To Mrs Monika Zabranska  
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Belfast, 24/5/2024  
RE: Mr Filip Grepl – Assessment of PhD thesis  

Dear Mrs Zabranska  

Having read the thesis submitted by Mr Filip Grepl towards the award of a PhD degree, I submit here, as required, an assessment of his work.  

The thesis reports on the development of new optical probing capabilities for the diagnosis of ultrafast plasma dynamics, capable of providing multiframe images of high-intensity laser plasma interactions. The specific motivation for the work refers to the need for diagnosing plasma conditions during the process of laser-driven ion acceleration from thin foils, so that, for example, the effect of prepulses on plasma production and target integrity can be monitored at different time points within the same event. This is a very important capability in light of the shot-to-shot variability of plasma conditions often encountered in high-power laser-plasma interactions.  

The established approach is that of taking single snapshots of the interaction in different laser shots and changing the time delay of the probe between shots to reconstruct the temporal evolution of the plasma. Clearly, this is not an effective procedure unless the different plasma events probed in different shots are equivalent and behave in the same way. There are many situations in which this is not the case, and a clear example is provided in the thesis in relation to high-power interaction with a cryogenic ribbon target, where the target position changed significantly and uncontrollably between shots.  

The aim of the thesis is therefore valuable, up-to-date and important for the field of high-intensity laser-matter interaction. There have been several methods proposed and texted for multiplexing optical probing diagnostics and delivering multi-frame capabilities. The candidate has done an excellent job in surveying in the thesis the different methods proposed so far in the literature and reporting them while classifying them in different relevant categories. This is already a very valuable contribution made by this thesis. All these methods come with their own limitations and complexities – some are appropriate only to a particular experimental configuration, and in general they are not easily adaptable to the needs of ultra-intense interaction experiments, where compactness, ease of reconfiguration and portability are important requirements.  

The approach reported in this thesis, based on Non-Collinear Optical Parametric Amplification in a non-linear crystal is original, innovative and meets most of these requirements. This is based on the selective amplifications of time-separated short pulses, which couple to portions of the spectrum of a broadband chirped higher-energy pulse pulse, resulting in time separated pulses at different central wavelength, which can be
directed collinearly through an evolving plasma, and can then be easily separated to produce different images. The thesis reports on the first experimental implementation of this technique with 3 pulses, as well as proposing a design for 6 pulses, the maximum number of pulses which can be fitted without overlap within the spectrum of the seed pulse. The work shows high-level optical skills coupled to a strong knowledge of plasma physics diagnostics. The implementation of the technique is shown for a test experiment employing a moderate power, high-repetition laser system, where a fraction of the pulse is used to create a plasma channel in air, and the remainder is used for the generation of the probe pulses through the NOPA process. This shows very clearly the capabilities of the technique for multi-frame imaging by providing snapshots of the channel in 3 different frames at sub-picosecond delays, which allow following the front of the ionized plasma as the laser moves through the field of view at velocities close to the speed of light. The same technique is applied to moderate power interaction with a water jet, enabling the capture of interferograms at two different times in the same shot.

The thesis also discusses the implementation of the technique in the ELIMAIA target chamber at ELI Beamlines, with the aim of probing interactions at very high power (100s of TW) and the process of ion acceleration. The thesis discusses in detail the set-up and design specifications for this specific application, but unfortunately, due to technical issues not related to the diagnostics, the candidate could not carry out these higher-power tests within the timeframe of the PhD. Despite of this, the aim of the thesis is achieved, as the candidate has been able to develop a new arrangement which meets the diagnostic requirements (discussed at the beginning of the thesis) and has demonstrated its successful implementation, albeit at lower power than intended.

The scientific value of this work is very significant in terms of diagnostic development, and in fact the work has been reported in a publication on High Power Laser Science and Engineering, a high-quality scientific journal. Furthermore, exploitation of the new diagnostic capabilities provided by this work, e.g. on future ELIMAIA experiments, will certainly provide important scientific contributions and result in additional output. The thesis is of very good quality, both in the initial background sections, and in the chapters focusing on the new results. It is very clear and well written, with only very minor issues in terms of typos and formatting. I certainly can recommend it for presentation and defense in front of the PhD award committee.

Please do not hesitate to contact me should you require any further information or opinion.

Yours sincerely,

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