INVESTIGATIONS ON THE MANUFACTURING FLUX, MEANT TO BRING A CONTINUOUS IMPROVEMENT OF THE PRODUCT, BY ACQUIRING NEW KNOWLEDGE AND SKILLS

Under the first work-package (**WP1 - *Opto-mechanical design and glass processing***) the activity was focussed, mainly, to ensure high quality substrates for samples and deliverables. First stage of the activity was dedicated to establish what kind of surface is more suitable for the project accomplishment. After several tryings and a feasibility analysis, includding discussios with potential future customers such as CETAL, the decision was taken to concentrate the entire resources to achieve as qualitative possible flat surfaces, detrimental of spheric or aspheric. The two main reasons responsible for this decision are: The owned equipment used for finishing flat surfaces is one of the top polishing machine (Lapmaster Model 48 Air Bearing) while the CNC that could be used for spheric or aspheric surfaces can be used only to generate a fine grinding surface and not for polishing. On the other hand, a flat mirror is „universal", being able to be used in every optical system for laser beam trsansport while a spheric or aspheric mirror must be calculated and customized for each one. Also, the same work-package was responsible to design and achieve all the mechanical parts such as deliverable's frames and all other mounts and mechanical accessories needed by the entire project.
Regarding the achievement of the optical substrates, a summary of the results is reported in the table below (Tab.1):

Diameter [mm]	**Number of parts**	**Overall characteristics**
Φ=25 / Φe=24	50+	Flatness better than λ/8
Φ=63 / Φe=60	8	Flatness better than λ/8
Φ=80 / Φe=80	1	Flatness = λ/18
Φ=123 / Φe=120	2	Flatness = λ/12 and λ/14
Φ=156 / Φe=150	3	Flatness = λ/9; λ/13; λ/16

2.2 Under the second and third work-packages (***Optical coatings*** *and* ***Optical measurements and tests assurance***) the activities were interconnected and mutually supportive. These were focussed on investigations on the fabrication flux in order to improve the quality of the final product, by tuning the technological parameters for mirror fabrication and finally, to achieve the deliverable. To complete this activity we had to ensure capabilities in order to make the needed measurements and tests. While the capabilities for optical measurements were owned and ensured in house, by Pro Optica, to make tests, we had to establish collaborations with partners that own the appropriate facilities. In this regard, we have established cooperation agreements both with Institute of Opto-Electronics (IOEL) in order to rapid evaluate the resistance of a new lot of samples, to find if changing of a technological parameter (e.g. substrate temperature, oxygen pressure, evaporation regime etc.) is beneficial or not in terms of increasing the mirror resistance and CETAL laboratory from National Institute for Laser, Plasma and Radiation Physics (INFLPR) in order to ensure the official tests done on witness plates that accompanied the deliverables in the same batch. Both partners were exemplary accomplished their work. IOEL designed and achieved a smart accessory (fig. 1.a) that was mounted on the existing laser assembly and established a testing procedure for rapid evaluation of the tested samples, customized on the project's needs. The calculation sheets of the focusing system, the technical drawings and the testing report that includes the testing method were published on the project's web page. At the same time, researchers from CETAL were improved their facility TEWALAS in order to become able to do "S on 1" type tests (fig. 1.b). Until now, TEWALAS is the only laboratory in Romania, capable to perform such type of tests using a femtosecond laser.

Fig. 1.a The accessory mounted on the IOEL laser equipment

Fig. 1.b TEWALAS facility

It must be mentioned that while the rapid tests made by IOEL provided only comparative information for the tested samples from different batches, the tests made by CETAL provided quasi-exhaustive information regarding the tested samples, such as: a preliminary inspection of the sample; laser parameters, including temporal and spatial profile in the target plane; LIDT with 0% and 50% damage probability for 1 to 500 pulses, including an extrapolation for 10^8 pulses. Another mention is that, the official tests made by CETAL confirmed the hierarchy obtained by the rapid test procedure. All official test sheets provided by CETAL can be found on the project's web page.

The simplified scheme of the activity performed under the phase III of the project is presented in the picture below (fig. 2):

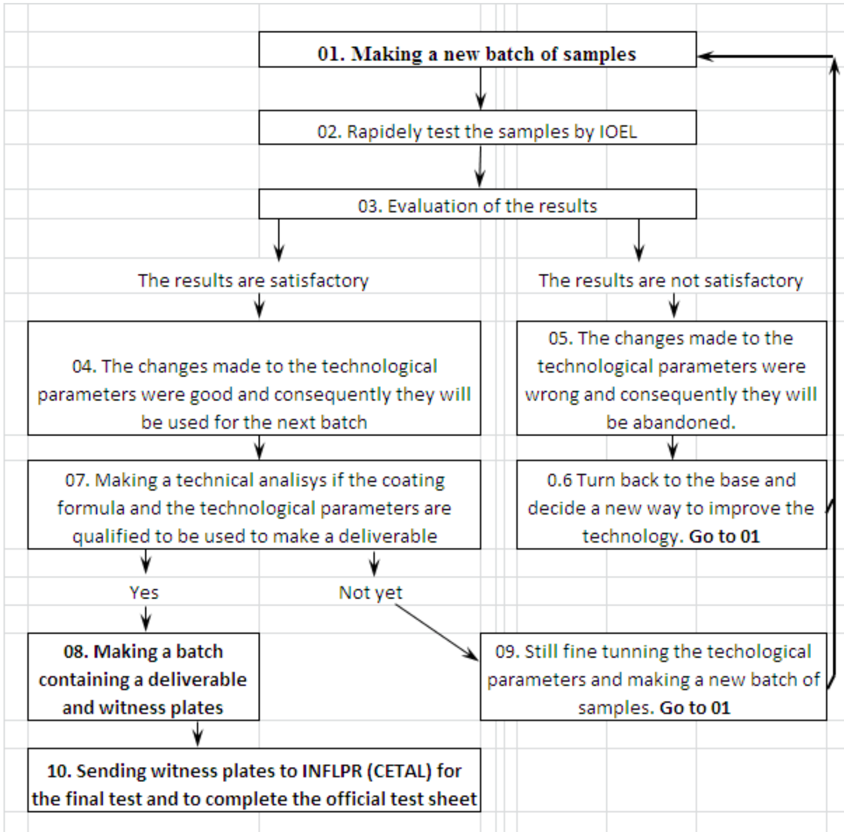

Fig. 2 Scheme of the performed activity by the WP2 and WP3 under the phase III of the project

The coatings formulas tested under the phase III of the project have been as follows (Tab. 2):

High index material	**Low index material**	**Number of layers**	**Average LIDT** for 500 pulses [J/cm^2]
HfO2	SiO2	24 - 26	H0 = 0.45; H50 = 0.66
Ta2O5	SiO2	24 - 26	H0 = 0.39; H50 = 0.58
Mixture of Zr-Ta Oxide	SiO2	24 - 26	H0 = 0.42; H50 = 0.59
Mixture of Ti-Al Oxide	SiO2	24 - 26	H0 = 0.29; H50 = 0.48

Where, in the last column, Hx = x% damage probability.

As it can be easily observed, the combination between HfO2 and SiO2 has won the competition, but Ta2O5 and mixture of Zr-Ta Oxide still remaining under interest.

2.3 Results and Conclusions

Following the procedure described in the figure 2 and after more than 20 batches, containing, many of them, samples for rapid evaluation and the others containing potential deliverables and witness plates, we decided to select for presentation, as prototypes for femtosecond laser mirrors, the assemblies from the table below (Tab. 3). Figure 3 shows a deliverable with 150mm as effective diameter.

Table 3 – Summary presentation of the deliverables:

Item code	**Effective diameter & thickness**	**Measured flatness**	**Coating**	**R[%] @ λ central**	**LIDT (**tests made on witness plates) H0 / H50 @ 500P [J/cm^2] [Hx = x% damage probability]
Item No. 01	Φ_e150mm g = 45mm	λ/16	HfO2 – SiO2 26 layers	99% @ 862 nm	H0 = 0.45 / H50 = 0.66
Item No. 02	Φ_e150mm g = 55mm	λ/17	HfO2 – SiO2 26 layers	99% @ 800 nm	H0 = 0.45 / H50 = 0.66
REMI 1	Φ_e60mm g = 20mm		HfO2 – SiO2 26 layers	99% @ 800 nm	H0 = 0.45 / H50 = 0.66
REMI 2	Φ_e60mm g = 20mm		Mix of Ta2O5/ZrO2 – SiO2 24 layers	99% @ 835 nm	H0 = 0.42 / H50 = 0.55
REMI 3	Φ_e60mm g = 20mm		HfO2 – SiO2 26 layers	99% @ 785 nm	H0 = 0.45 / H50 = 0.66

As a conclusion, we consider that the following aspects can be noticed: HfO2, is the most promising high index material, while SiO2 is the only one that can pair with. The difficulties of this situation are that HfO2 is a quite tough material to be processed. The very high melting point (around of 3000°C) and its very poor melting bath increases the risk of splashing with material from the crucible. This phenomenon must be very carefully managed during the coating procedure because, if not, the entire batch can be lost. Another difficulty consists in the variation of the HfO2 refractive index from a batch to the next one. Because of this, sometimes, deviations up to 50 nm of the central wavelength can be observed, compared to the calculated value.

Fig. 3 A finalized deliverable