

# 5<sup>th</sup> Order Harmonic Generation and High Harmonic Generation for Photoionization Experiments

Christian Kornelis, Vinod Kumarappan, Tomthin Ngamba Wangjam

<sup>1</sup> J.R. Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, KS 66506, USA



## Motivation

### Studying molecular dynamics using femtosecond pump-probe spectroscopy

- Excitation of molecules by ultrashort UV, high harmonic, laser pulses

Higher frequencies excite molecules with more energy allowing greater study of high energy states

- UV pulse generation and characteristic

High Harmonics are classified as a Harmonic Order greater than or equal to 10

The High harmonic Plateau decreases intensity around the 35<sup>th</sup> order

Harmonics typically generate in the odd orders

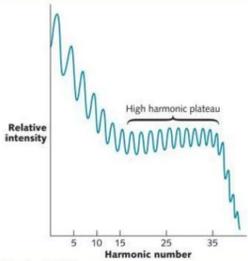
### HARMONIC GENERATION IN A GAS JET

#### Classical Harmonic Generation:

- Odd order harmonics
- Linear trend
- Multi-photon ionization followed by electron relaxation.

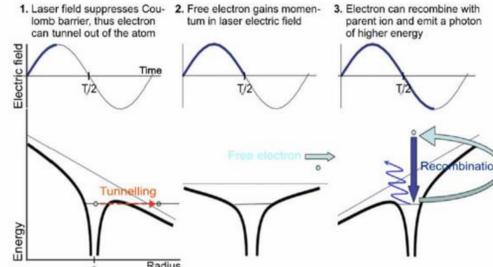
#### High Harmonic Generation (HHG):

- Plateau followed by linear decrease
- DIFFERENT PHYSICAL MECHANISM



New & World Physical Review Letters 1997, 18, 156.  
Hecht, J. "Photonics Frontiers: High Harmonic Generation," LaserFocusWorld 2012.

## The Process of High Harmonic Generation



The maximum harmonic photon energy is given:

$$E_c = I_p + 3.17U_p$$

Where  $I_p$  is the ionization potential, and  $U_p$  is the ponderomotive energy

$$U_p [\text{eV}] = E_0^2 / 4\omega_0^2 = 9.337 \times 10^{-14} I [\text{W/cm}^2] (\lambda [\mu\text{m}])^2$$

With  $E_0$ ,  $I$ , and  $\lambda$  being the strength, intensity, and wavelength of the driving field, respectively.

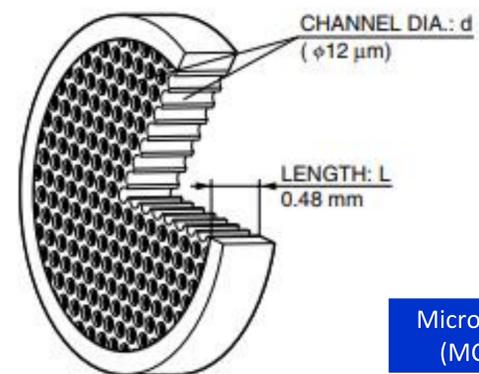
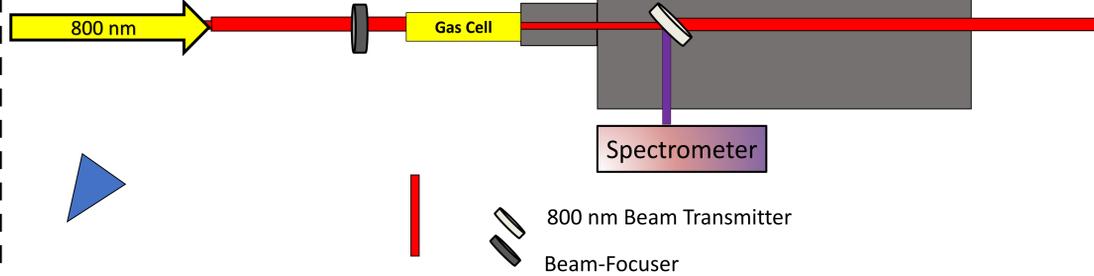
- High harmonics are generated in a gas or solid medium

- How the high harmonic photons are generated

- The electromagnetic laser pulse penetrates a gas.
- The coulomb potential and the laser potential combine to allow tunnel ionization
- The electron is accelerated by the electric field generated by the electromagnetic pulse
- The electron is forced back into the atom
- Due to conservation of energy the kinetic energy gained is released as high harmonic pulses

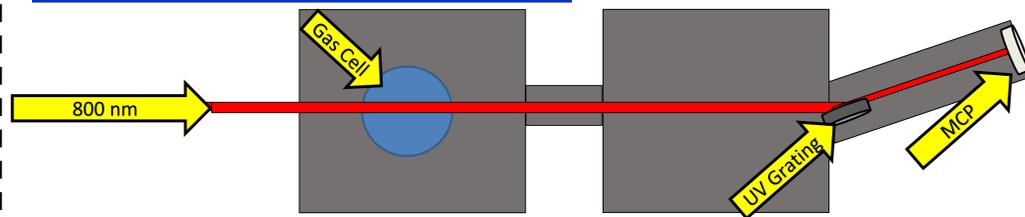
## Experimental Setup

### Third Harmonic Generation (THG) and Fifth Harmonic Generation (FHG)

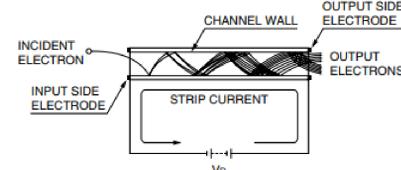


Microchannel Plate (MCP) Diagram

### High Harmonic Generation



### Microchannel Diagram



### Difference Frequency Generation (DFG)



## Trouble Shooting the Experiment



The high harmonic chamber consists of two pumping differential chambers that are connected to two turbo pumps. These turbo pumps allow the pressure to stay constant at  $10^{-6}$  torr. This pressure is needed to keep ambient air out of the chamber and only allow argon gas, the non-linear medium, to be ionized. The pressure is also needed to be low so that the MCP does not become defective and break when exposed to the water vapor present in ambient air.

Most of the inner parts of the chamber had to be custom designed and built so that the optimum intensity from the optics can be obtained. Without optimum intensity the harmonics can not be detected on any device. The design process takes weeks on order for the correct design to be designed and collectively agreed upon by the physics team, 3D designer, and machine shop builders. Due to this I was not able to finish my project, but now understand the full inner workings of a research graduate student.

