Detrmination of the Ultrashort Pulses Incubation Parameter of BK7 using the D-Scan Technique

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The ablation of solids by ultrashort laser pulses occurs when seed electrons are accelerated by the pulse electrical field, generating free electrons by collisions in an exponential avalanche process, which results in a structural breakdown when the free electrons density reaches a critical value and transfers energy to lattice ions, which expand away from the surface after the pulse. This process can be assisted by a Coulomb explosion resulting from the charge deficiency originated by electrons ejected from the solid surface due to their acquired kinetic energy. In metals, the seed electrons are the conduction band free electrons, and in dielectrics and semiconductors they are excited from the valence to the conduction band by the pulse leading edge, either by multiphoton ionization or by tunneling induced by the laser field. Once free electrons are present, the ablation evolves deterministically in time in the same way in all materials. Due to these mechanisms, the ultrashort pulses ablation has a nonselective character, and the only parameter that has to be known to etch a material is its ablation threshold fluence, F_{th}. In a given material, the ablation threshold value can depend on the presence of impurities, defects, excitons, etc., which either create intermediate levels in the bandgap or modify the local electronic density. As a consequence, seed electrons are created and ejected more easily than in the ideal material, and the ablation happens at lower F_{th} values. The defects can be externally originated, such as laser created color centers. In this case, when processing solids with superimposing pulses, modifications can be induced in the material, which will decrease the F_{th} for subsequent pulses. These cumulative phenomena fall under the classification of incubation effects, and the ablation threshold fluence modifications induced by them must be taken into account when machining a material. A few years ago we introduced the D-Scan, a simple method to determine the ultrashort pulses ablation threshold fluence of solids. In this work we extend its theory to calculate the pulses superposition, and describe a procedure to allow the quantification of the incubation effects. The method was applied to determine the ablation threshold of BK7 samples in the 100 fs regime, and the results were compared to the ones obtained by the traditional method. The good agreement obtained validates our theory and method.