Rotational coherence created in the B state of N$_2^+$ in air lasing at 391 nm

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When intense femtosecond laser pulses are focused in air, coherent and unidirectional radiation at 391 nm called air-lasing is generated, corresponding to the emission from the B state of N$_2^+$ to the X state.$^{1,2}$ It was revealed recently by strong field Fourier transform spectroscopy that the A-X coupling in N$_2^+$ plays a crucial role in creating the population inversion between the B and X states,$^3$ resulting in the air-lasing. In this work, we investigate the rotational coherence created in the air-lasing by a pump-probe experiment and examine the mechanism of the population transfer induced by the post-ionization excitation in an intense laser field by adopting our theoretical model$^4$ in which the rotational degrees of freedom are explicitly included.

We simulate the experimental B-X emission spectrum recorded as a function of the pump-probe time delay by taking account of the population difference between B ($v = 0$) state and X ($v = 0$) state. The characteristic temporal evolutions of the intensity profiles appearing in the experimental spectrum are reproduced well. The appearance of the two R branch profiles can be ascribed to the rotational coherence in the B ($v = 0$) state prepared by the pump and probe pulses, reflecting the difference in the rotational selection rules of the A-X and B-X transitions as well as the difference in their transition intensities.