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Process Identification for Dismantling of Commercial Lens Assembly and Feasibility Study towards Earth Observation

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Abstract

Earth imaging is the unique feature of any satellite mission for technological advancements. This covers variety of applications like agriculture, forestry, fishering, weather forecasting and many more. For any Earth observation satellite mission, optics is playing very important role as it behaves transmissive media for focusing or dispersion of light beam by means of refraction characteristics for capturing high quality information through converting them into pixel frame. In current modernization scenario, commercial optics having enough characteristics and capabilities to suit run time applications which enables to use them in the direction of earth observation system. This feature of commercially of the shelf (COTS) optics leads to minimize the lead time, for predominantly during material selection, optics design, fabrication and testing required to suit space qualification. The main objective of this article is to identify step by step procedure for dismantling of COTS optics followed by accurate inter separation measurement and feasibility study to be utilized for space application. As a result of the identified procedure, various quantitative and qualitative information can be extracted such as pre performance test, geometrical features, dimensional features, weight measurement of each optical element, which provides foundation towards development of barrel housing consisting of all optical elements.

Keywords: Refraction, Dismantling, Lens elements, COTS

INTRODUCTION

The quality of the image from camera essentially depends on the imaging optics, detector and associated electronics. The preliminary function of imaging optics is to transfer the radiance from the object space to image plane which means ability to maintain the shape, orientation, relative dimension, and relative radiance values as in the object space. The selection of a specific imaging optics for a satellite mission primarily depends on (1) the spectral range to be covered, (2) total field of view (FOV), and (3) aperture size [1].

Optical system to be used in the earth observatory design, should have capacity to withstand wide range of environmental loads encountered fabrication, launch, and during functioning in space. These include mechanical and thermal stresses, and the radiation environment. Therefore, it is required to pay utmost attention to opto-mechanical design to ensure that the shape and position of the optical elements of the system are unaffected under these loads, so that the system performance requirements are satisfied [1-5].

In order to achieve the requirements of realizing of the camera within a short span of time and achieving miniaturization in terms of size and weight to the extent possible, it is advisable to use readily available off the shelf optics with the consideration that these optical elements would be used in earth observation. This gives an adequate opportunity for miniaturization of this lens assembly through dismantling of its lens elements from the present housing and a subsequent reassembly into a newly designed miniaturized housing for achieving the initial performance.

This article provides the complete top down approach stating optical performance measurement, dismantling of the lenses from the lens housing and the subsequent cleaning procedures.

Commercial Optics Description

Figure 1 depicts optical layout of the COTS lens assembly. As per the datasheet specifications, the lens assembly includes six spherical lens elements (L1 to L6) with built in rear glass plate for dust protection. The lens assembly has a focal length of 105 mm and a large maximum aperture at f/2 shooting in dim light with adjustable f-numbers at f/2.8, f/4.0, f/5.6, f/8.0, f/11 and f/16. The minimum focusing distance is 0.9 m and ranges up to infinity.

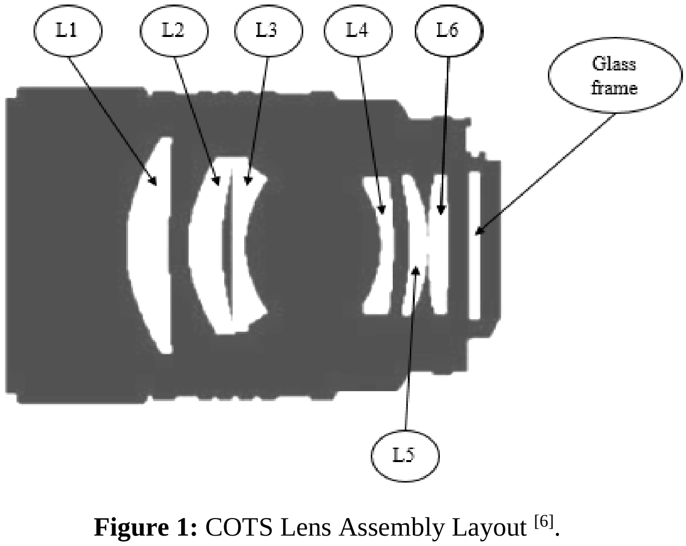

Figure 1: COTS Lens Assembly Layout [6].

The lens operates in the visible spectral region and has a field of view of ±11.5 degrees. The physical dimensions of the lens assembly are nearly 111 mm along the length and 79 mm along the diameter. This lens has additional features like Auto Focus (AF) and Defocus control (DC) mechanisms operated electronically via ultrasonic motors (USM) which makes lens housing intricate and a little heavier. The total weight of the lens assembly including mechanical housing is nearly 640 grams [6].

Pre Performance Test

Initial tests will be carried out to form a base line for subsequent tests required for comparisons after dismantle and reassembly. The modulation Transfer Function (MTF) for f/4 and infinity focus mode is the only parameter to be measured with the purpose of evaluating the performance of the lens assembly [7]. The set up includes for MTF measurement by attaching the lens assembly to Nikon camera and white LED panel with Knife edge Blades used as target which is shown in fig. 2.

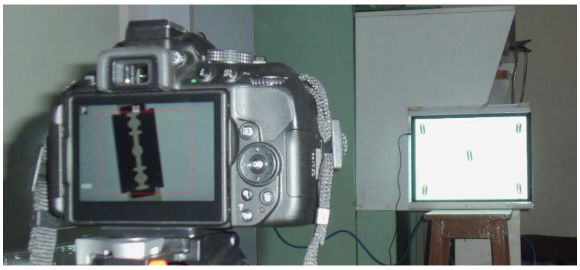

Figure 2: MTF Test Setup

The test results are obtained by capturing image from infinite distance of 3 meters which is technically considered the twenty times of the focal length and aperture stop set as f/4. The captured image has been taken to the software for computing MTF by selecting slant edge as area of region which gives result as 91.7 cy/mm with Imatest SFR plus Test Chart of contrast ratio 4:1 as shown in fig. 3.

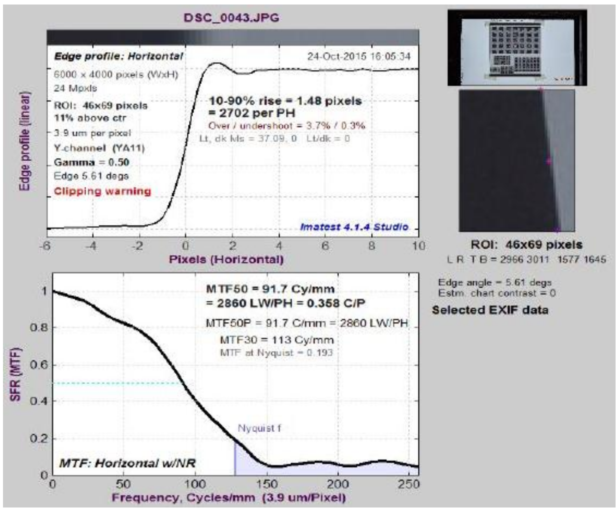

Figure 3: Imatest result for MTF

Dismantling Procedure

There are various tools and accessories used for dismantling the lens assembly which are as follows; Micro Screw driver set, Nose head and flat head pliers, Paper tape, Adjustable Spanner with two legs for lock ring opening, Solvent toluene/Zorric-88, clean rust free cloth and Digital camera as shown in fig. 4.

Figure 4: Tools required for dismantling of lens assembly

Before opening the lens assembly, some critical points are required to follow. The First foremost thing is the total procedure should be carry out in clean room under controlled environment only. Second thing is to identify the critical components of the lens housing like screw, lock ring, etc. The last thing is to make a test setup with the use of surface plate and dial gauge indicator, as calibrated for getting separation distance between consecutive lens elements.

Now, the next step is to put the lens assembly over the surface plate and make the front face of the lens assembly as a reference plane as shown in fig. 5. It will give the distance from the bottom plane to window lens as 114.45 mm. So with this arrangement, the total height of lens assembly can be concluded.

Figure 5: Measurement of height from window glass to front face of lens assembly with the use of dial gauge indicator

Afterwards, Apply small quantity of solvent on the collar face for 4 screws and along the diameter for 5 screws from outside as shown in fig. 6. Apply the solvent with the help of thin stick so that it should not spread over optical components. Leave the assembly for 15 minutes after solvent is applied.

Figure 6: Application of solvent on the screws

Thereafter, remove all screws from the rear end of the lens assembly. Take out the rear glass window with mount from rear end of the lens assembly as shown in fig. 7.

Figure 7: Removal of Rear Glass Window in its mount.

The very next step is to remove the aperture (f-number) adjusting ring and the aperture index ring around the lens assembly at its rear end as shown in fig. 8.

Figure 8: Removal of aperture adjustment ring

After removing aperture adjustment ring, we come to know there is one group of three lens elements which drives as focusing element with appropriate focusing distance. The height measurement of this group with the reference of front end hood at different focusing distance with the help of marking provided over the focusing ring as shown in fig. 9. These measurements are essential to get information of lens element group position at infinite mode for fixed focal length camera application.

Figure 9: Height measurement of lens group at various focusing distance

Again start removing the stack of five golden spacers and the focus adjusting ring around the lens assembly. With this also remove the screws (2 big and 4 small) and press the knob for opening of the focusing ring after applying the solvent on them and leave them for 10 minutes as shown in fig. 10.

Figure 10: Removal of focusing ring

Remove the screws in the periphery of the lens barrel and phosphor bronze plate for coming out of gear attachment after applying solvent on them and leaving for 10 minutes and slowly rotate the outer ring in the periphery of the lens barrel clockwise and take out carefully the lens group consisting of lens 4, lens 5 and lens 6 mounted in a single inner barrel and measure the height of aperture as shown in fig. 11.

Figure 11: Removal of Lens Group (4, 5 and 6) and height measurement of aperture stop

Remove the front lens from the front end with the help of adjustable spanner by opening the lock ring. Remove the second and third lens from the front end with the help of adjustable spanner by opening the lock ring as shown in fig. 12.

Figure 12: Removal of Lens 1 and distance measurement and Removal of Lens 2 and 3.

After dismantling of all the lens elements from the assembly, the remaining parts are shown in fig. 13

Figure 13: Components obtained from the dismantled lens assembly.

Apply solvent and leave the inner barrel for 10 minutes. Gently rotate the lens 6 mount at the two diametrically opposite notches using adjustable spanner with two legs. Take out lens 6 with its mount carefully and measure the distance accordingly as depicted in fig. 14.

Figure 14: Removal of Lens 6 and measurement of separation distance from consecutive lens elements.

Remove the lock ring for lens 5, the golden ring adjacent to it and take out carefully lens 5, leaving lens 4 in the barrel mount as shown in fig. 15.

Figure 15: Removal of Lens 5

The lens elements are taken out after dismantling of the lens housing and their diameters, edge thicknesses, centre thickness and radius of curvatures will be precisely measured. Similarly the dimensional measurements for each metallic parts of the housing will be performed. Based on these measurements, newly miniaturized lens housing will be designed meeting the system requirements and surviving the environmental loads. Figure 16 shows all the lens elements after removal from the barrel.

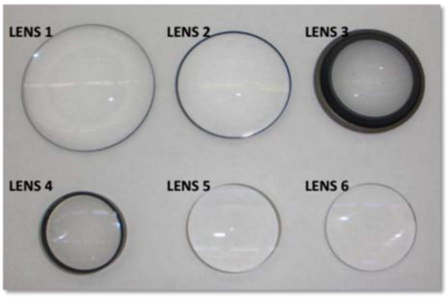

Figure 16: Lens elements after removal from the barrel

At last, with the help of calibrated weighing machine, accuracy up to 1 gms, individual lens element's weight is measured which is shown in Table 1.

Table 1. Weight of individual lens elements

Sr. No.	**Item**	**Weight in gms**
1.	Lens 1	54.67
2.	Lens 2	34.01
3.	Lens 3	24.18
4.	Lens 4	12.61
5.	Lens 5	13.69
6.	Lens 6	13.90
Total Weight in Grams		153.06

DISCUSSION AND FUTURE SCOPE

The overall study highlights following outcomes,

- For the study of utilization of lens elements in space domain, one need to consider only the weight of individual lens elements which is approximately 153 grams, which are only necessary items from COTS optics.
- Through this study, one can extract physical details of the each lens elements like, shape, diameter, center thickness, edge thickness, radius of curvatures, which will cater ahead to design and develop respective mount for arresting them to stay at predefined position as per the procedural measurement.
- For earth observation from space, various materials are available for housing structure for lens elements such as AL6061-T6, AL7075, Kovar to sustain the mechanical and thermal force encountered during space craft launching and temperature change in space.

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