High Harmonic Generation using a Two Color Driving Field

Sean Buczek

Ultrafast Lasers

- Laser pulses that have a very short duration
  - Picoseconds and shorter
- Need specialized laser sources for this
  - Free Electron Lasers are nice, but too costly for most labs
  - Ti:Sapphire is the most common tabletop laser used in the field
- Shorter pulses are needed
  - Short pulses = Faster camera

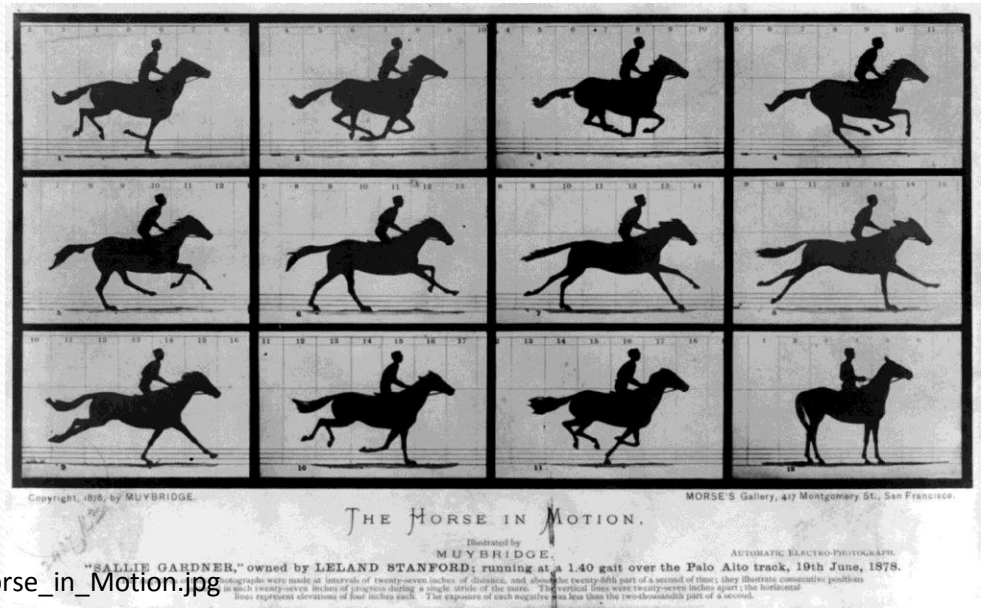
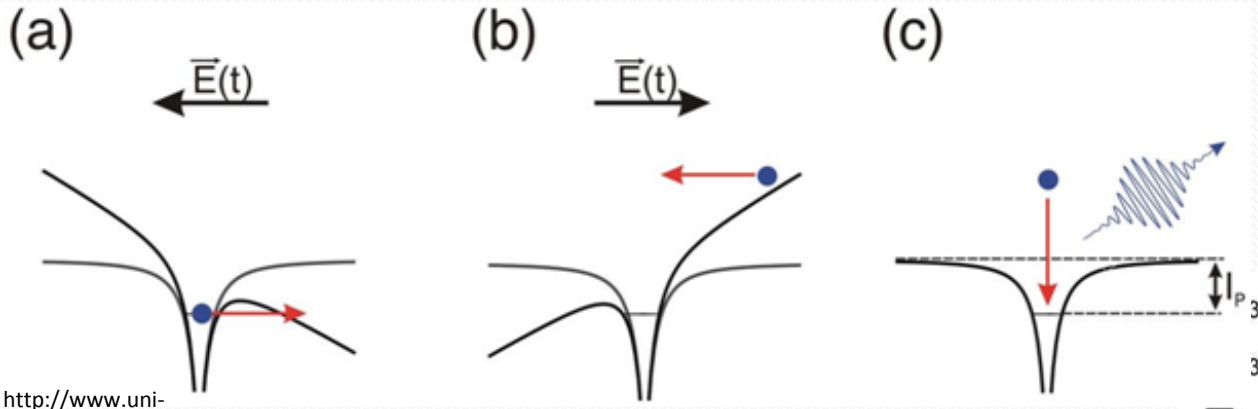


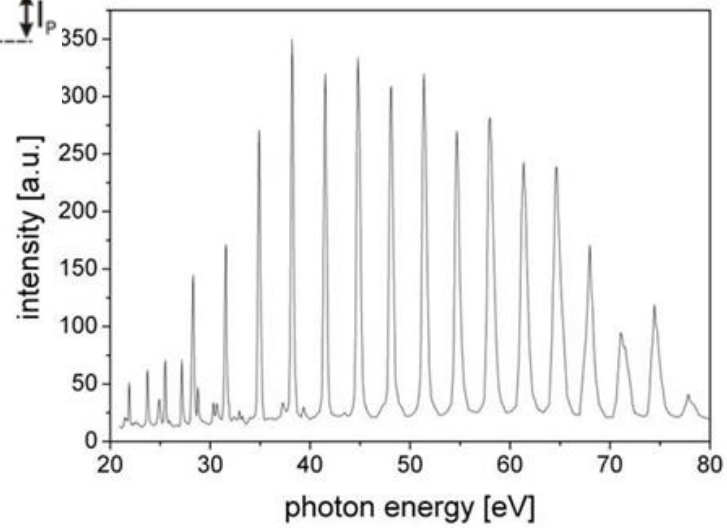
Image credit: https://upload.wikimedia.org/wikipedia/commons/7/73/The_Horse_in_Motion.jpg

High Harmonic Generation

- High intensity laser (10^{14} W/cm^2) through a noble gas
- Three Step Model[1]



http://www.uni-muenster.de/imperia/md/images/physik_pi/zacharias/research/hh/high_order_harmonic_generation.png



http://www.uni-muenster.de/Physik.PI/Zacharias/en/research/hh/hhg.html

[1] P.B. Corkum, Phys. Rev. Lett. **71**, 1994

High Harmonic Generation

- Two different possible electron trajectory
  - Long and short
  - Long trajectory electrons contribute less to the total HHG spectra[2]
- Able to create VUV-XUV wavelengths (200-10nm)
  - Very short wavelength allows for sub-femtosecond pulsesForms a train of attosecond pulses[3]
- Limited flux
  - Low conversion efficiency: much lower pulse energy
  - Greater flux is needed for many experiments

[2] Jin et al., Nature Communications **5**, 4003 (2014)
[3] Zenghu Chang, *Fundamentals of Attosecond Optics* (Boca Raton: CRC Press, 2011)

HHG using Two Colors

- To increase photon flux[2]
  - Optimizes short trajectory of electron
  - 2 order of magnitude increase over single color driving field possible
- Pulses are more separated in attosecond pulse train
- Intensity of individual pulses increases

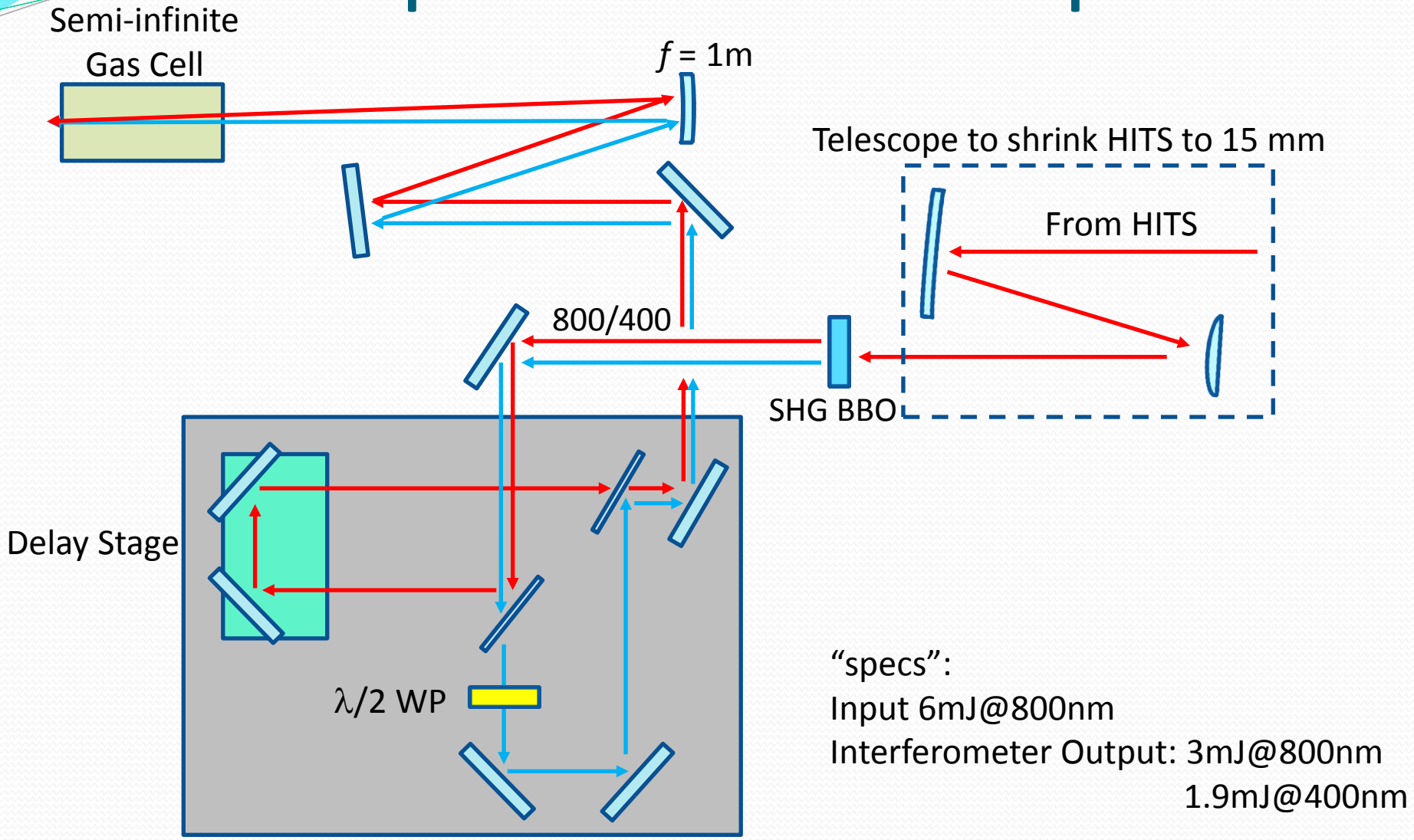
[2] Jin et al., Nature Communications **5**, 4003 (2014)

Experiment Overview

- Confirm HHG using fundamental (800 nm) and second harmonic (400 nm)
- Significant increase in flux over single color expected
- Observe oscillations in flux due to phase relation between the two colors
- Use HITS laser at J.R. Macdonald Lab at Kansas State University[4]

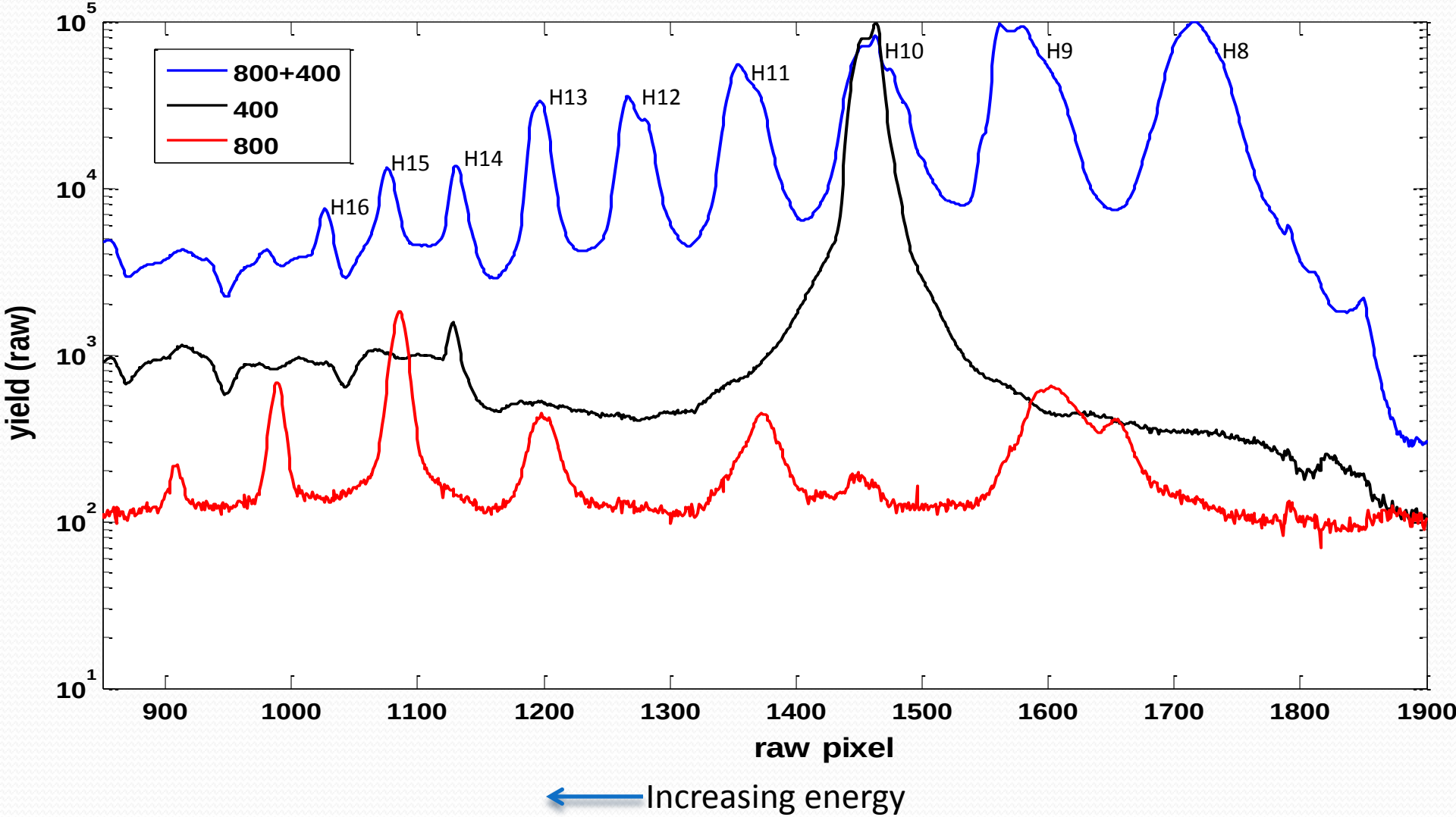
[4] Langdon et al., Optics Express **23**, 4563 (2015)

Experimental Setup



"specs":
Input 6mJ@800nm
Interferometer Output: 3mJ@800nm
1.9mJ@400nm

Harmonic Spectra (log)



Conclusions

- Were able to see a two order of magnitude increase in the flux of the high harmonics
- Oscillations in flux were visible, but a more stable apparatus is needed for further study
- Showed that third harmonic generation is possible using our setup
  - Were able to generate third harmonic, but did not have time to generate high harmonics with it

Future Interests

- Two color HHG using fundamental and third harmonics
  - In theory, this gives an even greater increase in flux
- Experimentally confirm the ability to selectively increase harmonics using chirped pulses[5]

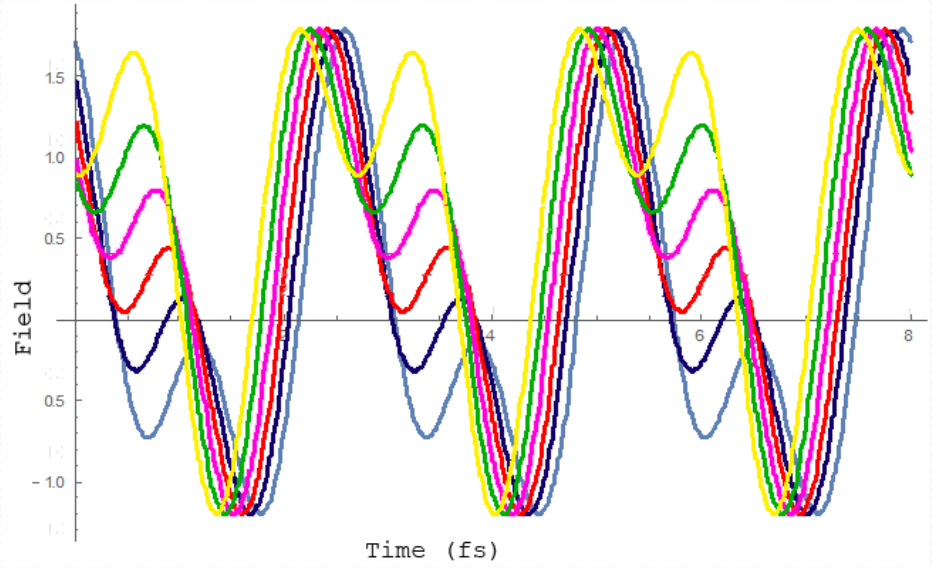
[5] Xu Wang et al., Phys. Rev. A **90**, 0.23416

Acknowledgements

- Travis Severt, Jan Tross, and Pratap Timilsina
- Itzik Ben-Itzhak and Carlos Trallero and their groups at Kansas State University
- Funding provided by NSF MRI (The laser), NSF EPSCOR (Travis, equipment, maybe others), DOE (laser), NSF REU (me)

Oscillation Explained

- A graph of the superposition of two cosine functions describing the two lasers
  - Simplified form of the affects of a slowly shifting time overlap between the two colors
  - Field will affect the trajectory of electrons



Oscillation Example