Optomechanical design and implementation with 3D printing

Diseño e implementación optomecánica con impresión en 3D

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Received March 28, 2018; Accepted June 20, 2018

Abstract

When carrying out the design and assembly of an experimental system (technological prototype), the optical engineer finds problems with the commercial availability of the optomechanical components and devices. The problem is that most of these elements are imported to Latin America or possibly for manufacturing specialized infrastructure and qualified personnel is required. In addition, existing designs are limited and the cost and time often delay implementation. Recently, in optomechanics, the possibility has arisen of designing, manufacturing and producing three-dimensional objects at a low cost from a CAD software and a 3D printer. Among the benefits found, it stands out that accelerates the process of implementation of an experimental system, has greater freedom in the design with respect to the commercial optical mounts, allows visualized scenarios of the mounts before being manufactured. In the same way there are disadvantages, because they do not have the same resistance, rigidity and life time that a metal or plastic emptied piece. In this paper we present both an analysis and an explanation of the process of design and development of various pieces that were implemented in the research laboratory.

Optical Mounts, 3D Printing, Optomechanical Design

Resumen

Al realizar el diseño y ensamble de un sistema experimental (prototipo tecnológico), el ingeniero óptico encuentra problemas con la disponibilidad comercial de los componentes y los dispositivos optomecánicos. La problemática radica en que la mayoría de estos elementos son importados por distribuidores de Latinoamérica o en su caso, para su fabricación se requiere infraestructura especializada y de personal calificado. Además, los diseños existentes son limitados y los costos y tiempos de entrega retardan muchas veces su implementación. Recientemente, en la optomecánica, ha surgido la posibilidad de diseñar, manufacturar y producir objetos tridimensionales a un costo bajo a partir de un software CAD y una impresora 3D. Entre los beneficios encontrados se destaca que acelera el proceso de implementación de un sistema experimental, tiene mayor libertad en el diseño con respecto a las monturas comerciales y permite visualizar prototipos de las monturas antes de ser fabricadas. Del mismo modo existen desventajas, pues no presentan la misma resistencia, rigidez y tiempo de vida útil que una pieza metálica o de plástico vaciado. En este trabajo presentamos tanto un análisis, como una explicación del proceso de diseño y puesta a punto de diversas piezas que fueron implementadas en el laboratorio de investigación.

Monturas Ópticas, Impresión 3D, Diseño Optomecánico

Citation: GOMEZ-VIEYRA, Armando, VERGARA-VAZQUEZ, Karla Beatriz, FLORES-MONTOYA, David and MIRANDA-TELLO, José Raúl. Optomechanical design and implementation with 3D printing. ECORFAN Journal-Taiwan. 2018, 2-3: 8-14.

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Introduction

The limited allocation of resources for research and teaching have hindered the development of exact sciences and engineering in Latin America and developing countries. In particular, the instruments and developments where optical engineering intervenes, are of high costs for both the optical components, as for the mechanical frames, this is mainly due to the levels of measured tolerances from the wavelengths that are used in the system.

Many of these components are imported, which is why they are expensive for our economy. This is largely due to currency and tariff changes, which cause a considerable increase in their cost. While there are optomechanical elements that can be manufactured in local workshops, the configuration of the optical assemblies must have a high precision and as a result, some problems have arisen at the time of positioning and alignment with commercial products (lasers, diodes, detectors).

The characteristics of each experiment are unique and the products that are offered in the market are also limited, so they require a specific design and special manufacturing by numerical control equipment, which is not commonly accessed. Table 1 presents the various existing technologies for the manufacture of optomechanical parts.

The possibility of designing and manufacturing three-dimensional objects at a low cost and in a shorter time from a software and a 3D printer, offers the opportunity to develop custom parts designs and with particular specifications. Therefore, the option of using 3D printing in plastic as an alternative to the manufacture of metal parts made by casting, casting, forging, among others, or the acquisition of the same components at an obviously higher price, represents a very important viable option in the work of research and development of prototypes in optomechanics.

Process	Advantage	Disadvantages
Emptying plastic	• It is used for parts that must be reproducible. • If the mold is suitable the piece is obtained in a short time and the production cost is low. • Additives can be added to the plastic to improve qualities such as hardness, color, transparency, density, etc.	• You need to create a mold that contains the exterior details of the desired geometry; the complexity increases if holes are required or there are millimeter sections. • The piece is not homogeneous, it can contain air bubbles. • The mold can generate unwanted sections that will be evident until the piece has solidified. The mold, sometimes, is destroyed to extract the piece.
Metal machining	• The procedure can be performed for, in addition to metals, plastics, ceramics, wood or any solid material. • This process also refines flat surfaces and improves sections with rounding. • The cuts that are achieved with this technique are accurate.	• The machining machine is large. Its acquisition price is high compared to the other two methods. • For parts with great detail, the operator must perfectly control the movement of the material and the machine. • To obtain the piece, the metal must be larger than this. • There is waste of material and chips.
3d print	• The pieces that are obtained are reproducible, personalized and modifiable through the design software. • Plastic parts, ceramics, metals and even biomaterials can be printed. • The unit cost of production of the piece is low and can be manufactured quickly without the need for an operator to take care of the process.	• Pieces with millimeter sections are subject to the sensitivity of each printer. • The final piece contains remnants that must be removed by the user. • The surface finish of the piece, depending on the speed and temperature of the printer, can be rough or grooved. • The procedure must be carried out in an environment without air currents that cause the piece to contain dust particles, vibrations in the printer must be avoided because it can be decalibrated.

Table1 Comparison of technologies for the manufacture of optomechanical components
Source: Self Made

3D printing can be defined as a set of technologies that allow the manufacture of pieces with different geometries, because a CAD design software is used, which facilitates the manipulation of an element without needing to be tangible.

The program grants a wide variety of positioning with other parts thanks to its option of assembly, coupled with this, anyone with basic knowledge about the program can maneuver with the shape, tolerances, dimensions and thus project the need for assembly in a piece of support, retention, support, union, etc.

When you have the final sketch, the file must be saved with .STL extension, because it is the format that recognizes the printer software, this, commonly, is integrated with the machine and allows access to other types of parameters, for example: melting temperature of the material, thickness of the printing lines and the speed with which each layer will be deposited. It is at this point that the design process is completed.

When it comes time to manufacture the piece, you must also select the type of printer that will do the work; there are printers by photo-hardenable polymer, stereolithography, plastic extrusion and polymer injection printers. To choose the appropriate in general should be considered the following factors: printing speed, material, hardness and final finish desired in the pieces, as well as the prices of inputs.

In the case of optomechanics, we usually work with plastics, however, these devices can work with clays or metals. The most used thermoplastics are ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic Acid), the preference of some will depend on the conditions of the experiment, the physical and chemical properties, if there is a possibility that it can undergo machining, its interaction with the light, heat, humidity, among others.

On the other hand, the hardness of the piece will depend on the thickness of each line and the printing speed. To obtain the designed piece, the printer melts the material, through an extruder, or the printer deposits the material to make the photo. The material is added layer after layer in a xyz plane on a base (bed) where "parts" of the piece that have no support "rest", finally a three-dimensional piece is obtained.

At the end of the manufacturing, the cleaning is carried out, final adjustment for the coupling of the piece in the experimental assembly and it is observed if it fulfills its function in the system.

Subsequently, both dimension and geometry errors are looked for to analyze if a modification and reprint is necessary, which is feasible because the design software allows the correction of the element and the printing cost is not excessive. If there is no other change, we continue with the integration of the elaborated piece to the experiment (or prototype) and the alignment of the same.

Development

When problems arise in the experimental assemblies or in the design of optical and optoelectronic prototypes, it is necessary to define if the optomechanical parts involved require a support or union piece.

To design the optomechanical parts to be manufactured, any CAD program can be used, in this work SolidWorks® is used. In this program the system of units is defined and the design of the piece that is regularly a support is proceeded.

This means that some element within the experimental setup needs to maintain a specific position and there is no existing commercial item that can be used for this purpose. The manufacture of the optomcanic component is done using a 3D printer.

A typical example of the disadvantages that can be solved is that of a suitable support for some source of lighting. In the low-power optical assemblies, LEDs are used as the source of light, either the standard 3 or 5 mm model, as well as sources with special characteristics such as the 1W LED that needs a suitable heatsink (Fig. 1), that there is no commercial model that adapts and supports the LED mounted on its heatsink.

Next, the design process for a mount is shown, which suits the conventional 1-inch ophthalmic. In general we proceed to consult the specification sheet of the device or measure its dimensions.

ISSN-On line: 2524-2121

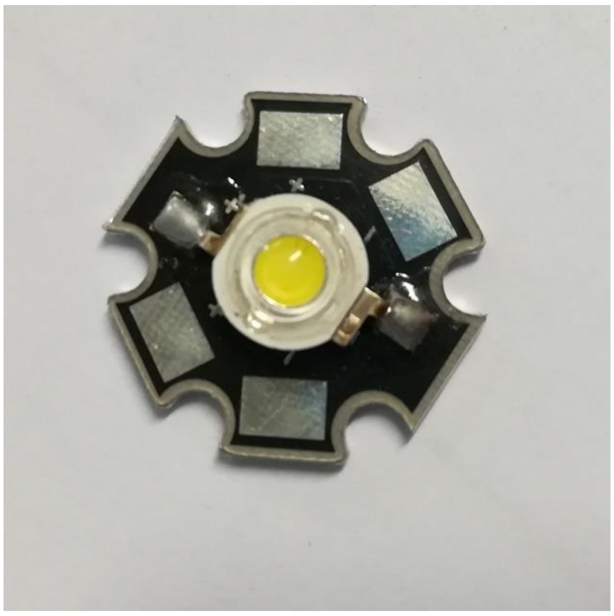

Figura 1 Power LED assembled with the heat sink
Source: Self Made

From the obtained dimensions, a sketch of the piece is established that is required in a three-dimensional plane with the specified dimensions. When working in a CAD program, it is possible to observe the different perspectives of the frame.

At the moment of designing a support, the dimensions of the element to be held must be considered, in this case a 1W LED, the possible remnants of the material, the expansion or contraction of the printing material and the minimum dimension that the 3D printer can work.

The printers to which we have access allow us a minimum dimension of 1.5 mm of thickness in the pieces, with which a support and a suitable hardness is obtained. The brands Makerbot®, Createbot®, Wanhao® and Creality® are the ones we have used with acceptable results, although in the market, there can be 3D printing systems with the same or better characteristics.

The second step is to extrude the piece to observe a three-dimensional sketch, verifying all the measurements and that the dimensions are homogeneous. It is analyzed if it is necessary to add or remove any sub-element such as: tabs or holes, add sections or holes for opresores screws, ensuring that the support complies with: fasten the component and fits the commercial optomechanical frame used in the system.

In Fig. 2, the consolidated sketch of the designed piece is shown, here we considered both the support of the piece and the space needed for the electrical connections of the LED. If there are no more modifications to the design, a map of views is created (the cross section and isometric), where the final dimensions of the object are observed, the assembly can even be presented with the external parts if its designs are available.

It is very convenient to make a backup of the file to make changes to the drawing if necessary, and store it in .STL format to be able to transfer it to the printing system.

The designs created in CAD design programs, consider a construction of solid models with exact measurements, so when creating the .STL files, these in principle do not fit one hundred percent with 3D printers. So you have to resort to mesh editing programs such as Autodesk Meshmixer® to verify the solidification, that is, you must ensure that there are no construction errors in the drawing (damage) that cause sections to be deleted in the printing process, as well as presenting a suitable mesh for printing. To avoid this, the .STL file is analyzed with the Autodesk Meshmixer® program.

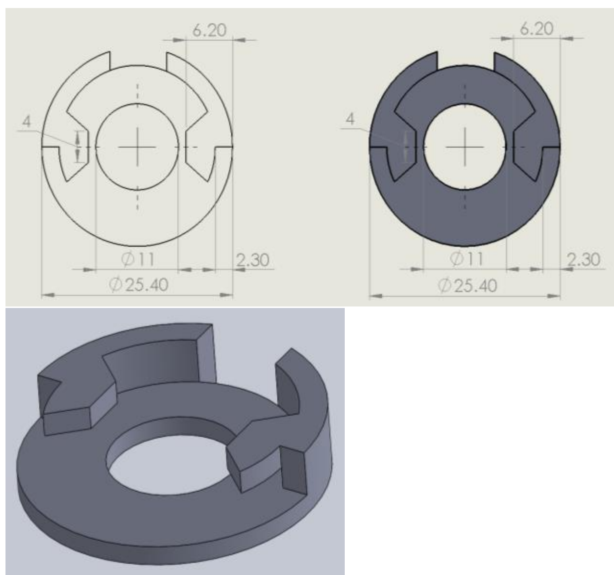

Figure 2 1W LED support (measures in mm)
Source: Self Made

Our experience has shown that it is preferable to modify the design in the software where it was originally designed. Although it can also be done in the mesh editor. In Fig. 3 a screen print of the mesh of the LED frame is presented.

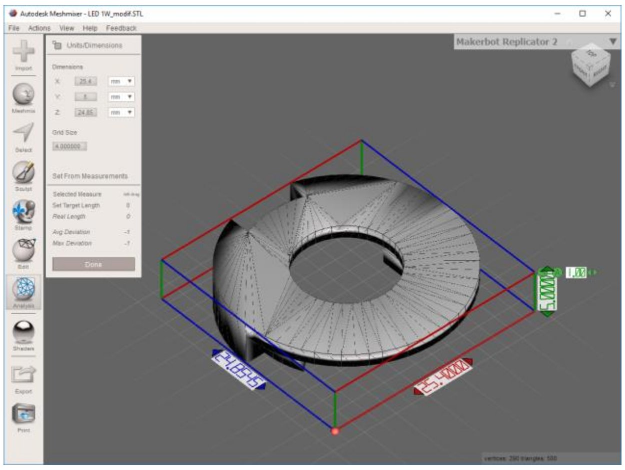

Figura 3 Review of dimensions in the MeshMixer program
Source: Self Made

The next step is to set the parameters of the printer, generally the ones that are modified are: printing speed, minimum thickness, density and printing temperature. Because the pieces that are regularly printed are not continuous, the software of each printer defines the trajectories and auxiliary supports, as shown in Figure 4.

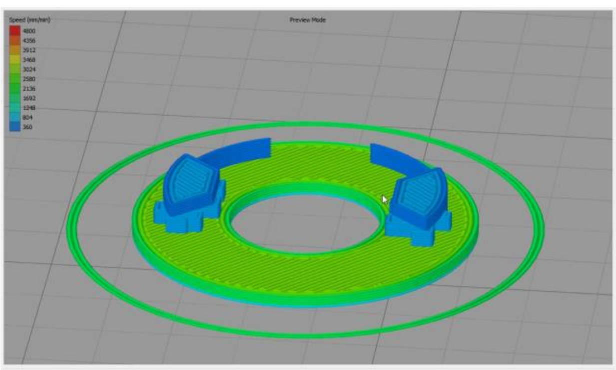

Figura 4 Scheme of the printing speed in the piece
Source: Self Made

While the printer works it is important to avoid vibrations or movements that may disturb the printing process. When this step is completed, the beds of the sections are removed and their air cooling finished. Due to the resolution of the printers, for a better finish the frames must be sanded.

Figura 5. 1W LED stand finished and mounted
Source: Self Made

After making the corresponding adjustments (remove auxiliary supports and unwanted material), the optomechanical mount is ready. Figure 5 shows the final result for our example. Figures 6, 7, 8 and 9 show examples of support for an LED laser, a mirror support to decentralize it, a base for coupling travel tables and a 45 ° support for a one-inch mirror, respectively. In summary, Table 2 describes the procedure necessary for the fabrication of an optomechanical frame by 3D printing.

1.	Identify the part that requires support, union, support, etc.
2.	Draw a sketch of the geometry that covers the need for support.
3.	Draw the required part in the CAD program. 3.1. Select the unit system. 3.2. Select the plane on which the piece will be worked (plant, elevation, etc.). 3.3. Draw the piece.
4.	Extrude the piece to generate a solid. Verify if holes are needed for screws, chamfer, rounding or some special feature for the design.
5.	Save the piece in .STL format and send the file to the meshing program for the analysis of dimensions, construction and meshing.
6.	Select printing speed, material temperature, thickness of each printing line, etc. in the printer software.
7.	Print the piece.
8.	Remove the supports generated by the printer, check the geometry and if necessary, clean the remnants of the material.
9.	Place the piece in the experimental assembly and confirm its purpose of subjection.
10.	Check if the piece that was printed needs corrections.

Table 2 Procedure for the manufacture of an optomechanical part with 3D printing
Source: Self Made

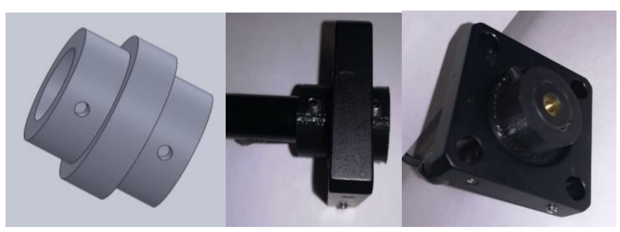

Figura 6 Support for diode laser
Source: Self Made

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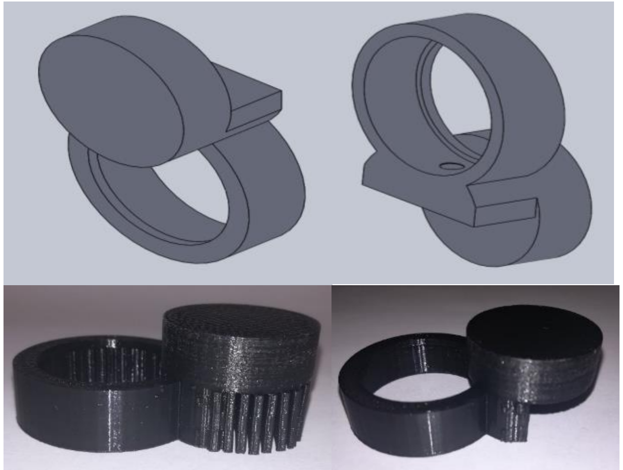

Figura 7 Mirror support
Source: Self Made

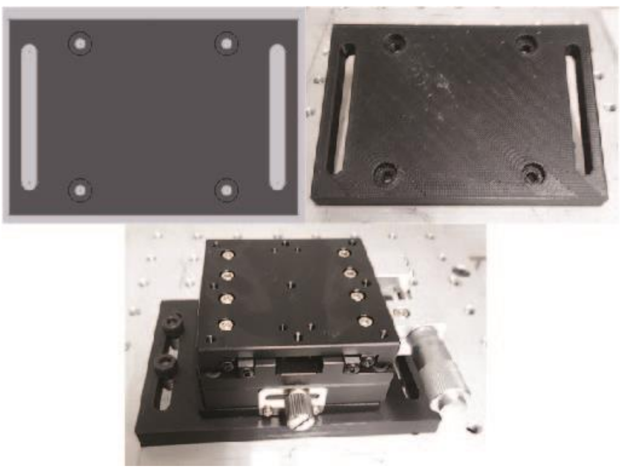

Figura 8. Base for coupling of sliding tables
Source: Self Made

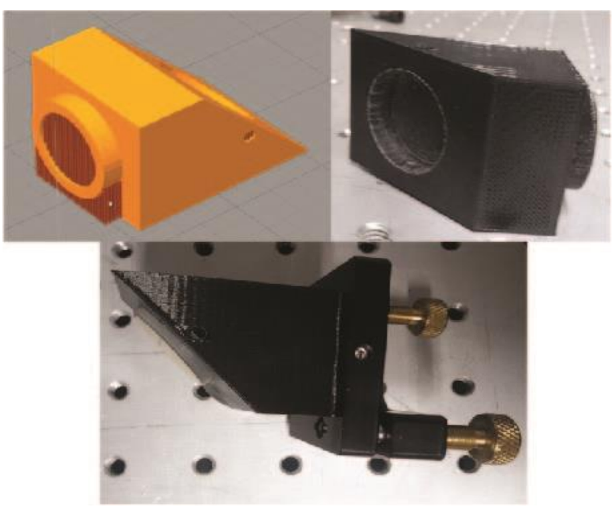

Figura 9. 45 ° support for one-inch mirror
Source: Self Made

The design time will depend on the geometric complexity and technical details of the optomechanical component, taking up to several days in the design, but if the piece is very simple it can take a couple of hours.

The printing time will depend mainly on the size and the working speed of the printer.

Thanks to the freedom with which you work in SolidWorks®, more complex geometries can be built, with space to place oppressive screws and although it has a limited life time and rigidity, the cost benefit of 3D printing makes this technology cost-effective the implementation of fixed experimental arrangements, design and testing of frames before manufacturing them with more expensive technologies, as well as for the construction of prototypes. It should be noted that, at the end of printing, the pieces usually have excess material and unwanted reliefs, so it is necessary to remove and sand the imperfections, this does not alter the function performed by the piece, the strength or density of this.

It should be clear that the disadvantages presented by the optomecanics designed and manufactured by 3D printing, limit its use in some situations, mainly those that present continuous adjustments for the use of oppressors or screws, as well as those that demand continuous stresses and stresses.

Due to the advantages presented, it can be applied in the realization of prototypes at high speed, with many degrees of freedom and low costs. In addition, in research laboratories they allow to substantially reduce costs and waiting time, mainly in developing nations. However, it is necessary to have trained personnel with sufficient experience for the proper design of these optomechanical components.

Conclusions

This paper shows some examples, advantages and disadvantages in the design and manufacture of optomechanical parts based on 3D printing. It also shows that this technology is one of the most promising inventions, being accessible in cost and management, so its inclusion in various fields, from industry to education, has been very promising.

The advantages of 3D printing in optomechanics are clear, the customization of the pieces allows them to become a common means of manufacturing them, the materials they use are, for the most part, recyclable or biodegradable, their use has been extended to Medical areas where organic tissue is used to create prostheses.

It is important to mention that the optomechanical parts rarely need maintenance and their surface finish is suitable for the fixation of sensitive parts such as lenses or mirrors. Also, the time needed to obtain a piece with 3D printing is much less if it is contrasted with the time required when ordering the piece abroad and the cost of importing it. It must be taken into account that the useful life of these parts will depend on the technology and printing material. In some cases, it is an intermediate step to develop the molded metal or plastic frames.

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