Title: The spectroscopy study of focused short-wavelength laser-matter interactions

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Abstract: This thesis is focused on processes occurring during and immediately after an interaction of intense short-wavelength laser pulses with matter. Extreme states of matter (warm dense matter - WDM and hot dense matter - HDM), induced by EUV/SXR/X-ray lasers of two kinds, i.e., free-electron lasers (FEL) and plasma-based lasers, were investigated by emission spectroscopy over various spectral ranges and mass spectroscopic techniques. Absorption/transmission experiments revealed an effect of saturable absorption of soft X-ray laser radiation in aluminium WDM. Then, an ionisation potential depression (IPD) in dense plasmas was investigated by means of X-ray emission spectroscopy. Results obtained with the X-ray FEL-produced plasma exhibit very good agreement with computer simulations considering the Ecker-Kröll model. Analysis of optical emission spectra (OES) supports the key role played by fast recombination processes in the ablation plume created by focused short-wavelength laser beams on the solid target surface. Mass spectroscopy provides information both about various processes occurring in expanding ablation plumes and on the chemical (mostly elemental and isotopic) composition of the irradiated target. For full and correct analysis of the beam footprint on a scintillator screen, an experimental study of FEL-induced radioluminescence saturation is required. Optical emission from an FEL-illuminated Ce:YAG crystal was recorded by OES. A linear response range was investigated experimentally. Together with other scintillators, i.e., ZnO and PbWO4, Ce:YAG damage thresholds were determined for a single SXR-FEL pulse. In poly(methyl methacrylate) – PMMA, the C=C double bond formation was revealed by Raman spectroscopy. Based on the spectroscopy results, two rate-equation models were developed to describe a sub-threshold erosion induced in PMMA by multiple FEL pulses. A very good agreement was achieved between theoretical predictions and experimental data.

Keywords: spectroscopy, laser plasma, laser ablation, free-electron laser, plasma-based laser, extreme ultraviolet radiation, X-rays