Form B1_EN - Project Summary

Programme / Sub-programme / Module	5/5.1/ELI-RO
Project type	RDI
ELI-NP thematic	RA35/III.3 Testing of Irradiated Optical Components; RA1/II.6 Focusing Optics
Project title / Acronym	The physics and engineering of fs laser defects incubation/ PHEOLDI
Project duration	26.5 month

PROJECT SUMMARY

Optical mirrors are key components of any PW laser system. The quality of the laser beam in terms of time duration, intensity distribution and focus dimension critically depends on the used mirrors. Experiments in CETAL using the available 1 PW fs laser system showed that mirrors, even when used in the correct manner, below the single pulse laser damage threshold (LDT) tend to deteriorate rather fast, which increases the operational costs.

Mirrors are fabricated using metallic layers (not very efficient since no metal has a 100 % reflectivity at the used wavelengths) or dielectric layers. Multilayer dielectric mirrors, combining high and low refractive index materials could achieve 99.9% reflectivity and usually exhibit higher LDT than metallic mirrors, but are much more expensive and difficult to manufacture.

Traditionally, various types of optical techniques and miscroscopies (scanning, transmission or atomic force) have been used to estimate the single or multiple pulses fs LDT. These techniques are not very sensitive to low concentration of atomic defects in the bulk, which are supposed to be the main cause for the incubation effect, which lowers the LDT for multipulse irradiation. Also, the techniques could not offer any predictions when a mirror will fail and provide useful feed-back to engineer better quality dielectric layers.

Since the most used low refractive index material is SiO_2 (fused silica) while the high refractive index materials are HfO_2, Ta_2O_5, Sc_2O_3, TiO_2, Al_2O_3, Nb_2O_3, etc. we propose the use of advanced electrical characterization techniques for the investigation of defects induced by fs laser irradiation in dielectric layers deposited in INFLPR. The original idea came from analyzing two very recent articles [1, 2] that investigated the fs LDT in films. In ref. 1 the LDT was measured for several HfO_2 films, obtained using different deposition techniques and conditions. The results (see Fig. 3 from ref.1) showed differences but there was no explanation provided why, because the structure, composition and electrical properties of those HfO_2 layers were not measured. In Ref 2 the role of defects pre-existing in materials on the lowering of the multi pulse LDT was clearly evidenced (see Figs. 3 and 4). The quality of dielectric layers used in microelectronics is assessed by electrical characterization techniques: I-V, leakage current, and C-V, capacitance-voltage measurements, or ESR, electron spin resonance. We will use the same techniques to assess the quality of the dielectrics used for mirrors. The theoretical background for these measurements and their interpretation is readily available and the density of atomic defects that could be detected is orders of magnitude below that of the most advanced SEM or AFM instruments. In addition we will use X-ray specular and diffuse reflectivity to observe the evolution of roughness of the interfaces in multilayer structures during multi-pulse fs laser irradiation and understand its role in the LDT value. The use of these new diagnostic techniques will allow to understand the early stages of defect formation and incubation in dielectric materials, at laser irradiation fluences below the single pulse damage threshold and provide engineering guidance for the manufacturing of higher quality mirrors in INFLPR. We will incorporate these findings in dielectric mirrors produced in INFLPR using magnetron sputtering and pulsed laser deposition techniques to provide high quality / low cost mirrors for the fs laser systems.