CHAPTER 1

INTRODUCTION TO INFRARED PHOTOGRAPHY

1.1 Historical Account of infrared photography may be summarized as follows :-

In the 17^{th} century, Sir Isaac Newton discovered the "spectrum" by passing a beam of sunlight through a prism of glass. At the acreen it was broadened out into a band which exhibited the colors of the rainbow which is known as the spectrum.

In 1800 Sir William Herschel discovered the invisible region of the spectrum beyond the red end (as known as the " infrared "). He concluded that the invisible rays of heat and light were different in nature.

In 1834 J.D. Forbes showed that heat radiation can be polarized in the same manner as light.

In 1835 Ampere was able to proclaim the indentity of the rays of light and those of heat.

In 1837 A.H.L. Fizeau and J.B.L. Faucault actually determined the wavelenght of near infrared waves from interference fringes, and the identity of infrared ray and light rays become generally accepted.

In 1840 Sir John F.W. Herschel (the son of Sir William Herschel) spectrum by the evaporatian of alcohol. Some forty years later Langley published his excellent solar spectra and showed that there were absorption bands superimposed on the solar continunm. Through the work of F. Paschen,- E. Aschkinass and other investigaters in the 1890 these bands were identified with those of water vapors and carbon dioxide. At the same time K.J. Angstrom demonstrated that the absorption bands of different gases consisting of the same atoms (e.g. CO and CO_2), have different infrared absorption spectra.

It became now evident that inffrared spectra are related to molecular rather than atomic properties. The pioneers of infrared spectroscopy in the field of Organic Chemistry were W. de W. Abney and E.R. Festing, who used photographic plates specially sensitized to wavelengths up to 1.3 μ. They could observe only the overtone and combination frequencies of the fundamental C-H vibrations which lie beyond 2.7 μ. This limitation was overcome by W.H. Julius who extended the spectra to about 10 μ. W.W. Coblentz studied the infrared spectra of organic compounds, whose work paved the way for the emergence of structural molecular spectroscopy, which J. Lecomte and others had developed in 1920. The characteristic of infrared spectroscopy which makes it invariable to the organic chemist is its ability to identify certain molecular groups in compounds; e.g. alkane group, alkene group, aromatic group and alkyne group and in various configerations. This is made possible by the fact that the energy of the infrared quanta is so low that it does not cause electronic excitation in the constituent atoms, but it suffices to excite vibrations and rotation of atom or groups of atoms as a whole. Infrared spectra can be observed in all three states of matter; gaseous, liquid and solid. All along, physicists have made the infrared both a subject of their study and a tool for exploring constitution of matter. Studies of lattice vibrations in ionic crystals by observing their "residual ray" reflectivity in the far infrared or the determination of energy gaps in semi conductors are typical examples of using the infrared in solid state physics. In turn, better knowledge of the nature of the interaction between radiation and matter has led recently to the development of a new type of intense visible and infrared sources (the lasers) radically different from the thermal sources in the sense that it generates monochromatic and coherent radiation. The way the laser was conceived and practically realized required that use be made of both the electromagnetic and the quantum nature of the radiation.

1.2 Chromatic Aberration of Camera Lenses[1]

1.2.1 The Simple Photographic Lens

In some box cameras, there is just a simple meniscus lens made of one piece of glass. When this lens is of the right shape and is placed in the camera properly, the image it produces at small aperture is quite satisfactory for the average snapshot.

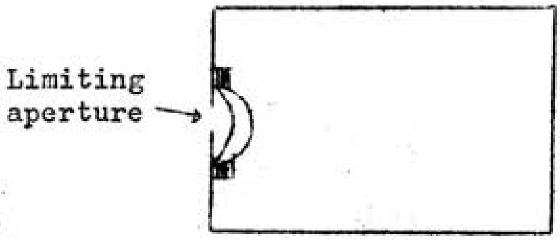

Fig. 1.1: Single lens of a box camera.

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[1] - Wall, H.J., Photo-Technique, pp. 52-60.

- Boucher, Paul E., Fundamentals of Photography, pp. 63-75.

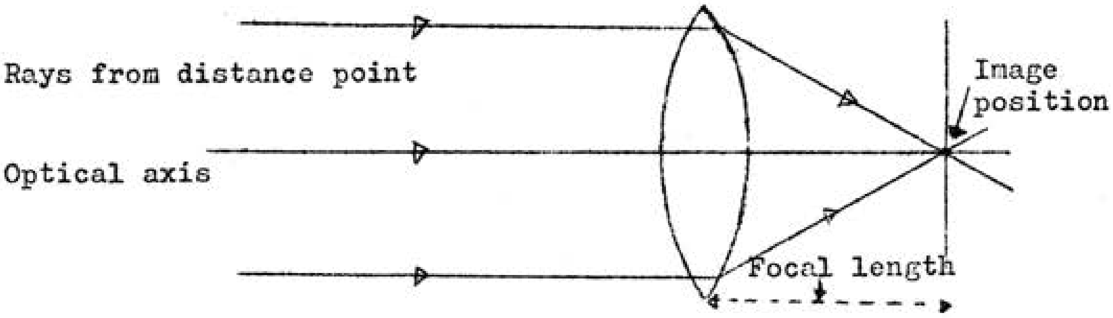


Fig. 1.2: Focal length of a thin lens.

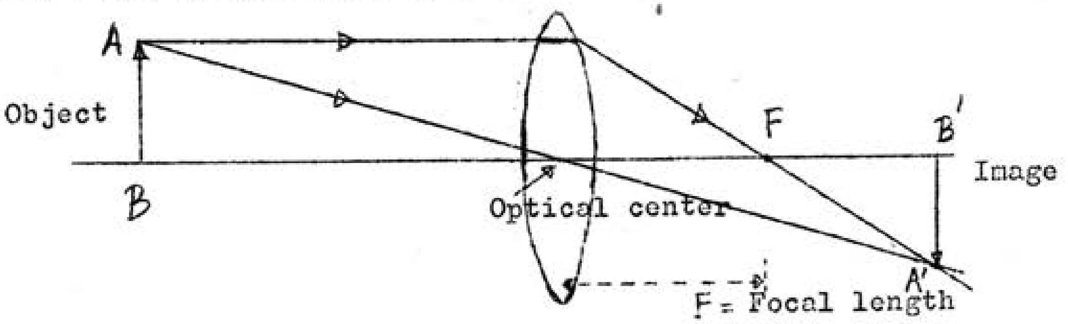


Fig. 1.3: Position of the image formed by a thin lens.

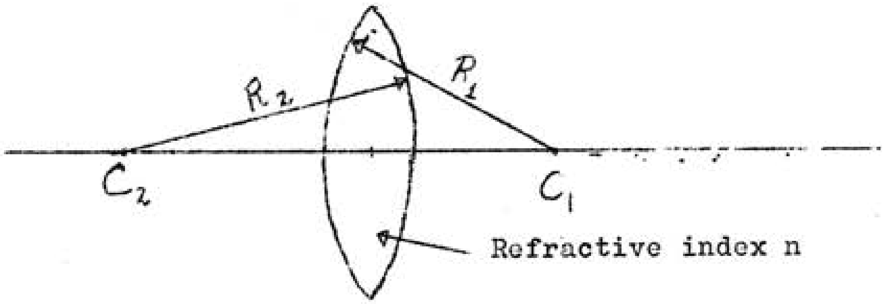


Fig. 1.4: Radii of curvature of lens surfaces.

The relation between the focal length, refractive index of the glass and the radii of curvature of the lens is

$$1/F = (n - 1)(1/R_1 - 1/R_2)$$

There are two types of simple lens, i.e. positive lenses and negative lenses. The shapes of them are shown in Fig. 1.5

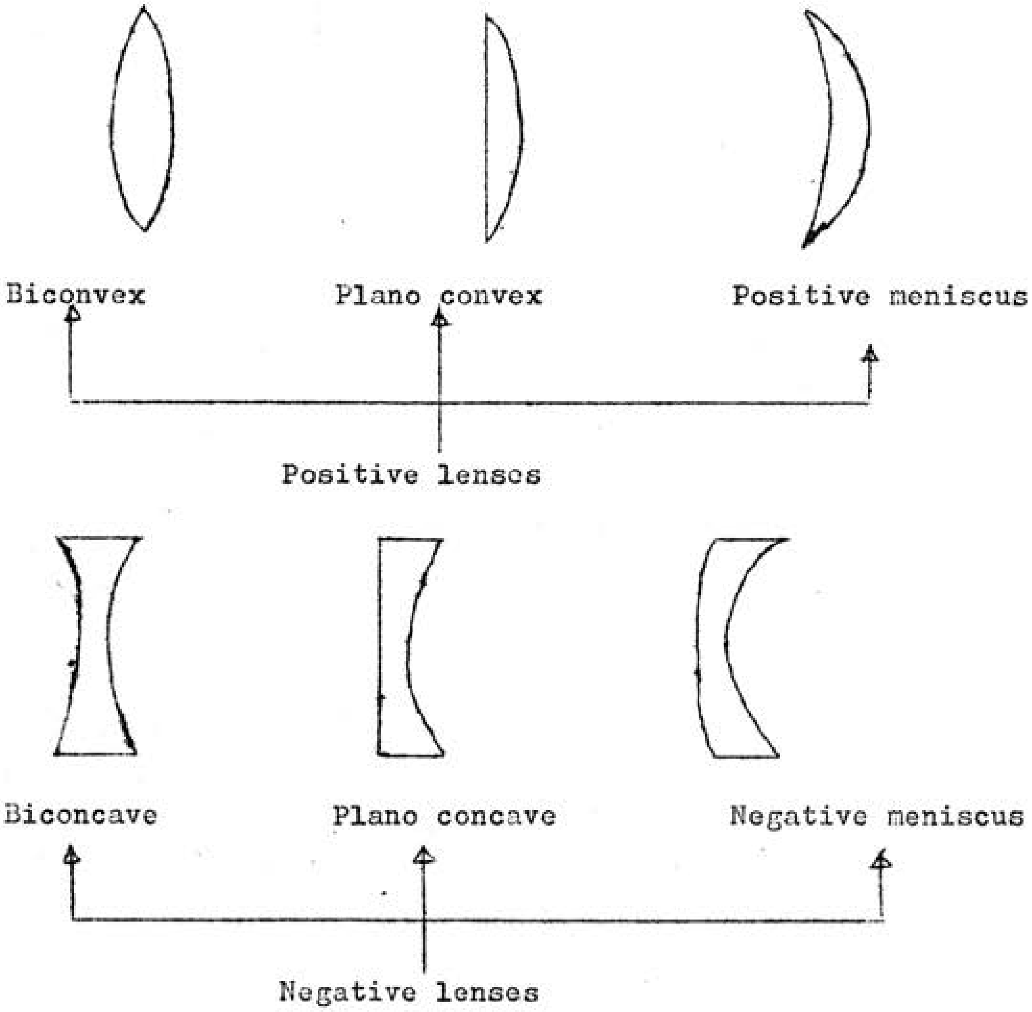


Fig. 1.5: The shapes of the simple lenses.

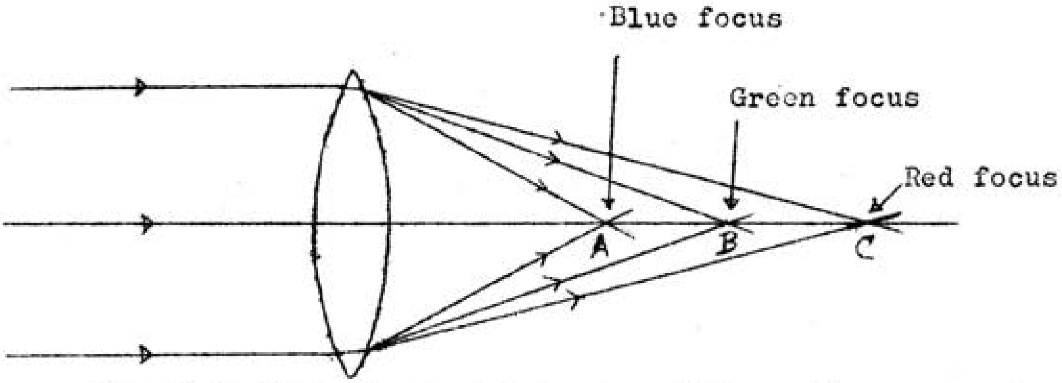


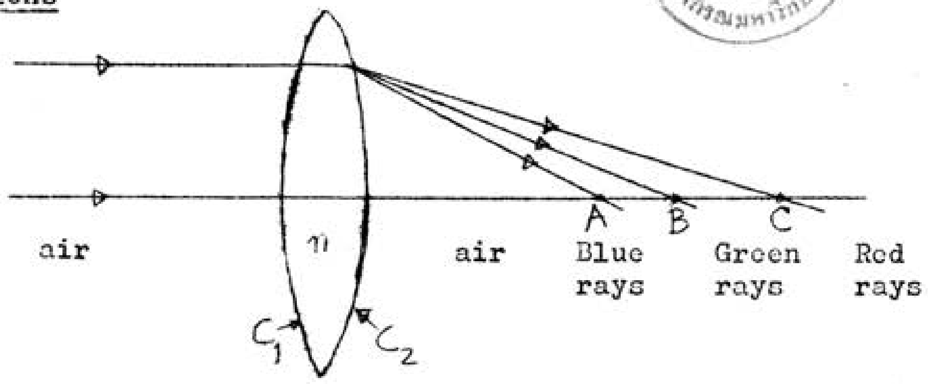
Fig. 1.7: Blue focus at A is more intense than green focus at B or red focus at C. The image at B shows reddish-bluish color fringes.

This defect is called the chromatic aberration[1] of the lens. If all other abbrrations, except chromatic aberration, are corrected to a minimum the image formed by a lens may look sharp to the eyes but gives a blurred, out-of-focus colored negative.

To obtain any correction at all, it is necessary to utilize different types of optical glass but complete correction for all colors is impossible and the situation is aggravated by the fact that the balance of other aberrations varies with the color of the light. In many instances the best chromatic correction of a narrow bundle of rays closed to the lens axis has to be sacrificed in order to obtain a better compromise. Correction may become unbalanced when the aperture is reduced by several stops.

1.3 Chromatic Aberration Calculation

For any lens



n = refractive index of a lens

C = curvature of a lens

$$\text{Power of lens } (K) = \frac{1}{F}$$

$$= (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= (n - 1)(C_1 - C_2)$$

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[1] - Purves, Frederick., The focal Encyclopedia of photography, pp. 3-6
- Neblette, C.E., Photography, pp. 23-26

$$K = (n - 1)(C_1 - C_2)$$

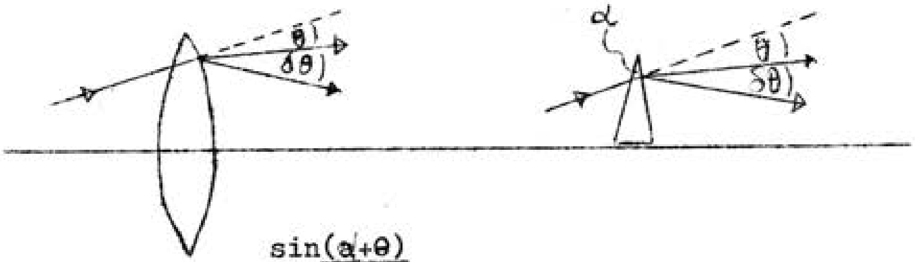
$$\delta K = \delta n(C_1 - C_2)$$

$$= \frac{\delta n}{(n - 1)}(n - 1)(C_1 - C_2)$$

$$= \frac{\delta n}{(n - 1)} \cdot K$$

$$\frac{\delta K}{K} = \frac{\delta n}{(n - 1)}$$

If light is passing through a prism with the same angle as that through the lens, and the deviation angle is small.



$$n = \frac{\sin\frac{(\alpha+\theta)}{2}}{\sin\frac{\alpha}{2}}$$

θ is small, then $\sin\theta = \theta$ radian

$$n = \frac{\frac{\alpha + \theta}{2}}{\frac{\alpha}{2}} = \frac{\alpha + \theta}{\alpha}$$

$$\theta = (n - 1).\alpha$$

$$\delta\theta = \delta n.\alpha$$

$$= \frac{\delta n(n - 1).\alpha}{(n - 1)}$$

$$= \frac{\delta n}{(n - 1)} . \theta$$

$$\frac{\delta\theta}{\theta} = \frac{\delta n}{(n - 1)}$$

Both lens and prism, the refractive index depends on the wavelength of the light.

From relative dispersion $\frac{1}{V} = \frac{n_F - n_C}{n_D - 1}$

n_F = refractive index of blue light

n_C = refractive index of red light

n_D = refractive index of yellow light

$$\therefore \text{V - value (V)} = \frac{n_D - 1}{n_F - n_C}$$

$$= \frac{n - 1}{dn}$$

$$\therefore dn = \frac{n - 1}{V}$$

That is dispersive power of a lens depends on refractive index of a lens.

There are 2 types of Chromatic Aberration:

1. Longitudinal Chromatic aberration (Chromatic variation of the plane of focus).
2. Transverse Chromatic aberration (Chromatic variation of image size, i.e. magnification).

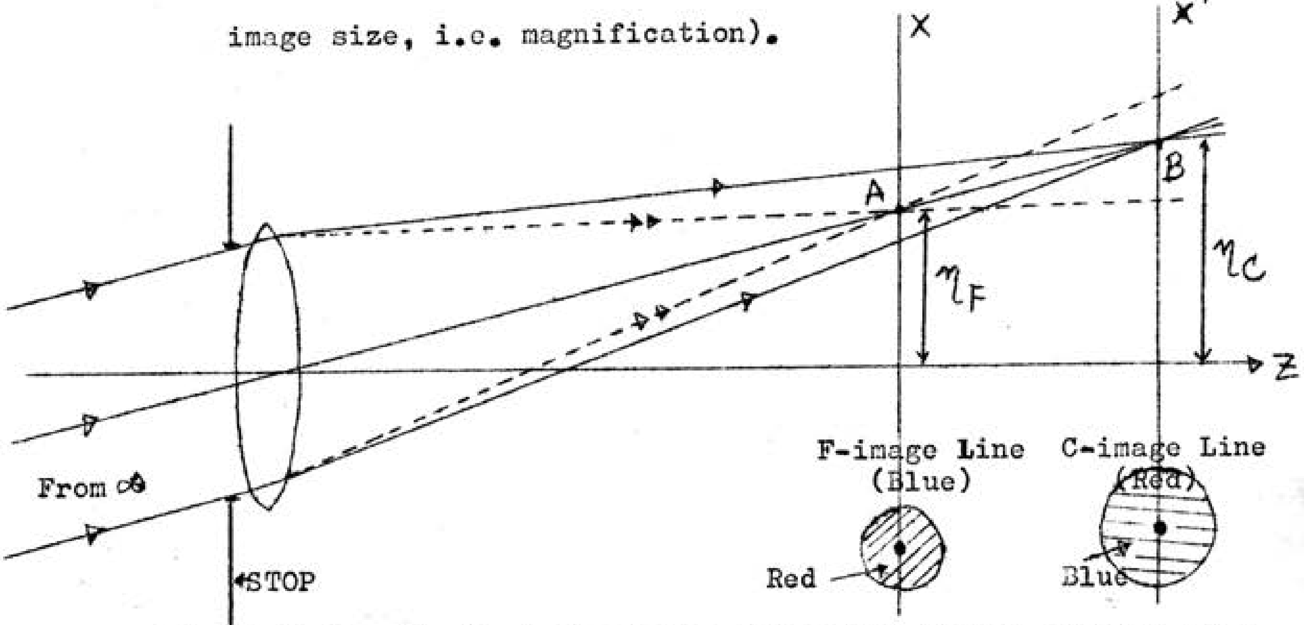
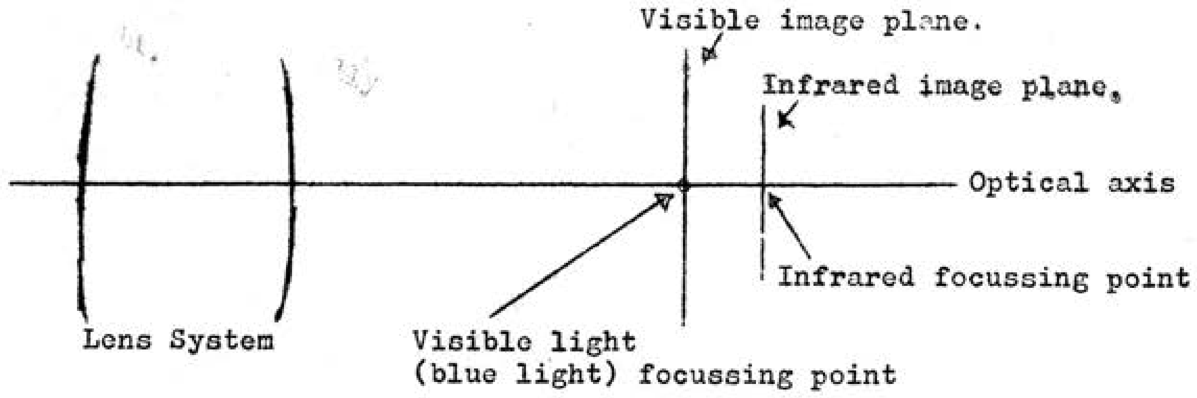


Fig. 1.8: Longitudinal Chromatic aberration varies along z axis, transverse Chromatic aberration varies along x axis.

We can see that the deviation of image size (dn) depends on the position of the stop. Hence, the camera lenses designer must calculate the correct position for the stop or diaphragm that should give the smallest dn and another factor is the size of the aperture or the diaphragm.

In general, photographic lenses were designed to be free from chromatic aberration for visible light, since the pancromatic sensitive material is sensitive to visible light, especially blue light. In the case of infrared photography, the infrared sensitive materials were used. Since the infrared wavelength is longer than the visible radiation, so that the infrared image is focussed away from the visible light. For the best infrared focussing, we must move the image plane (or the infrared sensitive material) to the infrared focussing point, further from the visible light focussing plane.



In practice we do not move the image plane but instead the lens system is moved to the left (the above diagram) or the bellow of the camera is extended.