Recent developments of laser optical coatings in Hungary

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Abstract. Optical coating suppliers specialized to meet special needs of laser developers often have to face new challenges to help them in building high-performance, high-efficiency lasers. Some aspects of laser optical coating design and manufacturing are discussed. First an unconventional coating deposition technology, termed the reactive electron beam evaporation under reduced oxygen pressure, is reviewed. The technology is applied for the TiO_2/SiO_2 and the Ta_2O_5/SiO_2 material pairs producing optical coatings with low absorption and scattering losses. Then some concrete application problems and their solutions are presented using our technology: high reflectance UV mirrors containing UV-grade HfO_2 layers; high-damage-threshold, visible/near-infrared power optics; mirrors with extended high reflectance bands (all-dielectric broadband reflectors); and elements of a specially designed mirror set for femtosecond pulse Ti:sapphire lasers. The mirror set for the Ti:sapphire laser has been optimized for both phase and amplitude characteristics.

Subject terms: optical coatings; vacuum deposition technology; ultraviolet laser optics; high-power laser optics; femtosecond laser optics.

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1 Introduction

Most lasers contain optical coatings as important functional elements, for instance, high reflectors (HR), output mirrors/couplers (OC), and antireflection (AR) coatings.[1] Laser performance strongly depends on the quality of optical coatings: reflectances of high reflectors should approach the ideal 100% value at the operation wavelength(s) to decrease losses in the laser cavity and the output coupling has to be set to a specific value to ensure optimum operation. In modern lasers, the reflectivity of the mirrors is usually determined at more than one wavelength, or a continuous reflectance versus wavelength function is required. Because of the appearance of widely tunable lasers, such as dye or Ti:sapphire lasers, which are capable of generating femtosecond pulses, broadband cavity mirrors are needed, or the cavity mirrors have to be optimized for both amplitude and phase characteristics leading to shorter pulse durations. Furthermore, surfaces of other cavity elements such as solid state laser active materials, frequency doubling crystals, optical fibers, etc. have to be coated to reduce resonator losses or to implement simplified resonator configurations.[2] From the technological point of view, the coatings have to be mechanically hard, impervious to environmental conditions such as temperature and humidity to improve laser stability and lifetime. In high-power lasers, these are constructed for high damage threshold. It seems impossible to list all of the requirements that should be taken into consideration during optical coating design and manufacturing, so let us focus only on economic considerations for example.

Practically, the features of deposited optical coatings never fit their ideal (theoretical) reflectance/transmittance characteristics perfectly because of the losses in the layers originating from layer morphology, chemical composition defects, and technological purposes.[3–6] Losses in the dielectric coatings can be grouped into two categories: light-scattering losses and light-absorption losses. Light scattering comes from the refractive index variations of layers in their volume or at their interfaces. Light absorption is determined by the electron and lattice structure of a given dielectric material, and is caused by the imperfect stoichiometry, chemical impurity, and multiphoton processes at high intensities in the high transmission range between the electron absorption (usually UV) and lattice absorption (infrared) ranges. Absorption loss is strongly related to the optical damage threshold, which is used to describe the quality of optical coatings applied in high-power lasers.[7]

In addition to having a proper design, losses in the layers must be minimized,[8] which basically depends on the evaporation technology, the choice of evaporation materials, and the manufacturing of substrates. In the case of high reflectors, which have the simplest traditional form

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