Supervisor's statement upon PhD. thesis "*Enhancement of XUV Emission from Plasmas Produced by Laser Interactions with Nanostructured and Flat Solid Targets*" by Ellie Floyd Abes Barte, MSc.

Mr. Ellie Floyd Abes Barte has prepared his thesis during his doctoral study at the Czech Technical University in Prague, Czech Republic and University College Dublin, Ireland in the frame of ERASMUS Mundus Joint Doctorate Programme "EXTATIC" under joint supervision by myself at the Faculty of Nuclear Sciences and Physical Engineering of CTU in Prague and by Professor Padraig Dunne at the School of Physics of UCD. I would like to express my gratitude to the Professor Padraig Dunne for thorough supervision of Ellie and I am also indebted to Professor Takeshi Higashiguchi who served as the candidate's advisor during his stay at Utsunomiya University.

Mr. Barte has a very friendly character, he is definitely a good team player and he has acquired good skills in laser laboratory and in the area of computer control of experimental equipment. Ph.D. study of Mr. Barte was longer than expected. First, his background from his previous studies in Philippines was weak, so he needed longer time for the studies of basic plasma and atomic physics and also of fundamentals of lasers and of interaction of intense laser radiation with targets. Second, the original plan to demonstrate enhancement of EUV emission from plasma produced by femtosecond laser in our laboratory failed. The experiments carried out by the candidate were not successful as the emitted energies in the studied spectral range were lower for targets with microstructured surface tin layer than for bulk tin targets. This was possibly due to a low contrast of our femtosecond laser pulses. The planned targets with microstructured rhodium layer were not produced due to unexpected technical problems.

The submitted thesis is based on experiments carried out by the candidate at UCD Dublin and at Utsunomiya University. While an enhancement of EUV yield was achieved via surface microstructures on the tin target in the former experiment, EUV yield from rhodium targets in the second experiment was increased by using a nanosecond laser prepulse ahead of the picosecond main pulse.

The thesis consists of 5 chapters and 2 appendices. In the first chapter, the research motivation and aim are briefly described. The main applications of EUV radiation sources based on laser-produced plasmas are presented and the present state of art is briefly discussed. The second chapter is devoted to the presentation of experimental and theoretical methods used in this thesis. First, the lasers used at UCD and Utsunomiya University are depicted. Then the spectrographs and the vacuum chambers are briefly described. Second, the basics of laser-plasma interaction and of atomic physics of multiply charged plasmas are depicted. Here, a simplified collisional-radiative model, used for estimation of mean ion charge, is presented.

The candidate's own results are described in the third and fourth chapters. The former chapter describes experiments carried out at University College Dublin. In the first experiment, emission spectra were analysed for the interactions of nanosecond and hundred picosecond laser pulses with targets with microstructured tin surface layer. Two types of targets were used – a tin layer on a monolayer of polystyrene microspheres on silicon wafer and a tin layer on a porous alumina substrate. Higher energy conversion efficiencies to EUV emission in the 13.5 nm region were measured for 170 ps laser pulses in comparison with 7 ns laser pulses. The results were presented at an international conference and published in a paper in the SPIE proceedings. In the second experiment, a spectrograph with an absolute energy calibration was used and the conversion efficiency (CE) of energy of 170 ps laser pulses to EUV emission at 13.5 nm inside 2% reflection band of multilayer Mo/Si optics was measured. Two thicknesses (40 nm and 200 nm) of the tin layer were used. The smaller

thickness was insufficient and the whole layer was ablated during the laser pulse. For the thicker layer, it was shown that the target with the tin layer on the porous alumina was superior to the target with microspheres. The maximum in-band CE of 1.49%/(2π steradians) was measured for 200-nm-thick Sn layer on a porous alumina substrate at the laser intensity of 4×10^{12} W/cm^2 (laser energy of 50 mJ), which is by 28% higher than the maximum CE measured for bulk Sn targets. For higher laser intensities, lines belonging to higher ionization states up to Sn^{21+} were observed and CE is decreasing due to an excessive heating and ionization of the target. The results of this experiment were published in the journal Laser and Particle Beams.

The latter chapter describes the experiment at Utsunomiya University where bulk rhodium targets were irradiated by single and dual laser pulses. The main 150 ps pulse was preceded by a prepulse of duration either 150 ps or 6 ns. Identification of a number of spectral features was performed from the comparison with previous results and ab initio calculations. While practically no impact on the emission was observed for 150 ps laser prepulse, an enhancement of EUV emission in intense lines in the water window region by up to 80% was observed for 6 ns long prepulse and the pulse separation less than 10 ns. The results of this experiment were published in the Journal of Applied Physics.

The last chapter is devoted to the conclusions and the plans for future research. The list of the candidate's publications is added in the Appendix A. Three main publications, where the candidate is the first author, are attached in the Appendix B.

The thesis is suitably structured. It is written in a compressed way, but clearly without significant errors. Some figures (e.g. Figure 3.3) could be better formatted, some formulations seem to be awkward. However, the contribution of the candidate to the presented results was significant in experiment setup, experiment execution, processing of the experimental data, interpretation of the results and drawing the conclusions.

According to my opinion, the Ph.D. thesis submitted by Mr. Barte fulfils all the requirements on Ph.D. theses and I strongly recommend it for the defence.

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