Focus Shift on Long-Range Thermal Lenses

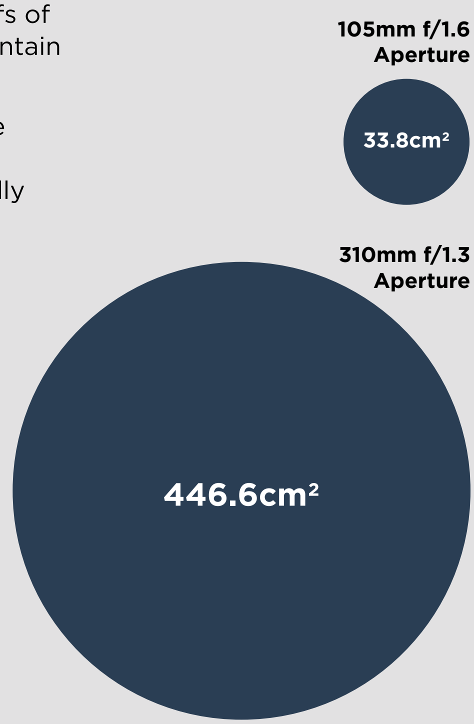
Long-range thermal lenses can experience focus shifts over time due to several factors related to thermal optics and environmental conditions. This is why Infiniti's thermal cores have a built-in autofocus timer to correct any shifts without the need for manual user intervention. This document explains the factors beyond our control that contribute to focus shifts, particularly in larger long-range lenses.

Physical size difference between a 310mm f/1.3 thermal lens and a 120mm f/1.4 thermal lens.

Thermal Expansion and Contraction

Material Properties: Thermal lenses are typically made from materials that expand and contract with temperature changes. When the lens heats up or cools down, its shape and size can change, causing the focal length to shift. Larger lenses will experience a greater shift in size due to thermal expansion, which can alter the focus point more than what is experienced with more compact lenses. Our uncooled 310mm f/1.3 thermal lens is very large, for example it will experience up to 5–10 times the focus shift of a smaller 105mm f/1.6 lens. Unfortunately one of the tradeoffs of longer-range lenses is that larger apertures are required to maintain a clear image, which does make focus shift more of an issue.

Temperature Variations: Over time, environmental temperature fluctuations cause the lens to continually expand and contract. This can lead to a gradual but significant shift in focus, especially in long-range applications where precision is critical.



Size comparison between a 105mm f/1.6 aperture (65.5mm diameter) and a 310mm f/1.3 aperture (238.5mm diameter).

Depth of Field and Aperture Size

Depth of Field (DoF): Depth of field refers to the range of distances within a scene that appear acceptably sharp in an image. A larger depth of field means more of the scene will be in focus, while a smaller depth of field means only a narrow plane of the scene will be in focus.

Aperture Size: Lenses with larger apertures (smaller f-numbers) have a shallower depth of field. In long-range thermal lenses, a large aperture is used to gather more thermal radiation which improves image detail by reducing the amount of noise. This is critical with uncooled sensors at long ranges, due to the smaller amount of light/thermal energy collected with a narrower field of view.

Impact on Focus Shift: With a shallower depth of field, any slight focus shift due to thermal expansion or environmental changes becomes much more noticeable. Small changes in the lens shape or position can cause the focus to move out of the critical plane, leading to a blurred image. Again, this issue is more present the

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more powerful the lens is (longer focal length) and especially the larger the aperture (smaller f-number).

Air Density Fluctuations

Refractive Index Changes: The refractive index of air changes with temperature. Warmer air is less dense and has a different refractive index than cooler air. This variation can alter the path of light rays passing through the thermal lens, affecting the focus.

Thermal Gradients: In long-range applications, there may be significant thermal gradients (temperature differences) in the atmosphere between the lens and the target. These gradients can bend light rays (a phenomenon known as atmospheric refraction), further contributing to focus shifts.

Heat Dissipation

Internal Heating: Thermal lenses will absorb some of the infrared radiation they are designed to focus. This absorption can cause internal heating, leading to non-uniform temperature distribution within the lens. Uneven heating can cause localized expansion, distorting the lens shape and shifting the focus. This effect is harder to manage with zoom lenses as opposed to a fixed lens, since zoom lenses require more complex designs that incorporate more lens elements than simpler fixed focal length lenses.

Long-range thermal lenses experience focus shifts over time due to a combination of material properties, environmental conditions, and optical system design factors. Thermal expansion, air density fluctuations, internal heating, and atmospheric disturbances all contribute to gradual shifts in focus. Additionally, the use of larger aperture lenses with a shallower depth of field amplifies the impact of these focus shifts, necessitating periodic recalibration and adjustment for critical applications.

Potential Autofocus Issues

At times the autofocus in thermal imaging cameras may not perform as well as expected or aniticpated. This is because autofocus systems in general often face challenges that can sometimes prevent them from achieving perfect focus. Here are some key reasons why autofocus may not always work well in these systems:

Larger Lens Focal Length: In any long-range lenses, but particularly in large aperture thermal infrared surveillance cameras, larger lens focal lengths result in a shallower depth of field. This means that the area in focus is smaller and more precise, making it harder for the autofocus system to lock onto the correct subject, especially at long distances or when the subject is moving.

User Intent: Autofocus systems in thermal cameras cannot discern what the operator intends to focus on. They may focus on the nearest heat source, the

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source with the highest temperature contrast, or the central object in the frame, which might not always be the subject of interest. This can lead to focusing on the wrong part of the scene.

Thermal Infrared Characteristics: Autofocus is particularly challenging in thermal infrared cameras due to the nature of infrared imaging. These cameras detect heat rather than visible light, and the contrast levels are much lower compared to regular optical cameras. Lower contrast makes it harder for autofocus systems, which rely on detecting edges and differences in contrast.

Atmospheric Issues Long-Range Surveillance: Autofocus is also more difficult in long-range thermal surveillance scenarios due to the increased distance between the camera and the subject. The much deeper atmosphere naturally reduces contrast and detail, making it harder for the autofocus system to find a precise focus. Additionally, atmospheric distortions, such as heat waves, can further complicate focusing.

Multiple Targets at Different Distances: When there are many different heat sources at various distances within the frame, the autofocus system may struggle to decide which target to focus on. This can result in inconsistent focus, where the camera repeatedly shifts focus between different objects, trying to find the “correct” one.

Contrast Requirements: Autofocus systems rely heavily on contrast to function effectively. They need good contrast to detect edges and make adjustments. In low-contrast thermal situations, such as environments with uniform temperatures, autofocus performance significantly degrades.

Edge Detection: Most autofocus systems in thermal cameras use simple edge detection algorithms to find the subject in focus. These algorithms look for areas of high temperature contrast to determine the sharpness of an image. However, when there are insufficient or ambiguous edges, the system may struggle to achieve accurate focus.

Overall, while autofocus technology in thermal infrared surveillance cameras has advanced over the years, it still faces inherent limitations due to the physics of thermal imaging, the complexity of real-world surveillance scenarios, and the varying requirements of different applications.