Abstract

Many fulldome producers adhere to the strong belief that only one type of lens should be used in a planetarium. That lens is a 180° fisheye as it perfectly fits the shape of the dome and causes no distortion of the image. However, this is akin to a film producer or cinematographer only ever using a 50mm standard lens by reasoning that it perfectly fits what the human eye naturally sees. In reality, cinematographers use a wide variety and range of lens sizes to their stories because they are incredibly useful and powerful tools which assist the narrative. So what is the range of lens sizes that can work in the dome? What are the advantages and disadvantages of using different lens sizes? And how can they be used to the best effect?
Abstract

Many fulldome producers adhere to the strong belief that only one type of lens should be used in a planetarium. That lens is a 180° fisheye as it perfectly fits the shape of the dome and causes no distortion of the image. However, this is akin to a film producer or cinematographer only ever using a 50mm standard lens by reasoning that it perfectly fits what the human eye naturally sees. In reality, cinematographers use a wide variety and range of lens sizes to their stories because they are incredibly useful and powerful tools which assist the narrative. So what is the range of lens sizes that can work in the dome? What are the advantages and disadvantages of using different lens sizes? And how can they be used to the best effect?

1. Introduction

At the 2012 IPS Conference in Baton Rouge, Warik Lawrance presented a paper titled, *Narrative Cinema and Film Language in Fulldome*. This paper explored a wide range of cinematic techniques used in fulldome production including, camera lenses, camera moves, lens flares, depth of field, editing and shot duration. While at the conference Warik discussed many of these techniques with other fulldome producers. He was surprised to find that all of them were strictly adhering to the concept that, in fulldome production, the only camera lens to be used must have a 180° field of view (FOV) also commonly referred to as a fisheye lens. Given that this self-imposed restriction had obviously become something of an industry standard, its practice warranted further investigation.

2. The 180° Myth

Through the last twenty years of Fulldome production the industry has begun to develop the idea that the 180° fisheye lens is the only lens to be used because:

- it matches that shape of the dome;
- images projected onto the dome will appear correct, without any distortion;
- this lack of distortion will increase the sense of immersion.

However a 180° fisheye lens is extremely limiting, and by examining how lenses are used in cinema, as well as how other lens can be used in fulldome production, it will be inevitable that this 180° myth be completely dispelled.

3. Camera lenses in traditional cinema

Claiming that the 180° fisheye lens must be used in fulldome production is the same as telling a cinematographer that only a 50mm standard lens can be used in cinema. The 50mm standard lens matches what the human eye sees (Figure 1). If one looks through a camera with a 50mm lens the image will appear exactly as it would without the camera. Any other lenses are creating a distorted view of how we perceive the world.

*Figure 1 - A 50mm lens*
Yet throughout the history of cinema, cinematographers have used an extraordinarily wide range of lenses (Figure 2).

![Figure 2 - A Range of Lenses](image)

These lenses have become essential tools for the cinematographer. They are used for a wide range of purposes, including:
- for aesthetic affect
- to help tell the story
- to evoke an emotional response in the audience
- technically achieve what would otherwise not be possible with a 50mm standard lens

This range of lenses has had an enormous impact on the entire history of cinema and the entire medium would be far inferior without them. None of the following shots (Figures 3-6) would have been possible without this range of lenses.

![Figure 3 - Ben Hur (1959) – Wide angle shot of Chariot Race. Cinematographer – Robert L. Surtees](image)
Figure 4 - Crouching Tiger Hidden Dragon (2000) – Telephoto Shot. Cinematographer – Peter Pau

Figure 5 - Un homme et une femme (1966) – Telephoto shot. Cinematographer – Claude Lelouch

Figure 6 - Mad Max 2 (1982) – Wide Angle Shot. Cinematographer - Dean Semler
4. Beijing Allskies

In 2008 the Beijing Planetarium underwent a major upgrade that included the installation of an 8K projection system. To help celebrate and commemorate this upgrade, the Beijing planetarium commissioned Sky-Skan to produce a series of 8K allsky images of famous Chinese landmarks.

To create the required images at such high resolution required image stitching; combining multiple photographic images with overlapping fields of view. For some of the Beijing allskies, Sky-Skan would use up to 73 separate images (3 rings of 24 images, plus one capping image) covering a 270° FOV. To capture as much detail in the images as possible, the images were created using bracketed exposures. Also known as high dynamic range imaging, this allowed the final images to be composited together with a much higher dynamic range than would be possible with a single image. Up to 7 different exposure settings (correct exposure, up to 3 stops overexposed and up to 3 stops underexposed) were created for each image. Some of the Beijing allskies were consequently made up of over 500 separate images (73 images x 7 exposures = 511 images).

Given this massive amount of images, Sky-Skan needed someone to composite the final 8K allsky images for them. They commissioned Warik Lawrance and Dermot Egan, to put the final images together. The final step in stitching all of the images together into one allsky image is to set the final field of view of the image. As the images were to be used in a planetarium with a 180° dome, the 180° Myth would imply the final images should have a 180° FOV to avoid any distortion. However, as this example (Figure 7) shows, the results are far from satisfactory. The ground cannot be seen at all, the viewer almost feels as though they are viewing the scene from a hole in the ground, and any sense of immersion is lost.

Figure 7 - Tiananmen Square Allsky with a 180° Field of view

The same allsky image can also be converted into a panoramic image with a 180° vertical FOV and a 360° horizontal FOV (Figure 8). Yet again, the final image feels very dissatisfying and unengaging.

Figure 8 - Tiananmen Square Panorama with a 180° vertical FOV and 360° horizontal FOV
After considerable experimentation, the final image that was created and delivered had a 225° FOV (Figure 9). This field of view proved the most immersive and natural feeling. The ground comes into view, the people in the square are visible, and the sense of immersion is palpable. With a lower FOV the image felt less immersive. However, if the FOV was increased beyond 225° the image started to feel unnatural, the buildings began to appear as though there were looming over the audience.

If this image is converted into a panorama (Figure 10), the final result is much more appealing and balanced than before.

Figure 9 - Tiananmen Square Allsky with a 225° FOV

Figure 10 - Tiananmen Square Panorama with a 225° vertical FOV and 360° horizontal FOV

5. Showing a Ground Plane

As the Beijing allskies showed, a 180° FOV is not effective for showing the ground. This is the same for any computer graphic (CG) content (Figure 11).

It does not matter how far off into the distance the background extends, it simply cannot be seen by the camera, as demonstrated in an illustration of a cross section of the camera’s view (Figure 12).

Figure 11 - Fulldome production test still using a 180° FOV

Figure 12 - Cross Section illustrating the 180° FOV of the camera
For producers who adhere to the 180° Myth, the only way to show a ground plane is to tilt the camera (Figures 13 & 14). However tilting the camera creates a different aesthetic, one that often has undesirable consequences, which is explored in the next section.

![Figure 13 - Fulldome production test still using a tilted 180° FOV](image)

![Ground Plane](image)

![Figure 14 - Cross Section illustrating the 180° FOV of the camera, comparing non-tilted to tilted](image)

With computer generated imagery it is possible to use virtual lenses with any FOV all the way up to 360°. Using a much wider FOV camera, in this case a 230°, created a much more immersive and more aesthetic result (Figures 15 & 16).

![Figure 15 - Fulldome production test still using a 230° FOV](image)

![Ground Plane](image)

![Figure 16 - Cross Section illustration comparing a 180° FOV camera with a 230° FOV camera.](image)
6. Tilting the camera

While tilting the camera, with a 180° FOV is an option for showing the ground plane, it is always going to be less immersive than using a wider FOV. In addition to this, tilting the camera in the dome can often have undesirables effects. Tilting the camera may have the effect of disorienting the audience, or creating an undesired effect of motion. When producing a 25 minute fulldome show called Tilt, a number of experiments were done to test tilting the camera in a sequence set on the deck of a rocket ship. The results looked quite acceptable on the monitor, but in the dome it created the effect that the entire deck was tilted up and the characters appeared as though they should be falling towards the viewer (Figure 17). Other viewers stated that it felt as though the rocket was taking off and accelerating upwards.

![Figure 17 - Test still comparing the effect of a tilted camera](image)

In some circumstances a fulldome producer may not have any option but to use a 180° FOV lens, and must tilt the camera in order to show the ground plane. This is generally the case when filming live action sequences for fulldome; it is extremely difficult to find lenses with a FOV wider than 180° (the widest ever made is the ultra-rare Fisheye -Nikkor 6mm f2.8 lens with a 220° FOV).

In *Our Living Climate* one sequence required the live action filming of stromatolites at Shark Bay in Western Australia. The cinematographer engaged for this sequence was restricted to a 180° FOV and consequently tilted the camera to get the stromatolites in shot (Figure 18).

While this shot worked in the dome, it had the unnatural effect (particularly in a non-tilted dome) of making the horizon appear curved. Unwrapping the image into a panorama further highlights this effect (Figure 19).

![Figure 18 - Fulldome still from Our Living Climate](image)
Interestingly, many of the problems with tilting the camera in fulldome had already been discovered in one particular form of widescreen cinema: Cinerama (Figure 20). Cinerama is a wide-screen format developed for cinema in the 1950s, part of one of many new technologies developed to combat the threat of competition from the television industry.

The original technology behind Cinerama involved three synchronized cameras sharing a single shutter. (Figures 21 & 22). This wide angle cinema format had a horizontal FOV of 146° and a vertical FOV of 63°.
All accounts of Cinerama indicate that it was a highly immersive cinema experience. Yet, due to the three cameras required to create the films, it was impossible to tilt the camera rig at all. As soon as a Cinerama camera rig is tilted the horizon begins to fall apart. Tilting the camera up would cause the left and right sides of the image to tilt downwards (Figures 23 & 24). Consequently, the Cinerama camera was never tilted in production. Given the wide vertical FOV this was never seen as a problem. Alternately, while the camera could not be tilted, it could be raised, and so crane shots were used to great effect.

Figure 22 - Demonstration of how the 3 camera, 3 projector Cinerama system works

Figure 23 - Cinerama Rig without Tilt - Westgate Bridge, Melbourne Australia

Figure 24 - Cinerama Rig tilted- Westgate Bridge, Melbourne Australia
7. More than 180

Using lenses with a FOV wider than 180° is incredibly effective in fulldome production. Whether they be used to show: the deck of a spaceship, an old world streetscape, a backyard environment, a Permian landscape, the mountains of New Zealand, or simply the balcony view of the night sky, the sense of immersion is powerful. Since the Melbourne Planetarium began producing fully-rendered fulldome productions in 2005, lenses wider than 180° have been in constant use (Figures 25 – 30).
8. Less than 180

As has been demonstrated, using lenses with a field of view wider than 180° can be of great benefit in fulldome production. So the question arises, can, and should lenses that have a field of view less than 180° be used in fulldome?

In the Melbourne Planetarium show *Tilt*, two major scenes are set in a girl’s bedroom. The confined space of the bedroom brought up a number of issues with the fulldome camera:
- The camera could see everything in each shot, making it difficult, if not impossible to have one character on screen at one time.
- Such wide angle lenses make it very difficult to avoid jump cuts.
- Tilting really wide angle lenses (i.e. more than 180° FOV) can easily disorient the audience and make them feel uncomfortable.

In one particular sequence of *Tilt* we need the character Max to exit the frame leaving Annie by herself, so that we could then cut back to Max re-entering through the bedroom door. (Figures 31 & 32). This could not have been achieved using a 180° FOV as the door would have been visible in both shots. However by reducing the FOV down to 160° it made editing between the two shots possible.

Earlier in this scene Annie is working at her desk, while Max stands on a chair behind her. Two different camera views of this scene could not be edited together as they resulted in a jump cut (Figures 33 & 34).
‘A jump cut is a cut in film editing in which two sequential shots of the same subject are taken from camera positions that vary only slightly. This type of edit gives the effect of jumping forwards in time.’ This type of cut can feel very unsettling and unnatural to an audience. To avoid this in traditional cinema a guideline called the 30 degree rule is used. ‘The 30 degree rule advises that for consecutive shots to appear "seamless," the camera position must vary at least 30 degrees from its previous position.’

While 30° works in cinema, this needs to be expanded upwards in fulldome, and quite often the camera position may need to be positioned by as much as 60°. In the example given above, the jump cut was avoided by turning it into a tracking shot. The camera simply tracked around the characters.

The very first shot of the bedroom was planned to be, what in traditional cinema would be considered, a high wide angle looking down over the room. However, this angle looked terrible and was terribly disorienting. It was very quickly discarded. A tracking shot became a much better solution, allowing the audience to see all around the room, and to be both immersed and oriented into the space.

9. Changing the focal length

It has been established that it is both possible, and in fact, desirable to use lenses with a FOV both more and less than 180° in fulldome production. However, one question remains, is it possible to change the FOV during a shot? In cinema terms, this would be referred to as changing the focal length of the shot or zooming. The zoom lens was developed for cinema in the 1960s. In the early days it was often used far too much and to a very poor effect. However, its use in cinema continues today and filmmakers have learned to use the technique much more judiciously, selectively, and to greater effect.

The effect can also be used in fulldome production, but it needs to be used even more carefully than in cinema. The opening bedroom shot in Tilt changes FOV during the shot, going from 190° to 160°. This allowed the shot to focus on the bedroom at the beginning of the shot, but then focus in on the characters at the end of the shot. This would never have worked if the camera had been static. The camera tracked throughout the shot, and this hid the fact that the shot changed FOV.

Changing the FOV can also be used to create the illusion of the camera rising up or sinking down. In Our Living Climate on particular sequence required the camera to sink down to the ocean floor. At the end of the shot on the ocean floor a very wide 230° FOV was used. However, using such a wide angle FOV at the start of the shot made it impossible for the camera not to see the ocean floor. No matter how high the camera was raised up, the ocean floor could be seen. And no matter how high the camera moved during the shot, the sense of sinking down was missing. The final option was to start the shot with a much smaller 150° FOV and have it widen out to 230° FOV during the shot (Figures 35). The sense of the camera sinking to the ocean floor was very effective.

Figure 35 - Our Living Climate zooming out from 150° FOV to 230° FOV
10. Conclusion

Throughout 10 years of fulldome production at the Melbourne Planetarium we have consistently used lenses with a FOV other than 180°. It is surprising that the 180° Myth is still so prevalent amongst fulldome producers. As has been demonstrated, using a FOV greater than 180° can create a much stronger sense of immersion and have a much more desirable aesthetic. Using lenses with smaller FOVs can be used to focus the audience, overcome editing limitations, drive the narrative and for aesthetic effect. And changing the FOV during a shot also has the potential to create shots not otherwise possible.

Most importantly, the FOV that is used is simply another means to engage with the audience and with which to tell your story. This FOV is a tool to be used in telling narratives. And the more tools that we have as filmmakers, the better we are able to tell our stories.

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Image Credits

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