Flexible Optical Injection Moulding of optoelectronic devices

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Deliverable D8.7

On-line training material

Work Package 8

DISSEMINATION, EXPLOITATION AND COMMUNICATION

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Executive Summary

Inside the Task 8.4 Technology Transfer Activities, the present deliverable was planned to make available on-line non-confidential training material to ensure training opportunities are widely available for EU workforce.

In order to achieve this goal, in this public deliverable a general summary of the developed technologies and their potential for different industrial applications are presented.

Contribution and revision history

Version	Author(s)	Changes	Date
V1.0	CEIT	Final version to be submitted after the QGC revision	19/08/2022
V1.1			
V1.2			
V1.3			
V1.4			
V1.4			

This deliverable was evaluated by the members of the Quality Control Group (QCG), following the procedure indicated in deliverable D9.1: Quality Assurance Plan.

Quality Control Group Member	Partner
Pablo Romero	AIMEN
Christian Rankl	RECENDT
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Mikel Gomez	CEIT

The final version of the document, after implementing the minor changes indicated in the individual evaluation of the QCG members, has been reviewed and approved for submission by the Project Coordinator.

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1 Training material in FLOIM

In FLOIM, diverse training material has been developed in order to assure the knowledge transfer from RTOs to involved companies in FLOIM project, so that the industrial partners can be fully confident about making use of the technology developed within FLOIM project.

In order to ensure training opportunities are widely available for EU workforce, this deliverable includes a brief explanation of the technologies developed, removing any confidential data that could be sensitive for any of the partners. The documents with the complete training material have been uploaded to the FLOIM website, under communication material, in the following link:

http://www.floimproject.eu/764/floim_online_training_material

1.1 Developed applications

Different applications have been developed to enhance the use of injection moulding inserts to replicate complex forms and to monitor the process in real time. These are the most significant ones:

- Direct laser writing of submicrometric structures
- High-performance DLC-based mould patterning technology with high control over micro and nano features
- Generation of submicrometric features with multiphoton polymerization
- Machining of micro-optical mould inserts
- In-mould measurement for mechatronic compensation of positioning errors in injection over-moulding
- Mould filling sensor

2 Summaries of developed applications

2.1 Direct laser writing of submicrometric structures

In the context of the Optical Encoder Head demonstrator, a grating with a micrometric period and submicrometric depth is a key element for its function. At the moment of the start of the project, there wasn't a technology that could generate this type of gratings on an insert.

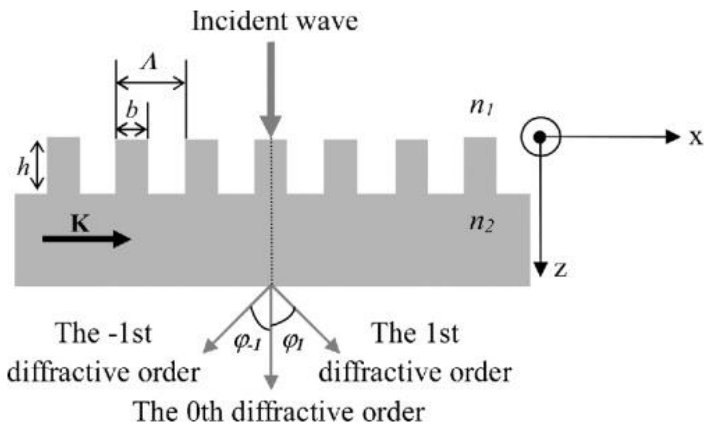


Figure 1. Schematic representation of a surface-relief phase grating (Feng. et al).

Due to the period, the equipment available in the market at that time, and the minimum laser spot size that they provided, only allowed for bigger periods, as there was a limit under which the contiguous lines tended to overlap.

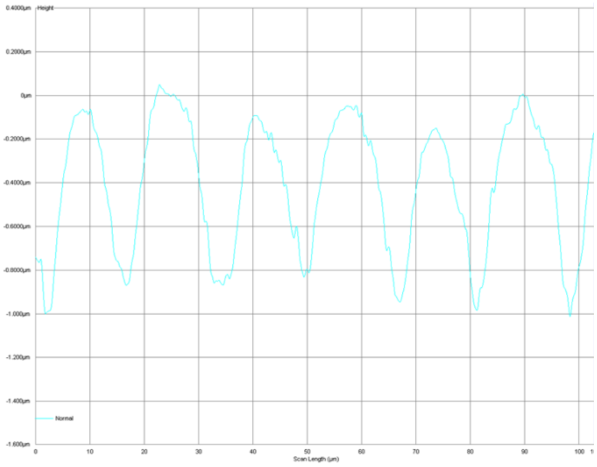


Figure 2. Grating with the lines partially overlapped.

In order to solve this, CEIT installed a new setup, in which an microscope objective with a 20X magnification was installed.

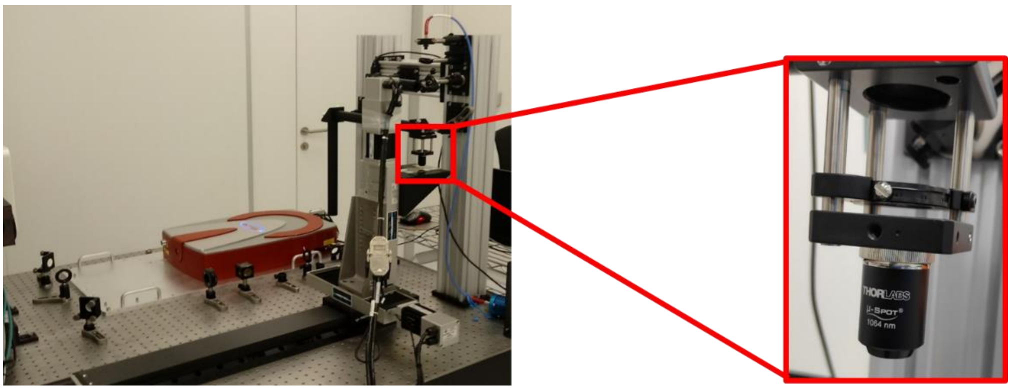


Figure 3. New setup installed at CEIT, with a 20X microscope objective.

This microscope objective reduced the spot size to 2 µm, which allowed for a suitable grating period. Nevertheless, this significant reduction of the spot size also makes the system extremely sensible to the variation in the propagation axis (Z). As the grating needed to have an area of a few millimetres, it was not possible of obtaining a regular grating throughout the entire area. For this reason, CEIT modifided again the setup, using a new source with a shorter wavelength and a 10X objective.

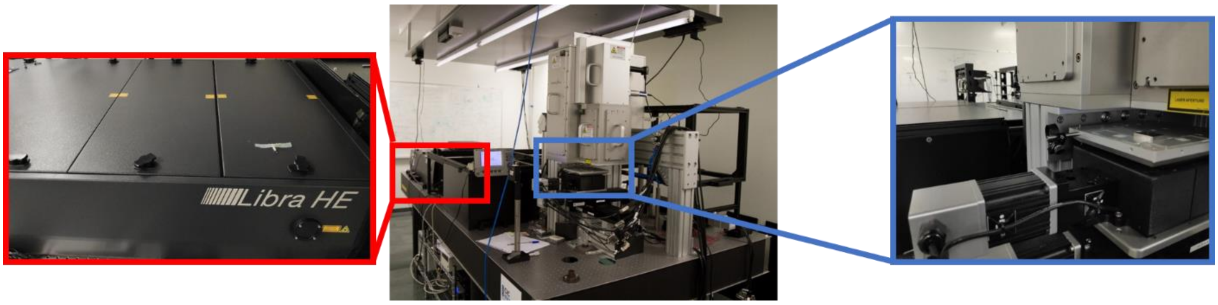


Figure 4. New setup wit the new laser source (left inset) and the processing stage (right inset).

With this new setup, CEIT was able to engrave a grating with the required period and depth on an injection moulding insert.

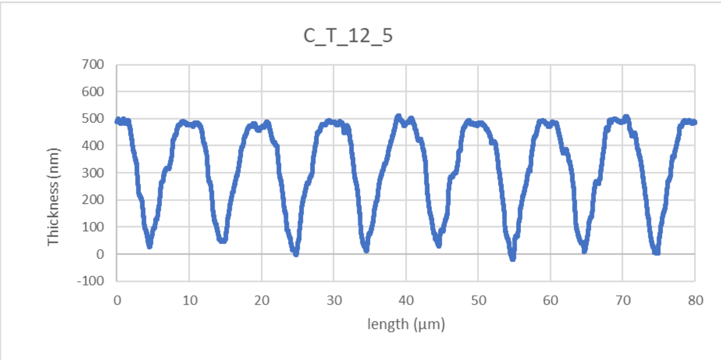


Figure 5. Grating inscribed on a moulding insert.

Once a correct replication in the injection process was confirmed and after several minor adjustments, CEIT proceeded to inscribe the final grating in the final OEH demonstrator insert.

Parallely, and in order to have a backup alternative, CEIT also developed micrometric gratings in volume, in this case in Borosilicate glass doped with a 1% of embedded CdSxSe1-x semiconductor nanocrystals. If the surface-relief phase gratings didn't work, a glass containing a grating would be needed to be installed in the final demonstrator. In the fabrication process the target sizes were achieved, and a robust signal was obtained.

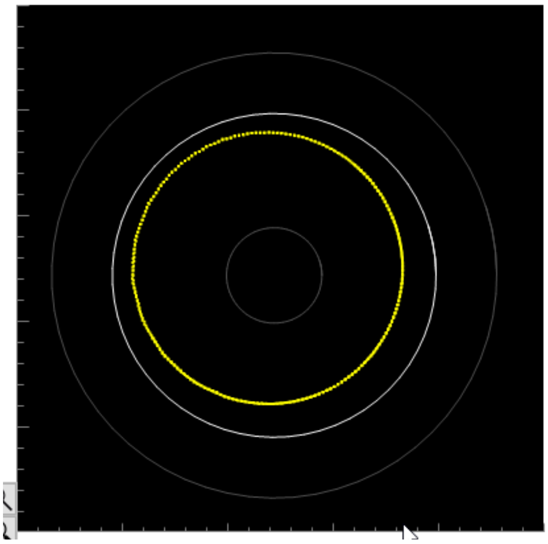


Figure 6. Signal obtained with the volume phase gratings inscribed in borosilicate glass.

As a conclusion, it can be said that a way to produce patterns with a period of a few microns and a depth of under a micron using direct laser writing has been achieved, and that this process can be extended to any application that needs this type of features.

2.2 High-performance DLC-based mould patterning technology with high control over micro and nano features

The DLC-based mould patterning technology from ADAMA is based in direct write, high performance *resistless masking* for diamond and diamond like carbon (DLC). In FLOIM, it was used to try to generate the grating for the OEH demonstrator. Although this technology is already used for some applications, in this case the challenge was to cover an area of few mm, a new approach considering that it is normally used for submilimetric features.

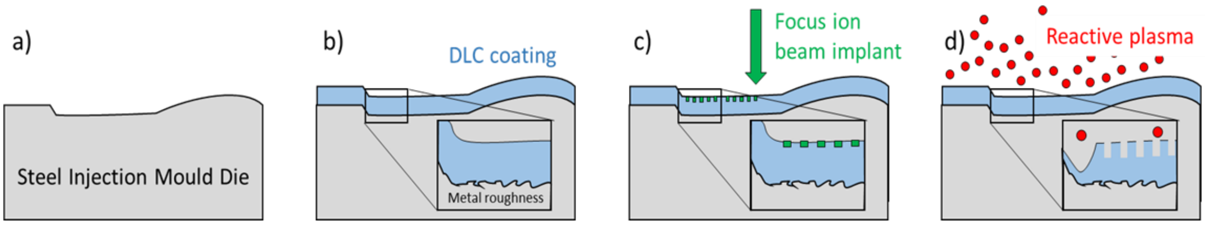


Figure 7. Schematic of the DLC-based mould patterning technology.

Although the precision offered by this technology meant that, locally, the requested sizes were quite easily attainable as shown in , the main difficulty aroused when trying to expand the patterned surface.

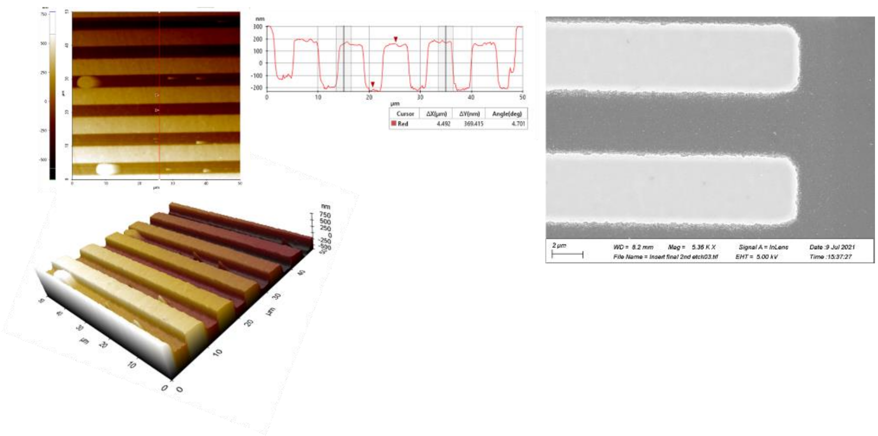


Figure 8. Grating manufactured with DLC technology, where the sharp profiles obtained with this technology can be appreciated.

Due to the fact that the area that the FIB can pattern at once is in the order of the hundredths of micrometres, the sample needs to be displaced between FIB processes. This means that, is the displacement is not accurate enough, there is a stitching problem, as seen in the following picture.

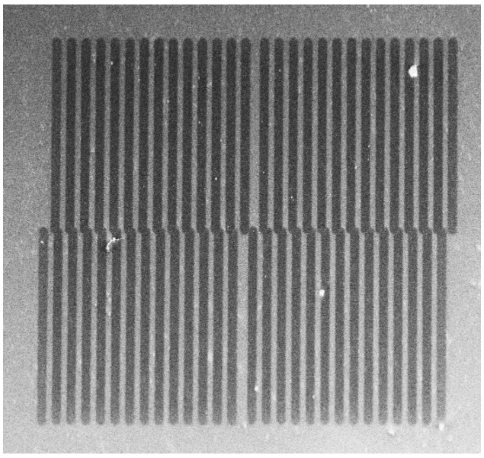


Figure 9. Misalingment observed in the grating due to the stitching.

ADAMA worked on this, and after several modifications they could attain a perfect stitching, which in turn led to the fabrication of a whole grating with the required sizes.

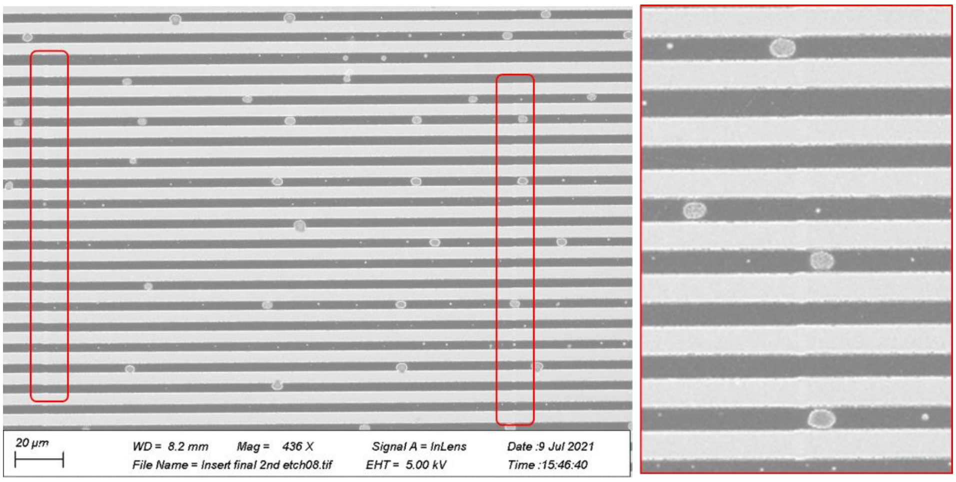


Figure 10. Left, stitching zones between areas. Right, stitching zone in detail.

Although this technology offered a very sharp profile for the manufacturing of the grating, due to the shape of the final insert of the OEH, the ion implant couldn't be made correctly in the grating area. Therefore, this technology was kept as a backup, in case the grating needed to be manufactured separately from the body of the OEH.

Once the stitching problems are solved, the DLC-based patterning technology is very promising for a lot of different applications both for injection moulding solutions and other sectors with precision is key.

2.3 Generation of submicrometric features with multiphoton polymerization

Multiphoton polymerization is a promising technique with which micrometric features can be manufactured. In FLOIM, this technique using laser was developed by AIMEN to find an alternative way to manufacture the OEH grating. Its principle when using a laser is the following:

The excited state of a molecule can be reached by the absorption of one photon of an appropriate wavelength, or by the simultaneous absorption of two photons of a larger wavelength and therefore lower photon energy, each of them having at least half the energy required for the transition.

When the photon energy is large enough to induce the transition between both molecular states, the absorption will be produced along the whole laser beam path through the material. However, if more than one photon is needed for the transition, which could be the case of the infrared radiation, the probability of the transition would be significant if we have a high enough temporal and spatial photon, therefore in order to increase this probability is necessary to use ultrashort pulsed lasers and high magnification microscope objectives. This can be clearly seen on the next picture, where it can be seen that when a femtosecond pulsed NIR radiation is used, it only induces the excitation in the focal volume of the microscope objective.

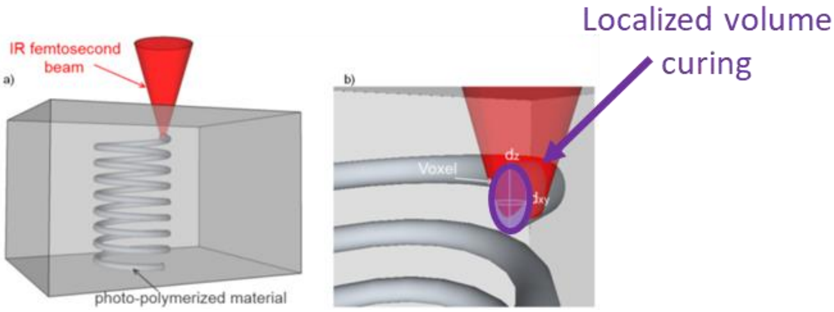


Figure 11. Principle of multiphoton polimerization with pulsed laser.

In order to find the best solution, AIMEN tested this process with a specific photoresist in different substrates. The setup was the following:

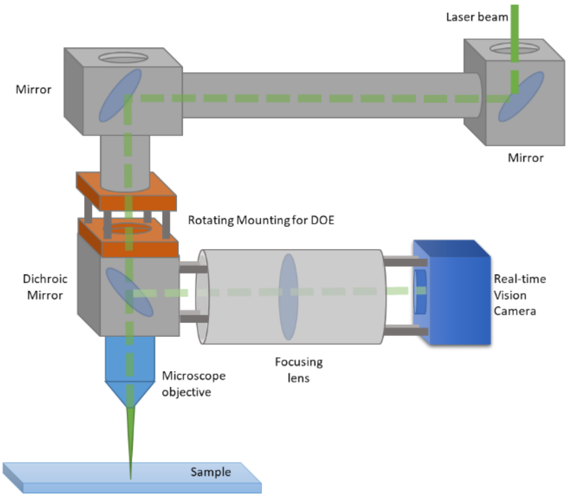


Figure 12. Setup used by AIMEN.

Despite the high precission required, AIMEN was able to obtain gratings with the specified period and depth.

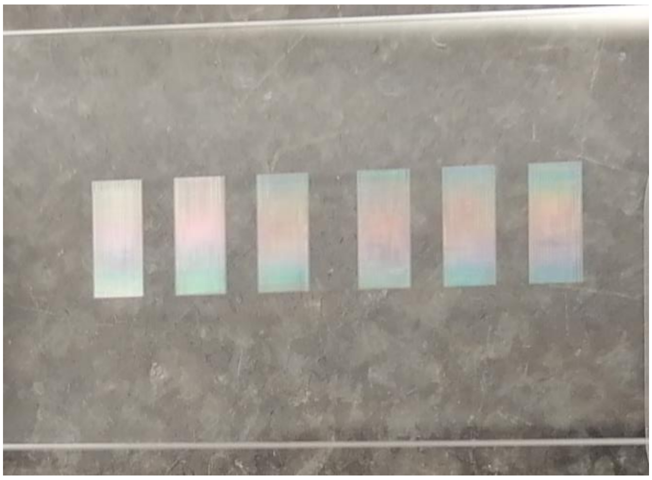


Figure 13. Fabricated grating with diffraction effect.

Although for the present project this technique was used as a backup, its potential for different industrial applications makes it a very promising technology.

2.4 Machining of micro-optical mould inserts

Machining of micrometric features present several challenges, two of the most important are:

- The minimum achievable size, which is directly related to the minimum tool size.
- The accuracy and repeatability, which are linked with motion control and surface regularity.

In order to overcome this challenges, Fhg-IWU has developed a process to generate micrometric lenses on injection mould inserts. These lenses were part of the OEH. For this purpose, it has used two types of diamond tools for precision machining of the lens geometry:

- Contour based tool for direct milling.
- Radius tool for line milling.

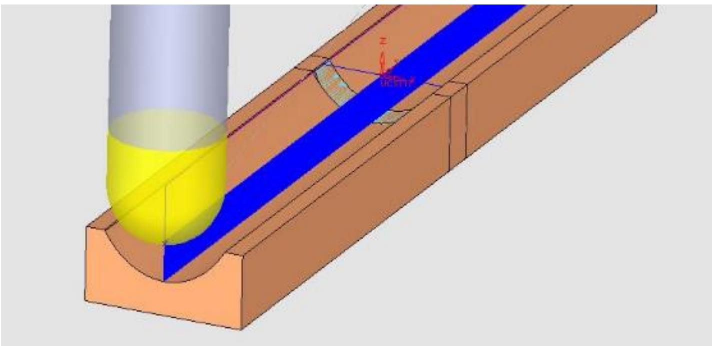


Figure 14. Diamond tool pre-machining in Z direction only.

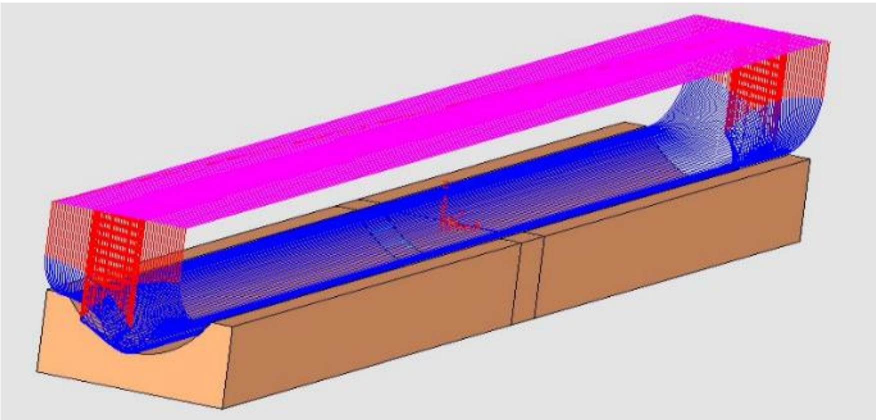


Figure 15. Diamond tool finish-machining in line milling (for higher depths/widths).

From the various tools available, it as picked R3mm and R0.5mm for machining lens geometries. In order to increase the accuracy, it has used CAM-based NC-coding for line machining with small cutting depths and cutting widths of only some micrometer.

The diamond tool adaption required high accurate balancing of air bearing spindle system with less than 0.02 mm/s. The target was a machining of real lens geometris under consideration of requirements of accuracy of geometry and surface quality. This target was met, as seen in the next pictures.

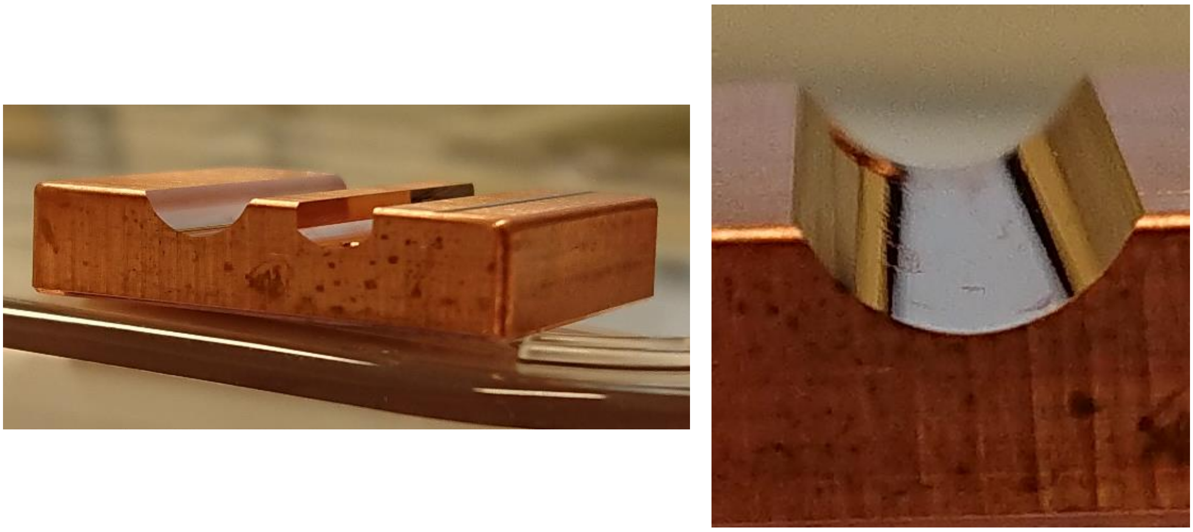


Figure 16. Left: Differences between a pre-machined (right) and finish machined (left) lens. Right: Detail of a finish machined lens.

This process can be used to produce any type of micrometric lenses, which are increasingly important in industrial solutions due to the increasing integration of photonics and electronics.

2.5 In-mould measurement for mechatronic compensation of positioning errors in injection over-moulding

In FLOIM, a system was needed to assure that the LED and leadframe of the FOT demonstrator were aligned when overmoulding both components.

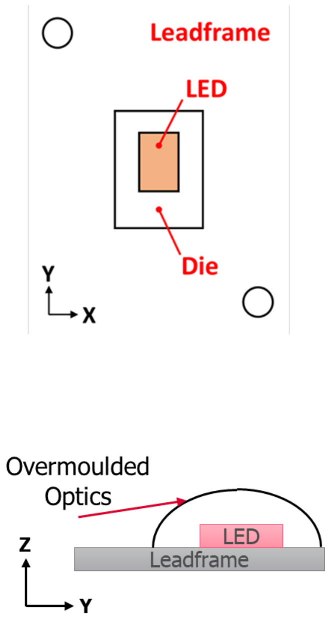


Figure 17. LED and leadframe view from two perspectives. When overmoulding both components with the optics, the alignment need to be accurate.

The movements to realign the components were generated by piezo actuators and transmitted by flexure joint mechanisms. The schematic of the system was as shown in the next picture.

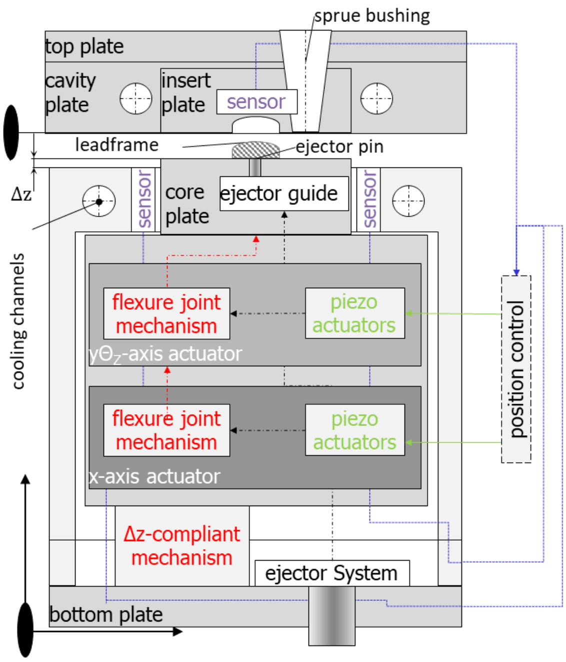
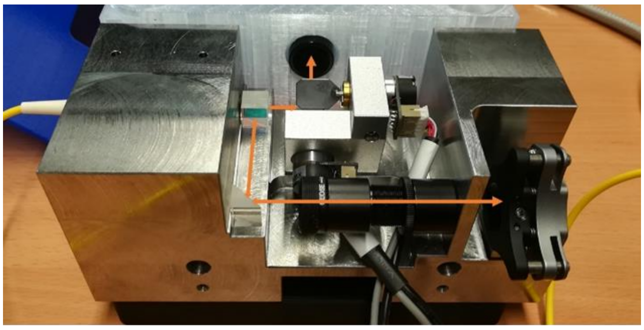


Figure 18. System to ensure the alignment of the different components of the FOT.

To measure the position with accuracy, RECENDT developed a system base on optical coherence tomography (OCT). For that, it needed a port to include an optical fibre from which to obtain the signal.



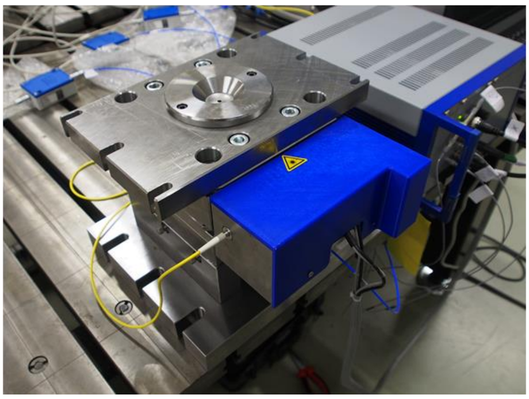


Figure 19. Setup with which RECENDT made the measurements.

Once this was done, the measurement is made as follows.

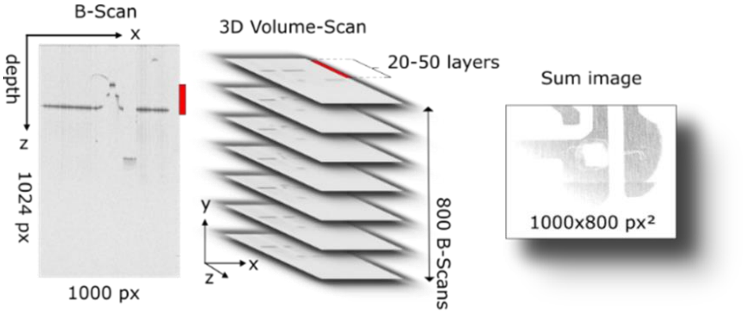


Figure 20. Measurement process with OCT.

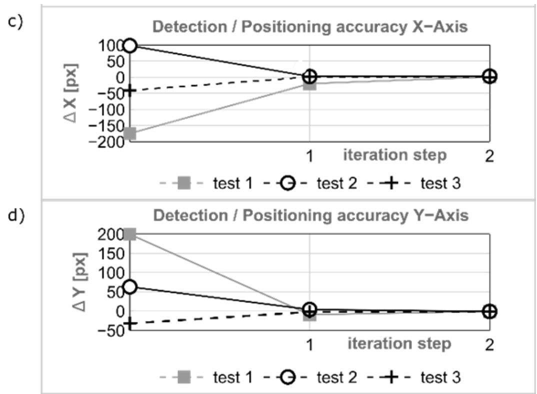


Figure 21. Examples of positioning accuracy obtained with the OCT system.

The accuracy obtained was remarkable, and it demonstrated the potentiality of this technology to be applied in any injection moulding process, as is the case of overmoulding of independent components.

2.6 Mould filling sensor

Other important feature needed in FLOIM when working with small cavity injection moulds was the need to confirm that the plastic filled the mould in a correct way. For that purpose, ADAMA developed a sensor based in fibre-optic interferometry. Below the schematic of the system used to test the sensor.

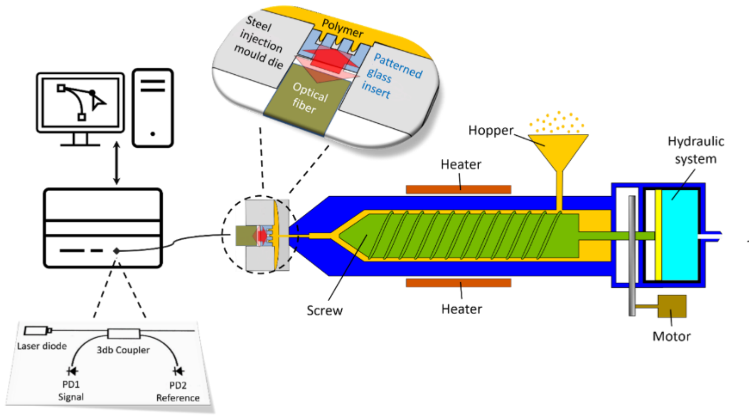


Figure 22. Schematic of the system used with the mould-filling sensor.

With this system, ADAMA was able to measure the filling of the mould in real time, which helps in terms of adjusting the injection parameters.

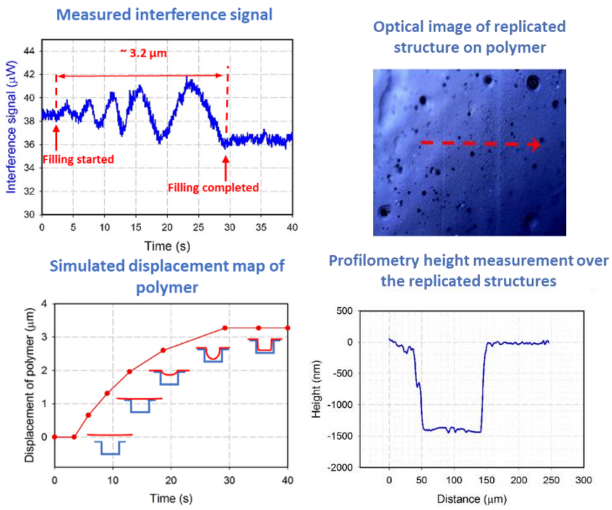


Figure 23. Different measurements obtained with the sensor, where the filling process can be identified.

Once the measurements where validated, ADAMA proposed a solution in which a transparent cover was attached to the stainless-steel insert used for the grating manufacturing. This system was equipped with a fiber connection.

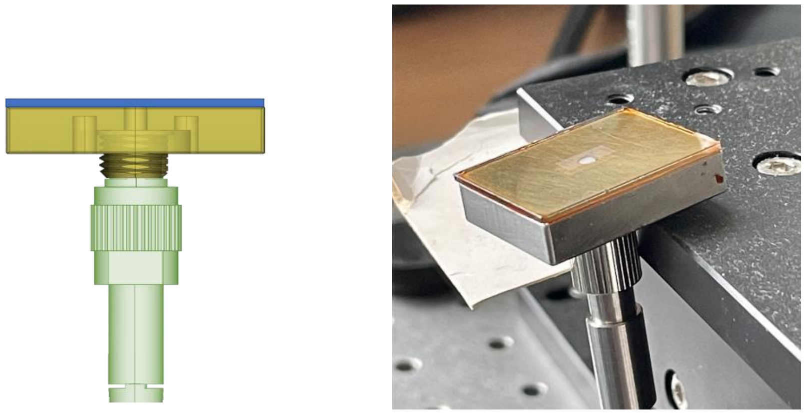


Figure 24. Solution proposed by ADAMA for the grating insert.

This solution was tested by ADAMA, and it offered a strong signal which allowed to follow the filling process of the mould during the injection.

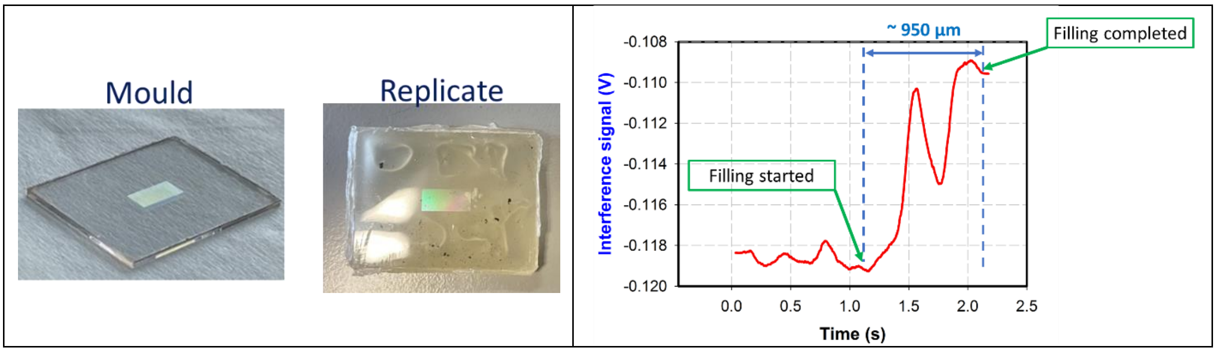


Figure 25. Left, mould and replicate of the grating. Right, signal obtained with the sensor, in which the start and finish of the filling can be detected.

This solution, although not used in the final mould, is an important tool for injection moulding, and it can be used for different industrial applications.

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