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The Examination Of The Creative Potential Of Cinema Lenses

by

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Současný pohled na výběr filmových objektivů

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Praha, 2020

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Abstract, English

This thesis is investigating the question of how a contemporary cinematographer selects his/her cinema lenses for a particular film, based on set criteria, their knowledge of and experience with, as well as testing of that lens. This thesis examines the lens from a technical point of view, observing how it works with light, knowing its parameters, qualities and shortcomings to better understand how one can determine its usage creatively.
The results of this thesis are based on interviews with three cinematographers with regard to the latest films they worked on: L. Sher (Joker, 2019), César Charlone (The Two Popes, 2019) and Vladimir Smutný (A Painted Bird, 2019). The interviews examine the cinematographer's process on the particular films and offer an insight into their work processes and give a comparison between their style and artistic choices and the trends of today, which are marked by the ongoing development in lens and camera technology.

The thesis shows that modern cinematographers have their own ways of understanding and use of the lens and employing what is understood as a "psychology" of lenses. This concept is about the idea that good lensing allows the viewer to get into the mindset of the films whilst following the story.

Abstrakt (CZ)

Tato diplomová práce zkoumá otázku, jak si současní kameramani a kameramanky vybírají objektivy pro natáčení svých filmů na základě stanovených kritérií, znalostech a zkušenostech s danými objektivity a taktéž jejich testování. Tato práce zkoumá objektiv z technického hlediska, sleduje, jak pracuje se světlem, jaké má parametry, vlastnosti a nedostatky, aby bylo možno lépe pochopit, jak lze určit jeho kreativní použití. Výsledky této práce vycházejí z rozhovorů se třemi kameramany s důrazem na nejnovější filmy, na kterých pracovali: Lawrence Sher (Joker, 2019), César Charlone (Dva papežové, 2019) a Vladimír Smutný (Nabarvené ptáče, 2019). Rozhovory zkoumají kameramanův pracovní postup a proces při práci na konkrétních filmech a poskytují srovnání mezi jejich stylem, uměleckými rozhodnutími a dnešními trendy, které jsou ovlivněny pokračujícím vývojem technologie objektivů a kamer.

Tato práce ukazuje, že moderní kameramani mají své vlastní způsoby chápání a používání objektivů a že též reflektují takzvanou „psychologii“ objektivů. Tento koncept stojí na myšlence, že vhodně zvolené snímání umožňuje divákům, aby se naladili na vnitřní svět postav a zároveň sledovali jejich příběh.

Table of Contents

Introduction

Lenses are like our eyes if a close up is on a wide lens or a long lens they are both close ups one is deep space the other flat space. Long lenses give you distance and make the viewer feel safer, wide lenses put the viewer in the present moment. The narrator of the story is the camera. It is about working with the lenses as a filmmaker to feel the position, the perspective, point of view of the film.
Marek Jicha A.C.K. (Interview via Skype, 8 th of August 2020)

This thesis primary focus is the enquiry into the application of cinema lenses by the contemporary cinematographer. In today's digital age there have never been so many different types of camera technologies, shooting formats both film and digital, and lens selection as large as it is now. From vintage lenses to modern day glass, spherical to anamorphic, prime lenses to zoom lenses, how does the working cinematographer select the lenses for a film and know its right for a certain style or mood. The lens selection process can seem overwhelming, and somewhat daunting. The goal of this thesis is to demystify this process.
The first chapter will give a definition for a simple lens and an explanation of how it works. Followed by the parameters of a lens, an observation of limitations, characteristics and technical aberration, which define the performance of a lens. The second chapter takes a look at the types of cinematic lenses and they differ from photography lenses.
The third chapter focuses on the process of lens testing for filming, thus moving the paper's focus on to the practical sphere. Three interviews with contemporary cinematographers shed light on the thought processes, the actual parameters of selection of lenses and how this is interwoven with the creative process of the making of a cinematic image. The interviews are relating to the cinematographers' latest work, which were all award-winning films that premiered in 2019: *Joker* (DoP Lawrence Sher ASC), *The Two Popes* (DoP: César Charlone) and *Painted Bird* (DoP: Vladimir Smutný).

This study will narrow down the thought process of the cinematographer in the selecting a working set of lenses for given film,
We shall do so by studying the work of the three prestigious winners of the Camerimage Cinematography film festival 2019. We will analyse the work of Joker by Lawrence Sher A.S.C. and discover how he selected large format lenses for Alexa 65 camera. We shall discover his own unique philosophy on the psychology of a lens. We shall then discuss in depth Cesar Charlone‘s A.B.C. work on The Two Popes, why he chose light weight 35mm and 16mm angenieux zooms with Red Camera. Finally we shall discuss anamorphic lensing with Vladimir Smutny A.S.C on The Painted Bird.

The core question of the interviews was how the cinematographer makes his or her artistic choice of lensing to best meet the vision of the director and hence work on the part of the story that is told visually on screen.

Chapter 1. Lenses

In order to discuss lenses one must understand the basic principles about how lenses work. To do so we must first briefly discuss light. Light is of primary importance; as it is what passes through the lens that is used to create the image in the first place.
Light travels in straight lines from the sun, essentially it is a form of energy which consists of electromagnetic vibrations or waves. The speed of light in a vacuum is 299,792,458 metres per second (approximately 300000 km/s, or 186000 miles per second)[1]. There are many different types of electromagnetic waves depending on the wavelength. There are gamma rays, x-rays, ultraviolet, visible rays of colours, infrared, microwave and radio frequencies these we can say are all forms of light.
The visible spectrum that human eyes can perceive is limited and lies between 380-780 nanometers. In cinematography we often reference the primary colours of light which are Red, Green and Blue. Blue has a wavelength of 450-485nm, Green 500-565nm and Red 625-740nm, see figure 1.

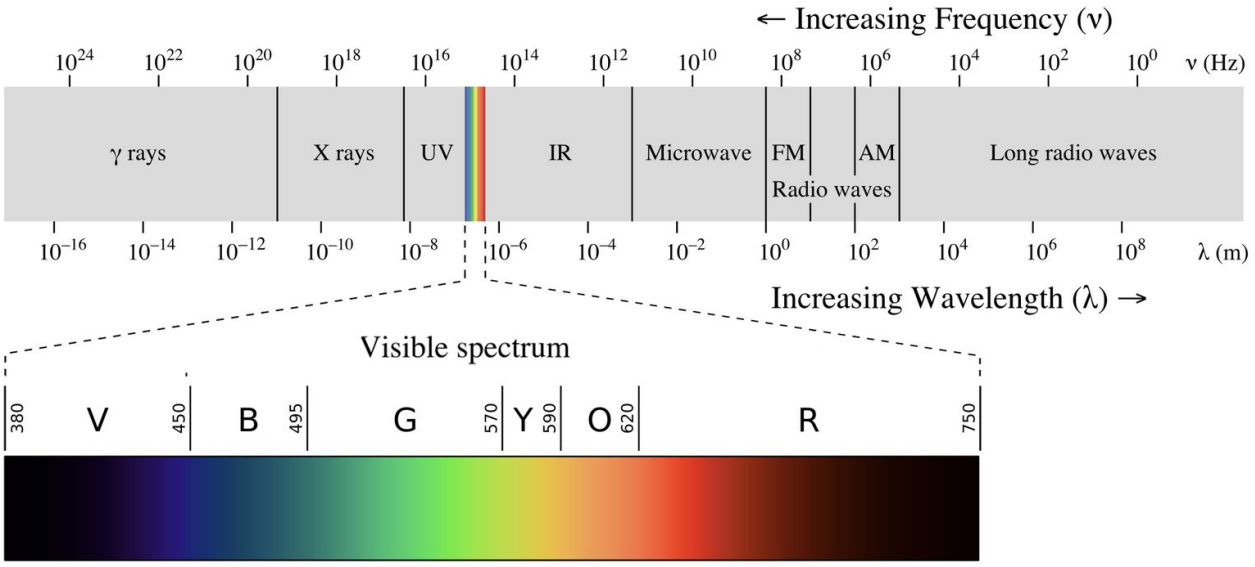


Fig. 1 The Visible Spectrum

The principle properties of visible light are intensity or amplitude, direction, frequency or wavelength spectrum (colour), and polarization[2] the latter is undetectable to the human eye. In this thesis we will only be concerned with lenses with the visible spectrum in mind.

1.a Refraction of Light

What is important to know in regarding the light to lens relationship is how a lens manages to focus. The lens can be focused due to the fact that light travels slower

[1] WIKIPEDIA https://en.wikipedia.org/wiki/Visible_spectrum

[2] Polarised light are waves of light in which vibrations only occur in a single plane. Transforming unpolarised light into polarised light is known as polarisation.

through the lens than it does in air. This is because the light refracts and without such the image could not be formed.

Refraction by definition is simply the change in the direction of a light wave passing from one medium to another, it is also a change in speed. To measure this difference in the field of optics, what is called the index of refraction is used. The index of refraction is a value calculated from the ratio of the speed of light in a vacuum, to that in the medium of larger density. This simplified equation (below) shows that **n** is the index of refraction that is calculated by dividing **c** which is the velocity of light in vacuum by **v** the phase velocity of light in the medium. [3]

$n = c/v$

To give an example the refractive index of water is 1.333 which means that light travels 1.333 times faster in a vacuum than in water. Therefore the refractive index is the factor by which the velocity of light that is passing through a material (i.e. water)..That being the case this index is an important parameter for lens designers. For example refractive indices are used for controlling the quality of different materials that are transparent or translucent to the light rays.

The phenomenon of refraction, is governed by Snell's Law, which states that the ratio of the sine of the angle of incidence to that of the angle of refraction is a constant (known as the index of refraction)[4] see figure 2. In Figure 3 we can see a real life demonstration of refraction. As we see the straw in the glass of water change direction compared to above the water in the air.

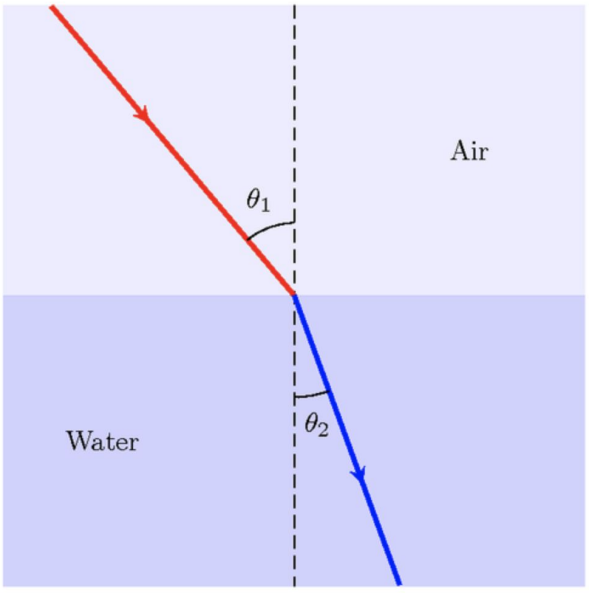


Fig 2. Refraction Diagram

[3] https://en.wikipedia.org/wiki/Light
[4] https://texample.net/tikz/examples/refraction/

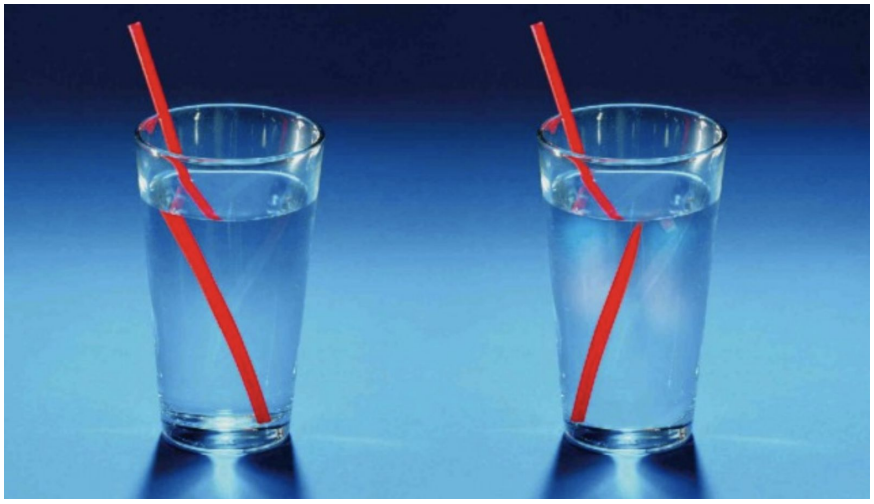
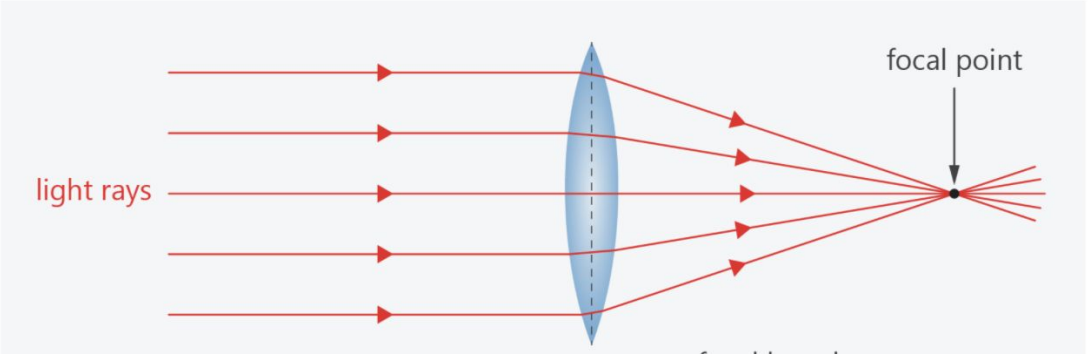


Fig 3. Real image showing refraction of light rays in a glass of water.

1.1 What is a Lens / How does it Work

The word lens comes from the latin for lentil (as early lenses resembled the pulse) it is either made from a transparent glass or polymer and has at least one curved surface. The objective lens (which means it gathers light from the object) is an image-forming optical device which comprises at least one simple lens if not more elements. Which are arranged in a series, in a straight line along axis that focuses the light by means of refraction and sometimes reflection [5]. Below we can see on this simplistic diagram (Fig.4) of a simple convex lens (idealised) how the light goes to the surface of the lens in straight lines then it is refracted meeting in focus at the rear focal point.



(Fig.4) simple convex lens (idealised)

A single or “simple” lens is just a lens that has a single element, an example for instance is reading glasses or magnifying glasses. The surface of a simple lens is either convex which bulges outwards or concave which is depressed or planar which is flat (see fig. 5). If we look at a simple lens it has two opposite surfaces, most lenses are spherical lenses

[5] https://en.wikipedia.org/wiki/Lens

which mean that the surface of the lens has a shape in part alike to the surface of a sphere.

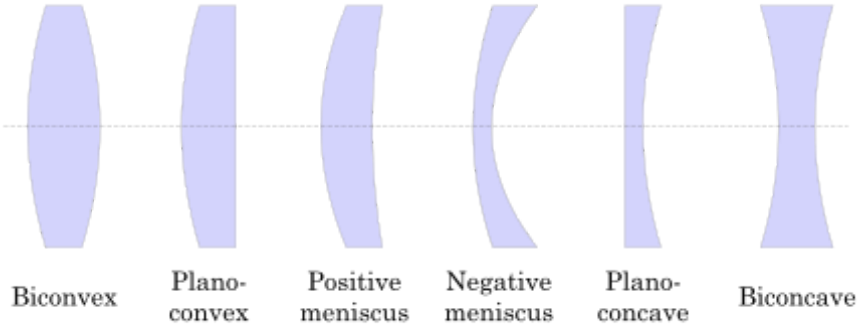
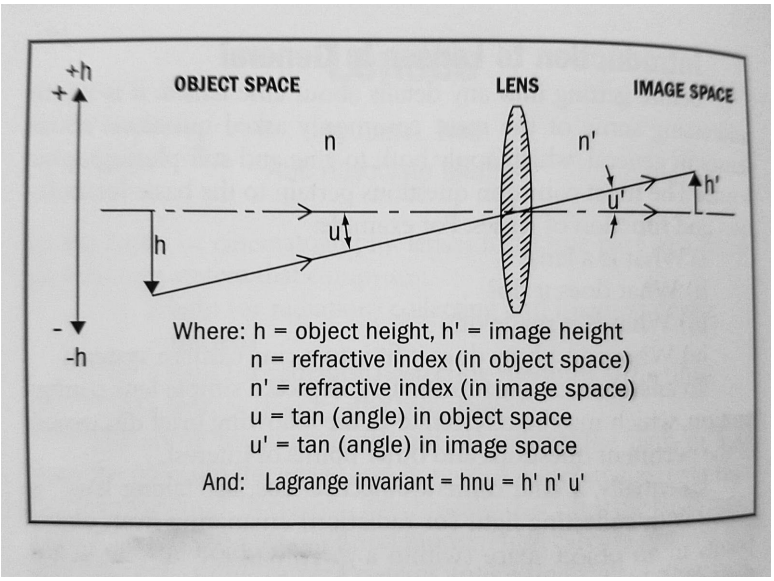


Fig 5. Types of lenses

The lens works by collecting light rays emerging (given certain field of view, focal length and format size) from the object in what they call in *Optics* as 'object space' (which is what the camera see's in front of the lens) and forms a real image in the 'image space' on the camera sensor or film negative[6] (Refer to figure 6). Important to note that object rays only form real images when they collect a point in the image side of the lens otherwise they are virtual images.

Simple lenses are not high enough quality to make up a finished professional lens on their own. A single will have aberrations for instance chromatic aberrations, where different colour light rays do not line up on the same focus point behind the lens (more about aberrations (Chapter 2.5). Therefore higher quality lenses are designed and manufactured combining multiple elements (lenses) each designed to refract light in concordance with others as determined by complicated calculations.



[6] Burum, Steven H. (ed.): ASC: American Cinematographer Manual; 9th Ed., Harcourt Brace College, Philadelphia 2009 p147

Fig. 6 Single Lens Configuration (above)

Looking (fig.6) at the schematic of the optical system (thin lens) we can observe some of the key factors that govern all cinema and photography lenses that allow the lens to form images of usable quality whilst controlling the light on the image plane.

The ***object focal point (F***) is at the front or object-side. It is the point at which light rays enter the lens parallel to the optical axis from the focal plane side where they converge on the object side of the lens (See Fig 6.)

Image focal point (F) is defined as at the rear on the image-side focal point and it is the point at which light rays from the object converge on the image plane side of the lens.

Focal plane or Image Plane is defined as the plane perpendicular to the optical axis generating from the focal point. The definition of focal plane is the distance from the camera at which the sharpest focus is attained. In this diagram the front and rear focal planes are 90 degrees to the optical axis which pass through the front and rear focal points.

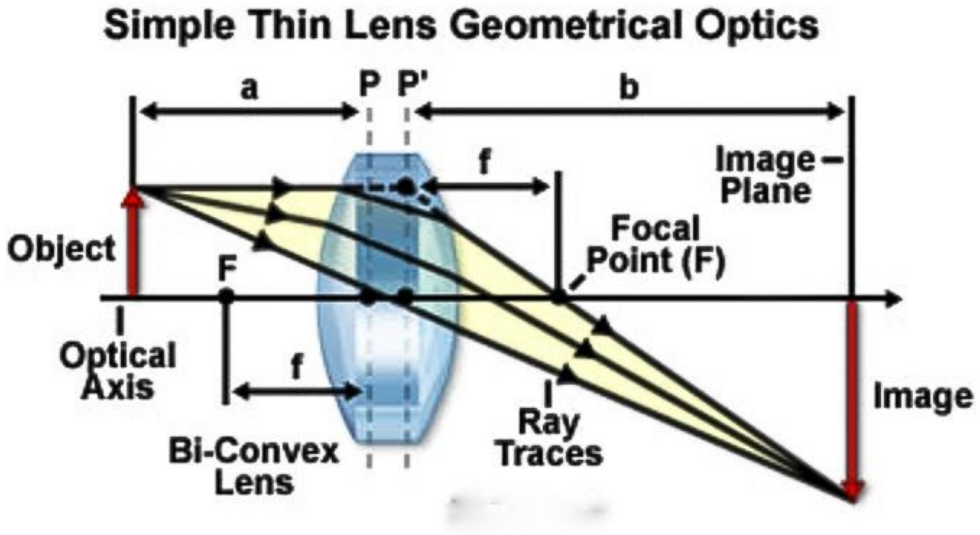


Fig 7. Optical system of thin lens

Focal Point Due to the curvature of simple lens surfaces, different light rays are refracted through differing angles, that cause an entire beam of parallel rays to converge, or to appear to diverge from a single point. This point is called the ***lens principal focus*** or more commonly as the *focal point* (depicted in lens diagram above as **F**). The refraction of rays which are emitted by the object or reflected cause the light to form a visual image of the object. The image could be smaller or larger depending on the focal length of the lens and on the distance between object and lens.

The ***principal point (P)*** is defined as the point on the optical axis at a distance equal to the focal length measured back toward the lens from the focal point. The distance between these two principal points is called the *principal point interval*. Important to know

the principal planes are crucial in defining the optical properties of the system because it is the distance of the object to the image from front to rear, the principle planes also determine the magnification of the optical system.

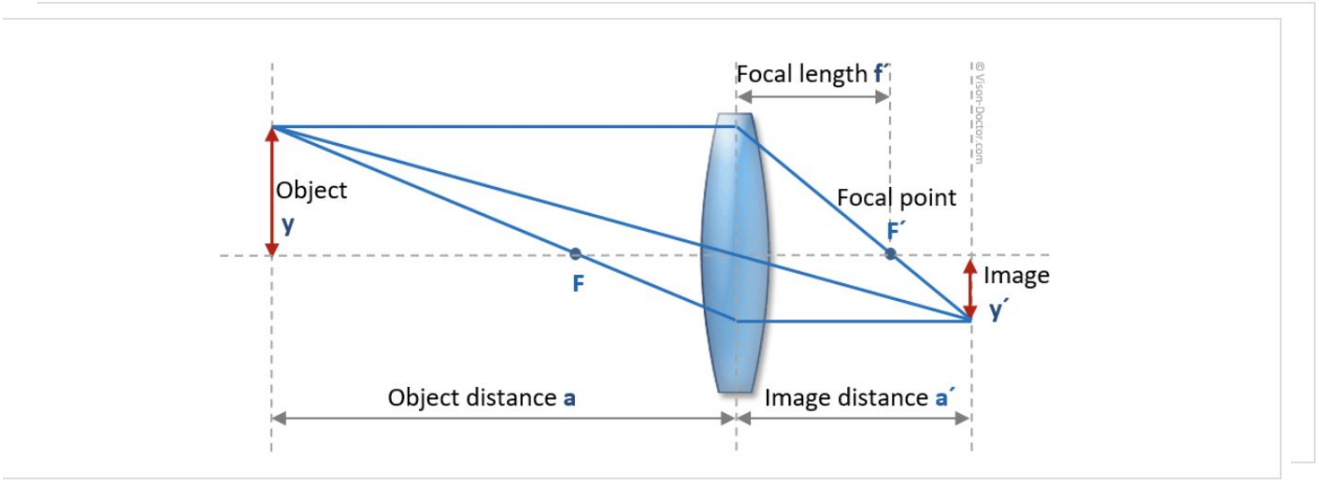


Fig 8. Focal length diagram /Focal length (f').

The focal length or focal distance of a lens (= f') is the distance along the optical axis from the lens second principal point to the focal plane (object focal plane) when the lens focuses at infinitive.[7] Or say in a simpler way the focal length of a lens is essentially the distance from the lens centre to the point at which the image of a object is formed (see Fig 8.)A lens system with a shorter focal length will bring the light rays more sharply to focus in a shorter distance and a longer focal length lens will bring the light rays more sharply to focus in a longer distance.

There is an important equation called the" Lensmaker's Equation"(Fig. 9) which relates to focal length. This equation makes it possible to calculated the focal length of a lens in air[8]

where

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)d}{nR_1R_2}\right],$$

(Fig. 9) Lensmaker's Equation

f - is the lenses focal length,
n - is the refractive index of the lens material,
R1 - is the radius of curvature of the lens surface closer to the light source

[7] https://www.britannica.com/technology/lens-optics
[8] https://en.wikipedia.org/wiki/Lens

R2 - is the radius of curvature of the lens surface farther from the light source,
D -is the thickness of the lens (the distance along the lens axis between the two surface vertices).

The focal length *f* is positive for converging lenses, and negative for diverging lenses. The reciprocal of the focal length, 1/*f*, is the optical power of the lens. If the focal length is in metres, this gives the optical power in dioptres (inverse metres).[9]

1.2 The Aperture

In order to control the amount of light that passes through the lens the aperture is installed[10]. The aperture is simply the opening or the hole through which the light travels through the lens. The aperture can change in size which increases or decreases the amount light that can pass through. It lets more light through the bigger the opening and less if the opening is smaller (see fig.10)

As the aperture closes each f number lets in half as much light. So for example if the lens is fully open at f1.4 then stopping down to f2.0 will let half as much light in (as f1.4) and then stopping down to f2.8 will let half as much light in (as f2.0). A change of one F number or one stop of light can either half the amount or double the amount of light depending which way one turns the F number. For example changing from a f-number setting of f8.0 to f5.6 doubles the amount of light that goes through the lens.

Fig.10 F-Numbers

[9] https://en.wikipedia.org/wiki/Lens
[10] One can control the quantity of light with the shutter as well but that is on the camera not the lens

To calculate the F-number we do so by dividing the focal length by diameter of the lens. See Equation below. Where F is the focal length, and D is the diameter of the entrance pupil (*effective aperture*).

The f-number *N* is given by:

$$N = \frac{f}{D}$$

We can see how this equation works for example if a lens focal length were 10mm and its entrance pupil were 5mm, the f-number or f stop would be 2, therefore f2.

1.3 Depth of Field and the Circle of Confusion

Depth of Field or Depth of Focus in the frame or image, is the distance between the nearest and farthest objects that are in acceptably sharp focus. As DoF is seen as a creative tool for the cinematographer in lensing it is worthwhile to discuss what it is and the laws that govern it. First let us observe an image with a shallow depth of field and then one with a large DoF.

One can observe the use of shallow depth of field (see fig.11) here, the image maker has used a shallow depth to isolate the subject in the foreground (in focus) and separate it from the background. In order to draw attention to what this image is about, in this case the lens. Whether one likes this effect or not the use of shallow dof is a creative choice.

Fig.11 Image of a shallow depth of field.

Whereas if compare a picture (fig.12) that has a larger dof it has a different effect. Here we have sharp focus throughout the image in the foreground, middle ground, and background. We are with the feeling we know our surroundings better than in the image of a shallow depth, this is because there is more detail to give the viewer in fig.11. Again this is a creative choice, to give a larger DoF.

Fig. 12 Image of a large DoF

We shall discuss the creative use of DoF in the interviews with the cinematographers chapter.

The parameters that determine depth of field are as follows

1) The object distance to the lens, as the depth of field is smaller for near objects than for more distant ones.

2) Focal length affects DoF because the longer the focal length has the narrower the field of view (See FoV below), the DoF is therefore reduced with longer focal lengths and the depth increases with shorter focal lengths.

3) The size of aperture used, for example the higher the f stop number (smaller aperture) the larger the depth of field, therefore more focus and detail in the image, the opposite is true for a lower f-number.

4) The Circle of Confusion is is simply, how we define what is in or out of focus (more information about the circle of confusion below)

5) Format Size, size of sensor or film negative size, affects the dof. For example the larger the format size the larger its field of view (fov). Therefore the effect of which is that longer lenses are used to maintain the same shot size and therefore the depth field is affected (more explained below).

1.4 Circle of Confusion

The circle of confusion is the smallest circle of light produced by a cone of light (not in perfect focus) when imaging a point source of light. It is also referred to as a blur spot or blur circle.[11] Lens makers accurately measure the circle of confusion in fractions of a millimetre on a target area and from this number it is used to calculate the depth of field. Different media have different circles of confusion. We can say the circle of confusion is how we define what is in and out of focus. But one must bear in mind that real lenses do

[11] https://en.wikipedia.org/wiki/Circle_of_confusion

not perfectly focus all light rays, so that even at best point of focus, a point is imaged as a spot rather than a point. The smallest such spot that a lens can produce, is often referred to as the *circle of least confusion* and therefore can be a theoretical measure of quality of how good a lens is. (see Figure 13). The smaller the size of the circle of confusion the better the lens.

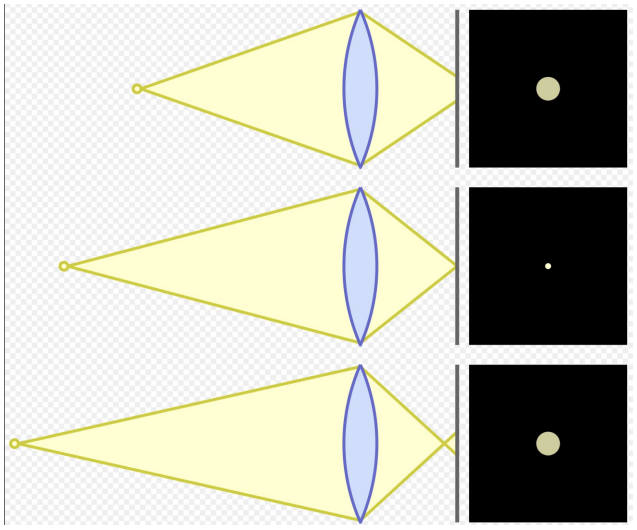


Fig. 13 The Circle of Confusion

1.5 Field of View and Format Size

Field of View is defined as the correlation between focal length and sensor or the film and the angle that determines the observable area of an optical system. The wider the focal length of the lens the wider the field of view and the longer the focal length of the lens the narrower the field of view.[12]

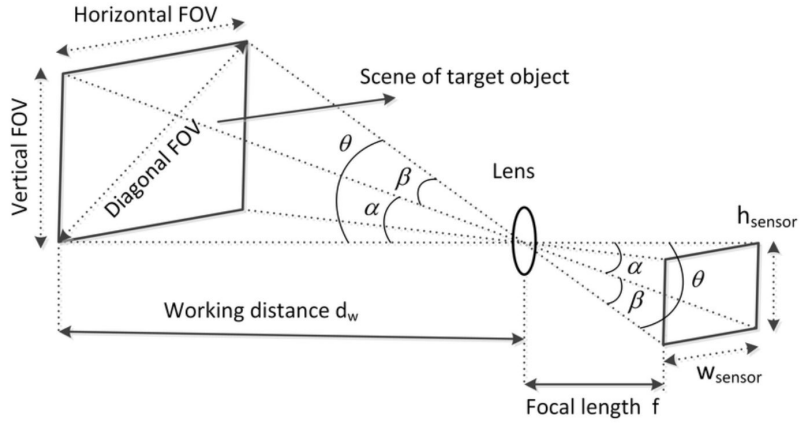


Illustration of camera lens's field of view (FOV).

Fig. 14 Camera lens FoV

[12] (http://georgeconwellcreativeblog.blogspot.com/2015/02/focal-length.html)

Here below (see fig.15) one can observe how different focal lengths change the field. The 18mm and 21mm lenses give a very wide view to this scene whereas the 85mm and 100mm give a narrower frame.

Fig.15 FoV (Real life) Different focal lengths

The format size impacts the field of view and therefore also the depth of field. For the larger the format the bigger the field of view. In figure 16, we can observe how the digital sensor size of the Alexa 65 (54.12 x 25.58) camera is almost twice as big as that of the Red Helium 8K resolution camera (29.9x15.7), therefore the field of view is almost double. Theoretically if we place a 50mm lens (that covers both sensor sizes) on these cameras then the Alexa 65 would see almost two times more than the Red Helium. How this impacts depth of field is simple for the larger the format the longer the focal lengths of lenses that need to be used. The longer the focal length the narrower the field of view.

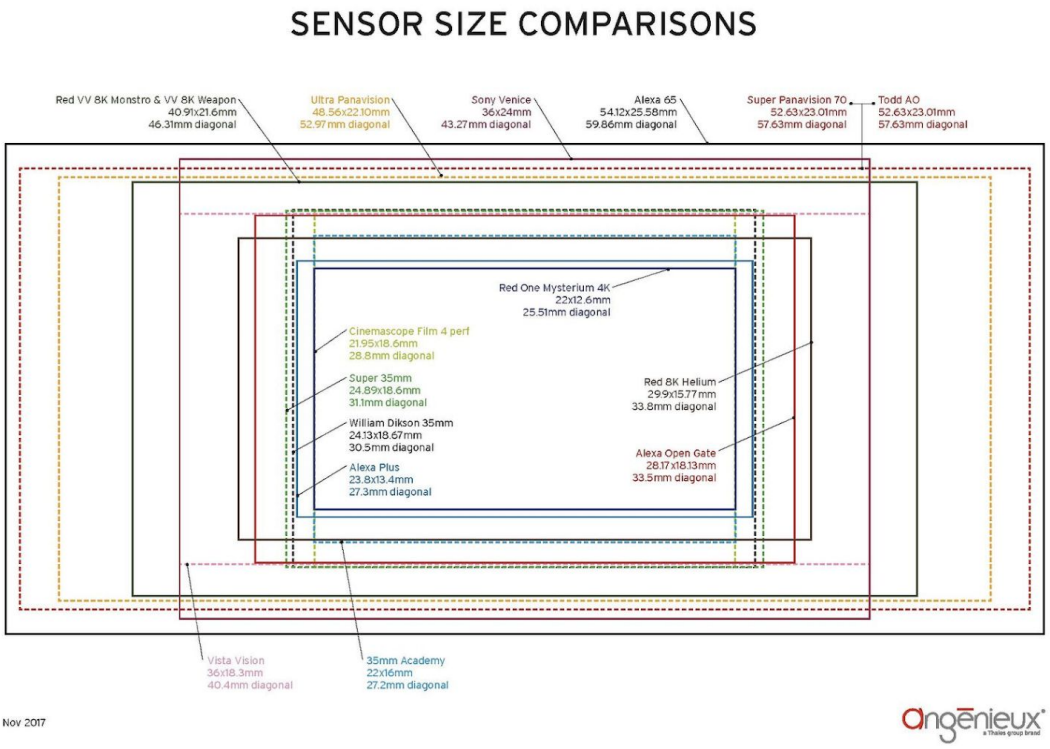


Fig 16. Sensor Size Comparisons

The lens focal measurement is a physical one and does not change if one changes the sensor size or film gate. Therefore a 50mm is still a 50mm on any shooting format. What changes when changing format is the increase or decrease in FoV. Important to note when selecting lenses for a given format is that they cover that the FoV is limited by the angle of coverage of the lens. If the angle of coverage of the lens does not cover the digital sensor or film gate then the lens image becomes visible . Typically this will result with a vignetting toward the edges of the frame.

1.7 Aberrations

The idealised lens in the field of optics, would allow all light rays emanating from the object to pass through the lens and come together focused at a single point in the image plane, free of aberrations or imperfections. In reality, this ideal does not exist, real lenses do not focus the light precisely to a single point, even when made perfectly. Therefore all lenses have aberrations, it is just that some suffer more imperfections than others.

"*In optics, **aberration** is a property of optical systems such as lenses that causes light to be spread out over some region of space rather than focused to a point".*[13] Depending on the aberration of the lens the image that aberration may produce could be unsharp, blurred and distorted.

13 Kirkpatrick, Larry; Wheeler, Gerald (1992). *Physics: A World View*(2nd ed.). Philadelphia: Harcourt Brace College Publishers. p. 410. ISBN 0-03-000602-3.

In this section we shall discuss the typical aberrations that the cinematographer should be aware of when selecting the lenses for a film. We will restrict the discussion to the five most common types of aberrations concerning cinematography which are field curvature, astigmatism, pincushion distortion, barreling and chromatic distortion[14]. Important to note that aberrations are seen (generally) by lens designers as flaws while this differs with many cinematographers who view certain aberrations of lenses not as flaws but characteristics desired that lend themselves to a given project they are working on.

Field curvature: which is also known as "Petzval field curvature," after mathematician Joseph Petzval's formula, is an aberration in which, **"**a flat object normal to the optical axis (or a non-flat object past the hyperfocal distance) cannot be brought properly into focus on a flat image plane**"**[15]. The result of this creates focus issues across the entire image. The centre of the frame is in focus while the edges are soft or blurred (see fig.17). This aberration is more prevalent in older spherical and anamorphic lenses. Artistically the effects are appreciated by some cinematographer and photographers.

Fig 17. Field Curvature

Astigmatism

Astigmatism happens in all lenses but lenses especially where the lens elements are off-axis and not perfectly aligned. Essentially, **"**astigmatism, results from the failure of a single zone of a lens to focus the image of an off-axis point at a single point, (As shown in the three-dimensional schematic) the two planes at right angles to one another passing through the optical axis are the meridian plane and the sagittal plane, the meridian plane being the one containing the off-axis object point**"**. In either case the rays do not meet in a point focus but lines perpendicular to each other**"**[16].

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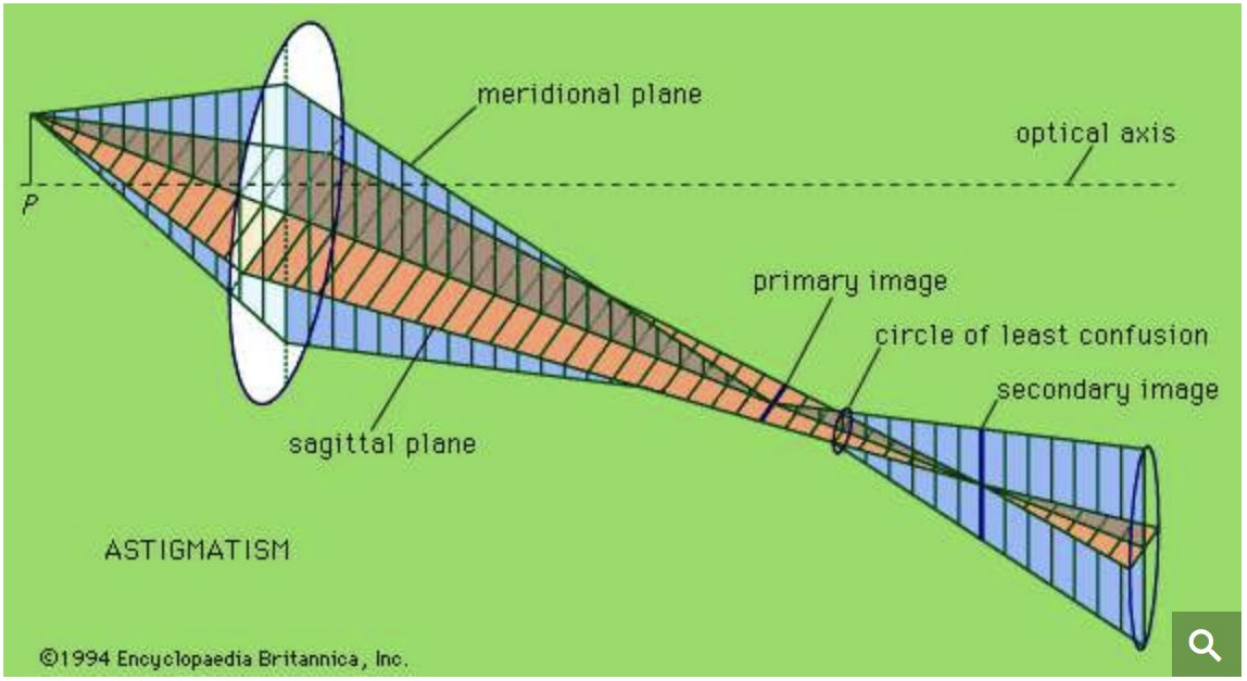
14 Wheeler, Paul (200) Practical Cinematography (1st ed). Focal Press Publishers. P31 ISBN 0-240-51555-2.

15 Riedl, Max J. (2001). *Optical Design Fundamentals for Infrared Systems*. SPIE Press. pp. 40–. ISBN 9780819440518. Retrieved 3 November 2012.

16 https://www.britannica.com/technology/aberration#ref61613

Fig 18. Astigmatism



This effect causes distortions along the edges of the frame and the corner of the image and images can look oval in shape. One can partially play this effect down by raising the f/stop for extra sharpness and therefore the increase in depth of field for extra sharpness.

Distortion

A good quality complete spherical lens very rarely shows signs of distortion; the only exception may be on the ultra wide angle lenses that do tend to barrel. The most highest quality zoom lenses show visually no detectable distortion even at the widest end of the range. Though cheaper zooms designed for TV news or video production may demonstrate distortion. However most of this distortion is at the wider range of the zooms range.[17].

Pincushion distortion and Barrel Distortion

The visible sign of pincushion distortion is that If one imagines lines across the horizontal and the vertical axis they look like they are drawn bowed inwards to the centre, like a pincushion (see fig. 19)

Whereas the Barreling distortion has the opposite effect (see fig.20), image magnification decreases from the centre of the lens. It looks like the image is coming out towards the viewer like it has been mapped around a sphere.

“Fisheye lenses”, which take hemispherical views, utilize this type of distortion as a way to map an infinitely wide object plane into a finite image area. In a zoom lens, barrel

[17] ibid. p.32.

distortion appears in the middle of the lens's focal length range and is worse at the wide-angle end of the range[18]".

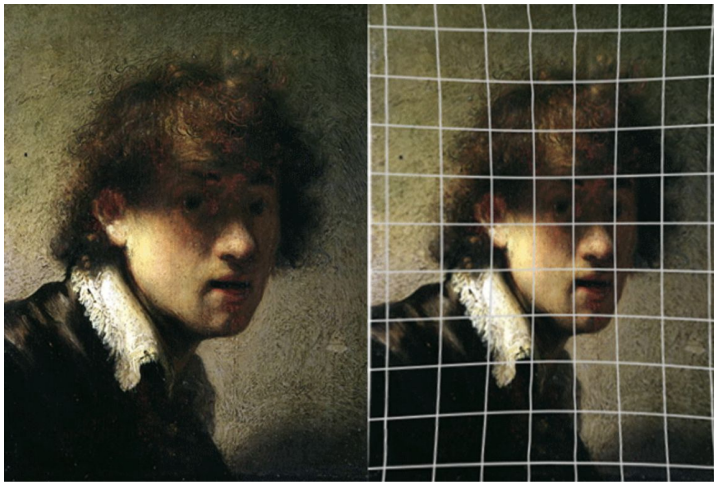


Fig.19 Pincushion Distortion

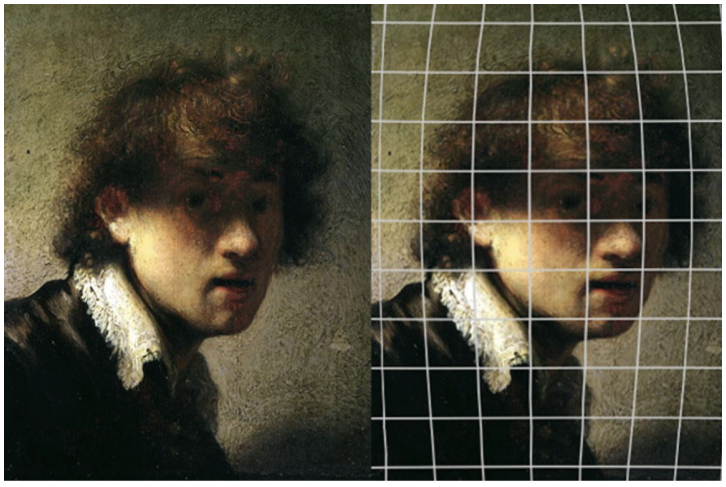


Fig. 20 Barrel Distortion

C**hromatic Aberrations**

Chromatic aberrations are a normal effect which appear on all simple lenses, typical signs are focus difference which result in colour fringes. Particularly when using wide-angle lenses. A chromatic aberration is a result of the lens inability to bring different colour wavelengths to a single focal point behind the lens. As seen in figure 21 and 22.

[18] paul van Walree. "Distortion". *Photographic optics*. Archived from the original on 29 January 2009. Retrieved 2 February 2009.P

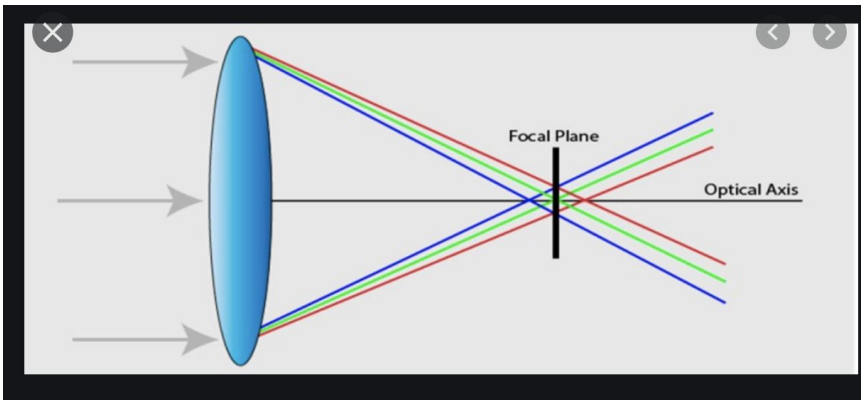


Fig.21 Diagram of a Chromatic Aberration

Fig. 22 Real C. Aberration

This aberration can be helped by stopping down the lens to have a larger depth of field and reduced blurred areas but this is not a permanent solution for a working lens. In order to accurately correct such an aberration it is important to combine lens elements (multiple single lenses). Some of which may be convex lenses, others concave highly refractive glass or material and others low-refractive glass or material. These lenses are either stuck together or mounted meticulously at precise separations in which to correct the aberrations of an element and obtain an image of sharpness.

The amount a lens suffers from aberrations has long been a measure of its quality, in terms of, both resolution and sharpness. The problem of chromatic aberrations for instance, as we have learnt about with rays of different colours focusing at different distances has been a well known
phenomenon for centuries. Issac Newton[19] believed it was such a conundrum to overcome he concentrated on using mirrors optics for his telescopes, where aberrations do not occur because the light passes through air thus remaining free of this predicament. Through the centuries as glasses of different densities became available and the understanding of designing and constructing more complex lens groups were understood it became possible to arrange and build lenses to focus wavelengths of different colours at the same point after passing through the lens.
This was accomplished by combining positive and negative lenses in gatherings so failings of the individual components combined to counteract one another, thus leaving the complete lens almost aberration free. The first lens that successfully corrected wavelengths of the visible spectrum to converge at the same point of focus were known as triplets. These lenses used three single elements made from glass that had different curvatures and densities. The triplet (see fig.23) was designed by what is now known as the company Cooke Lens by Denis Taylor in 1893[20].

19 Wheeler, Paul (200) Practical Cinematography (1st ed). Focal Press Publishers. P33 ISBN 0-240-51555-2.

20 Ibid p33

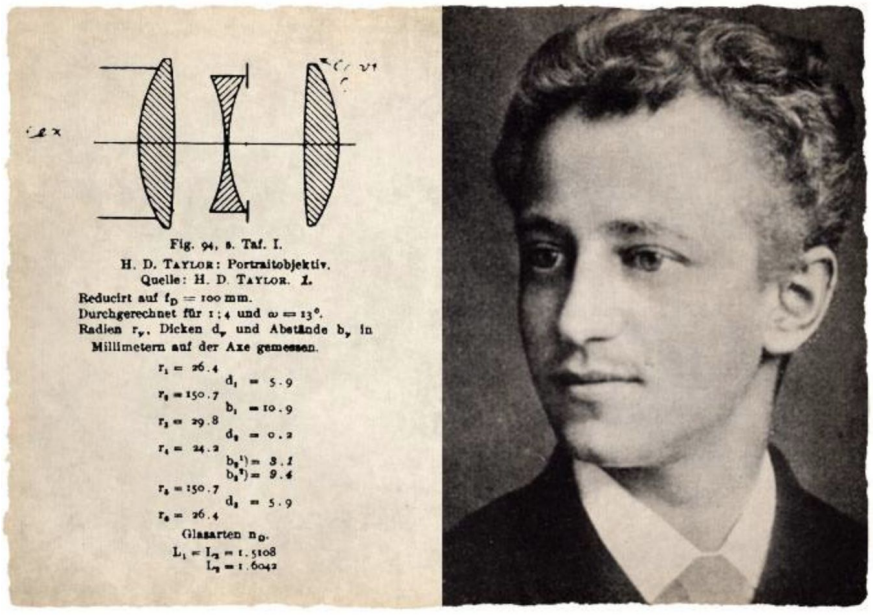


Fig. 23 Dennis Taylor and the Triplet 1893

"It was a revolutionary lens design and concept and ushering in the modern era of lens design.It was the first lens system that allowed elimination of most of the optical distortion or aberration at the outer edge of lenses... (the lens) consists of three separated lens elements. It has two biconvex lenses on the outer and a biconcave ***lens in the*** *middle and comprises a negative flint glass element in the centre with a crown glass element on each side"*[21].

The modern lens has come far since the triplet, for example the much revered Cooke S4 25mm has ten plus glass elements and the mechanics of focusing are much more sophisticated than screw thread. For contemporary high quality spherical lens aberrations are a minor issue compared to the past[22]. However I will briefly note that contemporary anamorphic lenses tend to display various aberrations and are revered for them, for example field curvature, distortion are astigmatisms[23]. Infact as we shall see in the interviews with cinematographers (with Vladimír Smutný especially) some of the typical aberrations are seen as a characteristics rather than a flaws,

[21] ibid
hhttps://www.cookeoptics.com/techdoc/B3D29DB118E18C8A85257BCF006922F8/Cooke%20Book%202016%20FDTimes-300.pdf

22 Wheeler, Paul (200) Practical Cinematography (1st ed). Focal Press Publishers. P33 ISBN 0-240-51555-2.

[23] Edited by Steven H. Burum ASC. American Cinematographer Manual, 9th Ed. 2004, Publisher The ASC Press Hollywood, California, 2004, p161

2. Types of Cinema Lenses

This subchapter is about motion picture lenses or the cinema lenses (cine lenses), named suitably as to be distinct from still photography lenses. Presently, we shall discuss in brief, the differences between cine-lenses and still photography lenses.

Later we shall discuss different focal lengths and shooting formats, contrast cinema prime to zoom lenses, and juxtapose spherical and anamorphic lenses. All in preparation and further or knowledge about selecting the lens.

There are many noticeable differences between the average cinema lenses and still photography lenses. For example in size, weight, build quality and cost. That is not to say that they are not very expensive still camera lenses, but generally speaking if one makes a comparison it is a wide difference. To make a fair comparison let's look at two comparable lenses with the same focal length and similar aperture from the same manufacturer. For example the Sigma short high speed 18mm to 35mm (light weight) zoom which one can buy as a professional photography lens or as a high-end cinema. The photography lens (f1.8), contains 17 glass elements, weighs 810g and 78mm x121mm (long) x 78mm big, the lens covers a 35mm format size and costs around 700 US dollars[24]. Its equivalent focal length, also contains 17 glass elements, 18mm to 35 Sigma T2.0 Cinema lens weighs almost double 1395g and is bigger 121.5mm x 95mm also covers a super 35mm format size and costs around 4000 US dollars[25]. The question is how come the price difference the build quality is visual more solid and the cine lens appears more durable than the photography. The aperture ring is de-clicked for the cine-lens to allow smooth aperture changes whereas this is not the case with the photography lens.

The cinema lens has more markings for different focus distances (from the lens to infinity) whereas the photography has not. This makes it easier for the 1st Camera Assistant (focus puller) to pull focus because the cine lens also has a focus turn of 180 degrees (for smooth focus changes) while the photography lens only has 131 degree focus turn which makes it harder to pull focus.

The other marked difference is that the cinema lens (and all cinema lenses) has T-stops which are an accurate measure of the amount of light that passes through the lens whereas a photography lens has F-stops, a less accurate measure.

The T. stands for Transmission which refers to light loss inside the lens that does not reach the image plane. Lenses marked with Fstops do not take into account the loss of light in the lens system. Which is fine for photography but for cinematography, when a scene from a movie can be made from shots (which should look continuous in terms of mood and illuminance) it is important for the cinematographer to maintain control over Tstop, especially when using changing between different types of lenses and focal lengths.

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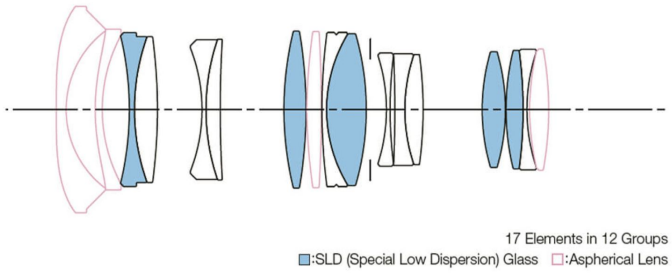
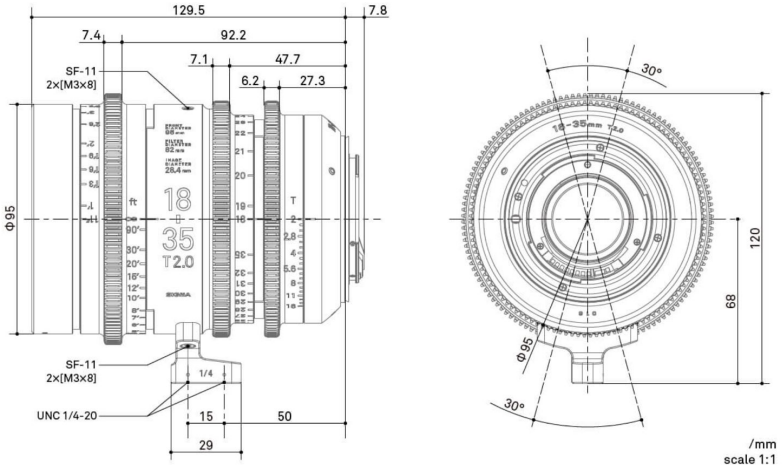
[24] https://www.bhphotovideo.com/c/product/967344-REG/sigma_18_35mm_f1_8_dc_hsm.html
[25] https://www.bhphotovideo.com/c/product/1324192-REG/sigma_210966_18_35mm_t2_cine_zoom.html

Lens construction



Dimensional drawing



Figs. 24, 25 Sigma 18-35 HS Cine - Zoom T.20

2.1 Primes versus Zooms

It should be noted that modern cinema prime lenses (spherical) show very few discernible issues regarding aberrations. When they do, it tends to be wide angle primes lenses which show flaws like barrel breathing and vignetting[26] .
It is also true that expensive high quality zoom lenses (spherical) show few visible distortions however the same cannot be said for low cost zooms designed for television broadcast, e.g. news gathering. Most commonly lower quality lenses will show barreling and other distortion aberrations, mostly this is seen at the wider and middle range of a zoom‘s focal length[27].
Primes lenses are generally faster lenses (smaller t-stops that let in more light), lighter and smaller than zoom lenses as they on average contain less glass. In fact **a prime cinema**

[26] Vignetting Is a reduction of an image's brightness or saturation toward the periphery compared to the image center.
27 Wheeler, Paul (2000) Practical Cinematography (1st ed). Focal Press Publishers. P33 ISBN 0-240-51555-2.

lens may contain between two to ten elements whilst a zoom lens may contain as many as 18-20 single lens elements.
The choice of using prime lenses or zoom lenses is dependent on the demands of the film project. For example, if a film is going for a long lensed documentary style approach this could influence the cinematographer towards using a zoom lens though the opposite could also be true. Selecting a prime over zoom or vice versa can have as much to do with the cinematographer's preference, as it does with an aesthetic consideration for the film.

2.2 Spherical versus Anamorphic

In comparing spherical lenses to anamorphic lenses we will just refer to the 35mm shooting format, as to not get confused.
'In terms of absolute or theoretical image quality and overall aberration correction, there is no doubt that spherical lenses are superior to anamorphic'.

Anamorphic lenses suffer from many more aberrations like astigmatisms, field curvature and barrel distortions. Whilst Spherical lenses are considered the standard lens type and almost always favoured when cinematographers are shooting aspect ratios of 1.33, 1.66, 1.78, 1.85. Whereas anamorphics have always been chosen for their increased field of view to produce a true 2.39 aspect ratio image (without cropping top and bottom like spherical lenses used in widescreen format[28]) .

Traditionally anamorphic lenses were designed and built to create a wider viewing experience that would attract audiences to the cinema and rival television. In the early years, the increased format size was used for such epic large scale movies like Lawrence of Arabia (1962).
The advantage of anamorphic lenses over spherical lenses is they produce an image 59% larger when one compares an aspect ratio of 1.85 to 2.39 where the anamorphic lens has a two time squeeze.[29] Anamorphic lenses work by squeezing the picture horizontally, (while not squeezing the vertical) to capture more image on the sensor or film negative and then later the image is unsqueezed in the cinema or edit room. For example anamorphised (squeezed) image of a 1.33 aspect ratio will be unsqueezed and broaden out into image with 2.39 aspect ratio.

The anamorphic lens is in fact a hybrid design which contains either a spherical prime or zoom lens in addition to anamorphic (adaptor) lens which is either fitted at the front or back of the lens. Usually these anamorphic elements are cylindrical in design that vary for example with the shape. According to American Society of Cinematography Manual a front fitted anamorphic lens is higher in quality to a back-fitted anamorphic element. The advantage with Spherical lenses is that they behave in a way that can be quantified, anamorphic lenses do not. The issue with anamorphic is that the depth of field behaves

[28] We are talking a widescreen format with a aspect ratio of 2.39
[29] Ibid p34

differently from the horizontal to the vertical. The horizontal axis is 2 times more shallow than 35mm where the vertical axis is the same.[30]
As we have observed, in choosing to work with a spherical lens over anamorphic lens, the spherical gives a more reliably sharp and technically better image. Whilst anamorphic lenses offer less than perfect image with an increase in image resolution a larger format and as a consequence a shallower depth-of-field.

Chapter 3. Testing Lenses

The cinematographer and their focus puller must be confident in the set of lenses they select. In general their set of lenses would most probably consist of prime lenses, wide, medium and long and perhaps a zoom or two. Generally speaking there are common aspects and characteristics that most working cinematographers and focus puller's are most interested in when looking at the lens for its overall quality.

Characteristics of the lenses is what lenses are tested for. Generally speaking, in testing lenses the cinematographer and his/her camera assistants test the lenses for their resolution which means the ability of the lense to resolve an image to its finest detail. This is a measure of both sharpness and contrast and can only be done with a lense chart. They test for aberrations in the lens. They test the colour of the lens against black and white images to see if the lense itself gives a chromatic tint. It is tested if the lens focus breathes. That means that when one shifts a lens focus it changes the field of view. Lens Breathing - essentially is a change in shift of the angle of view when focusing, it's like a small or big jump in the picture. (It is stronger in low quality zooms and anamorphic lenses).

They test for infinity focus of the lens. More commonly the camera assistant tests without the cinematographer the focus of the lens. They check the lenses' ability to close-focus and to focus on infinity. They test against the lens markings at measured distances which are in feet and metres for whether they are correct. If the markings on the lense are not correct, the camera assistant re-marks the lens.

Furthermore they test the flaring of the lens. Lens flare refers to the effect a light source has on the lens either if it is looking into the lens or just off the lens. The effect of which is a scattering of light by a lens flaring that affects the lens system. Commonly occurs when shooting towards the sun. Lenses that have a large number of elements usually show greater lens flare effects. Flare can manifest in different ways often in the shape of the iris diaphragm, when the light follows through the pathway of the lens that contains one or more reflections from the lens surfaces. Anamorphic flares are popular and often done for effect on films shot anamorphically where horizontal light streaks protrude from the light source shot by the lens. A typical example is on car headlights. The visual artefacts of

[30] Ibid p37

flare can also manifest as a glaring effect across the whole image reducing colour saturation and contrast.

ALso, they test the bokeh, that is the shape of the out-of-focus area, which means how the points in out-of-focus areas look. In the case of spherical lenses how round these are or polygonal. In the case of anamorphic lenses how thick or thin the ellipse is. Lenses with 11, 12, or 15 blade iris diaphragms are often claimed to excel in bokeh quality especially of spherical lenses. The shape of the bokeh is determined by types of lens Spherical (circular) bokeh and Anamorphic (oval) bokeh (elliptical which changes shape depending on squeeze factor) and the other parameter of bokeh is aperture blades of the iris diaphragm (right term).

In this chapter we will look at a case of focus puller Gregory Irwin (sourced from a cinematography forum) and at his process.[31]

Chapter 3. 1 Case Study of Focus Puller

Writing on cinematography.com forum for professional filmmakers, career focus-puller Gregory Irwin (Joker, Hangover II and III) went into detail about his process of testing lenses.

'As a career first assistant cameraman , I've been testing lenses for over 30 years. My first point is that ACs generally test lenses - not DoPs."

Irwin states that lens tests are done during camera preparation which he generally takes two to four weeks on a feature film for and one week exclusively just for lens testing.

"*First of all, I arrange ahead of time for the rental house to supply between 4-5 sets of similar primes and zooms.… On my first day of prep, I'll make sure that the camera body that I'm testing the lenses on is prepped as far as ground glass collimation, back focus, flange depth, etc. then I do my first pass of all of the lens sets by checking their focusing ability on a simple lens chart. "*

This is where Irwin starts if he does not like the sharpness and contrast of the lens, or the look from it. He eliminates it straight away from his pool of lenses. After meticulously going through all lenses in this way, those that passed go on to a lens projector. This projector beams a lens chart on a wall in a dark room through each of the lenses. This is where Irwin can scrutinise each individual lens, particularly observing evenness of

[31] The following passage is to be found in the online source:
https://cinematography.com/index.php?/profile/22146-gregory-irwin/content/

sharpness across the field of view, general colour, chromatic aberrations, astigmatism and internal flare. Through this feedback he takes lenses out of his pool and stage two of testing is complete.

The third round when shooting on film, is now testing the lenses that are left in the pool on film. This process is his own unique way of testing but interesting to observe. He makes a large lens chart approximately six to eight feet wide by four to five feet high. The chart consists of a collage of duplicates of contrasty black and white magazine photographs. He uses black and white images because he wants no colour bias and very sharp detail. One of his preferences is magazine advertisements for watches. Once he has collected the numerous photographs he selects one for the centre of the chart. After such he begins to build outwards, horizontally and vertically from the centre with all his duplicate photographs to achieve symmetry. Once complete, he lights this to a T2.8 exposure and records the response of his remaining lenses from the widest to the longest. He moves the camera back as he puts longer lenses on the camera so he fills his field of view with as much chart as he can. He uses post-its with the focal lengths and series number of each lens and sticks it on the chart for identification when viewing the test footage. Then he reviews the test footage on a large screen and it is very easy for him to see the colour differences between each lens, whether they are cold (blueish) or warm (reddish). He also observes the contrast and sharpness differences between lenses. He now makes his final choices for his lens set. He also checks that the selected aperture is accurate by scrutinizing the lenses.

'|As far as digital lens prepping is concerned, all of the above applies with the exception of actually recording the test. This assumes that you have a calibrated monitor to judge your lenses on. This completes my testing process and I now feel confident that I can go forth and trust my lens choices'.

Chapter 4. Interviews Intro

It can be a daunting task for the cinematographer to decide which set of lenses he or she should choose from. Since the advent of digital cinematography, lens trends have changed. Even more so in the last few years with larger sensor cameras available with capabilities of recording of 8K and even 12K[32]) resolution. We have seen cinematographers use a great variety of lenses and especially vintage lenses. The purpose is to pair a high resolution camera sensor with a softer lens to acquire a less sharp digital image that is more pleasing to the eye.

The cinema lens market is expected to grow from USD 3,050.5 Billion in 2017, to USD 4,518.0 Billion in 2024. Factors propelling the growth of the cinema lens market include strong demand in cinema and video production for higher quality & continuous motion recording lenses [33].

With higher demand for new lenses, and a greater selection of glass on the market including older vintage lenses being dusted down and brought out of storage, the choice can overwhelm the cinematographer. It is less common for DoPs to use one set of lenses for their entire career such as cinematographers in the past did for example Oscar nominated DoP Richard Greatrex. He stated that he used Canon K35s for his whole career (FN Cinemajam workshop, London 2016).
This thesis is taking a look at the ways, the criteria and methodology by which contemporary cinematographers choose the lenses for their projects. Tho following chapter is based on interviews with three working DoPs who were the winners of the 2019 CameraImage Festival of the Art of Cinematography
American DoP Lawrence Sher (Joker, 2019), Uruguayan DoP César Charlone (The Two Popes, 2019) and Czech DoP Vladimir Smutny ACK (A Painted Bird, 2019)

The CameraImage Film Festival presents one of the most celebrated cinematography awards. It is therefore a good benchmark for highly professional and contemporary use of lensing. Through the interviews we will be able to take a look at the individual approach which leads to the methods of selection. It can give an insight into selection processes for lenses in motion picture production.

4.1 Lawrence Sher A.S.C on Joker, (2019)

Joker won the Golden Frog and the Audience Award at Camerimage 2019, and was nominated for 11 Oscars, including Best Cinematography. The film was lensed by

[32] https://www.blackmagicdesign.com/products/blackmagicursaminipro
[33] https://www.globenewswire.com/news-release/2018/11/20/1654334/0/en/Cine-Lens-Changing-Dynamics-Of-Digital-Cinematography-Growing-at-a-CAGR-of-5-8-during-2018-2024.html)

Lawrence Sher, ASC[34], and uses cutting edge technology, large format cameras (Alexa 65) and some of the newest lenses. The film is a story based on a character from the DC Comics universe, the Joker. It centers solely on the character development of a mentally imbalanced middle-aged man, Arthur Fleck who after losing his job and dignity continues on a downward spiral to become the infamous Joker, Batman's nemesis.
The film cleverly crafts empathy for a disturbed and dangerous lead character, partly through the careful choice of lensing which keeps us inside the lead Arthur Flecks (Joaquin Phoenix) head space throughout the whole movie. The audience is left with the feeling we do not quite know what is real and what is Arthur's fantasy.

When director Todd Phillips sent DoP Sher the script of *Joker* he told him it was not going to be the usual action-packed comic book (like previous superhero films) movie but more of a character driven movie akin to those made in the American New Wave Era.
Sher and Phillips drew inspiration from seminal films from the 1970s, among them Martin Scoreseses, Taxi Driver and Sidney Lumets, Network.
These films had a look as well as a pessimistic anti-establishment energy, featuring a disenfranchised, mentally unstable lead character that inspired them. The pictures oscillate between reality and Arthur Flecks perception and so
Lawrence Sher and the director Todd Philipps tried to mirror an unreliable narrator (Fleck) by the format and senses they worked with.

Sher and Phillips devised a plan for the lensing for the outside world and the intimate world of Arthurs private life and mind. The two areas would be lensed differently.
For example when Arthur Fleck is photographed in the outside world in the street or on the bus in a public space he would predominantly be shot on longer focal lenses which would make the audience feel like they are watching him in a voyeuristic way. When he is in his apartment with his mother or at the psychiatrists office he is photographed on wider lenses to give an intimate feeling. But when Fleck is entirely in his fantasy world it is a wide lens again.

"(...) In his internal world it is all about being closer on wider lenses…So even on the Murray Franklin show, it is this external world focus where we shot with longer lenses further away. Whereas when he is on the fantasy set of the Murray Show and he goes down to talk to Murray that was shot with a little more with wider lenses close and you know because I wanted the intimacy – that is what is in his head… a little bit of the psychology of its choice is there." (Lawrence Sher)

In order to make apparent Arthur Fleck's isolation, shallow depth of field was considered throughout most of the film. The shallow depth of field renders the background soft and therefore the detail is on the subject solely.

[34] Member of the American Society of Cinematographers

The selection of lenses that were used on Joker was impacted not just by the approach but by the choice of shooting format and technology of the cameras. Phillips originally wanted to shoot on film, preferring the texture and grainy look and with a budget of around 50 Million US dollars, Sher considered to shoot on 70mm film. The reason being high quality image capturing but the format allows a shallow depth of field which is what Sher and Phillips wanted to isolate Fleck in the frame space.

The film´s producers however discouraged 70mm because of logistics. Sher and Phillips then set their sights on 35mm Anamorphic film which also allows for the shallow look as the format is 59 percent larger than 4 perf 35mm (CHECK). They shot some tests which they both found to be pleasing. But there were some drawbacks to shooting anamorphic. There was an anamorphic lense with close enough focus. What they wanted to do was stay close to the actor for most of the film. Furthermore they were concerned about monitoring the focus during the shoot.
So when at the last minute the director suggested they should shoot a test with the Alexa 65 (A digital camera with the largest sensor on the market) Sher agreed. He had worked with it before when he shot *Godzilla* which was shot with Anamorphic lenses. Sher had shot on the Alexa 65 before the film *Godzilla*, where we shot on anamorphic Panavision Primos, Primo 70, C-, D-, E-, G-, T-Series lenses. So he was confident with this format.The Alexa 65 offered a large depth because of the increased sensor size compared to S35 format and it requires longer focal lengths which result in a more shallow look compared to short ones.

'We wanted an intimate portrayal, close to the actors but wider lenses the Alexa 65 gave us even longer focal length..like a water-depth field of view. So that the separation thing that happens with large format was perfect for the intimacy'.

The camera tests with the actors were successful. But they still favoured the look of the film material.

Another factor was the best working practice throughout production. In their case, Sher explained that they were working with a lead actor (Joaquin Phoenix) who prefers to work in a free, improvised way and would not necessarily hit focus marks on the floor. This and the fact that monitoring the image from the camera digitally is more accurate than shooting with film leading Phillips and Sher to agree that a large digital format that the Alexa 65 provides was the way to go.

"(…)The beautiful thing obviously about digital is you can be really precise in term of like, Oh you can see what T2.8 looks compared to T1.3 instantly, you see if we change this little thing, you see how to focus right close…You can see that on digital on a monitor…I say the one thing about digital is it allows camera people to be a little bit more adventurous and precise."

During the tests with the Alexa 65, Sher decided, because he was shooting on a bigger format he didn't need to shoot on anamorphic lenses because the format was already giving him a shallow aesthetic with large apertures.

“ (…) In the tests using the spherical glass with a 1.85 aspect ratio with large format camera like Alexis 65, it just was like from the moment we lensed up the first shot it felt right. It just had that separation that was just everything I wanted… Cinematographer liked anamorphic because of that inherent quality of the shallow depth of field. And you could have wide shots and still have separation, all these beautiful things that come with shooting anamorphic.Now suddenly 65 large format camera gives you a spherical version of the same fact. Which I think just really opens up the world. 65mm format spherical lenses absolutely felt the right choice. You think of a movie like Arrival or HER the DoPs were like we have got these digital cameras and now we don’t have to worry about the focus therefore let’s shoot wide open at T1.3 and it became a whole trend. Well now with Alexa 65, we don’t have to shoot it at T1.3, we can shoot it in T2.8 with those medium format lenses and have the same effect and because the formats larger (with a larger field of view) we can shoot in smaller spaces and get separation.”

With a busy pre production schedule, Sher instructed his 1st Assistant, Gregory Irwin, who has been a career focus puller for over 35 years to select the spherical lenses under the parameters set by Sher. These restrictions included that the lenses had to cover the large sensor size, they also had to have the ability to close focus at small distances to enable the camera to be as close to the character as possible. The lens had to be fast, apertures with low T-stops to shoot in low light levels and, crucially, the lenses were not to be overtly sharp because of the pairing of them with a large resolution camera sensor.

“ (...)I didn’t want the lenses to be too sharp. I wanted the film to feel like it could have been made back in the day (the 1970s or early 80s) therefore lenses were de-tuned to feel like they didn’t have that ultra-sharpness …As well as not being too contrasty because I knew I could light the contrast…I didn’t want them to add internal sharpness within the lens. “

Focus puller Gregory Irwin put together a lens set that has been described by Sher and Irwin as a Frankenstein set of lenses as they are put together from different manufacturers as they were the best for Irwin that fitted Sher’s parameter and met Irwins, standards of user-ability.

FIG. 26. List of Lenses on Joker

Irvin states, *'the Canon T1.3s Compact primes, the Nikon 58mm and the T2 Leica 90mm were the workhorses that they employed the most. I was able (along with the rental) to detune certain lenses to make them match better in terms of colour and contrast."*

Detuning is a process that involves altering the look of lenses, by making modifications like element adjustment, or the removal of lens coatings for enhancing flare. Work is carried out by skilled lens specialists. In observing the above list of lenses one can see how Shers prioritised fast lenses with big aperture and closed focus. It was less important to him to have them, all by the same manufacturer. Conventional wisdom suggests that cinematographers should stick to one or two lens sets in the past. But now with the advent of digital post-production and advanced lensing crafting techniques it is easy to match images shot with different cameras and lenses than ever before.

Fig. 27 A list of alternative 65mm lens

Sher and Irwin could have followed conventional wisdom of picking lenses from one or two manufactures and therefore choosing from one set of ARRI DNA lenses for the 65 Format but that would not have met Shers requirements. As stated by Irwin his workhorse lenses were the Nikon 58mm and Leica 90mm.

Well for me,…the idea that in the 70s and 80s we weren't as obsessed with the precision of things…So that's why I didn't even mind that my prime lenses were all from different manufacturers…So in that way it didn't feel like this studio DC movie.

After the lenses were selected, Sher did a few tests with Joaquin Phoenix. Shooting tests in the evening in a couple of the film locations in the city and in Chinatown. She tested the camera and lenses with the lead actor at a real location at night to see how the camera's lenses responded to the low/light conditions that were to be found in the street as it were. He tested the flare of the lens, different colour temperature settings in the camera at night and he tested the close-focus and the breathing of the lenses. Breathing is how big the picture actually jumps in size when you pull from one focus plane to another focus plane.

The Joker was almost exclusively shot on two cameras. The reason was to cover the nuances of Phoenixes performance as Fleck and to allow him space to move. However the 2 cameras were not employed in a standard multiple camera situation.

"(...)feels like traditionally in a two-camera-world you have the A camera in the wide lens and the B-camera for the close-up….But we never chose to shoot two cameras like one wider and one tighter it's always like one camera is over here, and the other camera wants brand new coverage as far away from the other camera. We were not always cross-covering…. But shooting divergently, so if one camera is here, the other one wants to be like a 45 degree angle difference instead of next to it. I might be wide in the corner of the room on B camera and then I'd tell Jeff, Ok you got to be here before I see your camera. So often I worked more on a medium lens as a "secondary master" and we both marched in, we both sustained our axises. We wanted it to feel like it was a single camera shoot. "

In treating the A and B camera in this way Sher avoided making two mediocre shots and often found he could have two very good shots.

" (...) The B-Camera was always secondary, but always, it had to be additive so not to compromise the A-camera. And if it was like the A-camera had such a field of view in which the only angel I could get with the B camera was quite experimental, I would go for that."

If we look at the second scene of the film where Arthur Fleck, works as the hired clown outside the music store spinning a big yellow sign advertising the store. Here Sher frames Fleck on long lenses with shallow depth of field to make him seem isolated in a big world.

After a gang of youths steal his sign and he gives chase, the scene is shot with multiple cameras, with long lenses with at least 45 degree angle changes throughout to create an exciting and dramatic scene.

It is only when Fleck is on the ground near the end of this scene after 30 plus long lensed shots that Sher slowly tracks the camera into Fleck on a wide angle lens.

First note I made on that scene was long lens, long lens, long lens, far away as possible (see fig. 28) So if he feels like he is like another human being lost in this world that's big. But it's only in the end, when they run away, Then we are finally alone with him. Then we have the wide creep in on the 58mm lens, suddenly we are closer on an intimate lens. You know the idea that closer intimacy will connect us more because we are basically in the same space. If you look at him generally speaking at a scene where he is surrounded by people or with other people, are longer lenses. But when he is alone and by himself generally we are in that sort of more intimate like 58, 80mm, 35mm.

Fig 28. *Joker*. Scene 2. Dir. Todd Phillips. 2019

4.1.a Psychology of the Lens

Sher talks about something he calls the ”Psychology of the Lens”. To him, close ups on a wider lens may feel more intimate but they do not necessarily feel more real and therefore he thinks the audience may feel the same. He makes the point that when the lens proximity to the main character is very close that it can have the opposite feeling of real, as in reality you may never get that close to a person - especially someone like Fleck.

“ (...) My theory might be different than another person’s. It’s like, sometimes I feel like it's more real the further away we are on a more voyeuristic long lens. There is something about the audience understanding that they are physically further away from the actor, for me feels like I am a fly on the wall watching this happening… That is like the way a documentarian would do. Whereas when I am physically two or three feet from the actor there is a sense of privilege and there is an intimacy (...) There is an exposure that happens when we are close to somebody. And I feel like when you are two or three feet away, it changes the perception of our relationship. When you are further away it has…it's very interesting When Fleck is sitting in Sophie's apartment (fig.29) he looks over his shoulder and he puts his gun to his head with that’s like on the 58mm. But like you think about a close-up like that versus the 350mm lens in the Psychiatrists office (350mm) in the end. You know it's fundamentally different. I mean I am always obsessing about the lens proximity…I just know like if I am looking at something that makes me feels like too much of a movie and feels fake to me, my solution is to go further away longer …because I feel it is less privileged, “

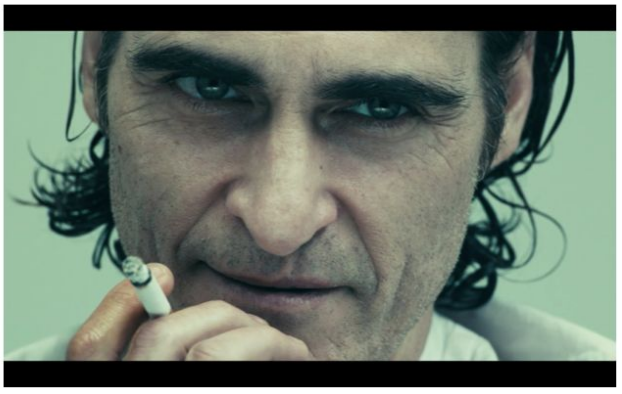


Fig.29 and 30. Neighbours apartment scene (left) Last scene, (right) Psychiatrist

Another aspect is the inclusion of so-called imperfections of the lens, such as flares. Sher embraces the imperfection and uses it as a tool of expression.There are three scenes in the film that embrace a direct flare in the lens but the most notable shot is when Fleck kills his mother at the hospital. Fleck is lit from behind by a film light simulating sunlight which penetrates the window and spills on to the lens (see fig. 31). It gives the scene a

quality of something miraculous is happening inside the character. The flare seems to suggest a drastic change in the character development.

Fig.31. Hospital Murder. Lens Flare

*“ (...)I put that light specifically, It’s like it is lighting him with a hard backlight but I put it in this spot so I knew when he came to kill her (his mother). And Jeff (the operator) went lower (…)he manifests much from that flare (…)but it is also his (*Fleck*) final release of the one thing that was probably keeping him in a box. With his mum dead, he could suddenly transform into his new self, that was like his final release. So to some extend the idea (*was*) to make this kind of ethereal and almost beautiful, terribly violent act.”*

4.2 Cesar Charlone A.B.C on The Two Popes (2019)

The Two Popes won the Silver Frog at the Camerimage 2019 and was nominated for 3 Oscars including best actor nominations for the two leads.

Approach

The cinematographer Cesar Charlone A.B.C[35] sat down with the director Fernando Meirelles and looked through the script. The two had subsequent discussions and carefully devised a visual approach that had to be flexible in the way the director wanted to work with the actors.

The plot which is a fictional approach inspired by real events is about Cardinal Bergoglio before he became Pope Francis. Back in 2012 Bergoglio, unhappy with the direction a scandalised Catholic church was headed, travels to Rome from Argentina to request that Pope Benedict XVI accept his early retirement. The introspective Benedict, facing self-doubt and widespread controversy, refused to succumb to one of his harshest critics' requests. The film depicts two polar personalities who slowly find mutual respect by confiding in each other in order to deal with their own controversial pasts. Resolution is found when they find forgiveness in one another which ultimately leads to the transition of papacy onto Bergoglio.

The Two Popes was originally conceived as a theatre play. Realising how important the spoken word is to the story, Charlone and Meirelles devised a style that would embrace the language of the script and put the full focus of the filmes gaze on the characters whilst being visually stimulating to hold the audience's attention.

We knew we were going to have two excellent actors (Jonathan Pryce as Cardinal Bergoglio and Anthony Hopkins as Pope Ratzinger) so one of the starting points was we want(ed) to see those two actors 100 percent of the time. We don't want any of those typical dark areas…

There are two distinct time periods in the film. Present day (2012) with the conversations between Cardinal Bergolio and Pope Benedict in and around the Popess Roman residencies. And the other time frame is Bergoglio's past in Argentina before and after the 1970s military dictatorship up until the 80s and 90s.
As the film moves from the present to the past and back, Charlone created two main contrasting moods for the audience to understand which time frame they find themselves in.

For the present day, Charlone drew inspiration from the paintings of the Sistine chapel, especially the ceiling by Michelangelo. Charlone noticed that the paintings depicted a flat

[35] Member of Association of Brazilian Cinematographers (ABC).

lighting style and that the workplaces a higher value in colour and shape than it does in light (see fig.32 -34)

“ (...) Not only Michelangelo but the other renaissance painters that are in the Sistine Chapel…prioritise the shape and the colour…the light comes later on with painters like Carravaggio and Rembrandt and others.”

Fig. 32+33+34 The Two Popes. Sistine Chapel scene.

Therefore Charlone chose to employ a flat front light. He decided to use colour instead of light (like in the frescos he observed) to separate the subjects from the background.

Here one could argue that it was a bold choice of Charlone given it goes against the trends of cinematography seen today which generally follow a less saturated colour palette, with low-key lighting and frames shrouded in shadow (Lawrence Sher discussed trends of cinematography briefly in 4.1).
As the film was a Netflix production with a small theatrical release, an aspect ratio of 1.85 which favours a televisual exhibition was employed. Because they also used a fair bit of TV archives from around 2012 and onwards the 1.85 aspect ratio matches the new footage. Because of the aspect ratio of the present footage of 1.85, he decided to shoot spherical. Charlene treats the past of Bergoglio visually different. Bergoglio's life before he joined the clergy is shot on 1.33 aspect ratio and in black and white and it is changed along with Bergoglio's life to 1.85 and desaturated colour. This period is given different stylistic treatment. Instead a higher key lighting of the present he uses a lower key lighting with higher contrast ratio across the actors faces, a more muted colour palette and a lensing change (preferring 16mm lenses to 35mm) for the past.

The Flashbacks, many of which was archive press footage that we received shot in times of the dictatorship in Argentina. I did a careful analysis of how it looked and put them on the computer and did tests imitating that. I decided to shoot on 16mm format style material to match the archival I did so by using 16mm zoom lenses on the Red camera using a smaller sensor.
So we had some Angenieux Zooms for the 35mm Format and on the 16mm format we would use, 16mm zooms that were available in the location we were shooting, in

Argentina we had some Zeiss and Canon. They were 16mm zooms on that camera and since it was 8K when we were shooting with 16mm lenses we had a very decent 4K crop so everything was ok with Netflix and there guidelines… I had the full sensor when I was using 35mm lenses. Using 16mm lenses with smaller sensor on flashbacks (fig.35-37)would help me take a little bit of quality out the sensor, it can be too crispy too harsh, I prefer to soften by reducing the amount of sensor.

Fig.35. 36. 37 Flashbacks (1.33 Aspect Ratio) B-W - 16mm lenses (1950s Argentina)

Fig. 38,39,40 Flashbacks 1.85 Desaturated Colour - 16mm lenses (1970s Military Rule in Argentina)

The top priority in terms of optics for Charlone apart from being cinema lenses, were that they had to be zoom lenses and they had to be lightweight like the camera.
In order to capture the essence of immediacy and intimacy in scenes between Johnthan Pryce (Bergoglio) and Anthony Hopkins (Ratzinger) in the present day, Charlone devised a documentary style to the camera work that tracked the actors and gave energy to their performance and tension to the spoken word.

The documentary look is something we talk very much about with the director, since it was just such a formal situation like theatre we discussed about how to bring it to life and make it less formal in the camera moves… (and) Basically give the actors more freedom and give the audience the feeling something is happening there like we are documenting it live.

To give the film energy and authenticity the DoP and director wanted to allow the camera to follow the actors in almost a documentary way in order to gain the feeling that the film catches all these moments between the Pope and Cardinal. This was the biggest factor for Charlone in terms of how he approached his selection of camera body and lenses.

I wanted to have a very light camera, to be able to do handheld and follow the actors and respect their movement and not make them be forced to be on marks… We chose the 8K capable RED Helium camera. I used zooms to allow me to reframe without having to change the lens. Therefore not taking time in the lens changing which takes time away from filming and thus giving more time to the actors and the director.

In the Present day scenes Charlone used a RED Helium camera (8K resolution) which was paired with Angenieux Optimo zoom lenses 14-40 (T2.6), and 28-76 (T2.6) both lightweight lenses, weighing 1.92 kilograms. For long lens shots on the tripod he used a Optimo 24-290 (T2.8)[36].

For the 16mm flashback sequences he employed 16mm Cooke light zooms 10-100. He paired all lenses with the RED Helium camera and when he shot with the 16mm lenses he cropped the sensor inside the camera so the lenses would fit the field of view and he would achieve a softer look in camera. This way the look was more accurate and the depth of field would be the same as a 16mm camera of the time.

He described the methodology of lens selection for present-day scenes and operating as follows

Normally when we start a scene we go to an establishing shot, which I do on 35mm Format so I get more information, So I would start with a normal lens 15-45 that gets me that first image. The handheld camera just followed the actors and helped them move freely, so in a more dramatic scene the camera will move more so there is more shake. if it is peaceful dialogue maybe we could even put it on sticks and have it more steady.
Composition goes on shot to shot bases, I feel one shot may have a lot of headroom in order to show the greatness of the place, there is no rule it follows intuition.

Charlone shot scenes with 2 cameras himself operating the A camera while Emiliano Leurin (for Italian scenes) operated the Steadicam and B camera. If we look at the scene when Bergolio comes to visit Benedict in Rome, he is taken to the summer residence(seefig.41-44), the Papal Palace of Castel in the countryside. What follows is a fascinating scene that plays out during a conversation in the garden between Pryce and Hopkins. As the debate becomes more heated, the characters get lost in the garden's maze.The scene which could be stale if it were just a standard shot reverse shot is given life through its blocking and lenses. Every shot in the scene has a moving camera whether long lensed subtle on the tripod, or wide angled and medium lensed handheld , or steadicam. The camera moves through space tracking the actors on voyeuristic long lenses and wide intimate lenses, exciting frames, images through foliage, little zooms and

[36] https://www.angenieux.com/collections/optimo-spherical-lens-line/optimo-compact-lens-zoom-28-76/

camera shake that follow the tension of the scene. Most of the scene has the energy of a documentary that are not perfectly composed frames and the feeling that they are just captured.
The scene could have been very monotone but the drama is always pushed forward through a combination of camera movement and lensing.
When conflict heightens, there are a number of methods employing little zoom ins or zoom outs, camera shake, or bringing the eye-line close to the lens, go back and forth between the two actors. These methods bring energy and tension to the scene.

Figs.nm 41,42, 43,44 Heated Argument in the garden

The operating on the zoom lenses, allow the DP and the operator to reframe fast, to gain a larger amount of coverage, the editor was able to use zoom pulls that were accidental and meant to heighten the drama but chiefly they managed to shoot more intense and dynamic material in shorter period of time (as they never had to lens change as often as with primes) whilst shooting a very exciting scene where the actors had time to explore their characters thought process and their physical environment which plays like a metaphorical maze. On the contrary the camera was nearly still, when the characters got lost in their thoughts.

This discussed scene is very dynamic and full of tension and has a high shot count.

I like to joke in lectures that my thing is quantity not quality, opposite to what you like to say…In my case I prefer quantity on set to have quality in the editing room…When you are shooting you are so involved…You are only going to really know afterwards if that was a good shot and say that is the one.
(Source Cinematographer Roundtable: Short Cuts With Natasha Braier, Rodrigo Prieto, CésarCharlone [37]

For Charlone the psychology of the different focal lengths can be simplified to the following principle. A long lens can make a softer, more romantic image, whereas a wide angle has a crueller look. Charlone manipulated his depth of field in line with his original concept. He shot with a large depth of field of the lens so the wide shots look like the paintings in the Sistine Chapel. Whereas the close-ups were shot with a shallower depth of field, T 2.8 - T 4, to create separation from the subjects to the background to avoid unnecessary distraction from the actors faces.

In terms of testing Charlone stated he does two types of testing. The lenses are tested in the rental house which is mainly tested by the assistants who test the resolution of the lens, definition, quality, framing, focus, vignetting, aberrations testing and such like. The testing that Charlone performs is with his own personal Black Magic Pocket camera, before they get the camera package. Early in pre production.

I can test the locations, the lighting, I test it with my own camera and develop at home on the computer and colourise it and play with the images. When the camera package comes we use it, but basically I have done make-up and wardrobe and art production tests on my own personal camera because for the tests we are doing it does not make much difference.

4.3 Vladimir Smutny A.C.K on The Painted Bird (2019)

Painted Bird lensed by Vladimír Smutný A.C.K.[38] won the Bronze Frog and the FIPRESCI Prize at the Camerimage 2019. The film is based on a novel by Polish writer Jerzy Kosiński. Set in an unidentified area of central Europe during the Second World War, a young unnamed boy is living alone in the rural countryside with his elderly aunt. When she dies and their house burns down, the boy sets off on a journey. His adventures lead him across a war torn Europe. He has to face violence and abuse, prejudice, violence and depravity. But the spirited child struggles forward surviving long enough to take revenge and return home to his father.

[37] *https://www.angenieux.com/collections/optimo-spherical-lens-line/optimo-compact-lens-zoom-28-76/*
[38] Member of Association of Czech Cinematographers (ACK).

The director and DoP discussed the style early in the preproduction and decided on a visual aesthetic that was based on published WWII photography of the 1940s. This decision led the filmmakers to choose to shoot on black and white Kodak XX film stock rather than to shoot digitally. Smutny felt the integrity of the film emulsion and texture was important for this project. He also strived to have the finished film closely resembling a movie finished on a positive film print (like films before the Digital Intermediate process) even though *A Painted Bird* was to be screened digitally. In order to understand the look of a film shot and projected on a film print, Smutny shot a reference scene on Kodak XX negative stock that was then graded photochemically, and transferred on a Kodak positive stock. From this test he could digitally scan frames of the positive stock and use it as a key reference for the colourist to match to in the grading.

“ (...) I did so for the reason that when we came to shoot on film I would try to match in the grade, the look of what it would look like if we finished the movie on a film print and that type of contrast. Because it's different and also the focus is different. I would say, one of the main differences from a digital projection to one on print is that in the print you lose some sharpness. “

Black and white was very important for setting the tone historically and also in terms of the dark quality of the story. From early in the preproduction, the director Václav Marhoul decided he wanted *Painted Bird* to be shot in black and white with a wide screen aspect ratio. Smutny agreed that a film as ambitious as this deserved a larger canvas approach than a 1.85 aspect ratio.
The cinematographer then shot and recorded many lens tests with both anamorphic and spherical lenses to be able to present these to the director.

“ (...) The lenses I tested were the anamorphic Hawk V-Lites, Master Zeiss Anamorphic lens, and also tested spherical lenses like the Zeiss Ultra primes and Cooke S4’s. You do not have to be overwhelmed with the choice of lens. It’s about the style of the movie, this eliminates many lenses before and during the testing.”

Smutný likes to do tests (with the camera, material film stock or digital video, lenses) in tricky lighting situations in the day and at night. At night for example he likes to shoot in the city under electric lights, in front of shops, street lamps, neon tubes. He wants to see how the camera and lenses are recording the various brightness levels and how they deal with shadow areas and bright highlight areas. He also does similar brightness tests in the daytime.

“ (...) I test at night but also the day I need to see the range of brightness. I shoot the test in a tunnel on a bright day with a sunny background on the outside of the tunnel. To test the range you see. To test the dark to light situation. If you have this situation, the lens must be wide open. I also test the vignetting to do such you must use a big aperture and close lens to T22, to see the contrast of vignetting at different T-Stops.”

Fig. 45 and 46 Landscape shots

For Smutny, like Charlone, it is the camera assistants task to see how well a lens is focusing along with other concerns of the lens characteristics.

“ (...) For the focus, this is the Assistant Cameraman´s work. He should also test the bokeh, the flare and other aberrations.”

When viewing the results of the tests on a large screen projection, Smutny felt that the Zeiss Master Anamorphic glass lacked the characteristics he was after and that the Hawk V-lites offered the type of so-called imperfections he was looking for.

“Zeiss had no distortion, the focus was perfect, middle to the edges. Technically the best anamorphic lenses….Whereas the Hawk V-Lites showed more problems in terms of aberrations but had nice character. What I liked was the out of focusing, the vignetting in the wide lenses, the centre of the lenses being a lot more sharp than the edges but in the Zeiss lenses the focus fall off is not visible it's just too clean.”

Smutny also noticed that the Hawk lenses had some strong colour aberration in the wider lenses but for shooting black and white this was no issue. The cinematographer also tested spherical lenses such as the Cooke S4s and the Carl Zeiss Ultra Primes. Although they were indeed high quality they did not have the character he was looking for. He preferred the Hawk V-Lites because being an anamorphic lens, it gave him a larger format. The consequence of this gives him a shallower depth of field (longer focal lengths used with anamorphic because of the larger field of view) as well as the oval bokeh. On viewing the projected test the director shared Smutnys opinion, that the Hawk lenses did indeed have the qualities and characteristics that he was also looking for. Smutny insists that because there are a lot of landscape shots in *The Painted Bird* the anamorphic lens is better for this as it gives more resolution (no crop involved) while the aspect ratio lends itself to horizontal picture making. The cinematographer argues the difference between

composing for 2.39 and the 1.85 aspect ratios is huge. In the 239 format, he states emotion can be imbued greater in the frames than than in the 1.85 format. In Smutnys words, *the camera operator can be more daring in 239 as compared to the 1.85 ratio where good operation is only confined to the golden ratio.*

However with the 2.39 aspect ratio the possibility to use edge compositions(see fig.49) for example that only showed half of the face work far better in this format than 1.85. Smutny put edge compositions to good use in Painted Bird to create tension and bold imagery. Example images you see half a boy face 3rd image, it stands out in a sequence more conventional frames.

Fig.47, 48,49 Use of closeups on anamorphic lenses. Far right half face composition suit to anamorphic lensing.

During the shooting, Smutný had the full range of Hawk V-Lites prime lenses available to him from 27mm-180mm. He paired the Hawk Lenses with a 35mm ARRI LT camera and used the ARRI 235 for handheld. He also used a RED Monstro 8K camera (V-Lites fitted on both cameras as they had the same Positive lock mount (PL) as the lenses), this was predominantly used for Green Screen work because of the high resolution. The RED camera was employed for shooting scenes with famous actors, which they shot both on film and on digital incase there were any accidents at the lab, as they could not afford to reshoot. Smutny states that 90 percent of the finished film is originating from film - A good example of how the cinematographers chose to work with unusual compositions for tension sake and how the anamorphic lensing allowed Smutny to place the actors in a close table scene and still create space in the frames and create separation from subject to background because of the format. This scene is also an excellent example of how Smutny works with the characteristics of the lens to add an extra layer distortion to the Millers crazed point of view.

During the section of the film once the boy is being looked after by Miller there is a dinner scene which is worth looking at. Before the scene where Miller comes back home in the rain with a young cat in a sack, it is suggested in the scenes before that he suspects his wife to have been cheating on him with a young hired man. When Miller comes home in the rain, his wife, the hired man and the boy all rise, one can feel the tension rising as he places down a sack which is moving but we do not yet know what is in it.

The Miller scene (see fig 50- 58) is an excellent illustration of how the Anamorphic lenses with their imperfections work and the scene and the film.
The lensing of the scene is very interesting as the anamorphic lens lends itself to the distortion of the Millers mind. The curvature on the lenses heightens his paranoid reality which manifests itself on screen. The shallow depth of field that the format offers works well in this enclosed space to offer separation to the characters from the background.

The scene appears graphic but on a second viewing much of what happens is off and screen and done in sound. The anamorphic lensing as described by Smutny lends itself to unconventional framing and through this framing demonstrated here one can read more into the shots than are seen on the screen. The composition like the depth of field not seeing everything clearly adds to the tension. The aberration like the curvature on the wide angle shots afdd to the distortion felt of the millers overactive mind.

Fig. 50-58 Miller‘s dinner table scene

I should note that the steadiness of the frames up until is knocked over and the camera becomes handheld expresses the tension and energy of the room. The tension of the room is like a coiled spring and when it goes off with the millers over the top violence, handheld feels like the right expression for this.
Smutny maintained familiar working TSTOPS 5,6 for wider lenses for increased depth of field for his wide shots whereas he uses his long lenses for closeups and likes separation

with the subject and background therefore uses a more open aperture of 2.8 These apertures were dependent on the lighting but are typical for his work.

He discusses his love of combining wide and long lenses in the same scene. The wide lenses for wide shots and long lenses for close up. He also stated for some close ups he chose to use a wide lens with a diopter to gain extra detail in the background. Long lenses he almost exclusively uses for closer shots. Where he likes to shoot on a large aperture so the background is missing in the close-ups to isolate the actors.

Chapter 5. Conclusion

The purpose of the thesis is not to say one lens type is better than another it is rather to understand when the cinematographer would choose one lens over another.
What has become obvious is that the professional cinematographer adapts their approach and way of thinking about lenses to every new project. Instead of following a dogmatic methodology, it is much more a flexible and intuitive approach. Each of the cinematographers had such a distinctive visual approach and yet they always allowed for their intuition to guide the way of lensing a scene depending on the mood and environment and feeling of the scene. The knowledgeable cinematographer does not use a lens merely because for aesthetic superficial reasons but rather they consider the desired effect it will have on the audience's viewing experience and how it will help best to tell the story. During the interviews with the very skilled cinematographers, one could ascertain a high level of craft but also that experience has taught them that to be dogmatic may be counter-productive to the creative and logistic experience of making films. Their approach could be flexible.
The diligent cinematographer is always in service of the story and putting across the emotion of the characters. In all three films we saw the cinematographer through their choice of lenses, managing to externalize the internal feelings of the protagonists.

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INDEX OF IMAGES

Fig 23 https://www.facebook.com/cookeoptics/posts/2118464414966448

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Fig. 28, 31 *Joker*. Dir. Todd Phillips.Warner Bros. Pictures, DC Films. 2019. Film

Fig. 31-44 The Two Popes. Dir. Fernando Meirelles. Netflix. 2019. Film

Fig.45-58 The Painted Bird. Dir.Vaclav Marhoul. PubRes, Silver Screen. 2019. Film