contributions of all emitted electrons in the interaction region. If we write the intensity coming from one point in this region, neglecting the contributions of the so-called atomic phase, we get for the 2ω oscillating component[33]:

$$\begin{aligned} SB_{q+1}(\omega, R, \theta) &= \cos\left[2\omega\tau_0 + \varphi_{q+2} - \varphi_q + \Phi_{q+2}(R,\theta) - \Phi_q(R,\theta) - 2\Phi_{IR}(R,\theta)\right] \\ &= \cos\left[2\omega\tau_0 + \varphi_{q+2} - \varphi_q + \left(\ell_{q+2} - \ell_q - 2\ell_1\right)\theta\right], \end{aligned}$$

where ω is the angular frequency of the driving laser and φ_q the spectral phase of the q-th harmonic order. For the intensity to keep oscillating after integration over θ, which is the operation mode of our detector, the θ-dependent term must vanish, giving $\ell_{q+2} - \ell_q = 2\ell_1$. In particular, if dressing with $\ell_1 = 1$, this condition is only met when having $\ell_q = q\ell_1$. The observation of SBs in this case is therefore another measurement of the multiplicative rule for OAM transfer. Supplementary Fig. 5 shows that the 2ω oscillation component disappears when using $\ell_1 = 0$, for which the θ-dependent term does not cancel. The RABBIT[33] analysis of the SBs' oscillations was carried out under the assumption of fully coherent light[36].

Data availability. The data that support the findings of this study are available from the corresponding author (T.R.) upon request.

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Author contributions

R.G., A.C. and T.R. conceived, built and carried out the experiment and analysed the data. O.G. developed the laser system and the mode-filtering stage. T.A. did the HHG simulation. J.C. and R.T. did the RABBIT simulations. All authors contributed to the writing of the manuscript.

Additional information

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