Durham University
Department of Physics

Shaped by the past, creating the future

27 January 2025

TO WHOM IT MAY CONCERN

Report on the Doctoral Thesis submitted by Ms Deeksha Kanti, "Radiative Recombination in Strong Laser Pulses"

The research presented in this thesis is an original investigation of the theory of laser-assisted radiative recombination and laser-assisted radiative attachment in ultrashort laser pulses. It goes well beyond the previous work on this topic, in multiple ways. In particular, the candidate showed how spurious oscillations in the calculated energy spectrum of the emitted photons can be avoided; demonstrated the importance of taking into account the possibility (previously neglected) that the incident electron emit radiation before or after the laser pulse; showed how the yield of photons emitted in these processes could be enhanced and/or tailored by assisting it by a chirped pulse or by a train of ultrashort pulses rather than by a single pulse of fixed frequency; discussed how to treat these processes beyond the often-made dipole approximation; explained how non-dipole corrections affect the emission of photons in this context, not the least in making it possible to enhance the range of energy of the emitted photons; discussed interesting asymmetries found in certain angular distributions; analysed the emission processes through the calculation of spectrograms; and studied the occurrence of phase vortexes and nodal lines in the relevant complex probability amplitudes and their effect on the spectrum of photon emission.

As this long list indicates, the work presented is substantial and addresses a wealth of issues. It is valid, at least to the extent that I could judge without redoing the calculations independently, and it significantly adds to our understanding of these processes. The discussion of the non-dipole effects is particularly interesting. That this work is a real contribution to knowledge is clear from the dissertation. It is also demonstrated by the fact that the candidate, her supervisor and other co-workers have already published a large fraction of these results in a quality journal – Physical Review A – in the form of two long research articles with the candidate as first author. The journal has highlighted the first of these two articles as an Editor's Suggestion, an accolade singling out contributions judged to be particularly important, interesting and well written.

There are a few points which may have deserved more detailed comments, though. In my opinion, there would have been value in completing the review of the literature on radiative recombination already contained in the thesis by a short review of non-dipole effects in the

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related process of high order harmonic generation, in view of similarities in the formulation of these two processes. Other issues which would have also been worth discussing, if only briefly, are the order of magnitude of the rate of radiative attachment, how the metrological method proposed in Section 2.3 compares to other methods, and perhaps also the practicality of achieving the kind of chirped pulses considered in Section 3.3.2. The calculations rely on two key approximations that are made without long justification, i.e., that the final atomic state is not strongly affected by the laser pulse and that in radiative recombination the incident electron can be described by a Coulomb-Volkov wave. These approximations are standard in this context, or at least are not unusual. I do not think that they compromise the validity of the results or need to be discussed at length. However, I would recommend that the candidate recheck the sign of the term in $\boldsymbol{n}\cdot\boldsymbol{p}$ in Eq. (3.39), as this sign appears to differ from the one given in the literature on high order harmonic generation for the equivalent correction [e.g., H R Reiss, Phys. Rev. A **63** 013409 (2000) and N J Kylstra et al, J. Phys. B **34** L55 (2001)].

The thesis is also completely satisfactory in terms of its organisation and presentation. The organisation into sections suits the work well, comprising an Introduction, a long section on laser-assisted radiative attachment, a second long section on laser-assisted radiative recombination (the content of which follows from the previous one), a Conclusions section and two long appendices. The latter contain much useful material likely to be valuable to future researchers. The written style is generally excellent. The standard of presentation of the numerous figures and equations is exemplary. Altogether, the care with which this dissertation has been written and produced gives further reassurance on the correctness of the abundant numerical calculations carried out by the candidate. Of course, this is not to say that the dissertation is entirely free of imperfections, e.g., typos, but those are few and very minor. This report is probably not the place for listing unimportant issues of this nature.

Altogether, this work compares well with good PhD theses on similar topics in the UK, which I am more familiar with, whether this is in terms of volume, scientific level or presentation. It is my opinion that it fulfils the requirement of the degree. I am happy to recommend that it be received and that the candidate be admitted to the next stage of the procedure.

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