Design, Integration, Verification and Validation of Dichroic Optomechanical Supports RATIR

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***Abstract*- We present the design, integration and verification of the optomechanical support for the dichroics of the astronomical instrument RATIR. RATIR is an instrument that will be installed in the 1.5 m telescope in San Pedro Mártir, México and whose primary function is to make a follow up of gamma ray bursts (GRB) detected by Swift Space Telescope. To achieve this, RATIR has been designed with three dichroics to study light coming from the GRB. Each dichroic has a support that has to meet specific weight and dimension requirements. Its design must minimize deformation and stress in the dichroic to comply with correct working specifications of the dichroic. Different designs were proposed and analyzed with classic thin plate theory and finite element analysis (FEA). The deformations obtained where less than 34 nm at the center of the dichroic. Using a Computer Numerically Controlled (CNC), we built a prototype of the support that is going to be used to make laboratory tests.**

***Index Terms*- Astronomical instrumentation, finite element analysis, mechanical design, optomechanics.**

I. INTRODUCTION

Gamma Ray Bursts (GRB) are the most impressive and energetic explosions in the universe. They can occur at any time, anywhere and can have a variable duration. The study of GRB began accidentally in the late sixties, when a satellite detected the first GRB [1]. Since then, the study of GRB has become more important and several projects have been made to study them [2]. One of these projects, a satellite called BeppoSax, discovered the first GRB afterglow [3]. These afterglows have a longer duration making easier the study of GRB. Afterglows have been discovered in X-Ray, optical [4], and infrared [5] light.

In 2004, NASA launched the Swift Space Telescope [6] to continue studying GRB. Its main task is to detect GRB afterglows in X-Ray, Ultraviolet and optical light. When Swift detects an afterglow of a GRB it sends its coordinates to ground telescopes to make the follow up. One of these telescopes will be the 1.5 m telescope at San Pedro Mártir, Baja California in México.

NASA, Berkley University and Universidad Nacional Autónoma de Méixco, are developing RATIR (Reionization and Transients InfraRed camera/telescope). This camera is going to study GRB afterglows in optic and infrared bands, detected by Swift. RATIR is going to have four simultaneous imaging channels that are going to be separated optically by three fixed dichroics [7]. The JH channel and the ZY channel are going to be equipped with an infrared detector each and a JH filter and a ZY split filter, respectively. The *i* channel is going to be equipped with a CCD detector and a fixed *i* filter. The *ugr* channel is going to be equipped with a CCD and a filter wheel containing at least an *r* filter.

The three dichroics that are going to be used have the next characteristics. Dichroic One (for *r*/ZYJH channels) is going to reflect 320-675nm and transmit 700-1800nm. Dichroic Two (for *i*/ZYJH channels) is going to reflect 680-810nm and transmit 840-1800nm. Dichroic Three (for ZY/JH channels) is going to reflect 810-1070nm and transmit 1170-1800nm and is going to be placed in the cryostat [8].

Each dichroic has a support that has to meet specific weight and dimension requirements. Its design must minimize deformation and stress in the dichroic to comply with correct working specifications of the dichroic. It should be aligned in the optical path without causing interference. An exhaustive search was made looking for commercial dichroic supports. Custom-made options were the only ones found but they were expensive and take too long. For this reason it was decided to design our own support.

II. DESIGN OF THE SUPPORT

The dichroics have dimensions of 120x90x10 mm [9]. Several proposals of design of the support where made. Each different support proposed different ways of supporting the dichroic. Each proposal was submitted to simulations and calculations described in section III and IV. The best support proposal was the one that showed the smallest deformation in the dichroic.

The final design consists of three rectangular surfaces that will support the dichroic in its bottom surface. Also it will have three leaf springs that will be in contact with the top edges. These leaf springs will be mounted on a base and this base will be mounted in the support base. Three contact points are enough to maintain the dichroic fixed.

Three semi-circular surfaces will act as references to position the dichroic during assembly (Fig. 1). Four lateral adjustable bolts will guarantee the position of the dichroic (Fig. 2). They will keep the dichroic in touch with the semi-circular references.

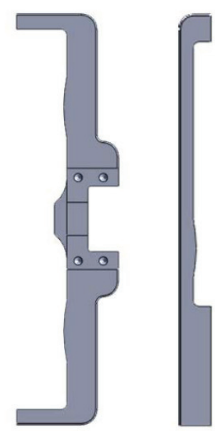

Fig. 1. Semi-circular references.

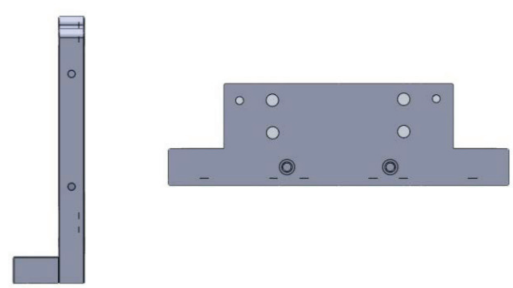

Fig. 2. Position of lateral adjustable bolts.

The support base and the leaf bases will be built of Aluminum 6061 T6 while the leaf springs will be built of Nylamid. Nylamid was chosen to minimize the effects of contact between the leaf springs and the dichroic. The bolts have nylon heads to prevent damage to the dichroic on its lateral faces.

III. DICHROIC VERIFICATION AND INTEGRATION WITH THE SUPPORT

Thin plate analysis and finite element analysis (FEA) was applied to the different support proposals. With these analyses we determined the deformation caused to the dichroic once it is mounted in the support.

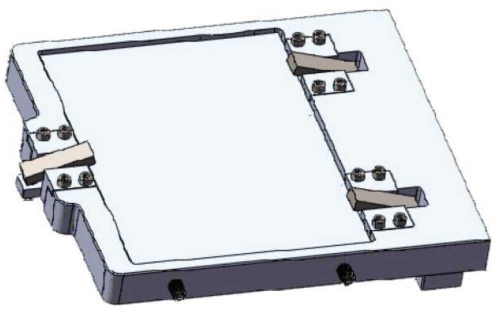

Fig. 3. Support base of the dichroic.

Using the differential equation for plate bending [10]

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{P}{D} \qquad (1)$$

and having its solution when having two opposite edges fixed, we got the approximate deformation of the dichroic for each of the support proposals.

FEA was used to determine dichroic deformation in all the support proposals. ALGOR® software was used to make these simulations.

IV. DEFORMATION RESULTS

The results obtained with both analytical calculations and FEA are shown in Table 1.

Table 1: Results for analytical and FEA deformations for all support proposals.

Proposal	Analytical deformation	FEA deformation	Difference
I	30.24 nm	32.23 nm	6.58%
II	30.24 nm	27.77 nm	8.16%
III	29.54 nm	14.95 nm	49.39%
IV	29.54 nm	27.71 nm	6.19%
V	30.24 nm	32.59 nm	7.77%
VI	30.24 nm	33.17 nm	9.68%

It is important to note that analytical results are only approximations because solutions to the equation (1) are only know to continuous boundary conditions. Our real boundary conditions are not continuous hence the result is only an approximation.

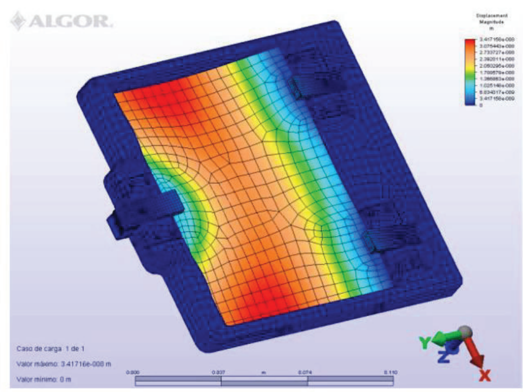

Fig. 4. FEA result for final support proposal.

In Fig. 4 the FEA simulation for the final support is shown. Maximum deformation occurs at the edges that are farther from the leaf spring. The maximum deformation is of $w_{\max} = 27.77nm$

One of the proposals with less deformation is the one that has more contact area with the dichroic surface. This proposal was selected as the final design. This selection was made according to the total deformation and the ease of machining the support.

V. CNC MACHINING

A CNC VMC EMCO 3000 milling machine was used to machine a prototype of the support. MasterCam 9© was used for generation of CNC trajectories. The leaf springs and leaf spring bases where machined using conventional milling machine.

The purpose of this prototype is to make laboratory tests to have a measurement of the stress suffered by the dichroic when the leaf springs are pressing it. To make these tests a common window glass will be used.

The complete assembly of the support is shown in Fig. 5. When assembling, the dichroic has to be put first and in contact with the semi-circular references. After that, the bolts are adjusted to keep the dichroic aligned. Finally, the three leaf-spring systems are put in their place and adjusted to supply the necessary force to keep the dichroic fixed.

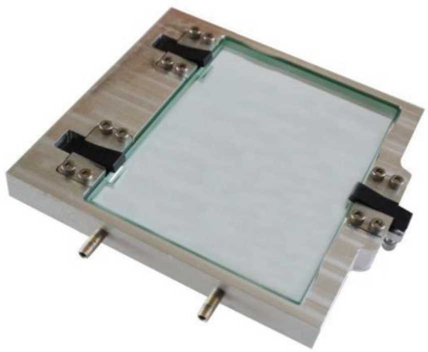

Fig. 5. Final assembly of the support.

VI. VALIDATION

We proposed a photoelasticity test to get the stress patterns in the dichroic caused by its support. We used a white light source and two Polaroid polarizers. After performing the test, we didn't observe the fringe pattern in the dichroic.

The dichroic has a stress optic coefficient of $2.77 \times 10^{-6}\,\mathrm{mm}^2/\mathrm{N}$. In order to be able to see the fringe pattern, another material for the dichroic with a higher stress optic coefficient can be used. Also, an automated polariscope with higher precision can be used to be able to see the fringe patterns in the dichroic.

VII. CONCLUSION

The final design proposal supports the dichroic firmly in its place causing an acceptable deformation in it. This deformation was calculated using thin plate theory and finite element analysis. This design ensures that all the requirements are met and that the dichroic will achieve its filter tasks the best possible way. Future work includes testing the dichroic to measure the amount of stress. We propose a photoelasticity test to evaluate the stress patterns in the dichroic. An alternate method to measure the stress patterns has to be used due to the characteristics of the dichroic. The support along with the entire instrument will be built and assembled in the 1.5 m telescope in San Pedro Mártir, México.

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