軟 X 線アト秒パルス列の干渉

Interferometry of attosecond pulse trains in the soft X-ray wavelength region

Objectives

我々は、高強度フェムト秒レーザー光によって発生する高強度のアト秒パルス列(APT)の研究を行ってきた。真空紫外から極端紫外域の波長の APT に於いては干渉フリンジ分解の自己相関測定に成功し、ほぼ単一サイクルに近いパルス幅、320 アト秒を得ている。さらにパルス幅を短くする為には、波長の短い軟 X 線領域のアト秒パルス列が必要になるが、我々の開発した自己相関計（通称アトコリレーター）が、この波長域に於いても使用可能であるかは自明でない。
この研究ではアトコリレーターの分解能を軟 X 線領域の APT の干渉実験で調べた。

We have investigated the generation and application of intense attosecond pulse trains (APTs), which are produced using the multiple high-order harmonic (HH) fields of a femtosecond laser pulse, and have demonstrated interferometric autocorrelation measurements of the APT in the vacuum~extreme ultraviolet (VUV~XUV) region. A pulse-duration of 320 was reached near the single cycle regime. To shorten the pulse duration of the APT even further will require the use of shorter wavelengths. It is not yet clear if our autocorrelation technique, which we call `attocorrelator', can be extended to the soft X-ray region. This research aims to test the ability of our 'attocorrelator' to resolve the interference fringes of an APT in the soft X-ray wavelength region ($\lambda < 30$ nm).

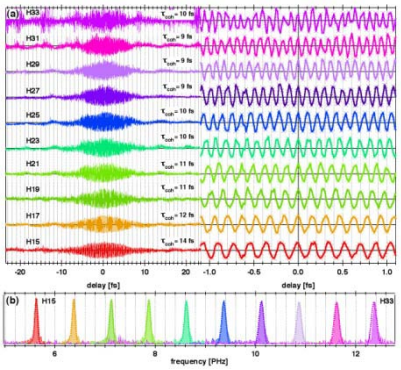

Fig. 1: (a) Interference trace of each harmonic field generated from Ar gas. The harmonic fields range from the 15th (H15) to the 33rd (H33) orders. (b) Magnitude of Fourier transform of each interference trace.

Achievements

- アトコリレーターの分解能は 24.2nm の波長の 33 次高調波でも十分であった。
- 干渉縞のフーリエ変換によりスペクトルの再現が可能。
- 干渉縞の遅延ずらしに対する対称性を時間領域で初めて確認した。これは APT が奇数次の高調波のみで構成されている事に起因する。
- 干渉縞の遅延ずらしに対する対称性が破れる現象も観測出来た。基本波レーザーの強度増大による高調波スペクトルの紫方変位が原因である。

- The resolution of our `attocorrelator' is sufficient to resolve the interferometric fringes of the 33rd harmonic field at a wavelength of 24.2 nm.
- Fourier spectroscopy is now available in the soft X-ray region.
- We observe clear translation symmetry of the interference fringes of the APT in terms of delay, which is the unique feature of the APT formed with odd-order harmonic fields.
- The broken translation symmetry of the interference fringes is also observed by increasing the intensity of the driving laser field. This is due to a spectral blue shift of each harmonic component.

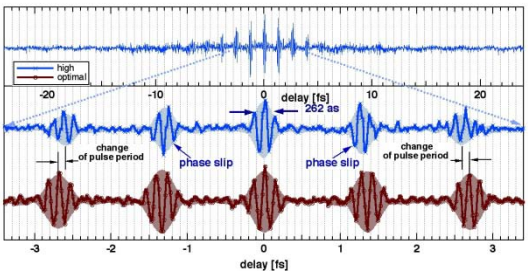

Fig. 2: Interference trace of the APT generated from Kr gas medium under the `high' intensity condition of the driving laser field (upper part), and a magnified view compared with that generated under the `optimal' conditions for maximum HH yield (lower part) .

References

1) Y. Nabekawa, T. Shimizu, T. Okino, K. Furusawa, H. Hasegawa, K. Yamanouchi, and K. Midorikawa, "Interferometric autocorrelation of an attosecond pulse train in the single cycle regime," Phys. Rev. Lett. 97, 153904 (2006).
2) Y. Nabekawa, T. Shimizu, Y. Furukawa, E. J. Takahashi, and K. Midorikawa, "Interferometry of attosecond pulse trains in the extreme ultraviolet wavelength region," Phys. Rev. Lett. 102, 3904 (2009).