

# Application of the Exact WKB Method to Particle Production and High-Harmonics Generation from the Vacuum

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I discuss the application of the exact Wentzel-Kramers-Brillouin (WKB) method to particle production (the Schwinger effect) and high-harmonic generation (HHG) from the vacuum-based on my works [1,2]. The exact WKB method is an extension of the conventional WKB method, which is achieved by applying the Borel resummation technique to resume the conventional WKB series and is a powerful tool to investigate the Stokes phenomenon ordinary differential equations. Using the exact WKB method, I derive wavefunctions under strong time-dependent electric fields that properly take into account the Stokes phenomenon at the leading order in  $\hbar$ . I then use the wavefunctions to discuss the vacuum particle production (the Schwinger effect) and compare the exact WKB approach with other approaches such as the semi-classical worldline instanton method. I also compute the induced electric current, including both intra- and inter-contributions, as the source of HHG and point out the importance of quantum interference effects (Stückelberg phase interference) to HHG.

## References

- [1] H Taya, T Fujimori, T Misumi, M Nitta, N Sakai, J. High Energ. Phys. **2021**, 82 (2021); arXiv:2010.16080 (2020)
- [2] H Taya, M Hongo and T N Ikeda, arXiv:2105.12446 (2021)