A definition of the SI second based on several optical transitions

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As the performances of optical frequency standards now overcome the cesium primary frequency standards by several orders of magnitude, the question of a redefinition of the SI second based on these optical transitions is topical. A road-map crafted by the CCTF and its working groups indicates a possible redefinition in 2030 [1]. However, in the current context where many competing optical frequency standards present performances that quickly evolve, finding a good candidate for the new definition, and ensuring that this choice will remain relevant over several decades is a difficult task.

Three options are currently considered for the redefinition of the SI second : in option 1, the Cs transition would be replaced by a single optical transition, yet to be chosen ; option 2 rather proposes to define the second based on the weighted geometric mean of several transitions [2]; in option 3, the numerical value of a fundamental constant (e.g. the Rydberg constant or the electron mass) would be fixed, in the spirit of the 2018 revision of the SI, but with the showstopper that the realization would be limited to about 10^{-12}.

In this paper, we present the theoretical concepts underpinning option 2, including the reason for choosing the geometric mean, how the concept of primary and secondary frequency are integrated in this definition, and the role of frequency ratios measurements in the realization of the unit.

Then, we discuss how gradually changing the weights of the various transitions composing the unit, and introducing new transitions to the pool of transitions composing the unit can be used to adapt to new developments in optical frequency standards. We show that these updates can provide a smooth and convergent process towards a constant value for the SI second, as compared to option 1, for which adapting to new frequency standards requires to abruptly change the transition used to define the second.

We also present how option 2 would be practically implemented and realized, using as input the set of recommended frequency ratios between optical transitions [3], as currently published by the CCTF. For this purpose, we simulate the implementation of option 2 based on the recommended frequency ratios published at the 2021 CCTF. We also describe a systematic method to determine the weights of the various transitions composing the unit.

Finally, we propose an analysis of the strengths and weaknesses of option 2, and compare how options 1 and 2 would satisfy a possible set of requirements for the redefinition of the SI second.

References

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