PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

A display model for the TOU of PLATO: just a cool toy or a benchmark of opportunities?

Dima, M., Greggio, D., Bergomi, M., Biondi, F., Farinato, J., et al.

M. Dima, D. Greggio, M. Bergomi, F. Biondi, J. Farinato, G. Farisato, D. Magrin, L. Lessio, L. Marafatto, M. Munari, I. Pagano, R. Ragazzoni, V. Viotto, D. Piazza, "A display model for the TOU of PLATO: just a cool toy or a benchmark of opportunities?," Proc. SPIE 9904, Space Telescopes and Instrumentation 2016: Optical, Infrared, and Millimeter Wave, 990432 (29 July 2016); doi: 10.1117/12.2232938

Event: SPIE Astronomical Telescopes + Instrumentation, 2016, Edinburgh, United Kingdom

SPIE.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020 Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

A display model for the TOU of PLATO: Just a cool toy or a benchmark of opportunities?

M. Dima [*a], D. Greggio [a,b], M. Bergomi[a], F. Biondi[a], J. Farinato [a], G. Farisato [a], D. Magrin [a], L. Lessio [a], L. Marafatto [a,b], M. Munari [c], I. Pagano [c], R. Ragazzoni [a], V. Viotto [a], D. Piazza [d]

[a]INAF-Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio, 5, 35122 Padova, Italy
[b]Astronomy and Physics Dept-Università degli Studi di Padova, Vicolo dell'Osservatorio, 3, 35122 - Padova, Italy
[c] INAF - Osservatorio Astrofisico di Catania, Via S.Sofia 78, 95123 Catania, Italy
[d]Physics Institute -Universität Bern, Bern, Switzerland

ABSTRACT

We produced a "toy-model" of one Telescope Optical Unit of PLATO, the Medium sized mission selected by ESA to fly in 2024. This is a six lenses dioptric very wide field camera with a window in front to take care of radiation impact on the first lens whose optical glass cannot be replaced with a radiation hardened one. The main aim of this project is just to produce a "cool" model for display purposes, in which one can "explore" the details of the inside through some openings in the tube, in order to visually inspect some of the fine details of the opto-mechanics. While its didactic and advertising role is out of doubt, during its construction we realized that some interesting outcome can be of some relevance for the project itself and that some findings could be useful, in order to assess the ability of producing with the same technology some (of course of much more modest quality) optical systems. In this context, we immediately dropped the option of producing the lenses with opaque material painted with a color resembling a refractive material (like blue for instance) and decided to actually produce them with transparent plastic. Furthermore the surfaces are then finely polished in order to give them basic optical properties. Such an optical system has only very coarsely the converging properties of the original nominal design for a number of reasons: the refractive indexes are not the nominal ones, the quality of the surfaces and their nominal values are only roughly, within a few percent, the targeted one, and the way the surfaces are built up makes them prone to some diffraction effects. However, the bulk of the lens and the surface roughness will give a large magnification of the scattering effects that will be experienced, at a much lower level, on the actual flight model. We investigated through propagation of a laser beam and by digital camera the main stray light modes that this toy-model offers. In other words, the model amplifies, to a large extent, the negative bulk scattering and spurious reflection just because surfaces and materials are orders of magnitude rougher that the intended ones. Even if this did not allow to attempt to make any quantitative measurement, in order to scale down to the actual one, we used it to look out independently for the main sources of stray light and we compared them with the one discussed by the optical design team, obtained using professional ray tracing code. Finally, we point out some of the technicalities used in the design to mimic the finest mechanical elements that cannot be safely incorporate in the final design and to produce pieces of size much larger than the maximum volume allowed by our 3D printer in a single shot.

1. INTRODUCTION

Briefly, PLATO is the Medium sized mission selected by ESA to fly in 2024. This instrument consists of up to 34 small telescopes named Telescopes Optical Units (TOU), with a wide field of view (~2250 deg^2) and a large photometric magnitude range (4-16 mag) because of the combined full well of the several involved CCDs. It targets on rather bright (4-11 mag) stars in wide fields to detect and characterize, using the photometric transits technique, Earth-like planets, whose masses can then be determined by ground-based radial-velocity follow-up measurements. Asteroseismology will be performed for these bright stars to obtain highly accurate stellar parameters, including masses and ages. The combination of bright targets and asteroseismology will translate into high accuracy for the bulk planet parameters: 2%, 4-10% and 10% for planet radii, masses and ages, respectively should be at hand. The planned baseline observing approach includes two long pointings (2-3 years), to detect and characterize planets into the habitable zone of solar-like stars, and an additional step-and-stare phase to cover in total about 50% of the sky. PLATO will observe up to one

Space Telescopes and Instrumentation 2016: Optical, Infrared, and Millimeter Wave, edited by Howard A. MacEwen, Giovanni G. Fazio, Makenzie Lystrup, Proc. of SPIE Vol. 9904, 990432 · © 2016 SPIE · CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2232938

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

milion of stars and will characterize and detect hundreds of small planets and thousands of planets in the Neptune to gas giant regime outside the habitable zone. It will therefore provide the first large-scale catalogue of bulk characterized planets with accurate radii, masses, mean densities and ages. This catalogue will include terrestrial planets at intermediate orbital distances, where surface temperatures are moderate. The range of this parameters covered by PLATO with statistical numbers of bulk characterized planets will be unique.

There are several reasons to build the prototype of a PLATO TOU, for example to have a visual perspective of the real dimensions of the structure and the relevance of each component, or to help in the divulgation process (showing a real model of a space telescope is most incisive than explaining it with words or pictures).

Moreover, as one of the responsibilities of the Italian team is the Assembly, Integration and Verification (AIV) of a Demonstrator Model with the purpose of validating the alignment procedure within the given requirements, to test its optical performances at its working environment conditions (T = -80°C) is one of the planned activities. The optics of the Demonstrator will be flight representative (but not radiation hardened) and the mechanical structure (provided by our Swiss partner) will be thermally equivalent, but with different shape and materials except for the interfaces, to the one of the Flight Model. The AIV of the final model will take place at industries premises, under INAF supervision. The construction of a preliminary model prior to the realization of the Demonstrator can be very helpful. A TOU is a fully refractive design made up of 6 lenses and this gave us the idea of printing the lenses with a trasparent material. Testing their optical properties, then, was a natural consequence.

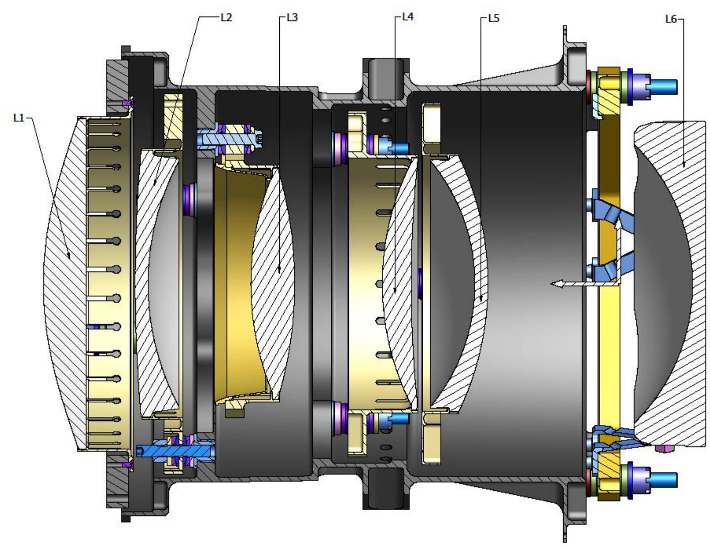

Figure 1: A mechanil drawing of TOU. We can see the optical train and how the lenses are labelled.

2. THE 3D PRINTER

Two kinds of 3D printers have been used for this work: a Dimension SST 1200 ES and a Object 500 both by Stratasys. With the first one, we printed the mechanical parts of telescope, while with the second one we printed the optical train.

The size of the Dimension printing volume is 254x254x305 mm and the layer thickness is 0.254mm (corresponding to the resolution of the printer). This machine used two kinds of materials to build the prototype. The first one is the Model Material (MM) and the second one is a Support Material (SM). The MM is “ABS plus”, a widespread plastic used in many everyday objects. This material has good mechanical properties like impact resistance and toughness. MM materials are available in a wide set of colors like, but for TOU we used neutral color materials. The SM, instead, is a particular polymer used to create a scaffolding for jutting out parts of the object. When the printing of the object is finished, the SM is removed either mechanically, if possible, or with a solvent in a particular “washing machine”.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

Figure 2. Left: the 3D printer; middle-top and right-top: the printing chamber; middle-bottom: the washing machine; right-bottom: the cartridge.

Both MM and SM consist on a filament rolled up inside a properly size cartridge.

In practice, a 3D printer consists of two important mechanical parts: the head and the Z-Platform. The head has two nozzles (one for MM and the other for SM) and it can move in the x-y directions across a rail. It has also an heater that reaches a temperature of about 280/300 °C to melt the material. The material comes out for extrusion, driven by two little wheels, which push the filament inside the nozzle that reduces the diameter of the filament to 0.254 mm. The Z-platform, instead, is a horizontal plate, which is moved vertically along the z axis through an endless screw. A removable base model is connected to the Z-platform. The base model has a rough surface where the SM adheres. All this mechanisms are inside a hot camera with a constant temperature of 75°C. The printing process is a combination of the head and Z-platform movements: the head movement (that extrude the plastic) is used to print within a layer while the Z-platform movement is used to develop, layer by layer, the height of the object. SM (for the jutting out parts) grows up at the same time of MM, layer by layer, in fact the head has a mechanism, called toggle bar, that conveniently switch on the required nozzle. The 3D printer works with STL (STereo Lithography interface format or Standard Triangulation Language) file format, which can be imported or exported by most 3D software, like Blender or Inventor.

As a second 3D printer, used to realize the lenses group, we selected the Objet 3D printer. This machine uses a different printing technique. The Objet works similarly to inkjet printing, but instead of jetting drops of ink onto paper, it jets layers of curable liquid photopolymer onto a build tray. Whit this technique, the machine is able to create models with several materials and several colors. This particular model of Stratasys printer has 16 µm of thickness layer and a building resolution of 600dpi in the x-y axis and 1600 dpi along z axis and a volume of the printing camera of 490 x 390 x 200 mm.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

Figure 3: The 3D printer used for lenses**.** This machine is multi-color and multi-material.

3. MECHANICAL PARTS

We will not go into a detailed description of this topic. Briefly, the TOU composed by a tube, on which we fix the optical mounts, which in turn hold the lenses. Obviously, the TOU lenses have different geometries, which required diverse mounts and several interfaces inside the tube for each mount. The lenses adjustment during the alignment is done combining particular washers and shims, including the ones for tip-tilt adjustment. In the 3D printed model, the tube is dissected in order to show the optomechanical parts, a little bit thicked for stiffen the structure. The particular screws, which fix the optical mounts to the tube, are made of aluminum, because they are more resistant then the analogous, printed in plastic.

4. OPTICS

The optics, printed with an Objet 500, are made of a material called VeroClear. According to Stratasys: "Transparent material (VeroClear-RGD810) is a rigid, nearly colorless material featuring proven dimensional stability for general purpose, fine-detail model building and visual simulation of transparent thermoplastics such as PMMA.". The index nominal of refraction is 1,49±0,03.

The first lens tested was L1. Such a lens is an aspheric plane convex lens with a diameter of ~185mm. We tested it with an interferometer with a collimated beam of 100 mm of diameter, at the usual HeNe and a wavelength of 632,8 nm. The first thing we could notice is a sketchy polishing, which could not completely remove the printing pattern. This pattern is clearly visible if we shoot a laser beam. We checked the outgoing spotbeam from the lens at several distance and compared it with what expected using the Zemax model. In Zemax, we put a mechanichal shape of L1 lens and reproduced the laboratory test. The measured lens spot shape, at a fixed distance, and the Zemax-modelled spot shape, at

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

the same distance, do not match, if we consider the index of refraction claimed by the provider. The spot shapes matches, instead, if we use a index of rifraction of ~1,54.

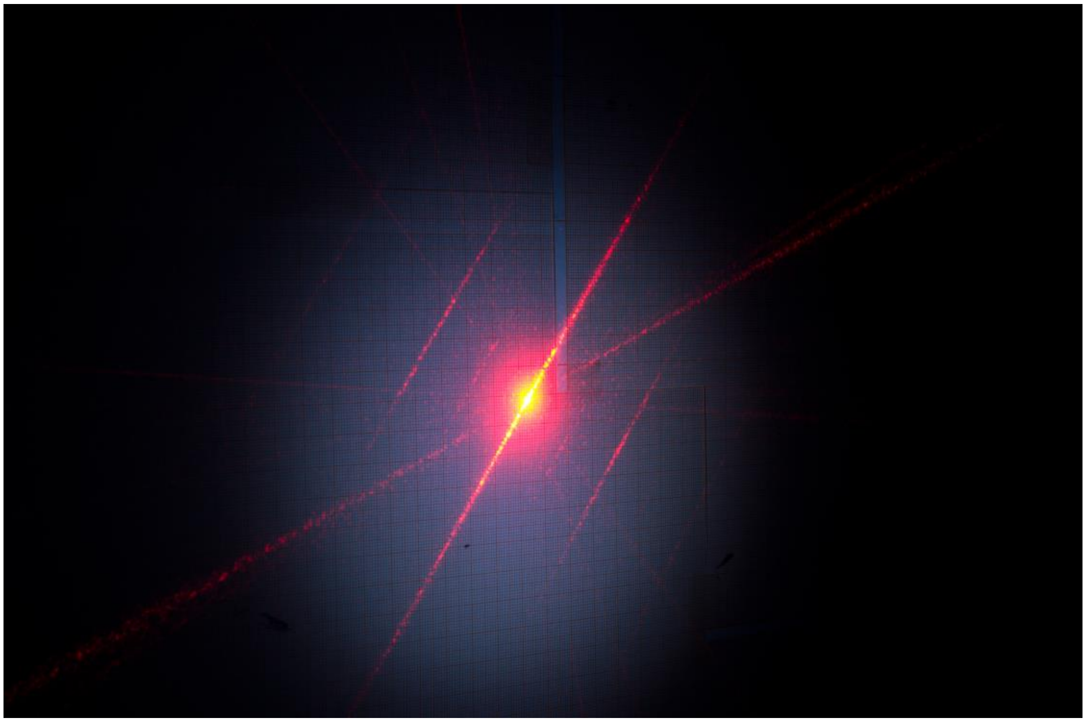

Figure 4: The image of Lens (L1) Spot with a laser on a screen. We can see the pattern of printing (parallel lines) and the effect of polishing.

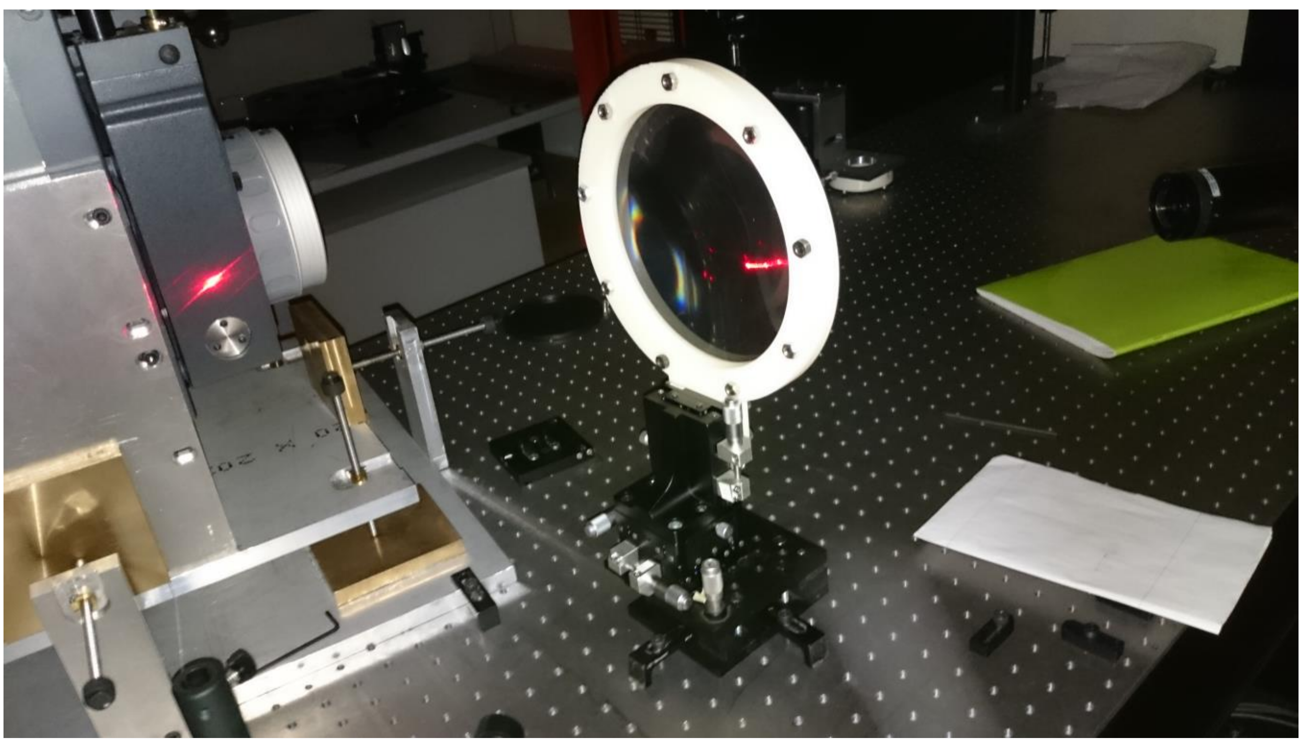

Figure 5: L1 test with an interferometer.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

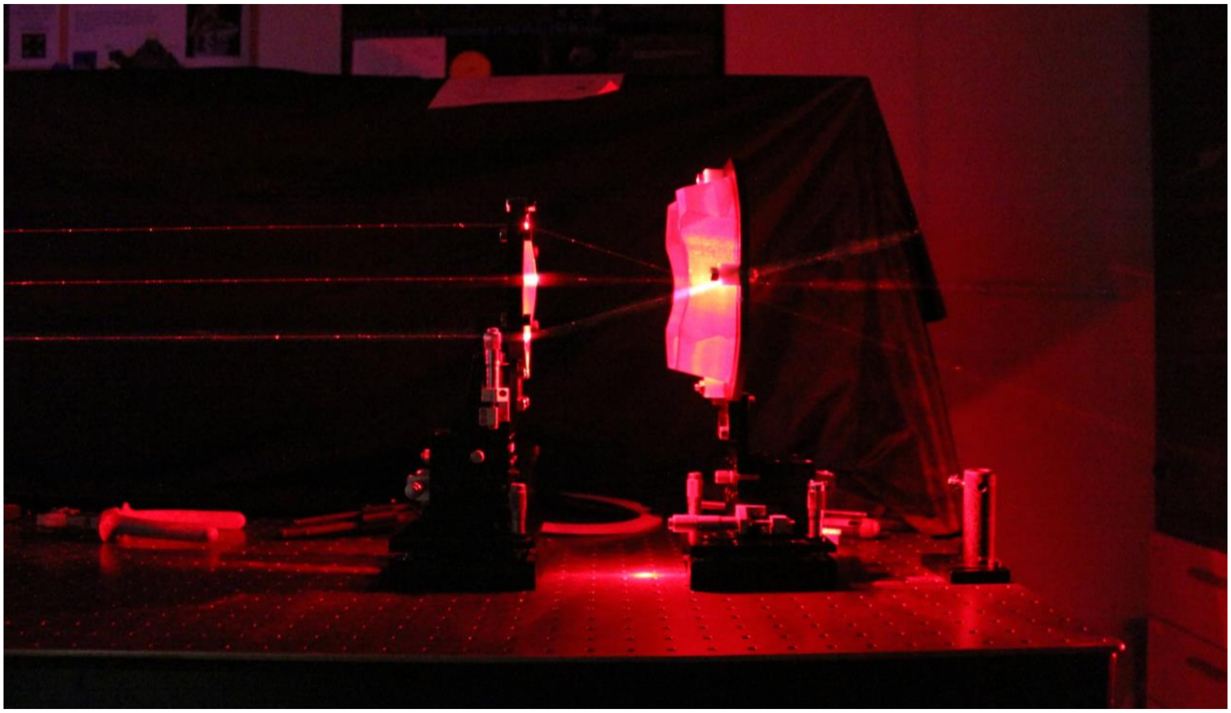

Figure 6: Ray tracing of two lenses: L3 and L6.

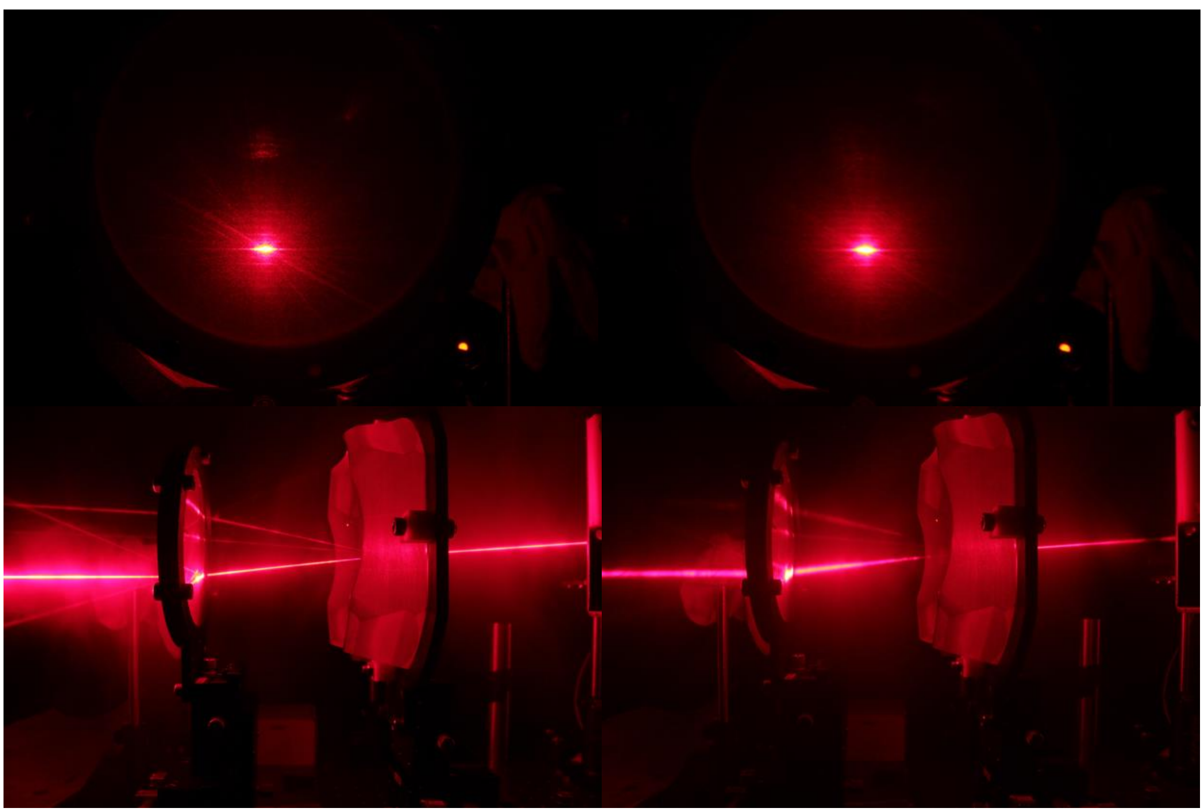

Figure 6: Ray tracing of two lenses: L3 and L6. Upper-left: Spot on the screen of a small laser beam. Upper-right: Spot on the screen of a bigger laser beam. Bottom-left: ray tracing test with a small laser beam. Bottom-right: ray tracing test with a bigger laser beam.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

Then we tested L3. This is a bi-convex lens with 119 mm of diameter. Also this lens shows the printer pattern and a sketchy polish. Here we tried to understand which, between the polish and the pattern effects, dominated.
The manufacturing of the lens is divided by an initial construction made up through the solely 3D printing machinery, and then it is polished with a combination of manual and machinery approaches, as it is usually the case for prototyping of mechanical components with a 3D printing machine. This is because even with very good 3D printers the quality of the surface can be annoyingly low with respect to the results of machining with other conventional techniques like milling. The use of transparent material furtherly exposes the issue of the effect not only to the surface, where some post-polishing or some etching treatment can be successfully achieved, but also to what the bulk of the material would provide in case of image formation through such optical components. In our cases, violently aspheric and conventional surfaces have been generated and some initial test have been performed in order to figure out which could be the quality attainable and to which extent these optics could be used for initial testing of our TOU or the related optical equipment.
It has to be noticed, in fact, that even a coarse manufacturing but within a certain quality could be useful to test in advance optical setup or manipulating devices. This could be useful to iterate and refine the development of the process of alignment and mounting with low risk because, in case of catastrophic or simple surface damage, the actual glass optics would be unaffected. The lenses, after the 3D printing, have been manually post-polished leading to the possibility to engrave a number of circular pattern onto their surface. While this was our first worry, we immediately noticed through simple examination of a laser pencil projected to a screen through one of the optical element, that the vastly more larger source of scattered light is due to the manufacturing process, and in particular to the piling up of material with the 3D printer. In this way the coordinates of the piling up process remain –in practice- embedded into the bulk of the material. While it is difficult to trace firm conclusions we suspect that the optical effects due to the bulk material still dominates with respect to the effect of the surface of the lenses. In order to support, from a qualitative viewpoint, such a statement we offer two simple observations: firstly, although we had in our hands various lenses with
different degrees of postpolishing (in order to test various approaches) the main observed pattern remains substantially unchanged and, secondly, we also checked using spurious reflection from a flat surface of the last lens. The last case ensure us that this effect is not introduced by, for istance, the discretization in the formation of the sag of the lens through the 3D printing process, as the flat is simply obtained directly be deposit of a layer of the transparent material used in the construction process. A minimal effect of the post-polishing is actually noticeable where one can see that the secondary scattering spikes rotates roughly accordingly to the position angle of where the laser pencil is prjected onto the lens, while the piling up structure remains unchanged.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

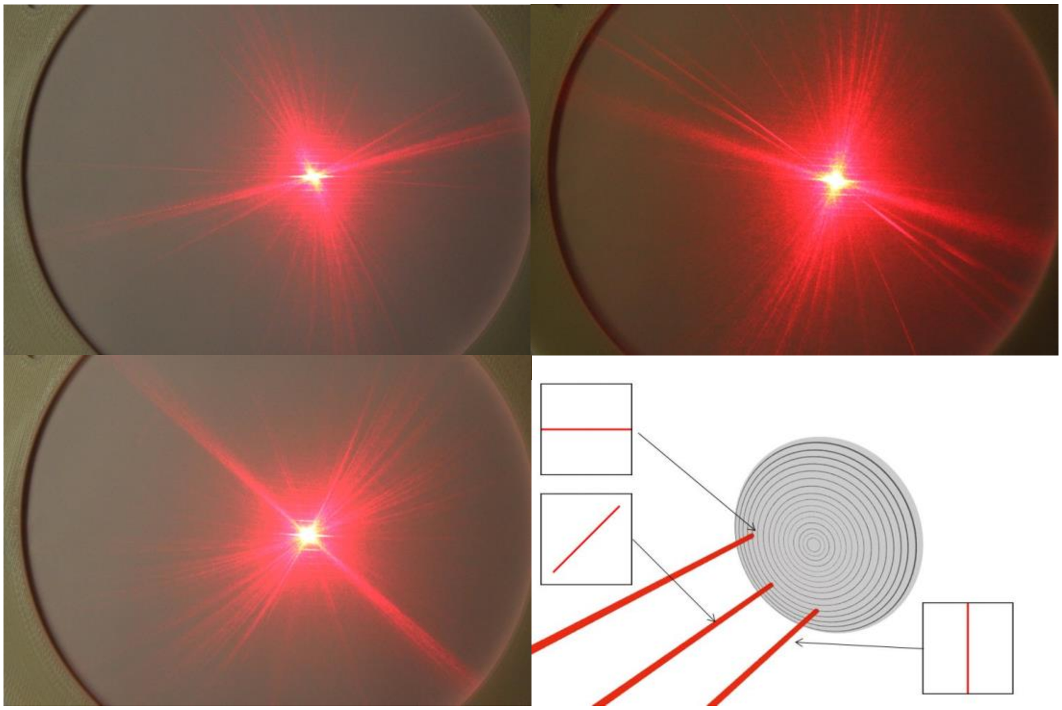

Figure 7: Effect of the circular polishing line on a screen.

A TOU build up with 3D printer optical elements represents a sort of analogical ray-tracing computer and we did not miss the opportunity to check this concept. While checking the optical quality would require a superb surface figuring and the deviation from nominal refractive index of the material would be unattainable, at least with the kind of 3D printing process we have been involved so far, spurious reflections represent potentially an ideal area of exploitation of such an approach. Multiple spurious reflections would rapidly require a huge number of computational power. With two only spurious reflections and six lenses the number of possible combinations is already very large as it involves the 11 possible first spurious reflections time the other 10, times the other 9, etc... But these numbers scale up vastly as soon as one allows for four or six spurious reflections. Moreover, as the surfaces of these optical elements are not AR coated, their intensity is significantly larger than the one of the actual system. Of course, these ghosts will turn to be, in the vast majoirty of case, too faint to be detected. However, if, by chance, some combination of spurious reflection will lead to a particularly dense reimaging of a source, even very off axis, onto the focal plane, this could be easily detectable. This is true because illuminating the system is equivalent to perform a full ray-tracing, including all the various combination of unwanted reflections.We initially tried to validate the concept by exploring on purpose some two spurious reflections as depicted in Fig.6. Once a spurious reflection is individuated, one can estimate its relevance by displacing the pencil or using a beam of a known size, and look at the corresponding size of that beam onto the detector, in order to have at least a rough estimation of the Jacobian of the transformation, giving a guess of how much this effect could lead to a degradation of the performance.

Of course, this approach will be hardly effective to give robust figures for such numbers, but it could be an easy way to individuate which couple (of groups of four, or group of six, and so on...) of surfaces are likely to produce deleterious effects, and to explore this with a dedicated ray-tracing session, vastly optimizing the need of computational time.

5. CONCLUSION

Optical elements with 3D printing for rapid prototyping is already a reality. We used these, for the moment, for mere didactical and display purposes. However, we noted and preliminary investigated that there is a huge potential behind this, even without approaching the optical quality attainable by conventional glass manufacturing. We think that individuation of the spurious reflection combinations, especially with illumination at high off axis distances, or involving

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

lenses edges, can be attacked with a sort of "analogical optical ray tracing computing", in order to identify the most potentially serious issues to be further analyzed.

The combination of the optical elements with their mechanical counterpart is unique in this kind of configuration and it would lead to notice effects that otherwise would never been simulated numerically, and hence discovered only in operation or through extensive testing of the various models.

REFERENCES

[1] C. Broeg, A. Fortier, D. Ehrenreich, Y. Alibert, W. Baumjohann, W. Benz, M. Deleuil, M. Gillon, A.Ivanov, R. Liseau, M. Meyer, G. Oloffson, I. Pagano, G. Piotto, D. Pollacco, D. Queloz, R. Ragazzoni, E. Renotte, M. Steller, N. Thomas and the CHEOPS team, "CHEOPS: A Transit Photometry Mission for ESA's Small Mission", EPJ Web of Conferences 47, 03005 (2013)

[2] Fortier A., Wehmeier U.J., Benz W., Broeg C., Cessa V., Ehrenreich D., Thomas N., "CHEOPS: a Space Telescope for Ultra-high Precision Photometry of Exoplanet Transits", Proc. SPIE (2014)

[3] Latham, D.W.; HARPS-N Collaboration, "HARPS-N: A new ool for characterizing Kepler Planets", AAS 221 (2013)

[4] Wheatley, P.J., Pollacco, D.L., Queloz, D., Rauer, H., Watson, C.A., West, R.G., Chazelas, B., Louden, T.M., Bannister, N., Bento, J., Burleigh, M., Cabrera, J., Eigmüller, P., Erikson, A., Genolet, L., Goad, M., Grange, A., Jordán, A., Lawrie, K., McCormac, J., Neveu, M., Walker, S., "Next Generation Transit Survey (NGTS)", Proc. IAU 299, 311-312 (2014)

[5] Ricker, G.R.; Winn, J.N.; Vanderspek, R.; Latham, D.W.; Bakos, G.A.; Bean, J.L.; Berta-Thompson, Z.K.; Brown, T.M.; Buchhave, L.; Butler, N.R.; Butler, R.P.; Chaplin, W.J.; Charbonneau, D.; Christensen-Dalsgaard, J.; Clampin, M.; Deming, D.; Doty, J.; De Lee, N.; Dressing, C.; Dunham, E.W.; Endl, M.; Fressin, F.; Ge, J.; Henning, T.; Holman, M.J.; Howard, A.W.; Ida, S.; Jenkins, J.; Jernigan, G.; Johnson, J.; Kaltenegger, L.; Kawai, N.; Kjeldsen, H.; Laughlin, G.; Levine, A.M.; Lin, D.; Lissauer, J.J.; MacQueen, P.; Marcy, G.; McCullough, P. R.; Morton, T.D.; Narita, N.; Paegert, M.; Palle, E.; Pepe, F.; Pepper, J.; Quirrenbach, A.; Rinehart, S.A.; Sasselov, D.; Sato, B.; Seager, S.; Sozzetti, A.; Stassun, K.G.; Sullivan, P.; Szentgyorgyi, A.; Torres, G.; Udry, S.; Villasenor, J., "The Transiting Exoplanet Survey Satellite", Proc. SPIE (2014)

[6] Magrin D., Ragazzoni R., Viotto V., Farinato J., Bergomi M., Dima M., Marafatto L., Greggio D., Munari M., Pagano I., Scuderi S., Benz W., Piotto G., Broeg C., Fortier A., "Shaping the PSF to nearly top-hat profile: CHEOPS laboratory results", Proc. SPIE (2014)

[7] Dima, M., Farisato G., Bergomi M., Greggio D., Farinato J., Magrin, D., Marafatto L., Ragazzoni R., Viotto V. "From 3D view to 3D print", Proc. SPIE (2014)

[8] Rauer, H., Catala, C.; Aerts, C.; Appourchaux, T.; Benz, W.; Brandeker, A.; Christensen-Dalsgaard, J.; Deleuil, M.; Gizon, L.; Goupil, M.-J.; Güdel, M.; Janot-Pacheco, E.; Mas-Hesse, M.; Pagano, I.; Piotto, G.; Pollacco, D.; Santos, Ċ.; Smith, A.; Suárez, J.-C.; Szabó, R.; Udry, S.; Adibekyan, V.; Alibert, Y.; Almenara, J.-M.; Amaro-Seoane, P.; Eiff, M. Ammler-von; Asplund, M.; Antonello, E.; Barnes, S.; Baudin, F.; Belkacem, K.; Bergemann, M.; Bihain, G.; Birch, A. C.; Bonfils, X.; Boisse, I.; Bonomo, A. S.; Borsa, F.; Brandão, I. M.; Brocato, E.; Brun, S.; Burleigh, M.; Burston, R.; Cabrera, J.; Cassisi, S.; Chaplin, W.; Charpinet, S.; Chiappini, C.; Church, R. P.; Csizmadia, Sz.; Cunha, M.; Damasso, M.; Davies, M. B.; Deeg, H. J.; Díaz, R. F.; Dreizler,

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

S.; Dreyer, C.; Eggenberger, P.; Ehrenreich, D.; Eigmüller, P.; Erikson, A.; Farmer, R.; Feltzing, S.; de Oliveira Fialho, F.; Figueira, P.; Forveille, T.; Fridlund, M.; García, R. A.; Giommi, P.; Giuffrida, G.; Godolt, M.; Gomes da Silva, J.; Granzer, T.; Grenfell, J. L.; Grotsch-Noels, A.; Günther, E.; Haswell, C. A.; Hatzes, A. P.; Hébrard, G.; Hekker, S.; Helled, R.; Heng, K.; Jenkins, J. M.; Johansen, A.; Khodachenko, M. L.; Kislyakova, K. G.; Kley, W.; Kolb, U.; Krivova, N.; Kupka, F.; Lammer, H.; Lanza, A. F.; Lebreton, Y.; Magrin, D.; Marcos-Arenal, P.; Marrese, P. M.; Marques, J. P.; Martins, J.; Mathis, S.; Mathur, S.; Messina, S.; Miglio, A.; Montalban, J.; Montalto, M.; Monteiro, M. J. P. F. G.; Moradi, H.; Moravveji, E.; Mordasini, C.; Morel, T.; Mortier, A.; Nascimbeni, V.; Nelson, R. P.; Nielsen, M. B.; Noack, L.; Norton, A. J.; Ofir, A.; Oshagh, M.; Ouazzani, R.-M.; Pápics, P.; Parro, V. C.; Petit, P.; Plez, B.; Poretti, E.; Quirrenbach, A.; Ragazzoni, R.; Raimondo, G.; Rainer, M.; Reese, D. R.; Redmer, R.; Reffert, S.; Rojas-Ayala, B.; Roxburgh, I. W.; Salmon, S.; Santerne, A.; Schneider, J.; Schou, J.; Schuh, S.; Schunker, H.; Silva-Valio, A.; Silvotti, R.; Skillen, I.; Snellen, I.; Sohl, F.; Sousa, S. G.; Sozzetti, A.; Stello, D.; Strassmeier, K. G.; Švanda, M.; Szabó, Gy. M.; Tkachenko, A.; Valencia, D.; Van Grootel, V.; Vauclair, S. D.; Ventura, P.; Wagner, F. W.; Walton, N. A.; Weingrill, J.; Werner, S. C.; Wheatley, P. J.; Zwintz, K., "The PLATO 2.0 mission", Experimental Astronomy, Volume 38, Issue 1-2, pp. 249-33 (2014)

[9] Ragazzoni, Roberto, Heike Rauer, Claude Catala, Demetrio Magrin, Daniele Piazza, Isabella Pagano, Valerio Nascimbeni, Giampaolo Piotto, Pierre Bodin, Patrick Levacher, Jacopo Farinato, Valentina Viotto, Maria Bergomi, Marco Dima, Luca Marafatto, Matteo Munari, Mauro Ghigo, Stefano Basso, Francesco Borsa, Daniele Spiga, Gisbert Peter, Ana Heras, Philippe Gondo, "A one meter class eye for the PLAnetary Transit and Oscillation spacecraft"Astronautica Acta vol.115, pages 18-23 (2015).

[10] Farinato, Jacopo; Viotto, Valentina; Gentile, Giorgia; Dima, Marco; Magrin, Demetrio; Piazza, Daniele; Ragazzoni, Roberto; Piotto, Giampaolo; Pagano, Isabella; Arcidiacono, Carmelo; Basso, Stefano; Benz, Willy; Gambicorti, Lisa; Ghigo, Mauro; Munari, Matteo; Pace, Emanuele; Scuderi, Salvatore; Catala, Claude, "The PLATO opto-mechanical unit prototyping and AIV phase", SPIE 7731, 77314k (2010)

[11] Magrin, Demetrio; Munari, Matteo; Pagano, Isabella; Piazza, Daniele; Ragazzoni, Roberto; Arcidiacono, Carmelo; Basso, Stefano; Dima, Marco; Farinato, Jacopo; Gambicorti, Lisa; Gentile, Giorgia; Ghigo, Mauro; Pace, Emanuele; Piotto, Giampaolo; Scuderi, Salvatore; Viotto, Valentina; Zima, Wolfgang; Catala, Claude "PLATO: detailed design of the telescope optical units", SPIE 7731,7731124 (2010)

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 23 Dec 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use