Temporal-spatial double slit interference of photoelectron

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Synopsis The electron displacement induced by an ultrashort pulse is theoretically investigated. We propose and numerically demonstrate a scheme to accurately measure the electron displacement using a ruler formed by the interfering spirals in the photoelectron momentum distribution generated by two oppositely circularly polarized pulses. It can be understood as a temporal double-slit with an additional spatial shift on one slit.

Recently, the helical vortex structures in photoelectron momentum distributions (PMD) was numerically observed [1] from atom induced by two oppositely circularly polarized, time-delayed pulses and then verified experimentally [2, 3]. It was interpreted as the interference between $M = \pm L$ continue states induced by two count-rotate pulse.

Here [4], we show that this vortex structure can also be regarded as double-slit interference in time domain. Apply the pulse with configuration shown in Fig. 1, the electron ionized at a certain time t has the final momentum $\boldsymbol{p}$ opposite to the vector potential $\boldsymbol{A}(t)$ approximately. Consider the time t_1 and t_2 for two delayed pulses with same vector potential direction, those electron ionized at t_1 and t_2 would interference with each other with phase difference $\varphi_0 = (I_p + \boldsymbol{p}^2/2)(t_2 - t_1)$, where I_p is the ionization potential of the atom. As t_1 gets smaller and t_2 gets larger, the corresponding vector potentials rotate the same angle $\delta\theta = \omega\delta t$ in the same direction. We have $\varphi_0(\theta + \delta\theta) - \varphi_0(\theta) = 2(I_p + \boldsymbol{p}^2/2)\delta\theta/\omega$, results evenly spaced fringes in photoelectron angular distribution with angular stripe spacing equals to $\pi\omega/(I_p + \boldsymbol{p}^2/2)$. By considering interference between different optical cycles, an additional condition $I_p + \boldsymbol{p}^2/2 \approx n\omega, n \in \mathbb{Z}$ is required, which corresponding to the n-photon process.

With such physics picture in mind, we now impose an additional attosecond laser pulse between these two opposite circularly pulses shown in Fig. 1. The electron ionized by the first pulse would gain a spatial displacement $\boldsymbol{r} = \int \boldsymbol{A}\,\mathrm{d}t$ from the intermediate pulse. Thus, a phase shift $\varphi_1 = \boldsymbol{p} \cdot \boldsymbol{r}$ is applied to the electron. Now, as the vector potential (momentum) rotate, we have $\delta\varphi_{\text{total}} = 2n\delta\theta + \frac{\delta \boldsymbol{p}}{\delta\theta} \cdot \boldsymbol{r}\delta\theta$, which approximately results a shift $\Delta\boldsymbol{p} = \omega\boldsymbol{n} \times \boldsymbol{r}/2$ in PMD. From the momentum shift in PMD, one can extract the electron displacement induced by the attosecond laser pulse.

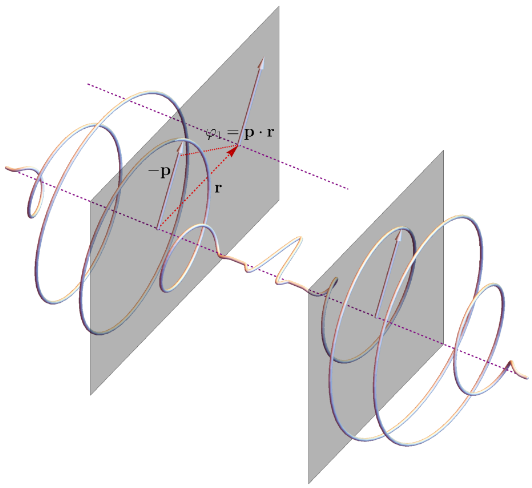

Figure 1. Demonstration for the present temporal-spatial double-slit interference.

References

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