Attosecond beam-line equipped with Angle Resolved Time of Flight (ARTOF)

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Abstract: We report the construction of an attosecond beam-line equipped with ARTOF measurement. A high rep. rate, high power, CEP-stabilized laser at 300 kHz is the main driver for attosecond XUV pulse and femtosecond XUV and UV pulses. Acceptance angle 44 degree and resolution up to 0.1 meV ARTOF is integrated. This beam-line is aimed to study the ultrafast change of band structure in 2D k-space and electron-electron correlation in condensed matter systems.

Angle Resolved Photoemission Spectroscopy has developed as a leading technique to study band structure. ARTOF, the advanced development from conventional ARPES technique, is a powerful tool since it provides direct views on 2D k-space. The measurement time to observe band dispersion could be dramatically reduced with this technique due to functionality to take 3D (k_x, k_y, E) data directly while using conventional ARPES, one should take data in a series of the rotation of facing direction. Considering that the short acquisition time is required for the pump-probe experiment, ARTOF is well suit for the photoemission dynamics.

Laser based light sources have enabled lots of groups to investigate dynamics of band structure, but still the electron-electron interaction in sub-femtosecond regime has not been investigated. Here, attosecond pulse, which is expected to overcome this temporal limit in previous studies, is a powerful candidate to investigate the electron-electron interaction.

In this work, we develop a time resolved ARPES system in attosecond time regime by combining ARTOF system with attosecond pulses from High Harmonic Generation (HHG) using a high power, high repetition rate Optical Parametric Chirped Pulse Amplification (OPCPA). For ARTOF measurement, a pulse with high repetition rate and low pulse energy is required to maximize signal-to-noise ratio and avoid space charge effect. Thus, a 300 kHz, 40 uJ pulse energy and pulse duration of less than 7 fs OPCPA laser [1] has been developed to generate attosecond pulse for ARTOF measurement.

The entire beam line is shown in Figure 1. In the first chamber, OPCPA laser is divided into two parts: pump beam (IR), probe (attoescond pulse generation). One beam is time-delayed with respect to the other. High harmonics, being generated from gas, pass through a Zr/Al filter for a proper condition to generate attosecond pulse. One IR beam and XUV beam are combined and co-propagate together into the 2nd chamber, where they are focused on the target. The monochromator with 2 multilayer mirrors gives wavelength selection. The monochromator for attosecond pulse is designed to give a bandwidth of ~ 5 eV centered at 93 eV. In the 2nd chamber, the beam can also be selectively delivered to an XUV spectrometer or a gas-streaking chamber for the characterization of the pulse itself. In the end, two pulses with a time delay are focused on a sample inside an analysis chamber under ultra high vacuum (UHV, ~ 10^{-11} mbar) through differential pumping line which allows vacuum level differences of 4 orders of magnitude. .

The combination of attosecond pulse & ARTOF technique would give a great opportunity to investigate electron-electron interaction of solid state materials.

References

[1] S. Prinz et al., Optics Express, **Vol.23**, Issue 3 pp. 2808-2818 (2015)

Figure 1 Attosecond ARTOF beam-line