Observation of molecular rotation during femtosecond laser filamentation in air by a pump-probe longitudinal diffraction method

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Utilizing a pump-probe longitudinal diffraction method, we have experimentally observed dynamics of air molecular rotation during femtosecond filamentation. By adjusting only the pump pulse energy, a recurrence of phase shift variation of the probe throughout a range of delay of at least 100 ps was achieved.

Femtosecond laser filamentation in air is a nonlinear effect and it occurs as a dynamic balance of two main physical phenomena [1]: the optical Kerr self-focusing and the plasma defocusing. Since the observation from Braun et al. in 1995 [2], femtosecond filamentation in air has stimulated tremendous research interest, not only because of the importance of its physical principle behind, but also its potential applications [1].

During femtosecond laser filamentation, lots of phenomena, such as intensity clamping, conical emission, ect, have been observed and extensively studied [1]. However, the microenvironment together with its physical and chemical features around the plasma channel created through filamentation has not deserved the same research enthusiasm. One important feature of the plasma wake of a laser filament is the occurrence of air molecular rotation dynamics which can maintain itself as periodic revivals of rotational periods of air molecules, especially of N_2 and O_2 [3]. By using a pump-probe longitudinal diffraction method [4], we have experimentally observed dynamics of air molecular rotation during femtosecond filamentation.

Here the laser adopted is a 1-KHz, 50-fs Ti:sapphire laser system (Coherent Libra) with an output pulse energy up to 3.6 mJ with a central wavelength of 800 nm. After a beam splitter, the transmitted high-energy pump pulse is focused by a thin lens (f = 400 mm) and transformed into a steady filament in air. The reflected low-energy probe pulse takes on a central wavelength of 400 nm after a BBO crystal and goes through spatial filtering to achieve a uniform wavefront of nearly a Gaussian form. The phase modulation from the pump pulse filamentation felt by the probe is recorded as diffraction patterns using a 12-bit industrial CCD camera.

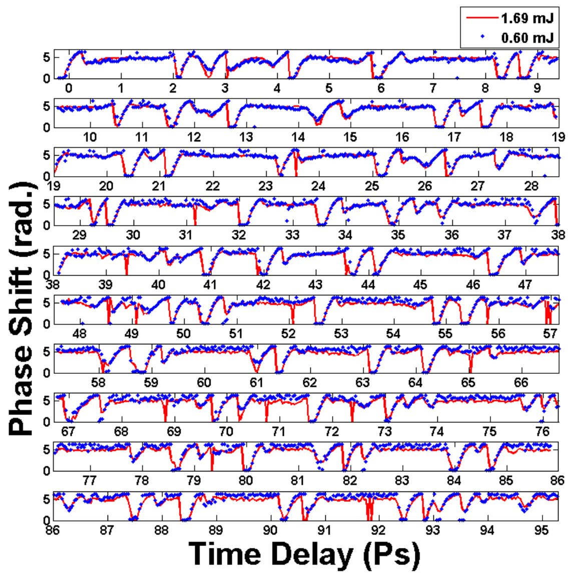

Figure 1. Phase shift of the probe as a function of time delay between pump(800nm) and probe(400nm).

In Fig. 1, the phase shift of the probe extracted from diffraction patterns as a function of time delay is shown. It's easy to figure out periodic revivals of phase variation occur at moments of multiple of the rotational periods of N_2 (T_r=8.3 ps) and O_2 (T_r=11.6 ps).

References

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