Achievement of technologies and testing methods for resilient mirrors under high power laser pulse, suitable for CETAL and ELI infrastructures

Stage 1 / Activity 3
(Work-package 2)

REPORT OF ACTIVITY

Cercetari in vederedea stabilirii tehnologiei de acoperiri optice reflectante, rezistente la pulsuri laser de mare putere - Partea 1

Researches to establish the technology of reflective optical coatings resistant under high power laser pulses – Part 1

Following the conclusions of the study achieved in the first two months of the project, the WP2 members have started the preparation of the coating machine Leybold Heraeus L560. First preparations were to perform a series of batches, in order to acquire information regarding the uniformity along the radius of the support plate (red line in the figure 1), of different materials deposited with assistance of the ion source (IAD). In this respect, we had to achieve several accessories needed to ensure a better orientation of the ion source (see red arrow from figure 2) and a series of mounts especially designed to fit optical parts (test plates) on the support plate, so that, only a part to be coated in order to facilitate the measurement of the layer thickness (figure 3).

Fig. 1 - The support plate

Fig. 2 - The tilted base of the Ion source

Fig. 3 - Various mounts executed to fit the test plates on the support plate

Next step, after these preparations, was to start performing batches with various materials and after that to measure the three thicknesses on the three test-plates, positioned in the center, at the middle and on the edge of the support plate (fig. 1). The first material subjected to these tests was TiO2. We used TiO2 for the first test because the ordered materials that we are considering to use for the targeted coating, as high index materials (HfO_2 – laser grade and Ta_2O_5 – laser grade) have not yet arrived from the producers.

The physical average thickness was 145nm and the coating parameters were as follows:

- T during coating = 250°C;
- P before start ion source = 10^-6 mbar
- P during ion source was used (Ar^+) = 2*10^-4 mbar
- P during coating (ion source and reactive gas (O2), working) = 9*10^-4

Figure 4 represents a screen capture of the Ion Source Controller, during the coating process.

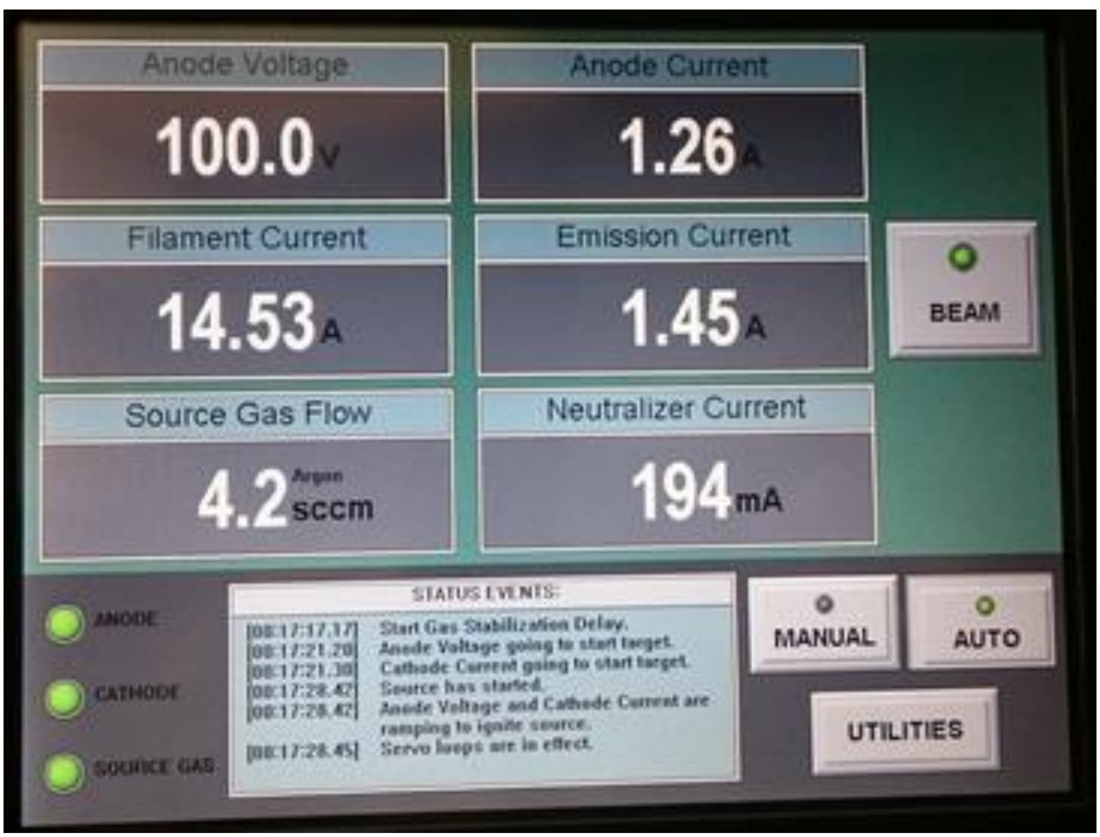

Fig. 4 - Screen capture with the parameters of the Ion Source

As a short comment, we found that the current pumping chain was not capable to sustain the two additional systems, ion source and reactive gas, to keep a coating pressure around of $2*10^{-4}$ mbar. This thing was determined us to start finding a solution to urgently upgrade this system in the next part of the project. Nevertheless, we succeeded to finalize the first coating, at a higher pressure and to do the first evaluation of the thickness distribution along the support plate. In the figure 5 it can be seen the three test-plates following that to be measured in order to do the proposed evaluation.

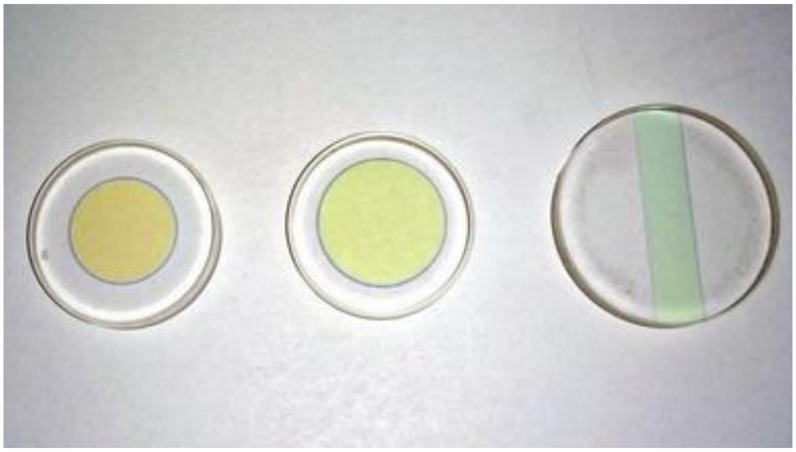

Fig. 5 - The three test plates, from center (left), middle (middle) and from the edge (right), ready for measurements

The evaluation was made by measuring the reflectivity of each one from the three test-plates, seeing the wavelength where the reflectivity has a maximum and considering that wavelength as being 4 times bigger than the optical thickness of the deposited layer, where optical thickness "d" is defined as

$$d = n * g \quad (1)$$

where: n = refractive index of the deposited layer; g = geometrical thickness of the deposited layer

The three graphics from the figure 6 represent the three spectral reflectivity curves from each test-plate that was positioned on the support-plate as is described above. It can be observed that the three peaks are positioned on three different wavelengths:

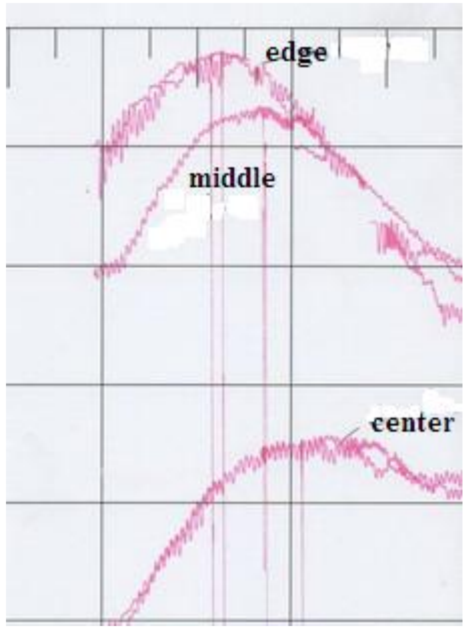

Fig. 6 - The three spectral reflectivity curves from each test-plate that was positioned on the support-plate

The conclusion taken after analyzing the three graphics is that the test-plate positioned at the center of the support was not enough warmed during the deposition process (this can be deducted from the poorer reflection on it) and, as a consequence, we must exclude the solution in which the mirror to be positioned at the center of the coating room. But, at the same time, we can see a very low difference between the middle and the edge positions. Considering the refractive index of TiO_2 being $n = 2.4$ and $\Delta\lambda = 20$ nm to be the difference from the two maxims; knowing that the maximum of reflection is happening at the optical thickness of $\lambda/4$ (so, $n*g = \lambda/4$), it can be calculated the difference between the geometrical thickness (g), using the formula:

$$n*\Delta g = \Delta\lambda/4 \Rightarrow \quad (2)$$

$$\Delta g = \Delta\lambda/(4*n) = 20/9.6 \Rightarrow$$

$$\Delta g = 2 \text{ nm}$$

This is an error that can be easy managed to design an effective coating over the entire distance from the middle position of the support-plate to the edge position. In other words, the conclusion is that the coating machine can ensure an acceptable uniformity for a mirror with a diameter around of 160 – 180 mm.

As a consequence, the technical decision was that the concept of the support evolved from the presented one at the first report to the model from figure 7. In this way it could be coated simultaneously three mirrors having diameters up to 160 mm.

Fig. 7 – The new concept of the support plate

In the second part of this activity, the new materials, foreseen to be used at the mirror (HfO2 – laser grade; Ta2O5 – laser grade; Al2O3 and SiO2) will be evaluated in the same way, being known the fact that every material has its own behavior in terms of vapor expansion in vacuum but, at the same time, the new support will be designed and achieved in order to start coatings on the larger optical parts.

The coating design will take into consideration the behavior of every used material so that the mirror to be effective at the highest level on its entire surface.

Another important activity performed this time was to identify, to order and do payment for the majority of materials and tools foreseen to be used in the next part of the project. In this regard, we already ordered materials for the substrate (fused silica (mostly) but other several optical materials as well); materials for coating, such as: HfO2 and Ta2O5 – laser grade, SiO2, ZrO2, Ni2O5, Silver and others.

An important attention was paid to acquire information regarding the possibility to do as many measurements in house, focusing on the measurements for roughness of the optical surfaces. In this regard, a study was ordered and received from IOEL S.A. The title of this study is "*Study for roughness measurements using the polarizing interferometry*".

In summary, it can be said that at this stage, after the short time of two months from T0, the following achievements could be noticed:

- There was established a connection with people from ELI project and with the leading team of the project "*The physics and engineering of fs laser defects incubation*";

- There was done a part of the measurements necessary for establishing the uniformity of the coating layer, along the support-plate radius;

- There were established the necessary upgrades of the coating machine, namely the evaporating system, the pumping chain and was established the concept of a new support-plate;

- There were ordered the majority of optical materials, coating materials, mechanical materials and tools foreseen to be necessary in the next stage of the project

- There was ordered and received a study regarding the possibility to do measurements of the super-polished optical surfaces.

As a conclusion, we consider that, the proposed preparatory activities, necessary for the next stage, named “Industrial research for establishing the execution technologies of the mirrors resistant under high power laser pulses” were successfully finalized.