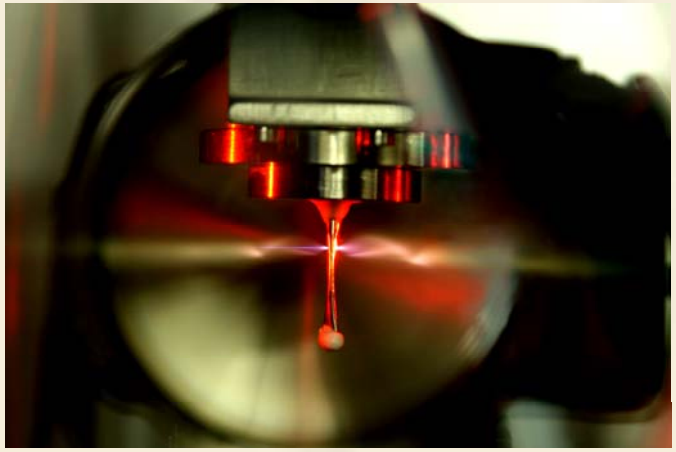
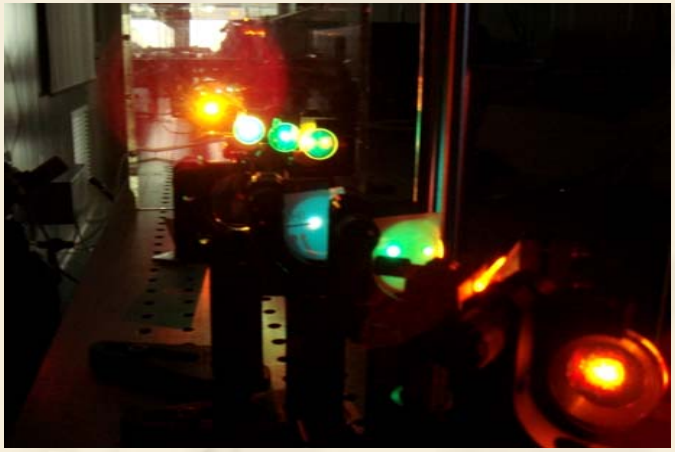
Generation of continuum XUV radiation by CE-phase stabilized 5-fs laser pulses





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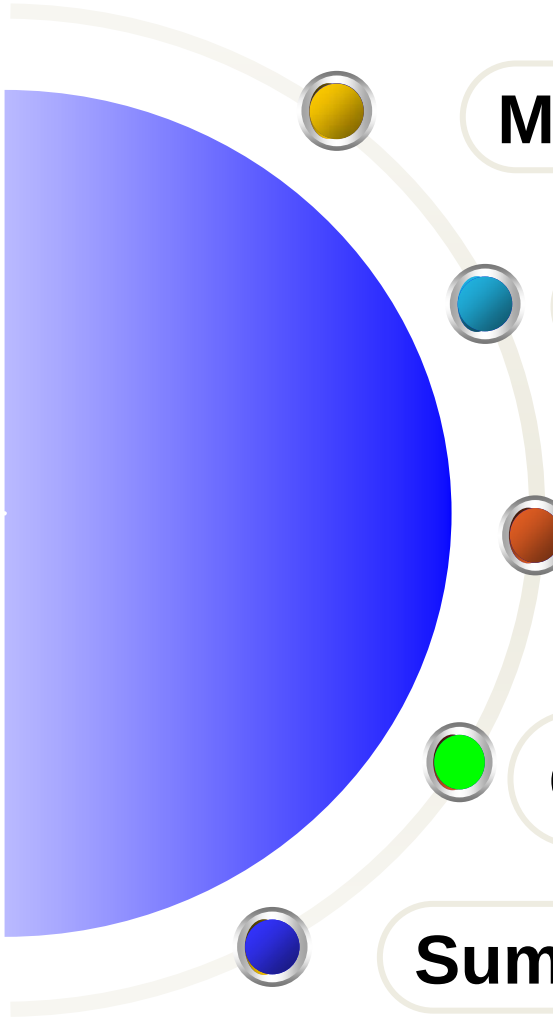
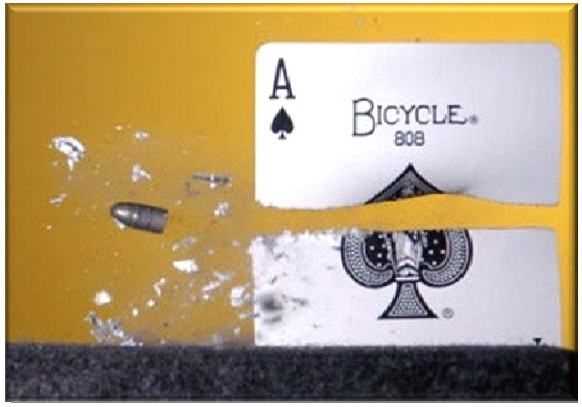


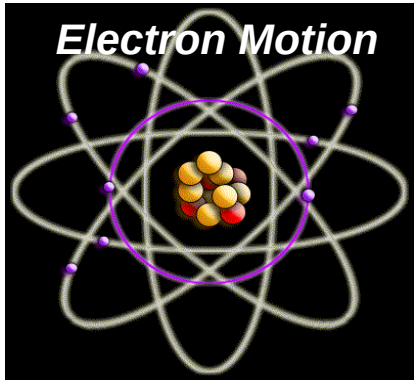
- Motivation
- How to generate continuum XUV radiation
- Carrier-envelope phase controlled 2-cycle optical pulses
- Generation of Continuum XUV radiation
- Summary

Covers highlight attosecond source and applications

why do we need attosecond pulse

To measure a "fast" event, we need to take a "snapshot" with *an exposure time << time constant of motion*





Electron Orbits in Bohr Model

T_{orbit} ≈ 150 *as* for H ground state

1 as = 10^{-18} sec

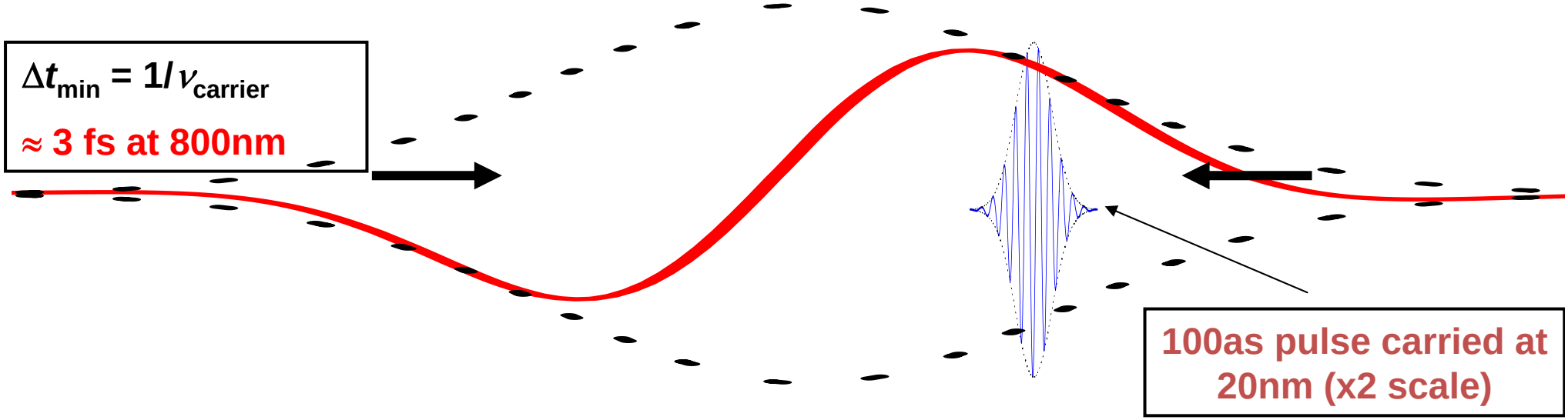
Attosecond pulses are needed to resolve electron motion!

The new "Atto-Science"

Electron motion determines how physical and chemical changes occur at a fundamental level.

----Drescher, M. *et al. Nature* 419, 803–807 (2002)

Attosecond pulses must be carried at short wavelengths



Sources with a large coherent bandwidth in the VUV-XUV region are required

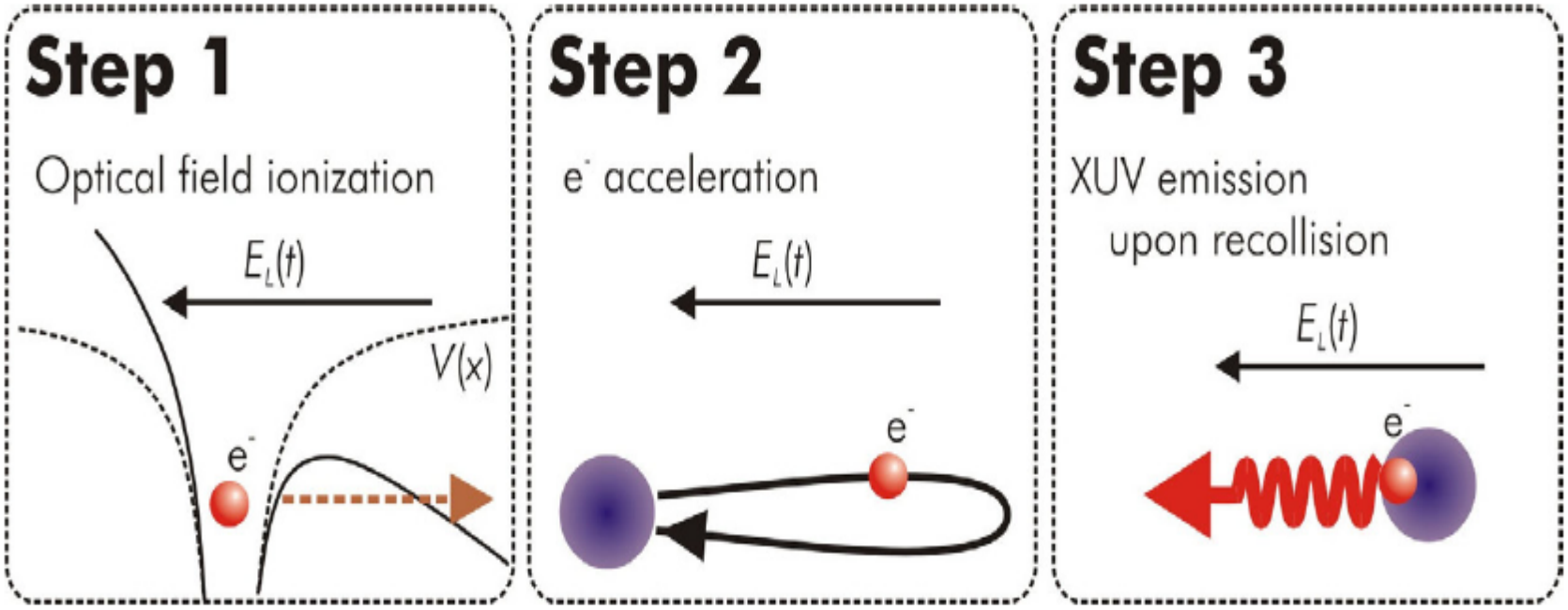
$\Delta\nu\Delta t \approx 0.4 \Rightarrow$ **for** Δt **= 100as, need** $\Delta\lambda/\lambda \approx$ **30% at 20nm**

High harmonic generation (HHG) is good candidate for generation of attosecond pulse

Simple 3-step model of HHG

- **A high-intensity effect producing short-wavelength, coherent light from laser-accelerated electrons in a gas.**

  Valid in “low-frequency” limit (IR and near IR lasers)

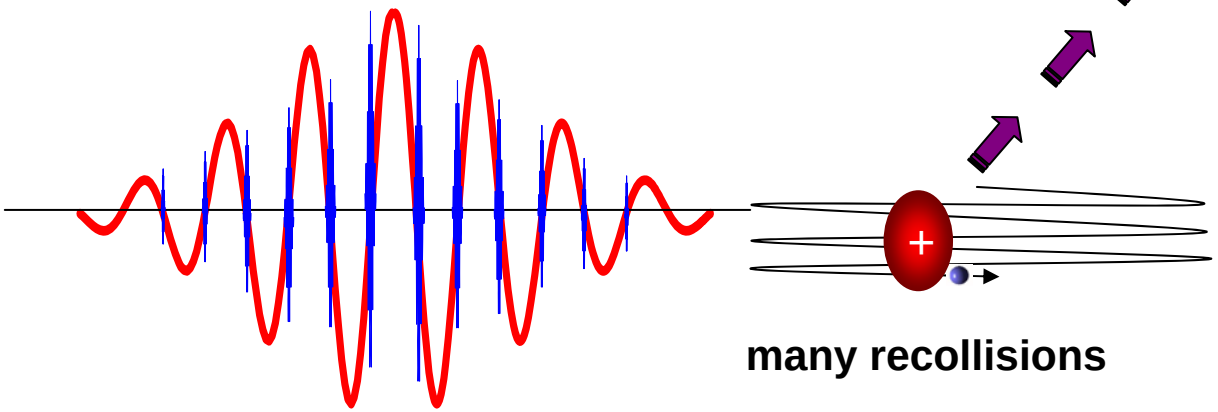


Repetition with period T/2 => comb of harmonics spaced by 2ω in frequency.

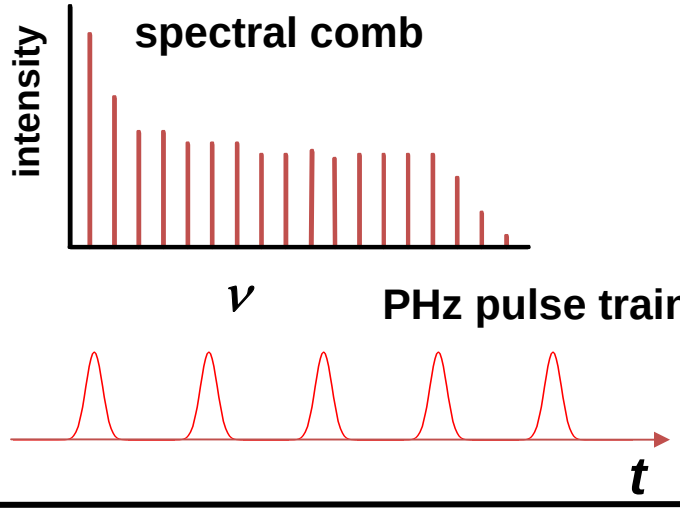
Techniques for single attosecond pulse_ driving by few-cycle pulse

HHG with few-cycle laser pulses present an “easier” route to single *as* pulses.

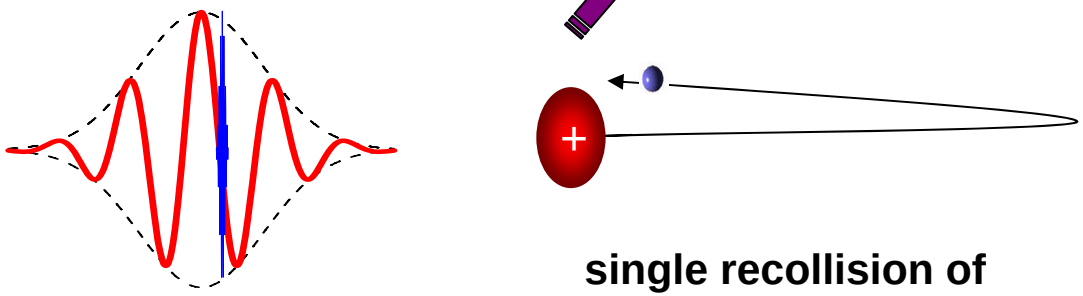
Long pulse



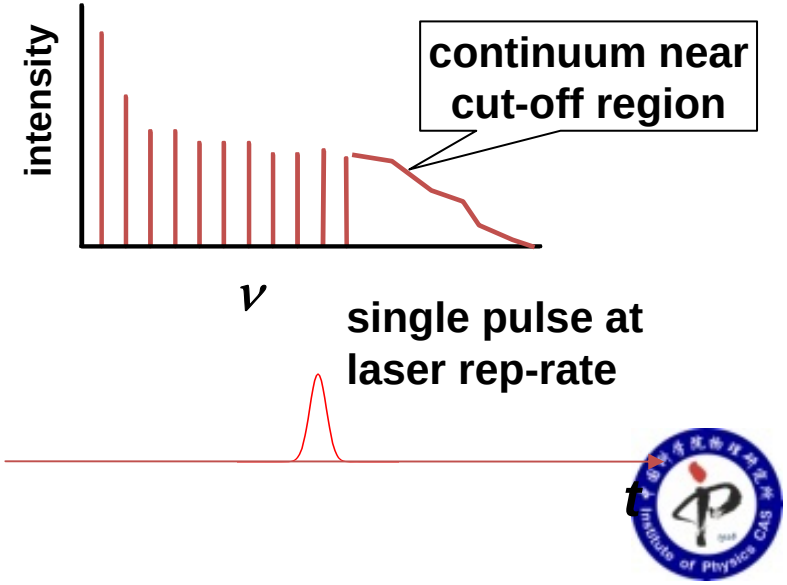
many recollisions



Few-cycle pulse

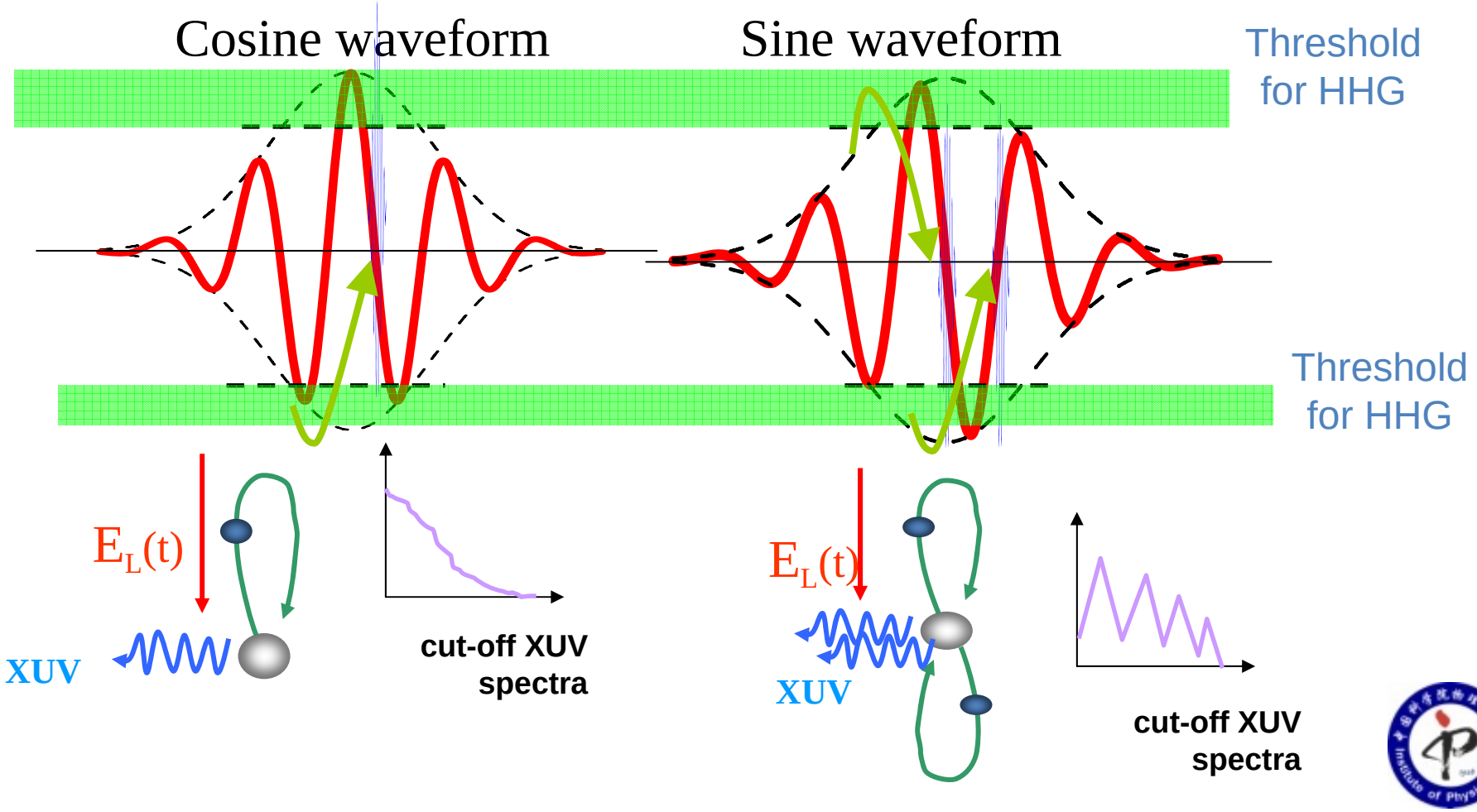


single recollision of maximum energy

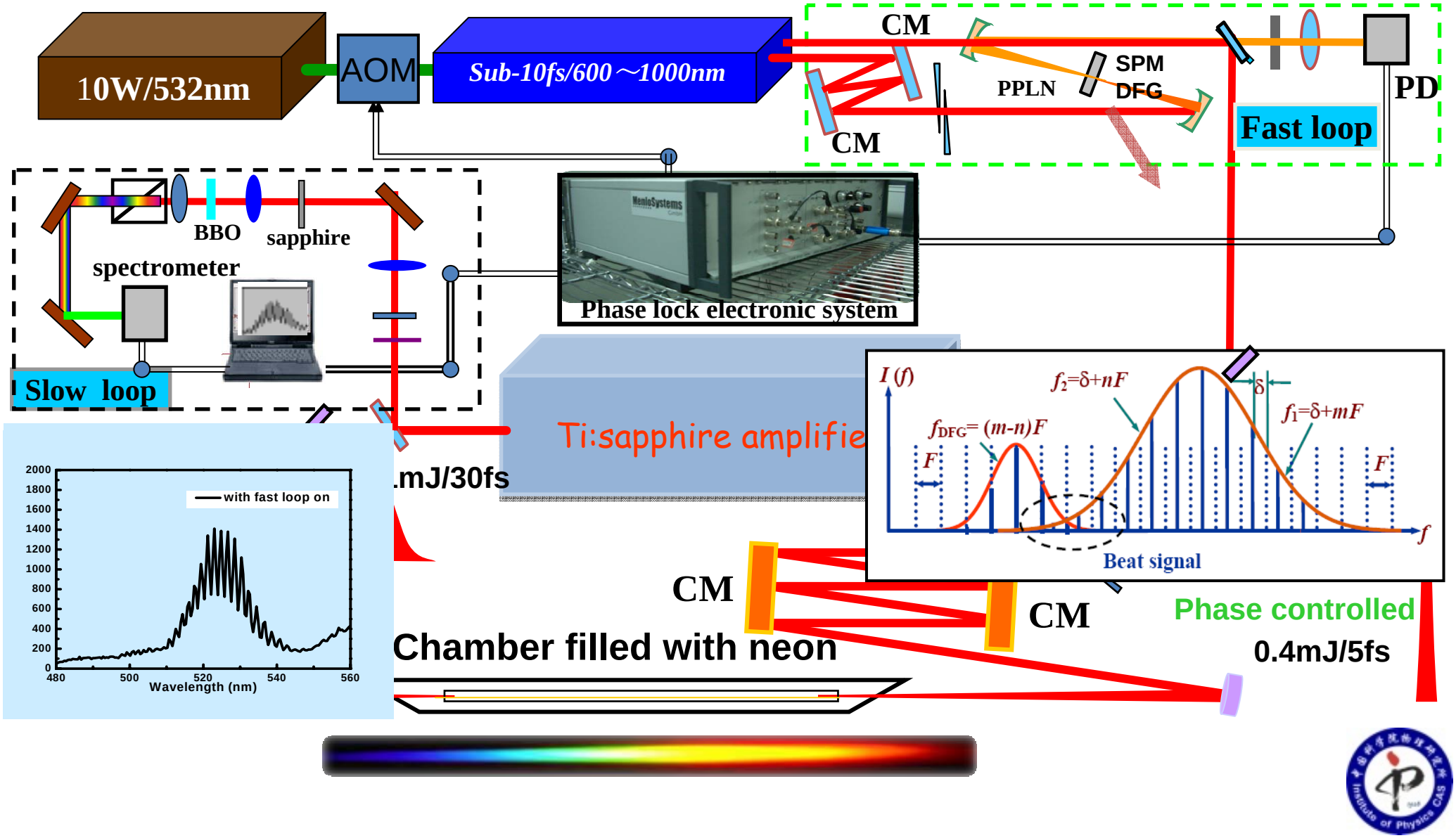


Techniques for single attosecond pulses:
CE-phase stabilized 5fs

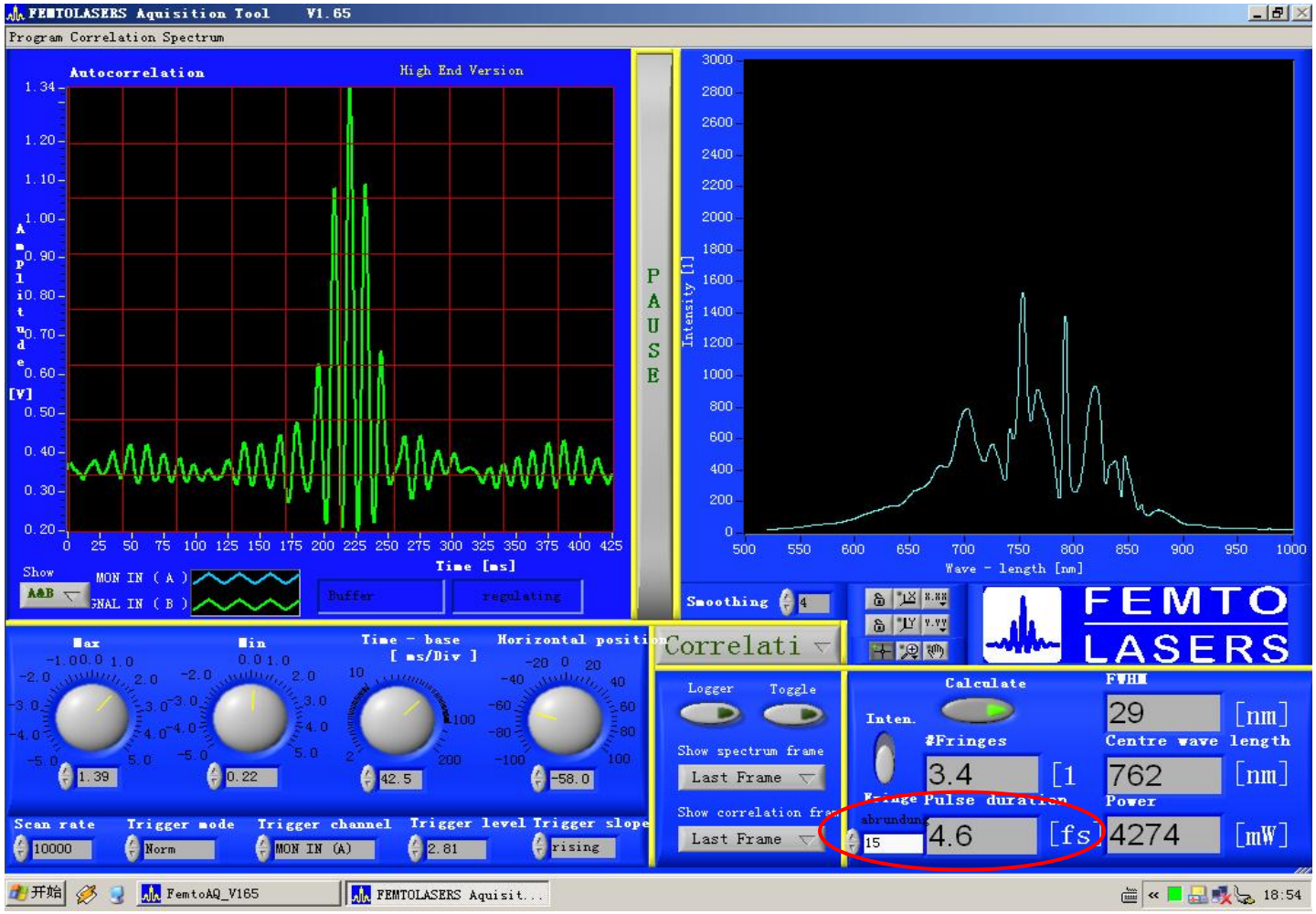
The CE-phase of few-cycle laser pulses is key to generation of single *atto* pulses. HHG is very sensitive to the peak intensity, which is higher for a 0° -abs phase (cos) than for 90° -abs phase (sin).



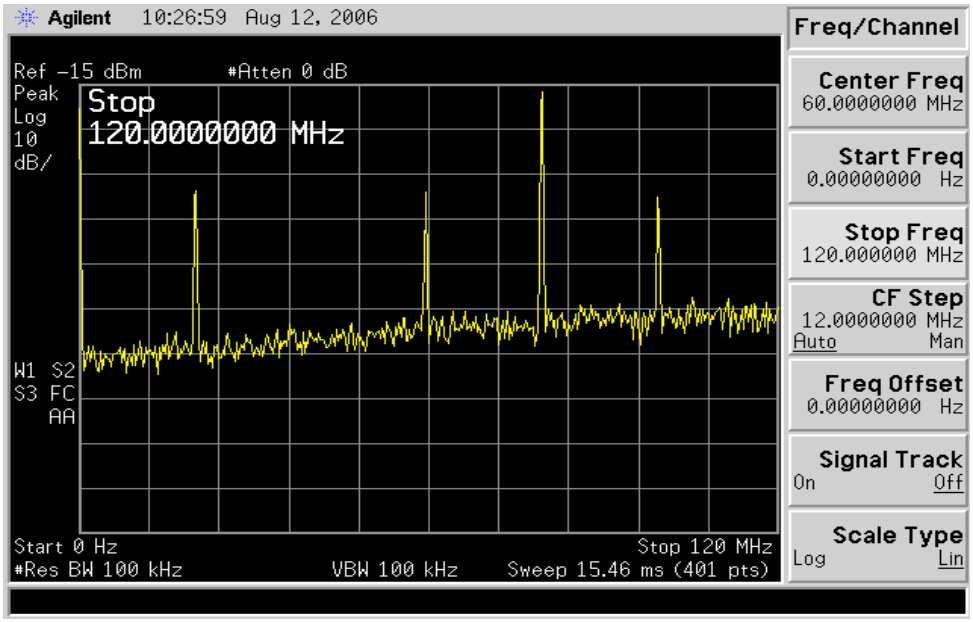
CE-phase controlled Sub-2 cycle optical pulses generation

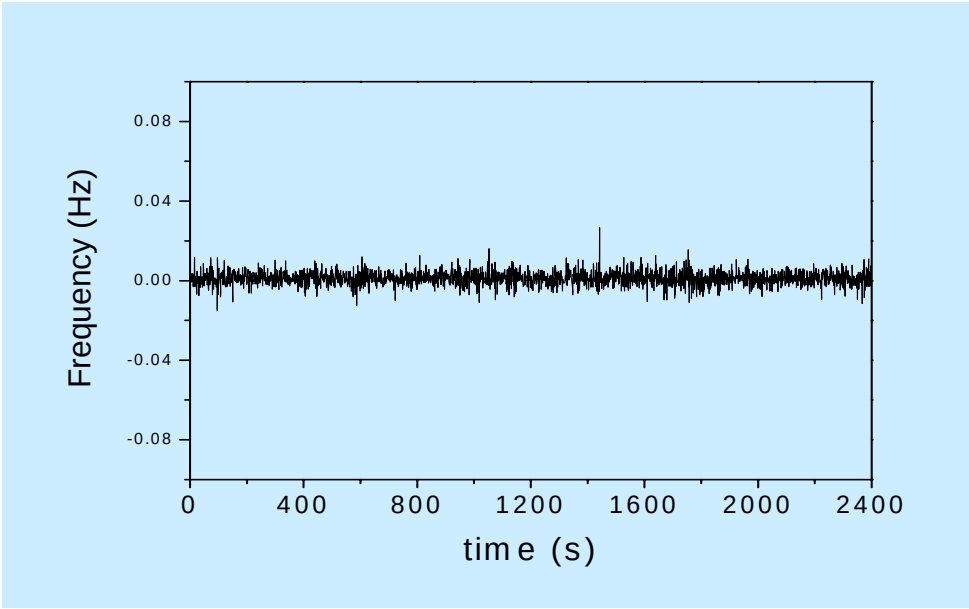


Pulse compression



Fast lock the oscillator

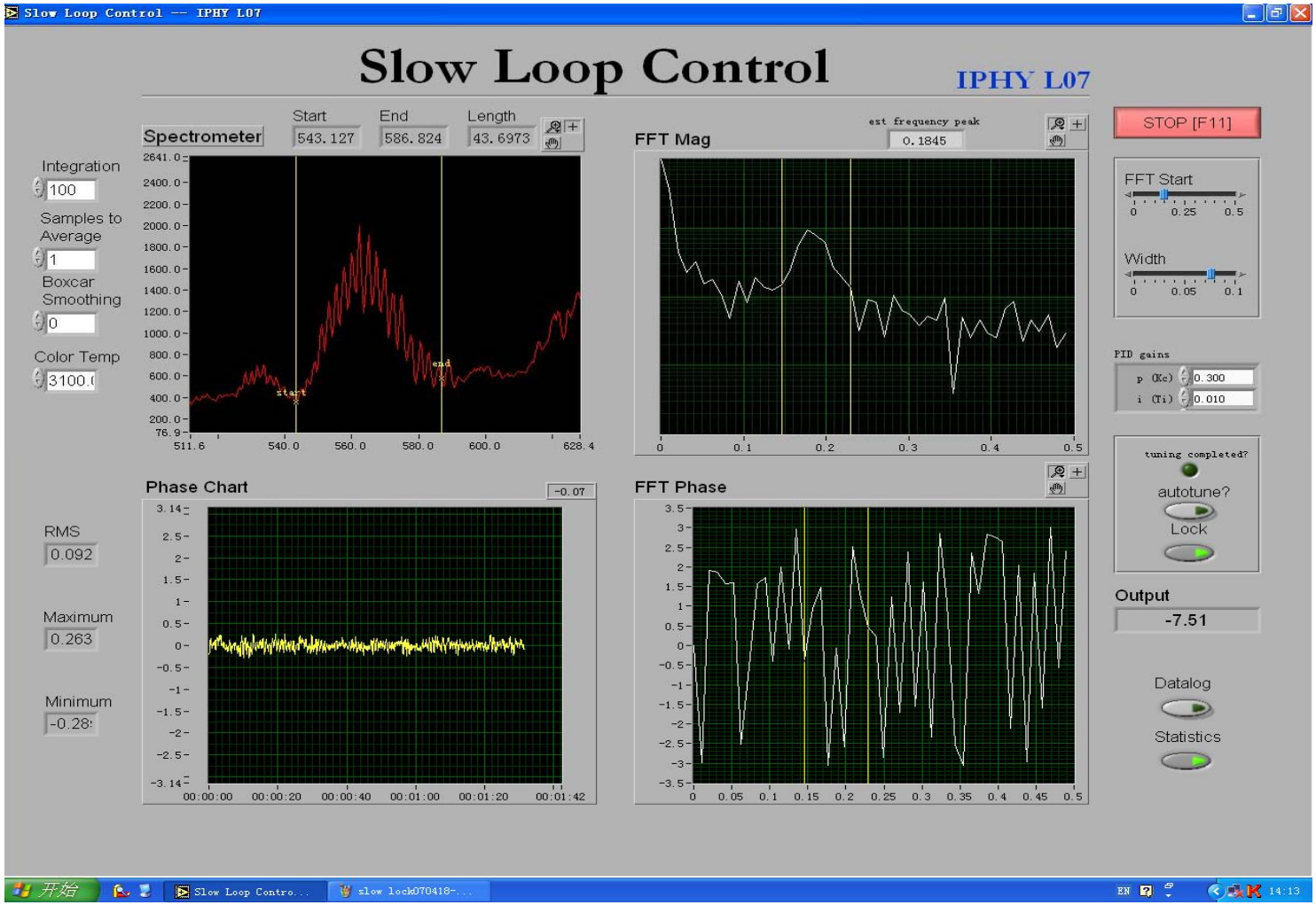




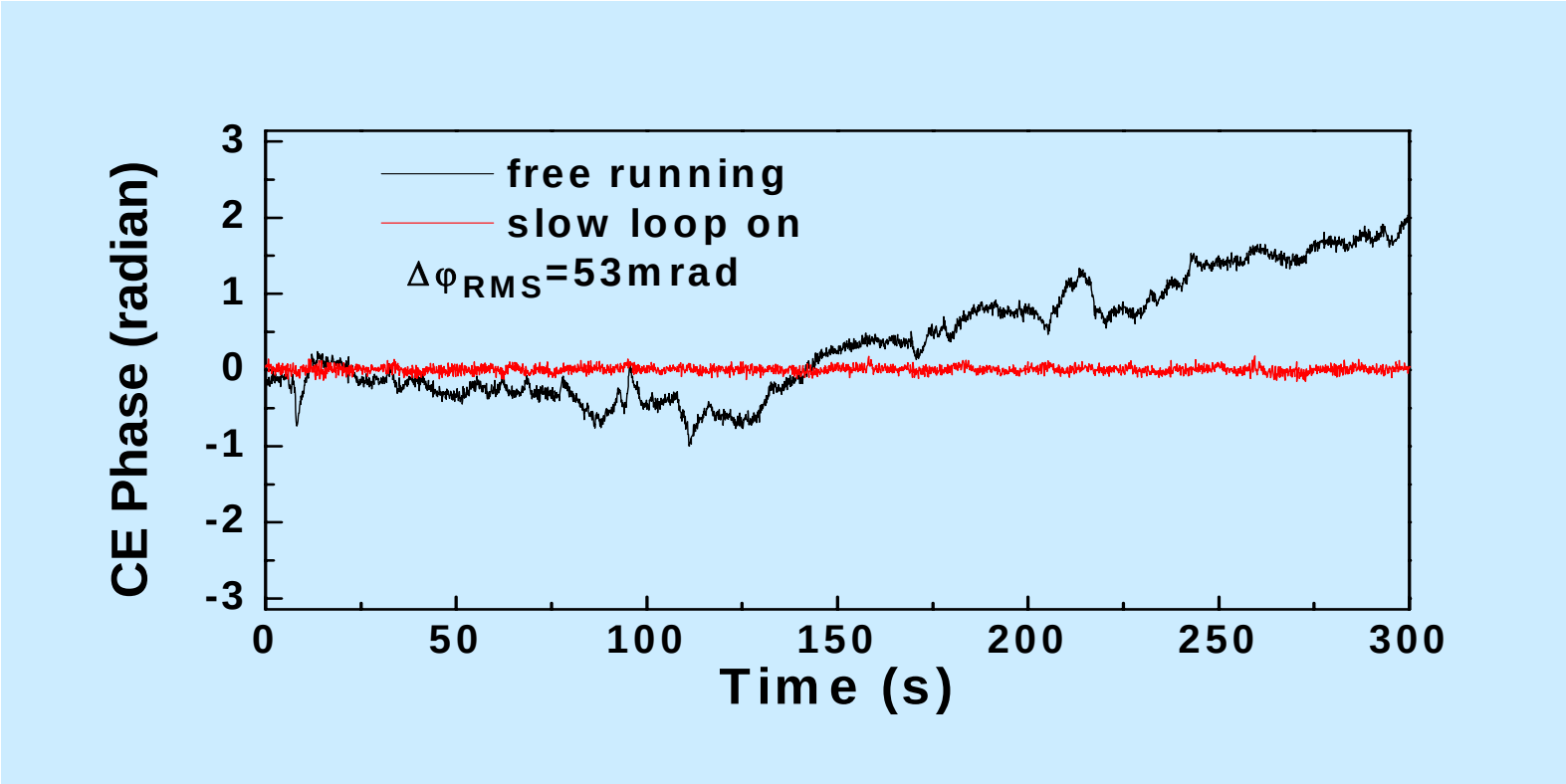
Left: Beat signal at 20MHz measured with spectrum analyzer;

Right: Locking data vs time.

Slow Loop Control

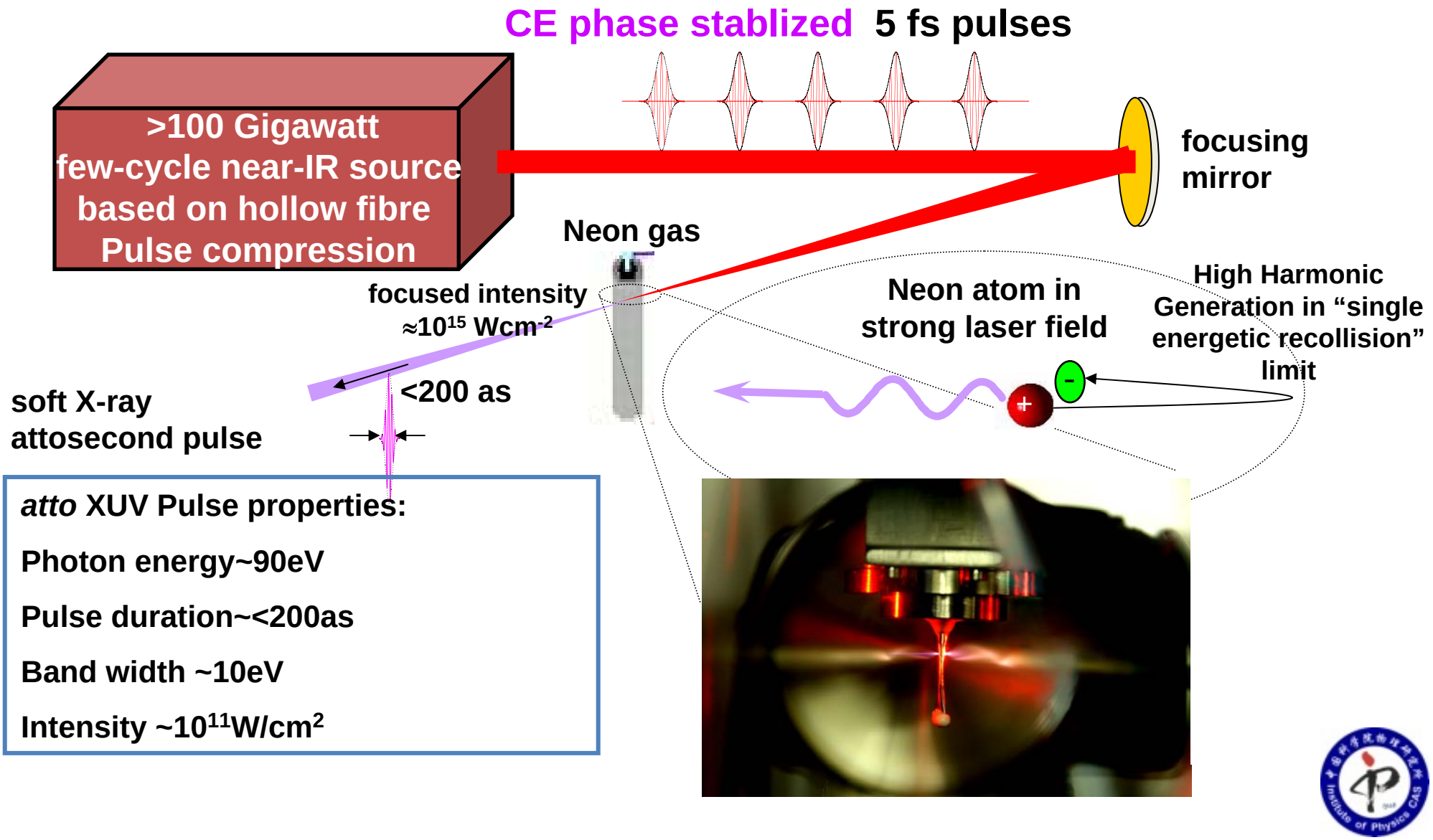


Experimental result

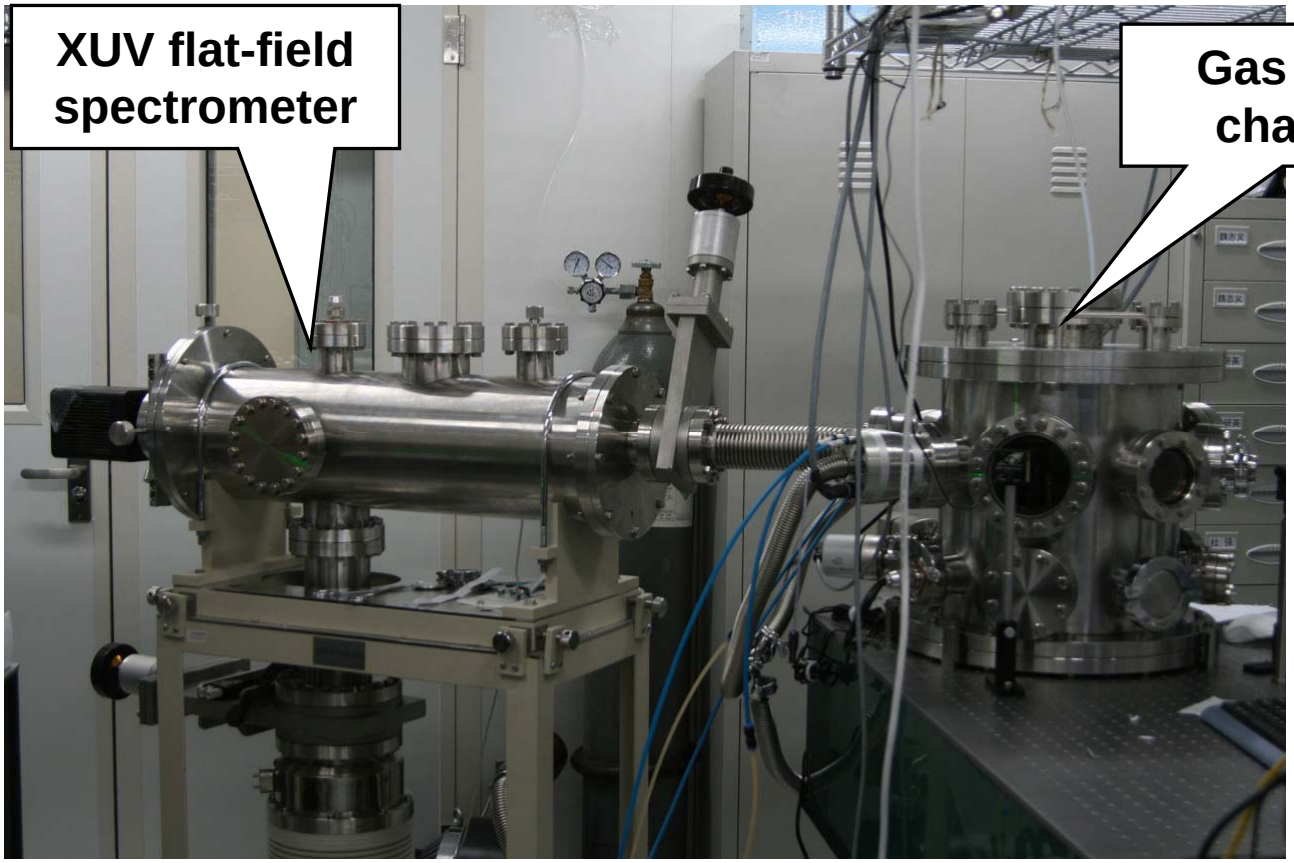


Variation of CE-phase is ~50 mrad over 5 hours when the fast loop and slow loop work simultaneously

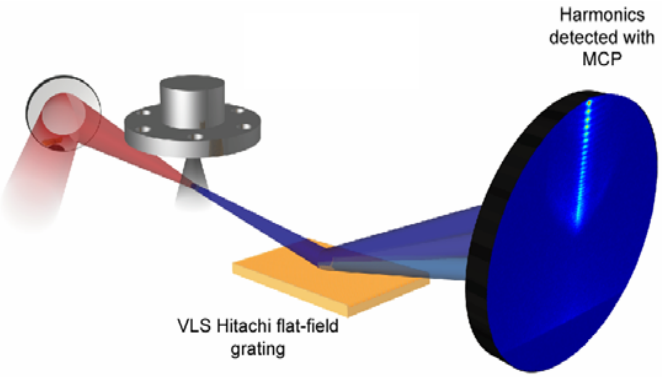
So making real single atto-second pulses



HHG from few-cycle pulses

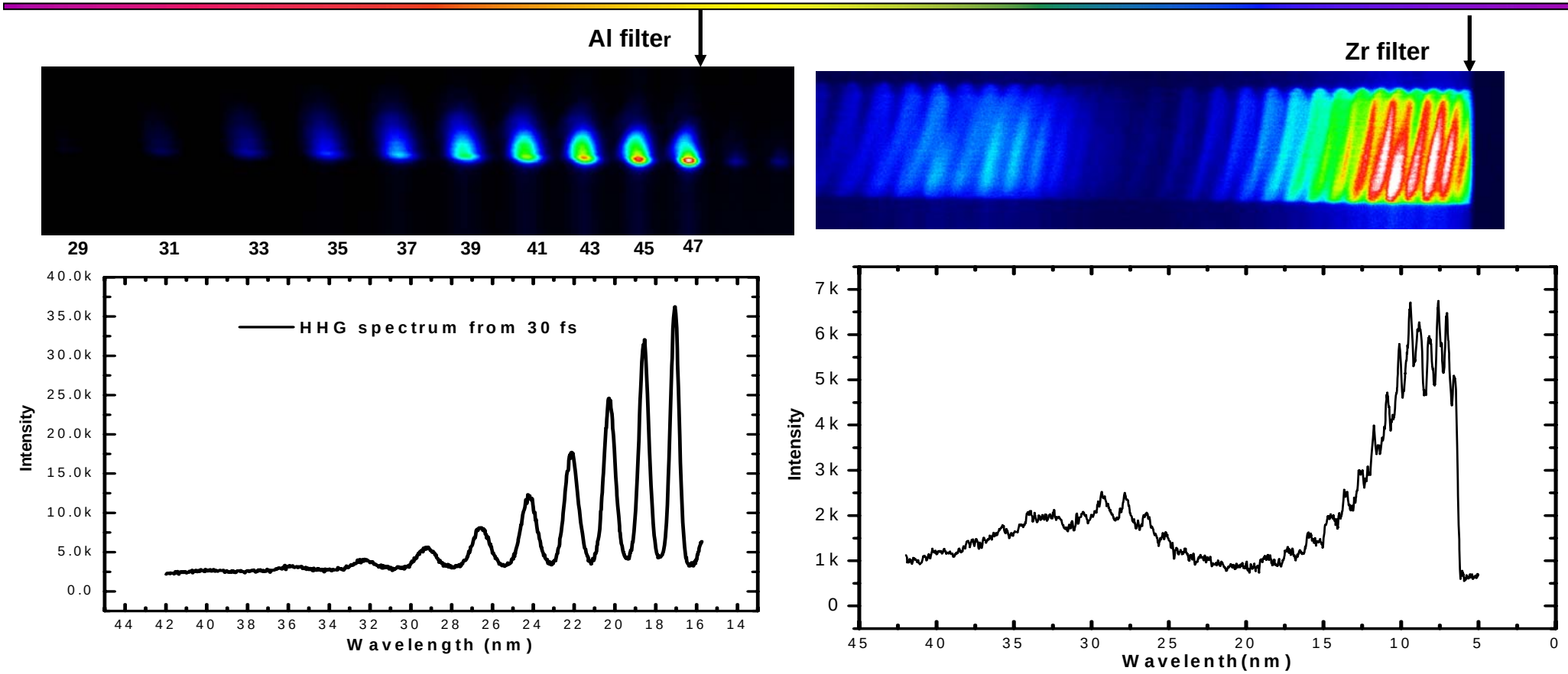


Experimental setup



Harmonic generation and detection system

HHG from long pulse



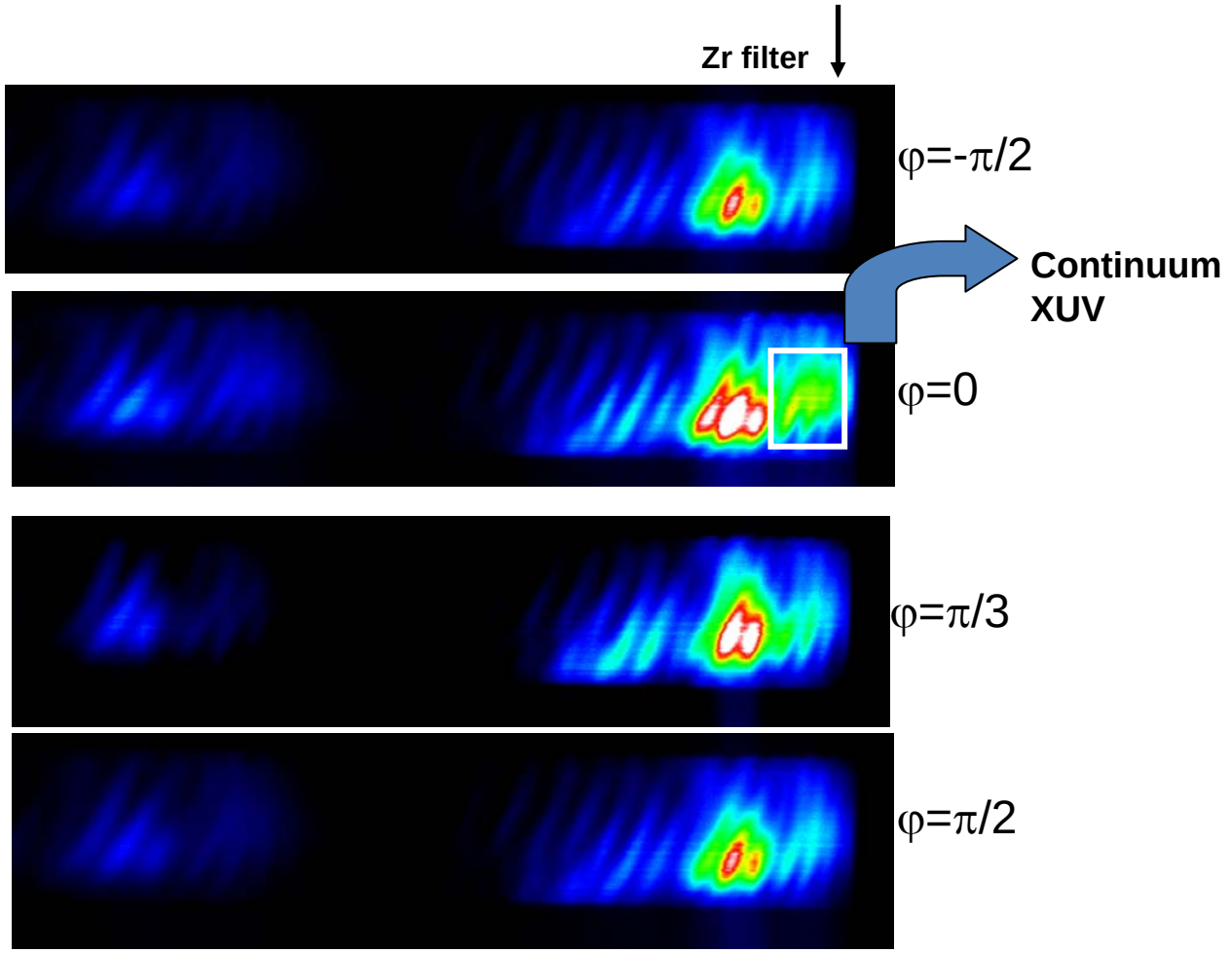
High harmonic generated from Neon gas with 30fs

High harmonic generated from Neon gas with 12fs

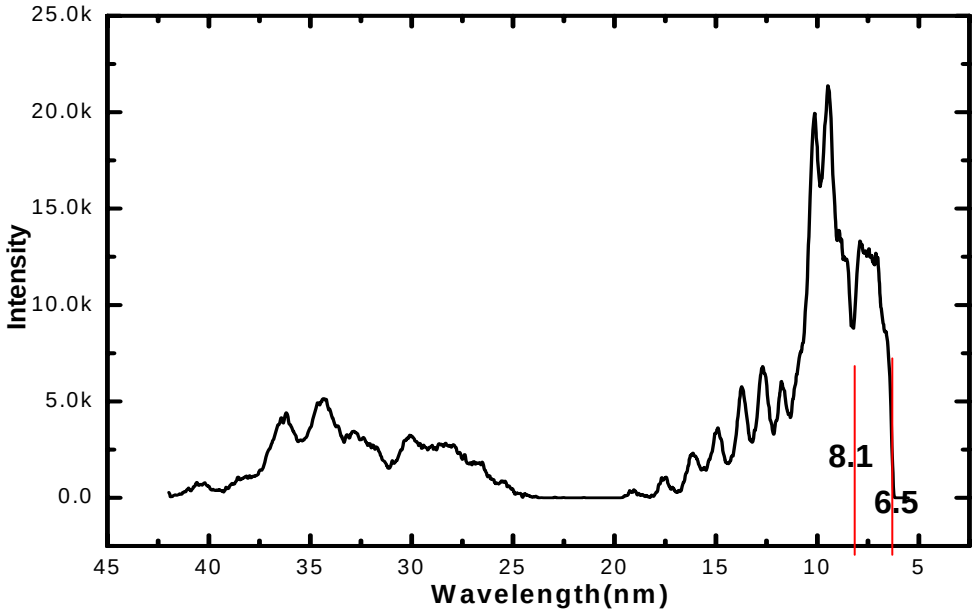
HHG show discrete spectrum when the duration of driver laser pulses is long

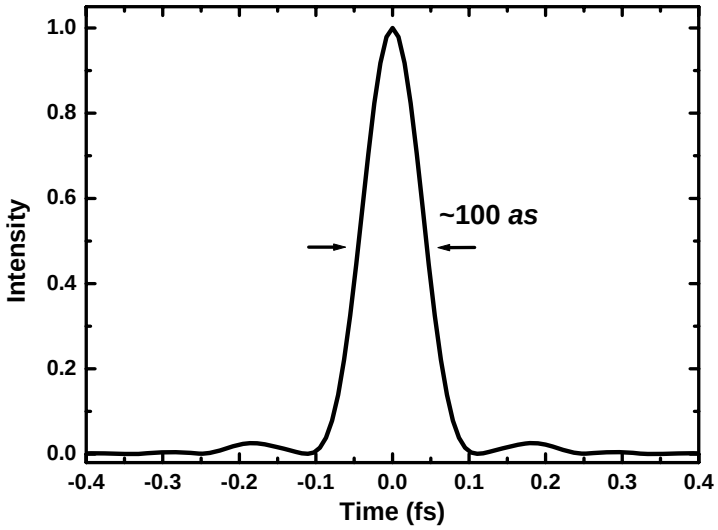
HHG spectrum for different CE phase of 5-fs laser pulses

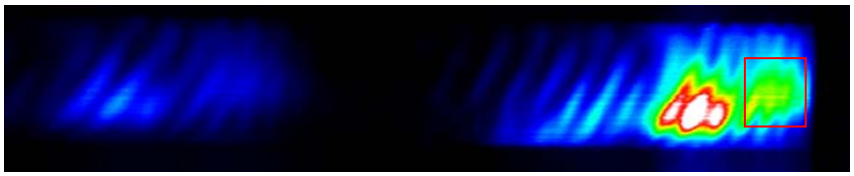
HHG produced with CE- phase controlled 5fs form continuum in the cut-off region when CE-phase is shifted to zero, which is corresponding to *single attosecond* pulses.



Continuum spectrum at cut-off region corresponding to single *attosecond* pulse







Fourier transform limited pulse

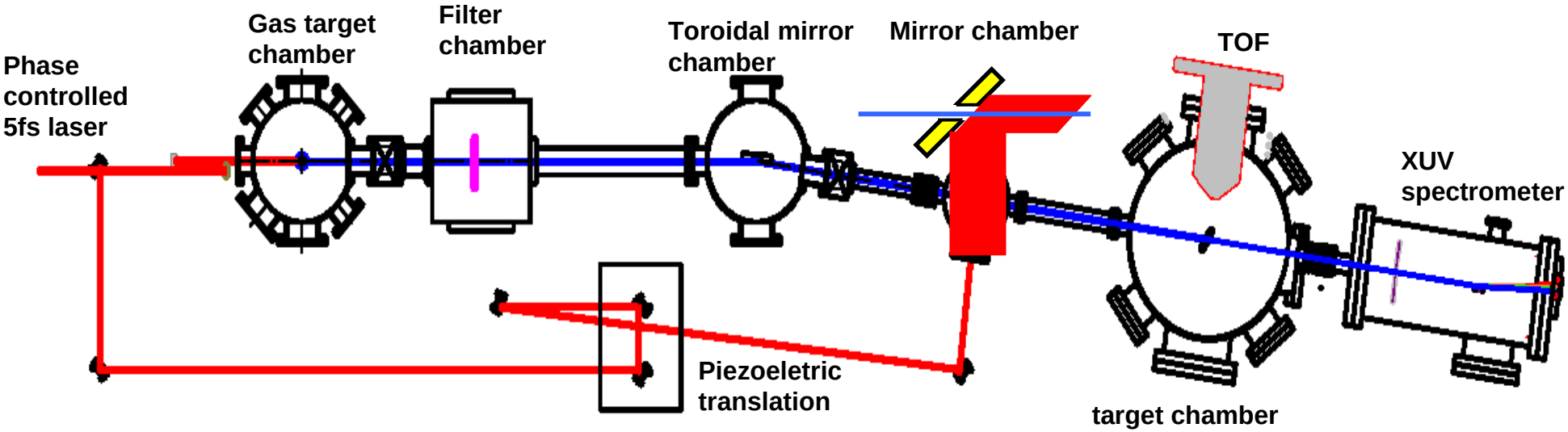
The continuum spectrum cover ~1.5nm at central wavelength of 7.5nm, the spectrum is capable of supporting a ~100 *as* duration.

What is being under development

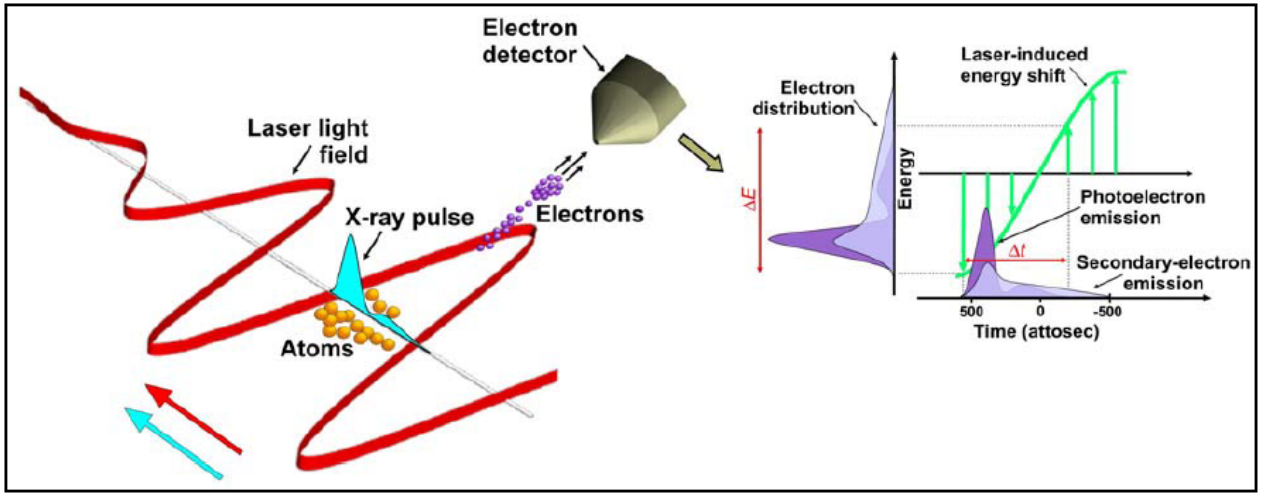
- **Optimize the HHG from noble gas with CE-phase stablised 5fs pulses**
- **The driving laser pulse is being upgraded to 1mJ/5fs**
- **Metrology of single attosecond pusles**
- **Applications**

Attosecond source system

(under development)



- Attosecond source
- Metrology
- Applications



Atomic streak-camera for attosecond soft x-ray pulses

Summary

- **CE-phase stablised 5-fs laser system is completed**
- **HHG with continuum spectrum is produced from CE-phase controlled 5-fs pulses, which corresponding to isolated single attosecond pulses**
- **Optimization of HHG from phase-controlled 5-fs pulses and Metrology of attosecond pulses are under development**


Thank you!
http://ultralaser.iphy.ac.cn/