasionally check the noise levels after compositing. Noise that is evident against a black background may be invisible on your final plate. The opposite can also be true, where noise is invisible against a black background, but becomes obvious when the alpha channel of the image is taken into account. As much as possible, refer to the Combined Color channel (or the composited final frame) to verify how your sampling is affecting the fidelity of your image.



Indirect Volumetric Lighting

Indirect Volumetric Lighting, which involves volumes which receive light from indirect sources such as other objects or through the scattering of light within the volume itself, can create significant amounts of noise in your renders. Indirect volumetric noise is most often noticeable in the shadowed areas of volumetric objects.

As with Direct Volume noise, begin by removing the noise caused by under-sampling the opacity of your volume by increasing Stochastic Samples. However, if you've already removed this type of noise from your direct volume component, you may find that increasing the value of this parameter has little effect since transparent samples are shared between these components.

The remaining noise is likely due to under-sampling the indirect sources of light in your scene. To remove this noise type, slowly increase the Max Ray Samples parameter until the noise is resolved. Like Stochastic sampling, this parameter is shared with the direct volume component. However, because indirect sampling of volumes can be especially noisy, it is likely you will need to increase the max ray samples further to remove noise from this component.

To identify this type of noise, enable the "Indirect Volume" image layer, this will allow you to examine the amount of noise caused by indirect volumetric lighting without interference from types of noise.

Pixel Samples 1x1
Stochastic Sampling 4

Pixel Samples 3x3
Max Ray Samples 36
Stochastic Sampling 9

Keep in mind that you do not have to completely remove noise from this component to have a clean image, often indirect noise is invisible when it has been combined with direct lighting information. Always refer to the Combined Color image plane to see how your sampling is affecting the fidelity of the final image.

Volume Quality

Unlike the other "Quality" parameters on the Sampling Tab of the Mantra Node, Volume Quality does not refer to the amount of indirect sampling. Instead, it explicitly refers to the number of voxels which are considered for sampling. (See "The Sampling tab" for more information on this parameter)

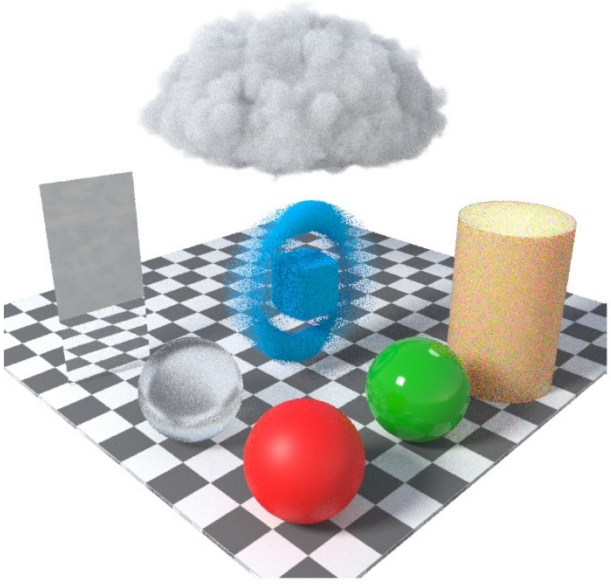
In general, it will be unnecessary to change this parameter so long as Stochastic Transparency in enabled. However, it is possible that small details will be missed when this Volume Quality is set too low.

If you feel that there is more information in the volume than appears in the render, consider increasing this value.

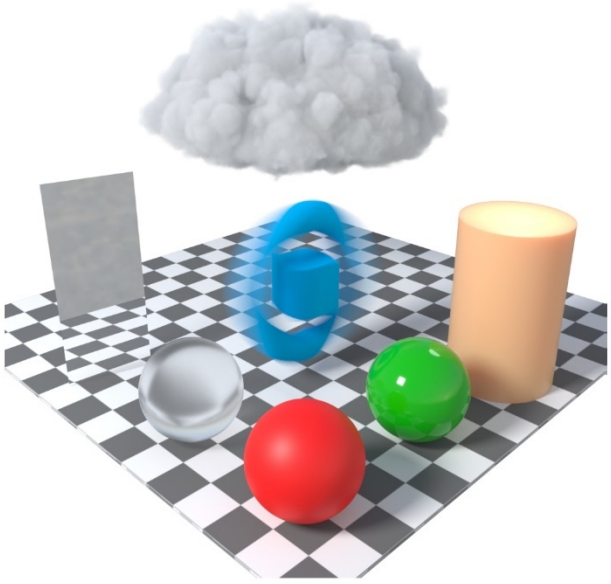
When Stochastic Transparency is disabled, this parameter directly controls the amount of sampling in the volume and will have a dramatic effect on render times.

Final Image

Here is a version of the complete scene with the rendering settings required to generate a clean image.



Pixel Samples 1x1

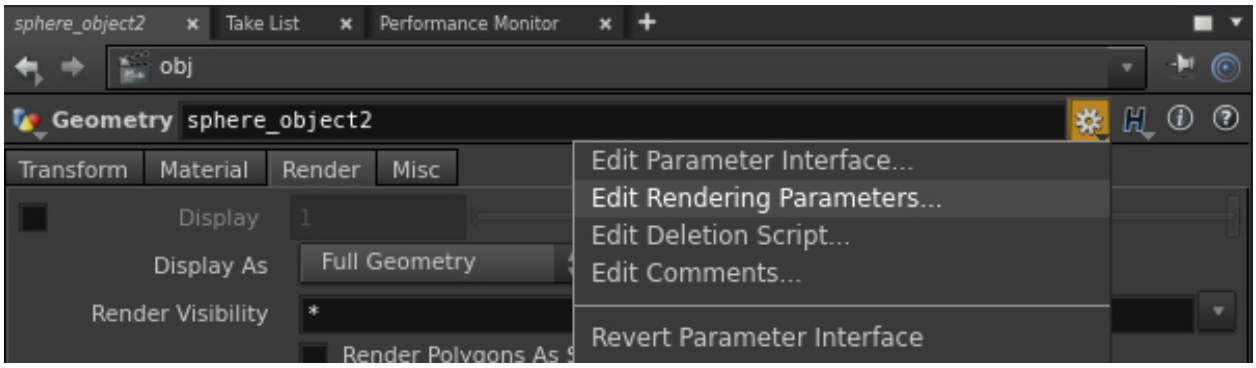


Pixel Samples 6x6
Diffuse Quality 2
Reflection Quality 2
Refraction Quality 3
SSS Quality 20

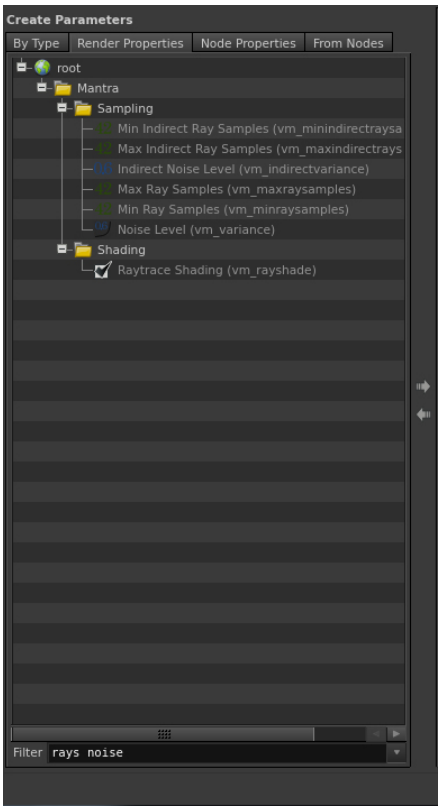
Special Cases

In some cases, there may be specific objects in your scene that are especially noisy in comparison to other objects. You may find that to get enough samples onto these objects you will end up over-sampling the rest of your scene. This can occur in many different circumstances, but a common cause would be a refractive or reflective shader with high roughness values.

To avoid this over-sampling problem, you can add the sampling properties onto the object itself. This will mean that only the problem-case will receive more samples. To achieve this, go to an object and select the “Edit Rendering Parameters” option in the gear icon.



Under “Render Properties”, navigate to the Mantra/Sampling folder (Or use the Filter Field to narrow your search). Add the following properties to your object:–



Diffuse Quality

Reflection Quality

Refraction Quality

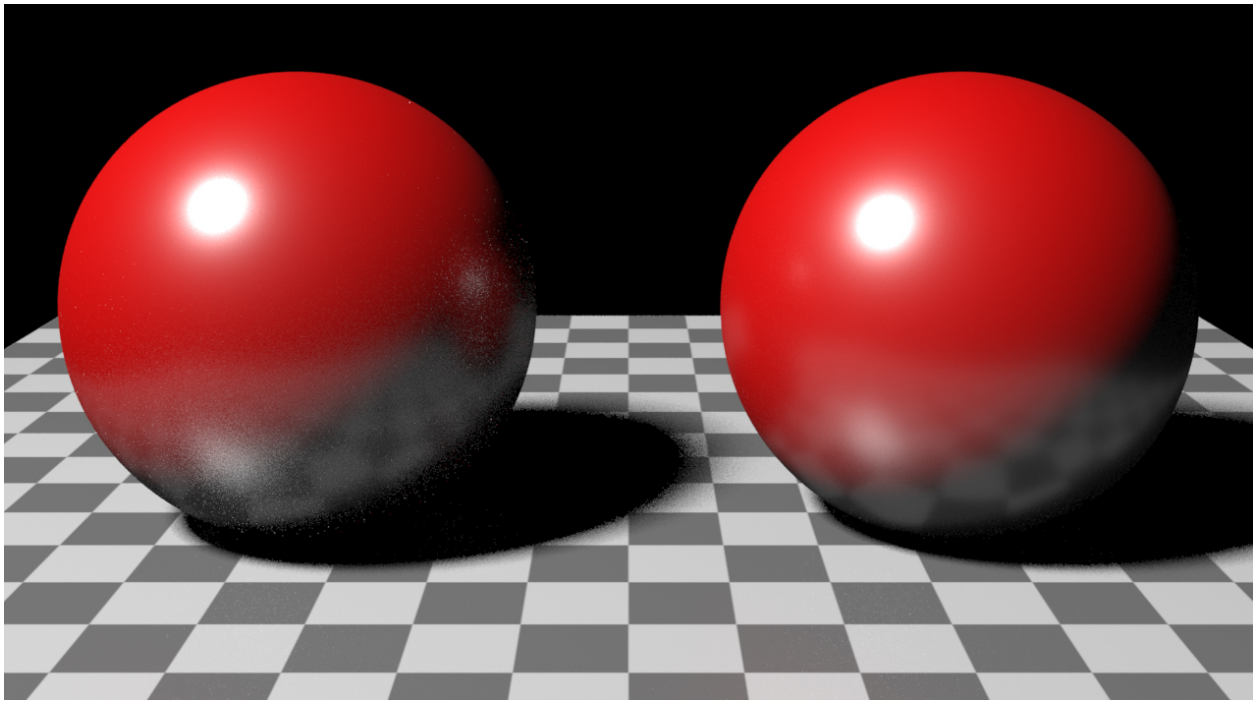
SSS Quality

Max Ray Samples

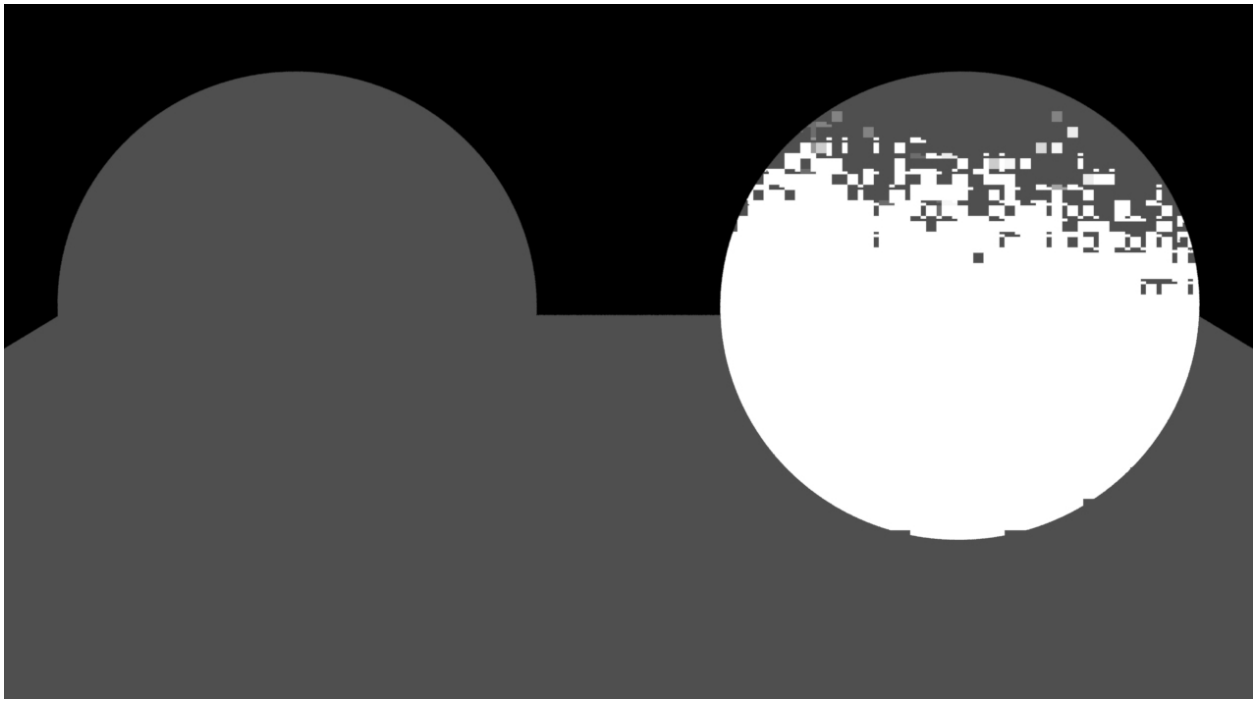
Min Ray Samples

Noise Level

These properties will give you the same control over sampling that you have on the Mantra node, but isolated to this specific object. Note that **Pixel Samples cannot be altered per object**, it is a global setting.



The sphere on the right has had the Sampling parameters added and the values adjusted to remove any noise. The rest of the objects in the scene use the sampling values set on the Mantra node. (For the purposes of this example, Noise Level: 0.01, Min Rays 1, Max Rays 2).



You can see that mantra samples the objects in the scenes at different rates, allowing you to optimize the rendering of specific objects in your scene without negatively affecting the overall sampling of your image.