Photoionization of atoms using high harmonics

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Project Focus

- Study ionization of atoms and molecules using high harmonics
  - **My specific focus:**

  - Compare multiphoton ionization by strong infrared laser and single-photon ionization with its high-order harmonics

  - Figure out what harmonics we were producing from the XUUS (eXtreme Ulraviolet Ultrafast Source)

Photoionization

- Photoionization happens when a photon hits an atom/molecule and ejects an electron

- Einstein's photoelectric equation:
  - $E_{kin} = \hbar\omega - I_p,$

where E_{kin} is the electron kinetic energy, $\hbar\omega$ the photon energy, and I_p – the ionization potential (electron binding energy).

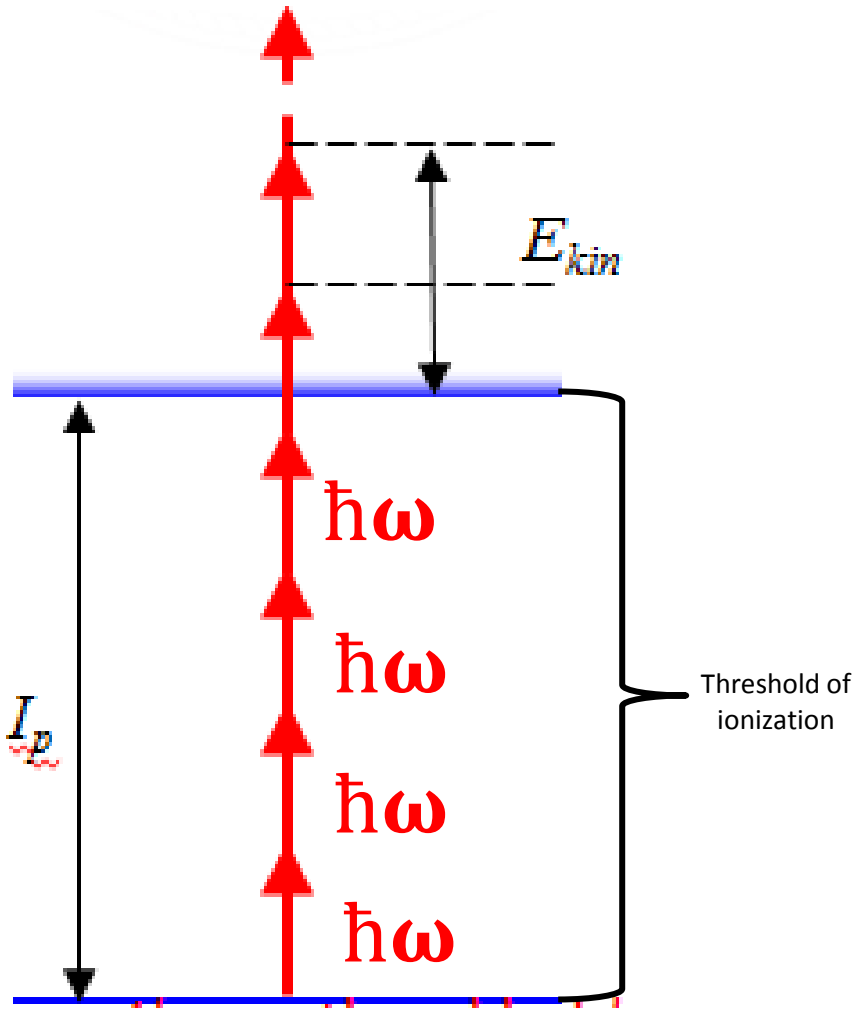
Photoionization: many photons

- Low frequency, long wavelength (visible or infrared light):

has to absorb multiple photons before it can overcome the ionization threshold

- Can happen only if the light has high intensity: "strong-field" regime

Multiphoton ionization



Generalized Einstein's photoelectric equation:

$$E_{kin} = n\hbar\omega - I_p$$

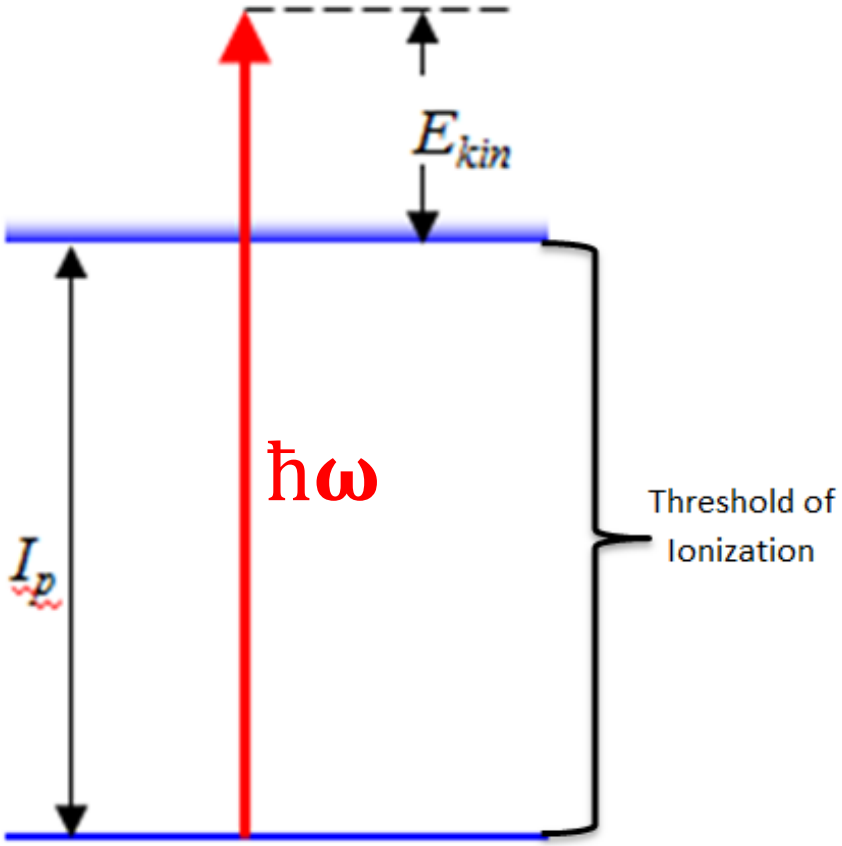
"Above-threshold" ionization: ATI

Photoionization: single photon

- High frequency, short wavelength:

a single photon (with a large energy) can overcome the ionization threshold

- Typically happens in a "weak-field" regime – only one photon is absorbed



Single-photon ionization

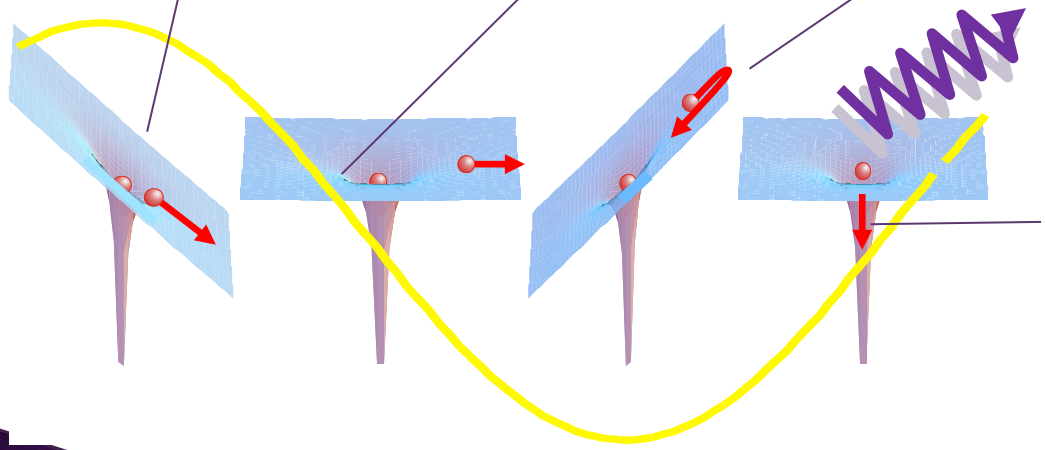
High Harmonic Generation

– happens when atoms or molecules are irradiated by strong laser field

A single electron is ejected from the parent atom/molecule

The electron gains energy in an electric field of the laser

The electron crashes back into the atom

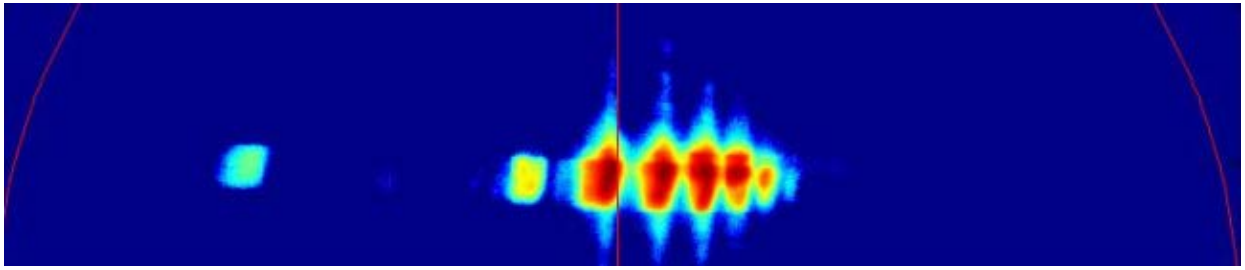


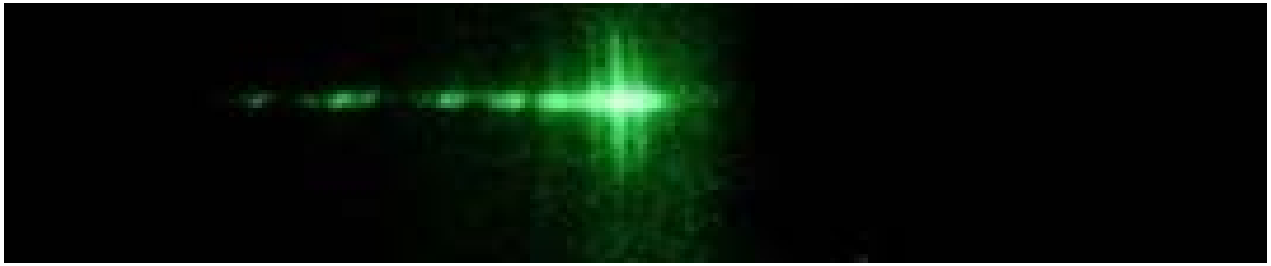
The electron recombines, the atom returns to the ground state

High-energy photon is emitted

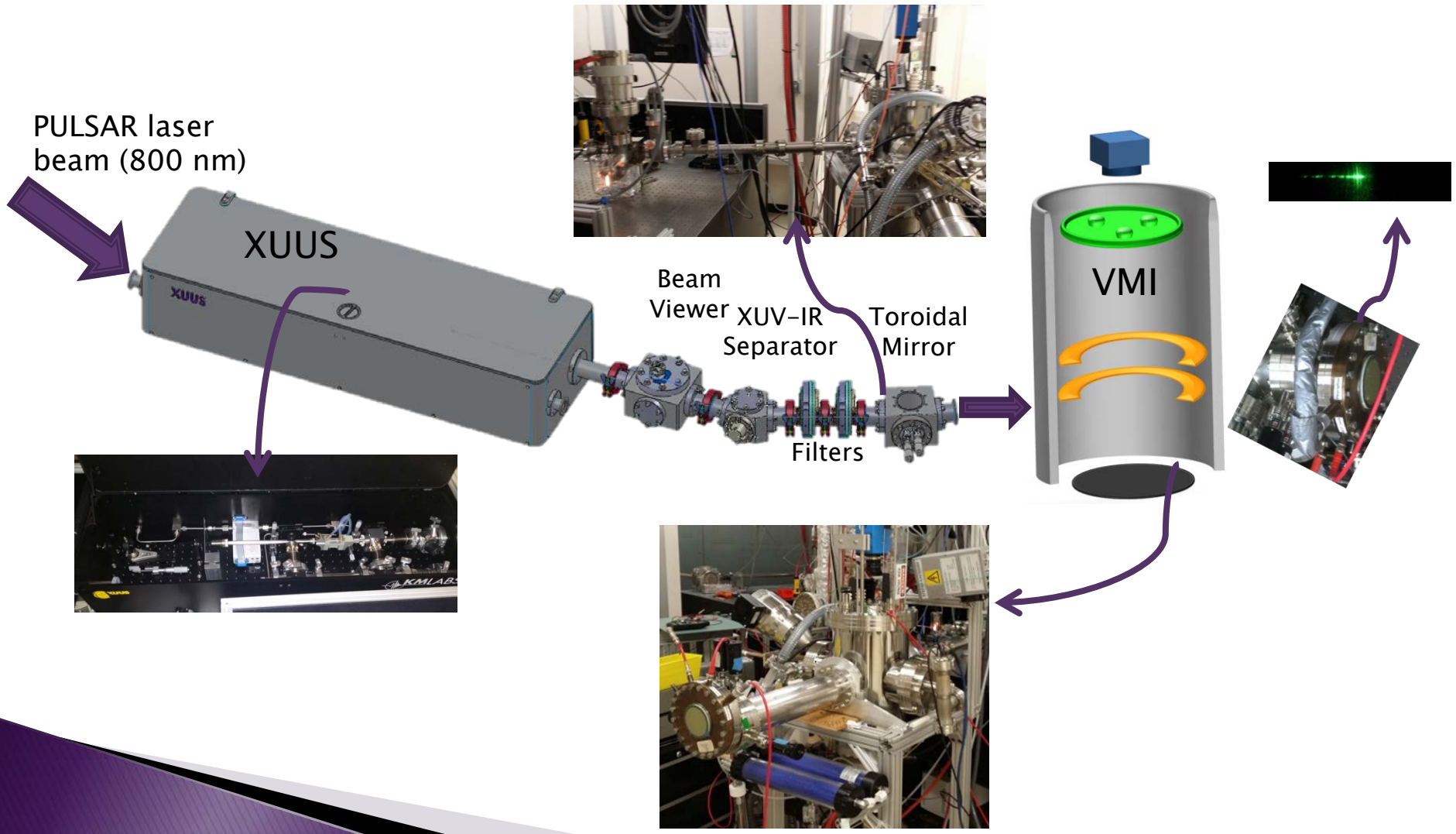
Since the electron has gained large energy, the photon energy also has to be large due to the conservation of energy

High Harmonics

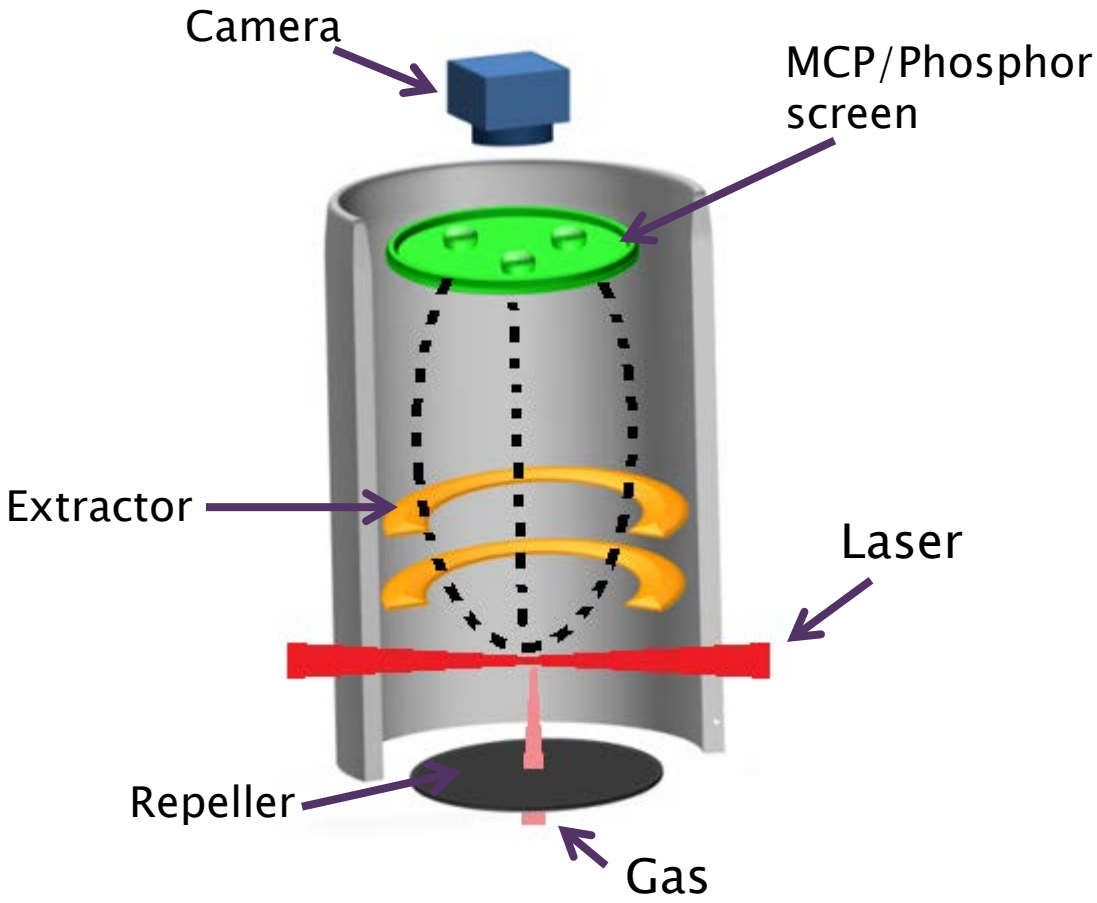




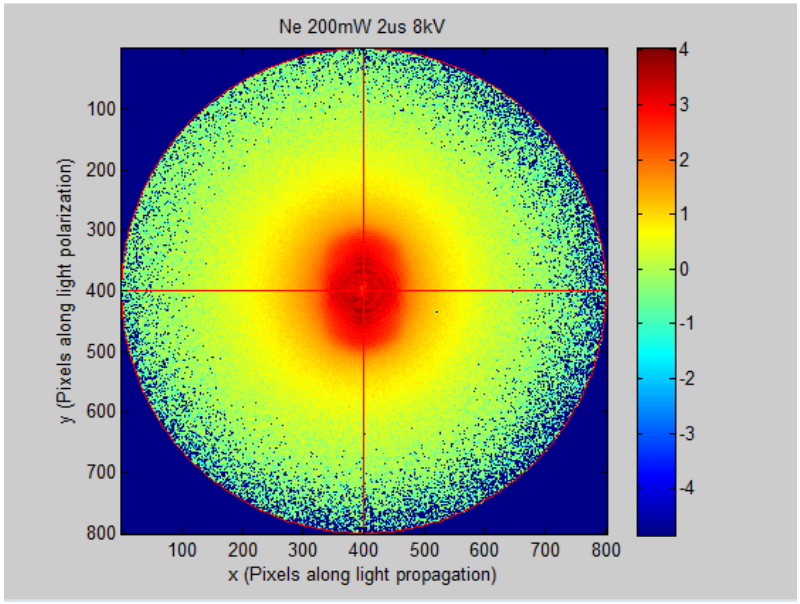
Experimental Setup



Velocity Map Imaging (VMI)

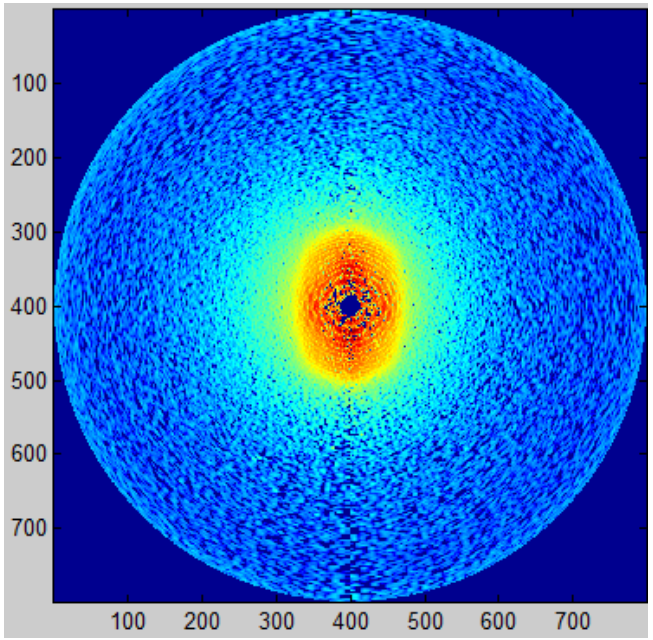


Photoelectron images with the laser



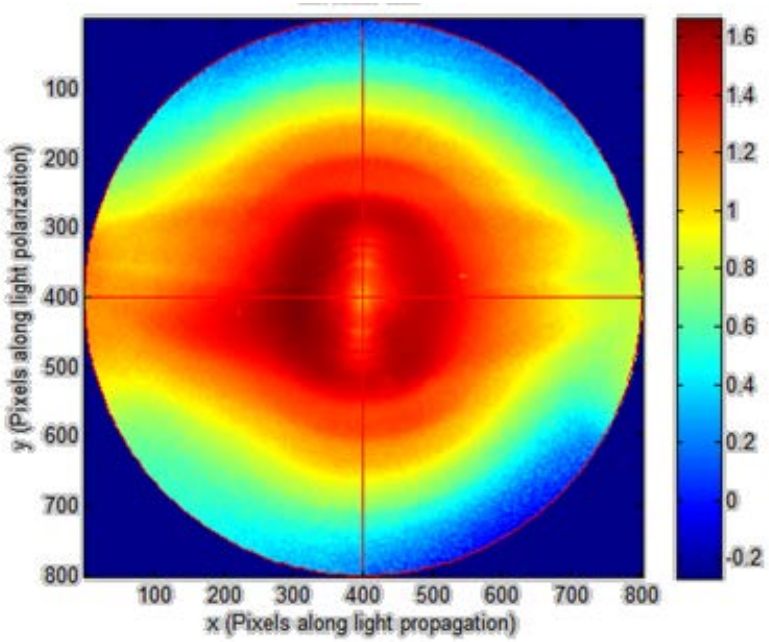
Non-inverted image (raw data)

Neon at 300mW laser power (ATI: Above-Threshold Ionization)



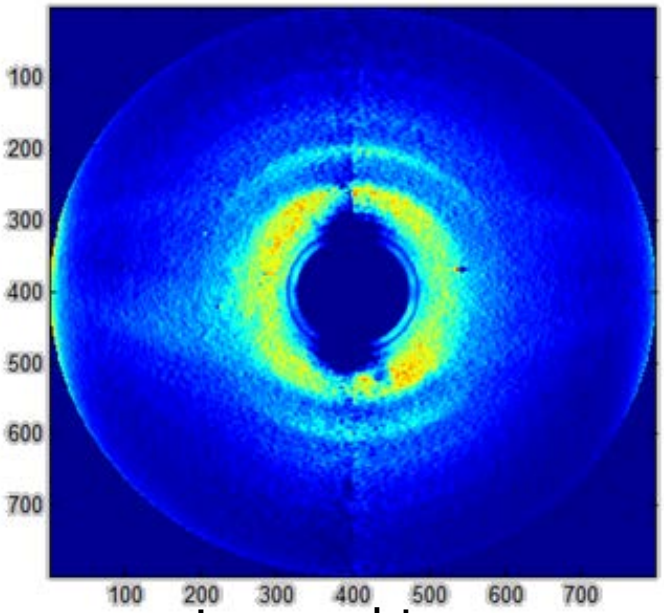
Inverted image

Photoelectron images with high harmonics



Non-inverted image
(raw data)

Helium with HHG



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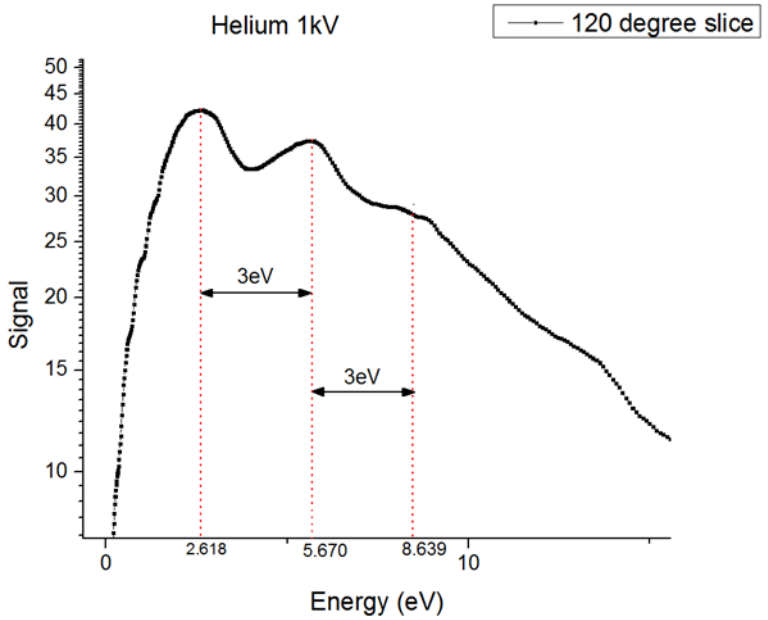
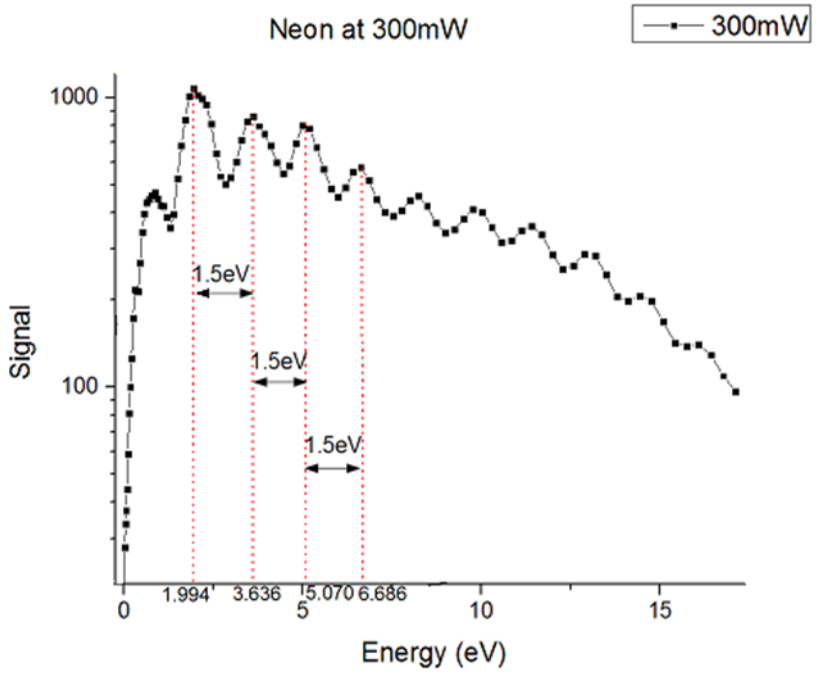
Photoelectron energy spectra

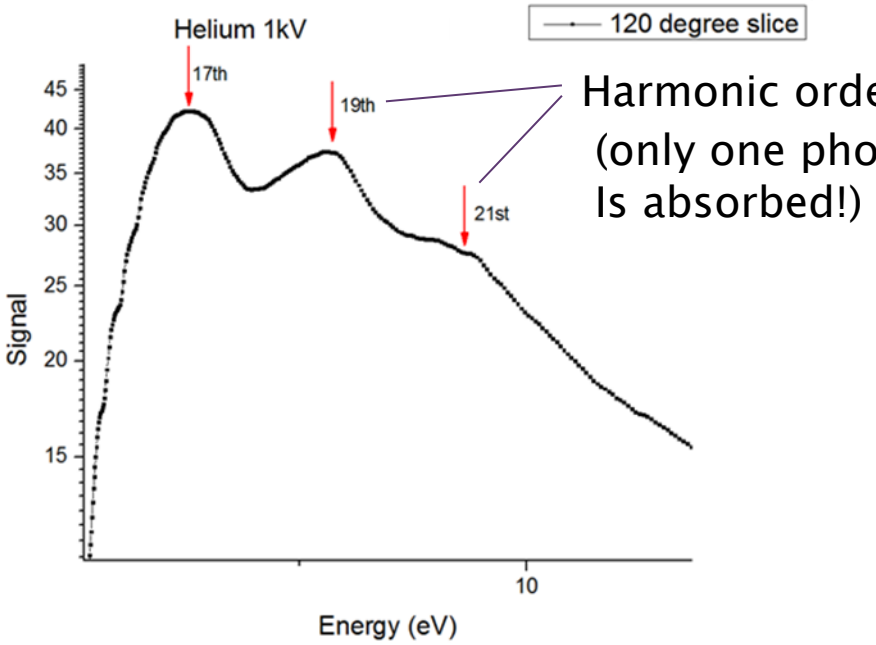


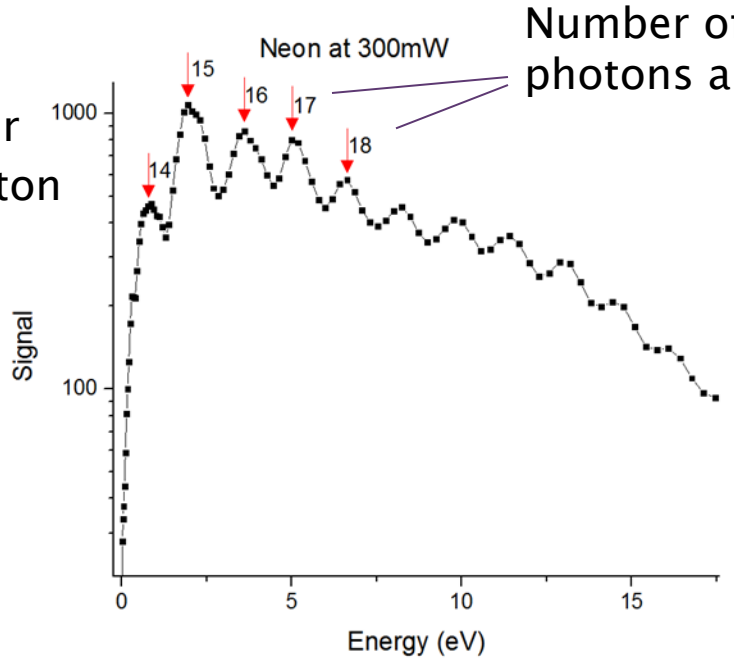


Ionization with high harmonics

Ionization with a laser: ATI

Photoelectron energy spectra

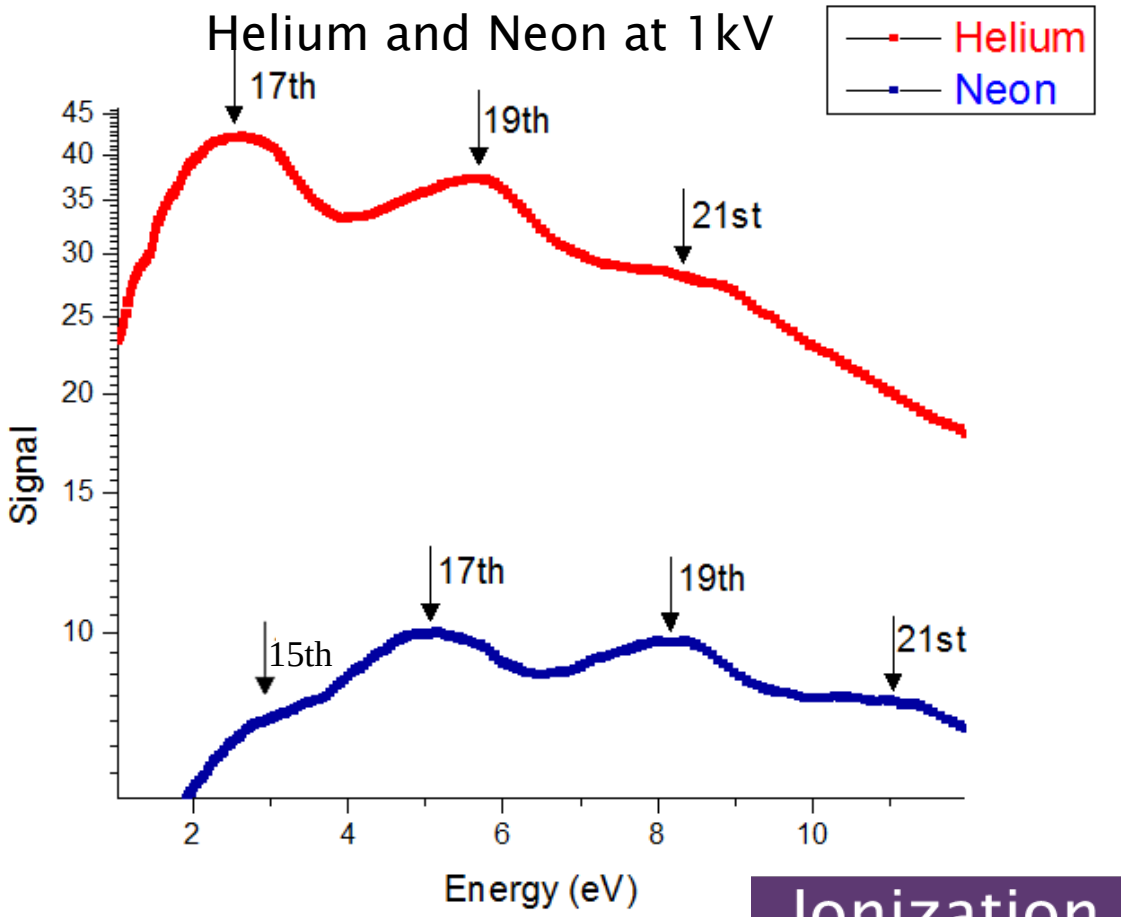




Ionization with high harmonics

Ionization with a laser: ATI

Photoelectron spectra with different targets



I_p(He) = 24.6 eV

I_p(Ne) = 24.6 eV

Ionization with high harmonics

What now?

- Characterization of the harmonic source
- Photoionization of different atoms and molecules
- Measurements of ions
- Pump-probe experiments using laser + high harmonics

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Questions?