Harmonic Generation for Photoionization Experiments

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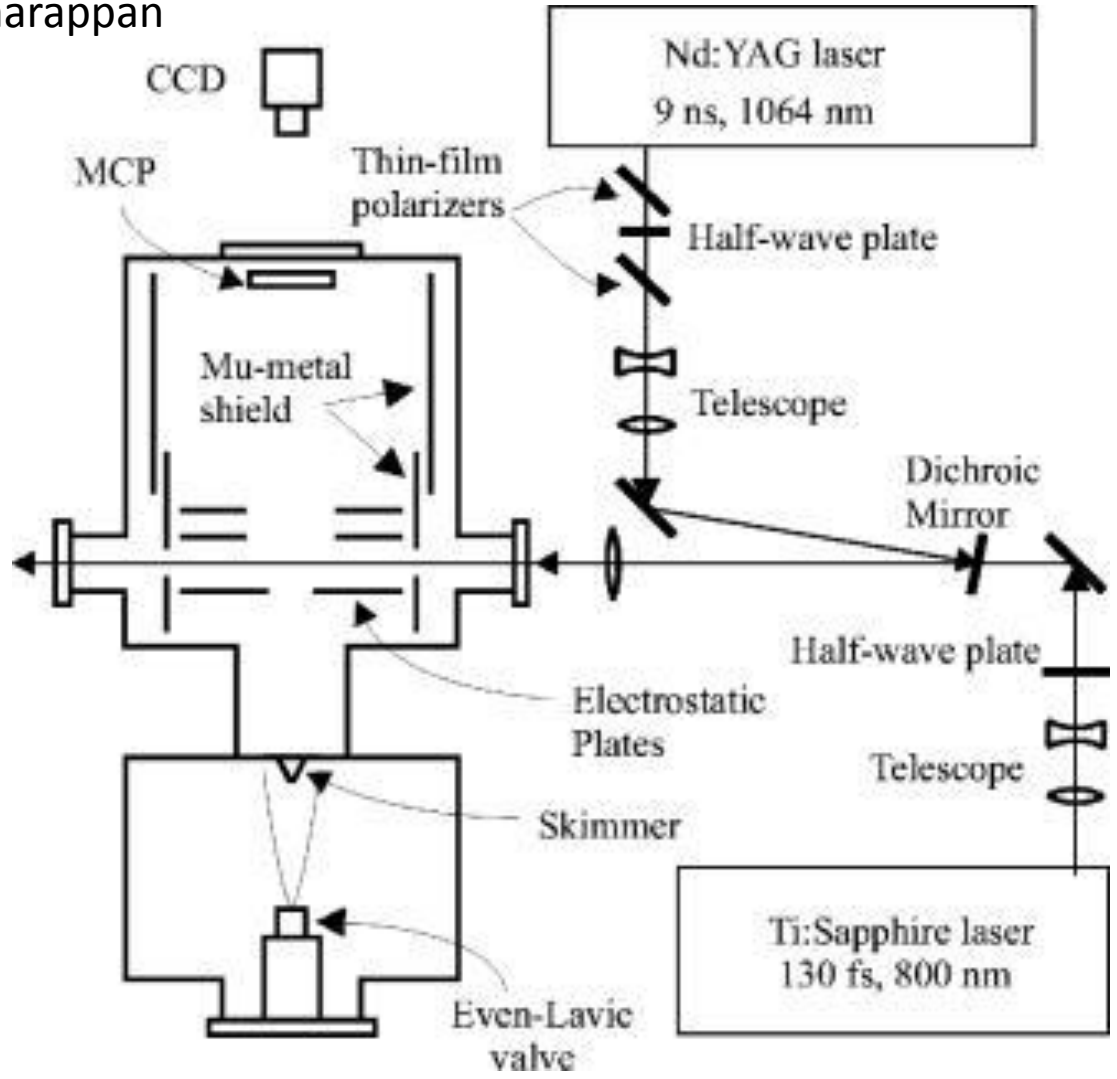
The Basic Setup for the KLS Photoionization Experiment

V. Kumarappan



Femtosecond Pump-Probe Spectroscopy

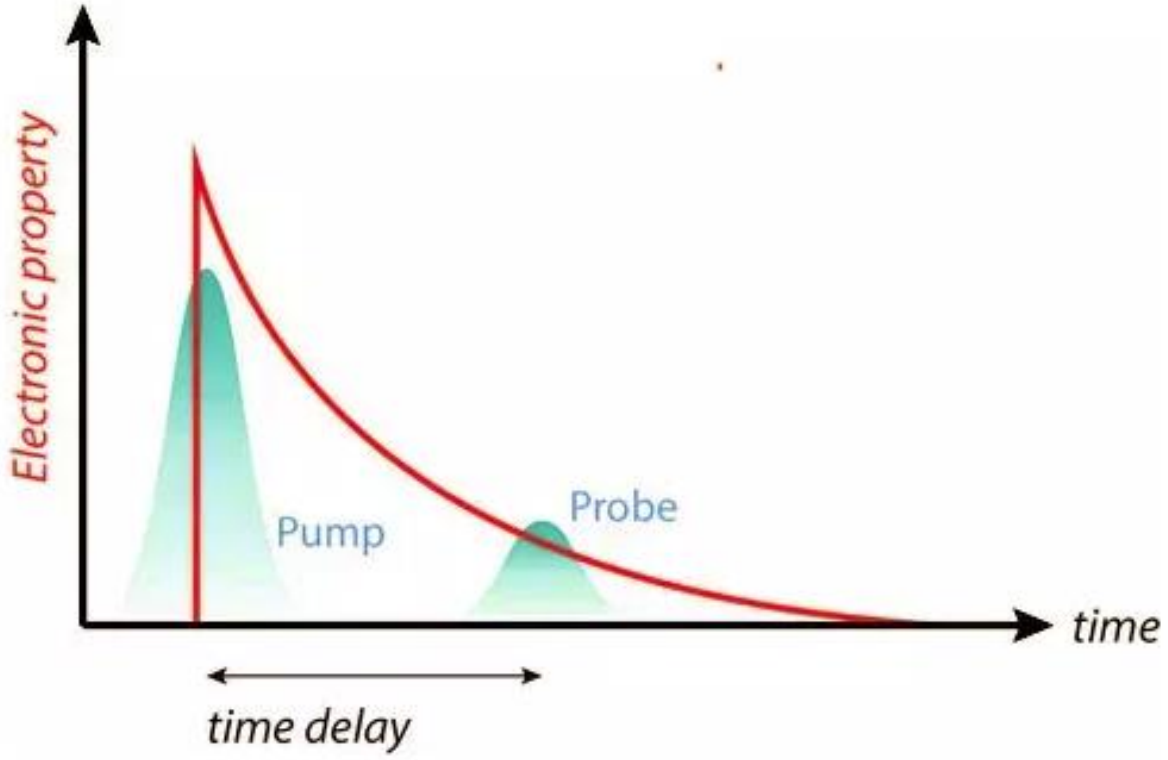
I. Vishik, P. Kamat

- **Uses of Pump-Probe Spectroscopy**

  This process allows us to measure processes that occur at a picosecond timescale.

- **Necessity of High Harmonic Generation**

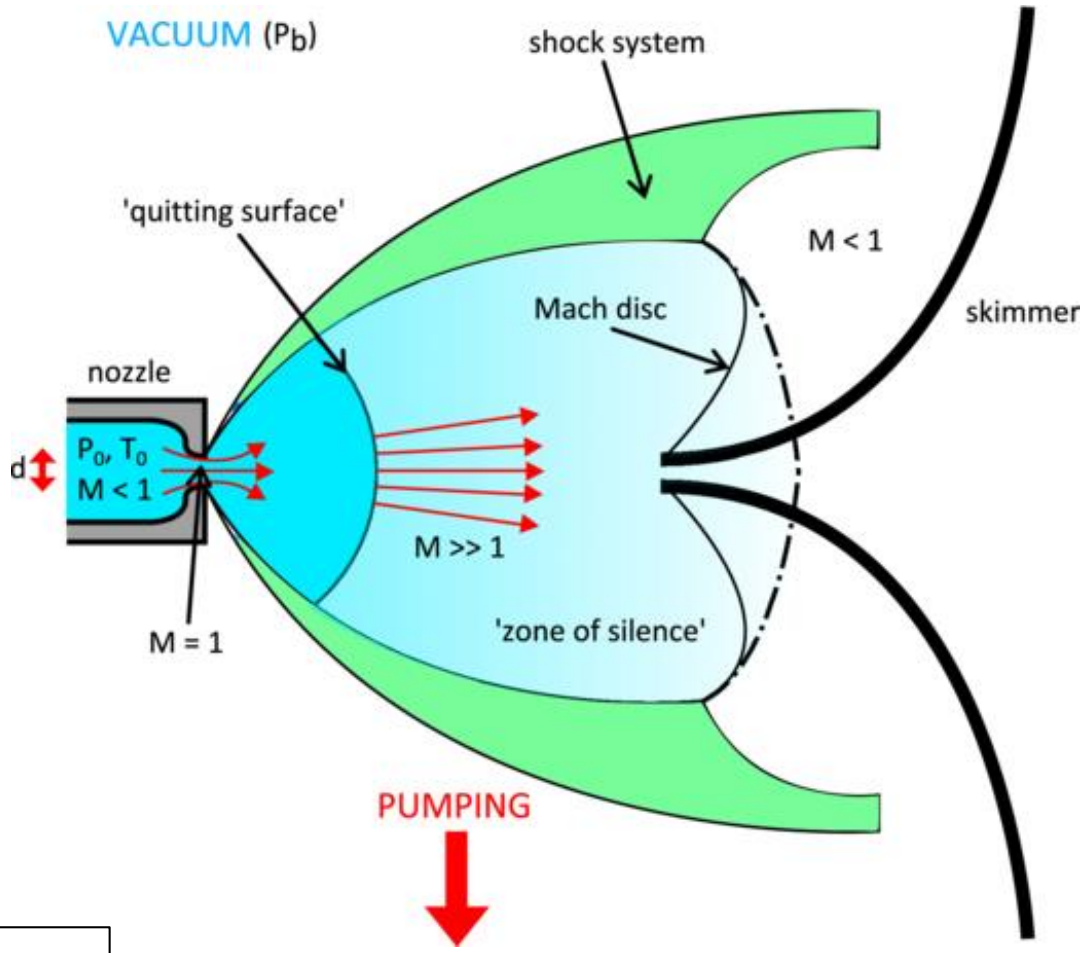
  The use of Extreme Ultraviolet light for Photoionization Experiments is ideal



Picture located at:
https://www.quora.com/How-are-ultrafast-dynamics-identified-in-femtosecond-laser-spectroscopy

Supersonic Jet Expansion

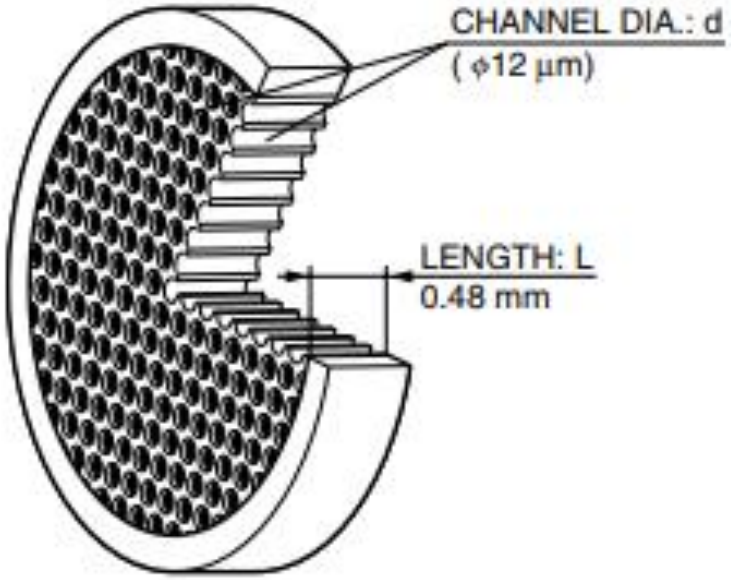
- The use of the jet is to create the non-linear medium for high harmonic generation
- The velocity increases past the nozzle
- Zone of Silence
- Skimmer

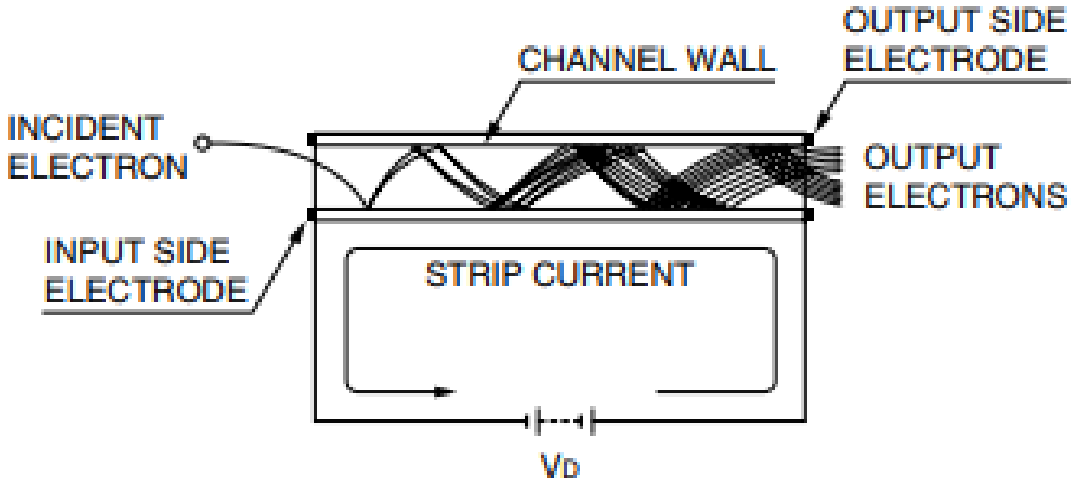


Picture available at:
http://iopscience.iop.org/article/10.1088/0957-0233/23/10/105901

Detectors: The Use of Microchannel Plates

Hamamatsu





MCP Assembly manual available at:
http://www.triumf.ca/sites/default/files/Hamamatsu%20MCP%20guide.pdf

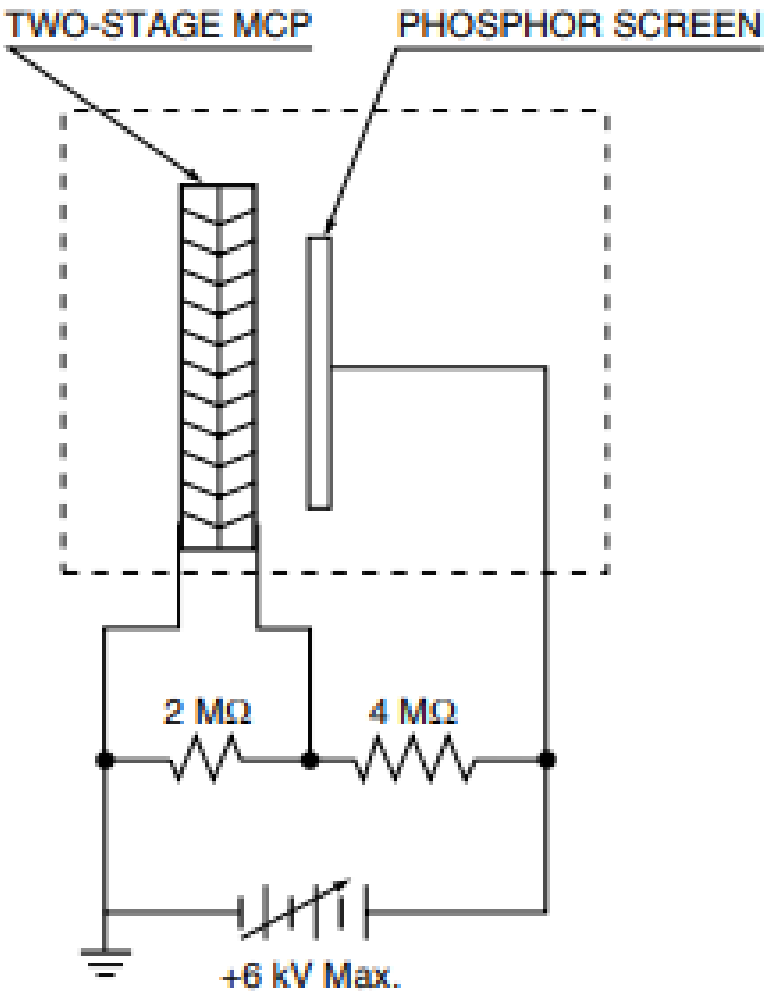
Signal Readout

Hamamatsu

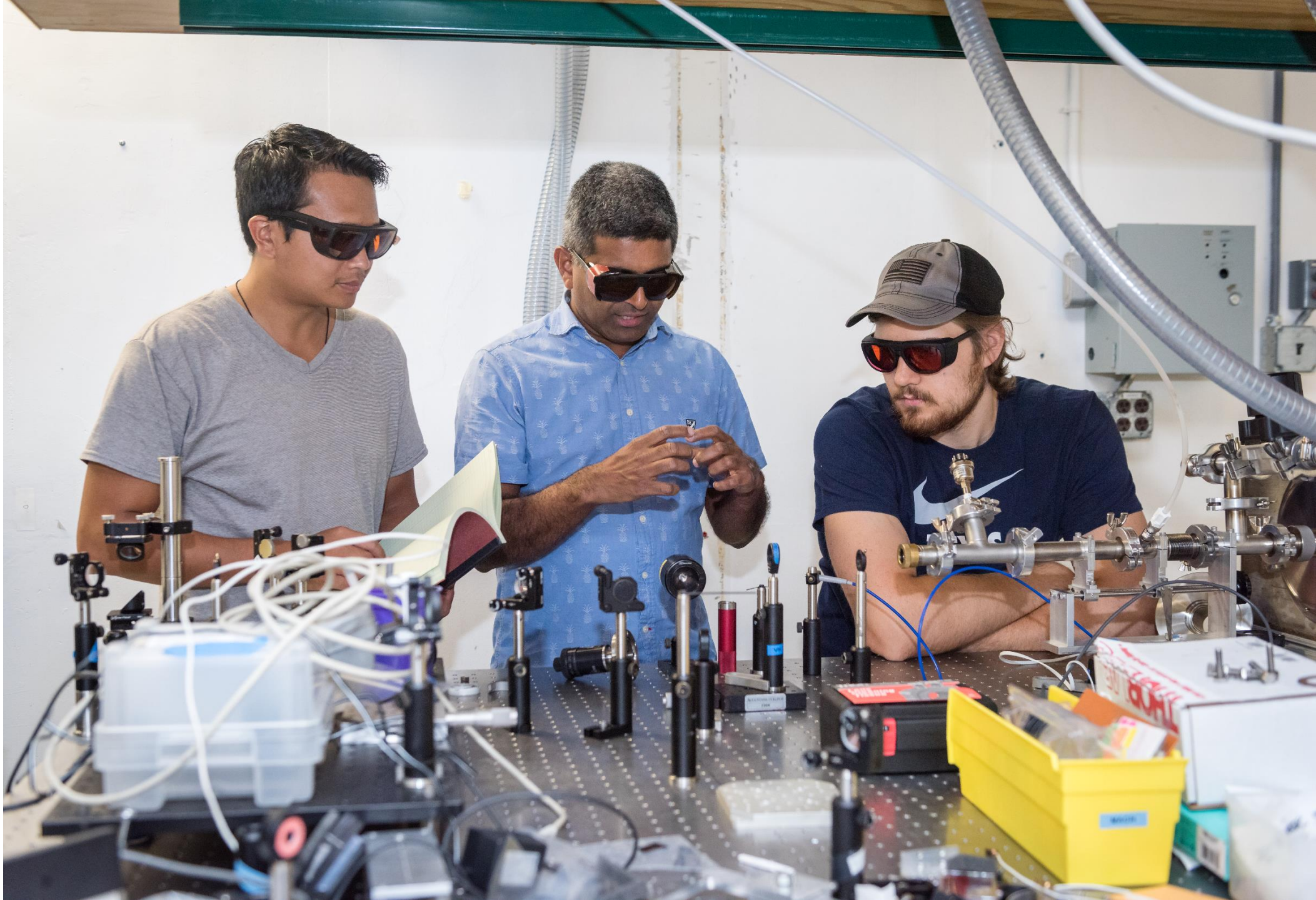
- The phosphor screen is made up of phosphor material coated onto a glass plate or a fiber optic plate
- Phosphor plates are used to convert output signals from an MCP into visible image
- The phosphor screen is placed about 1 mm away from the screen
- The images observed on the phosphor screen can be imaged using a CCD camera, as well as by eyesight

MCP Assembly manual available at:
http://www.triumf.ca/sites/default/files/Hamamatsu%20MCP%20guide.pdf

Phosphor Screen

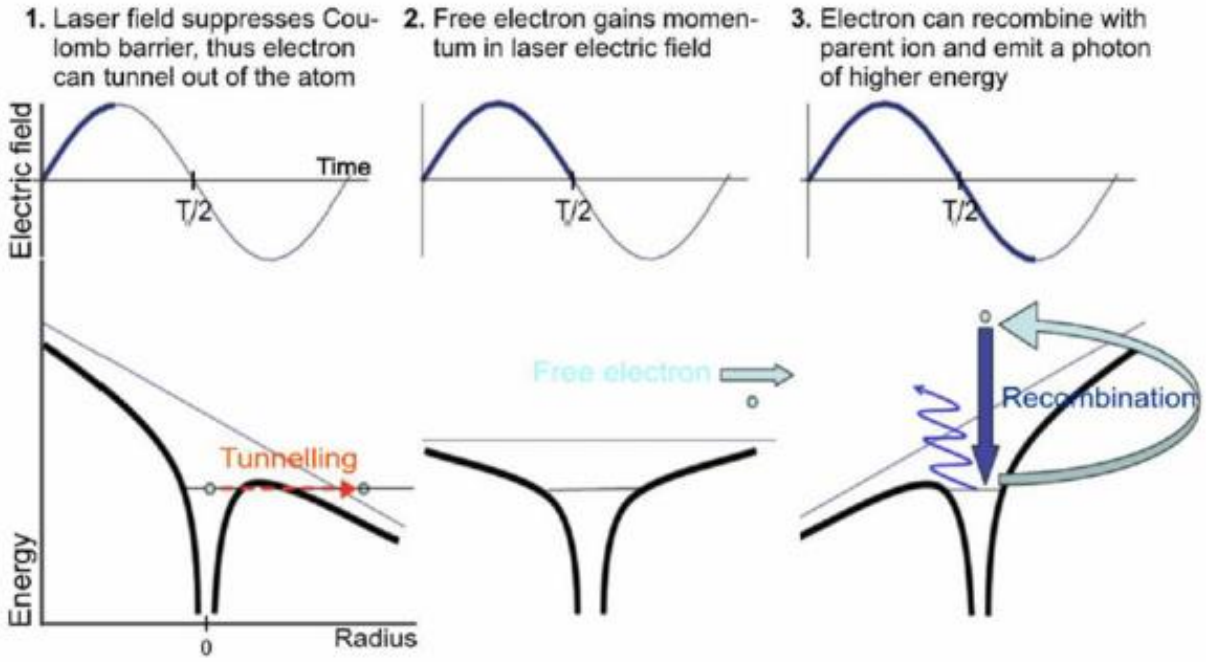


Harmonic Generation With Vinod Kumarappan, and Tomthin Nganba Wangjam



High Harmonic Generation

- High harmonics are generated in a gas or solid medium
- How the high harmonic photons are generated
    1. The electromagnetic laser pulse penetrates a gas.
    2. The coulomb potential and the laser potential combine to allow tunnel ionization
    3. The electron is accelerated by the electric field generated by the electromagnetic pulse
    4. The electron is forced back into the atom
    5. Due to conservation of energy the kinetic energy gained is released as high harmonic pulses



The maximum harmonic photon energy is given:

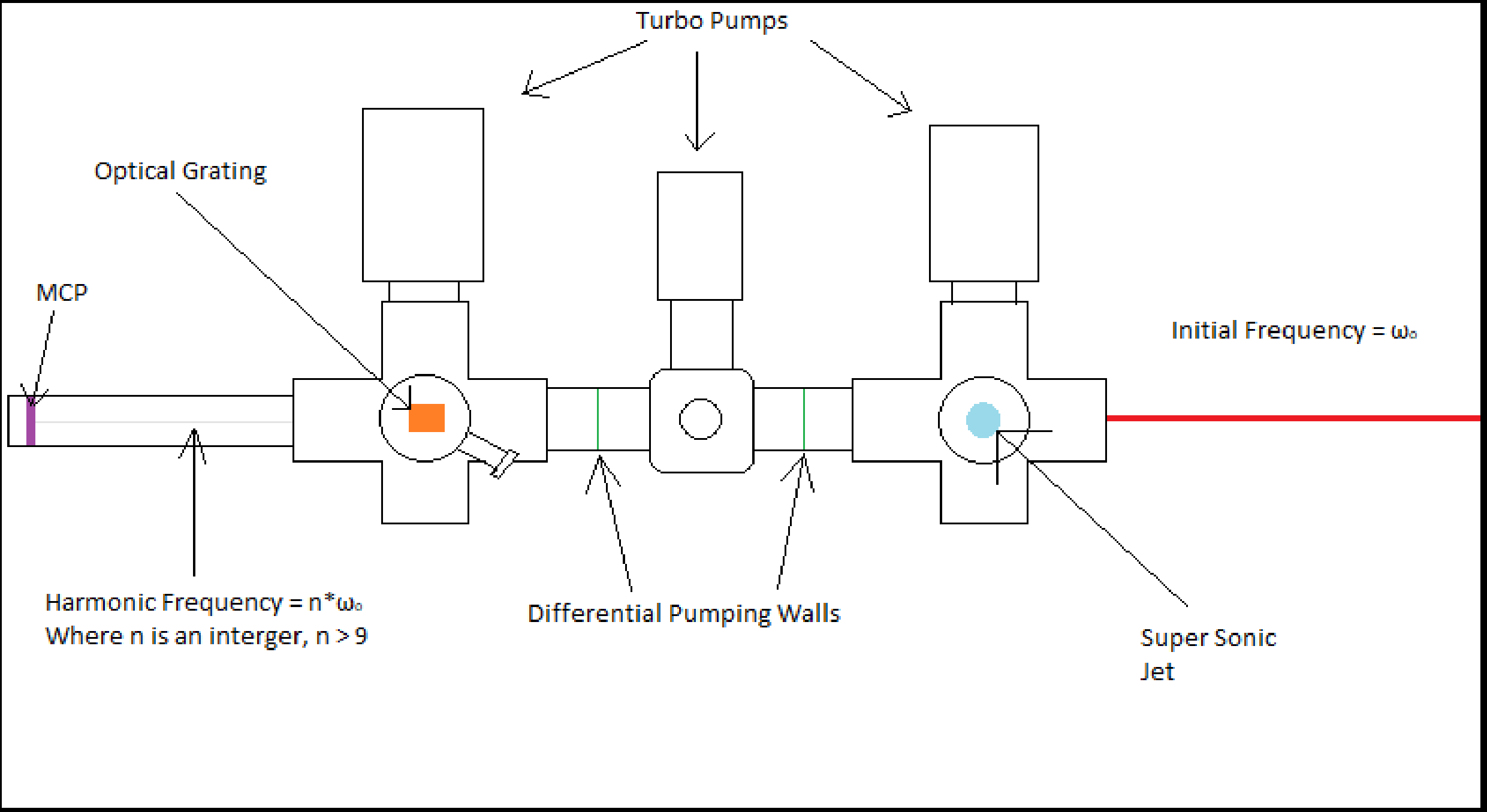
$E_c = I_p + 3.17U_p$

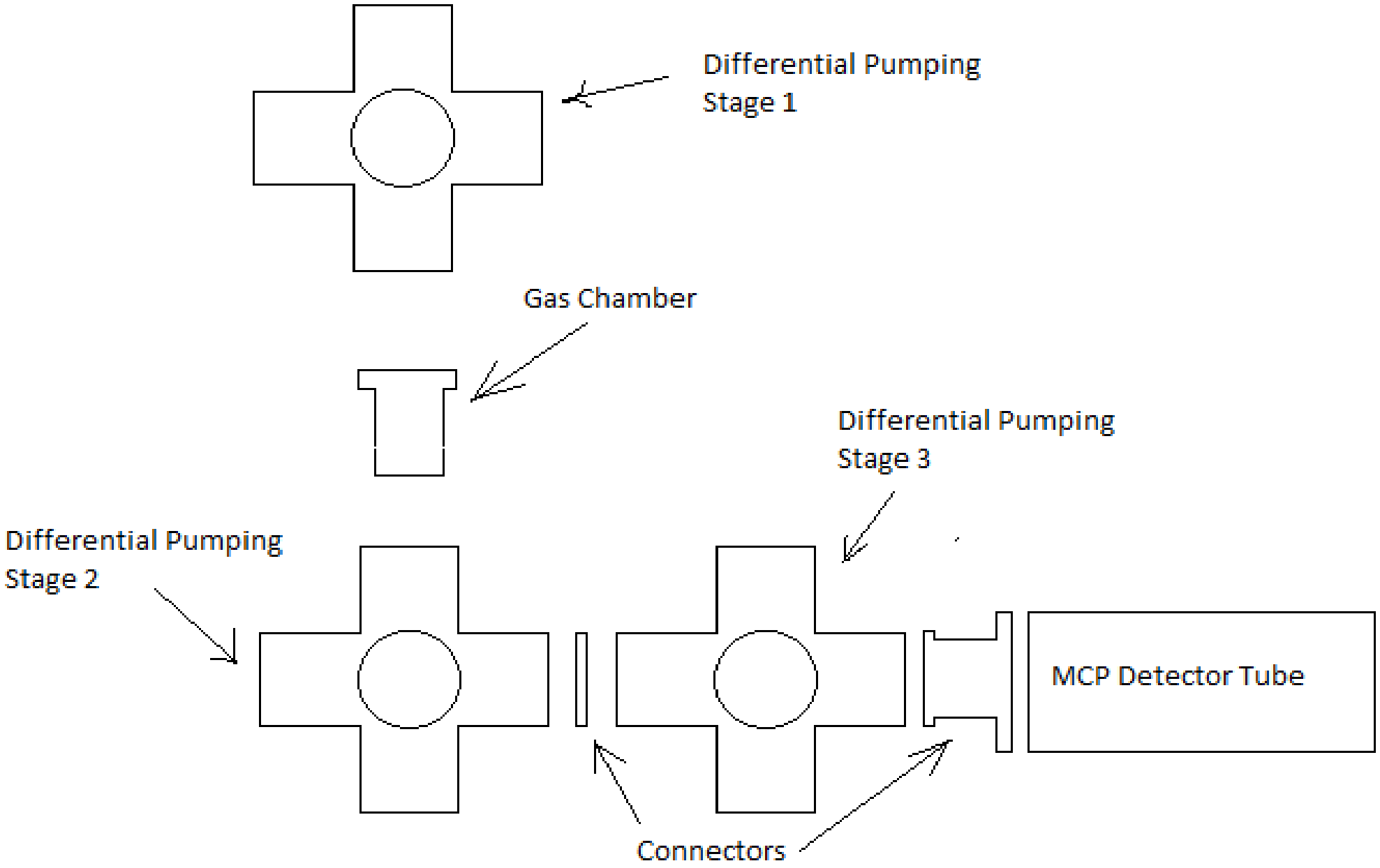
Where I_p is the ionization potential, and U_p is the ponderomotive energy

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

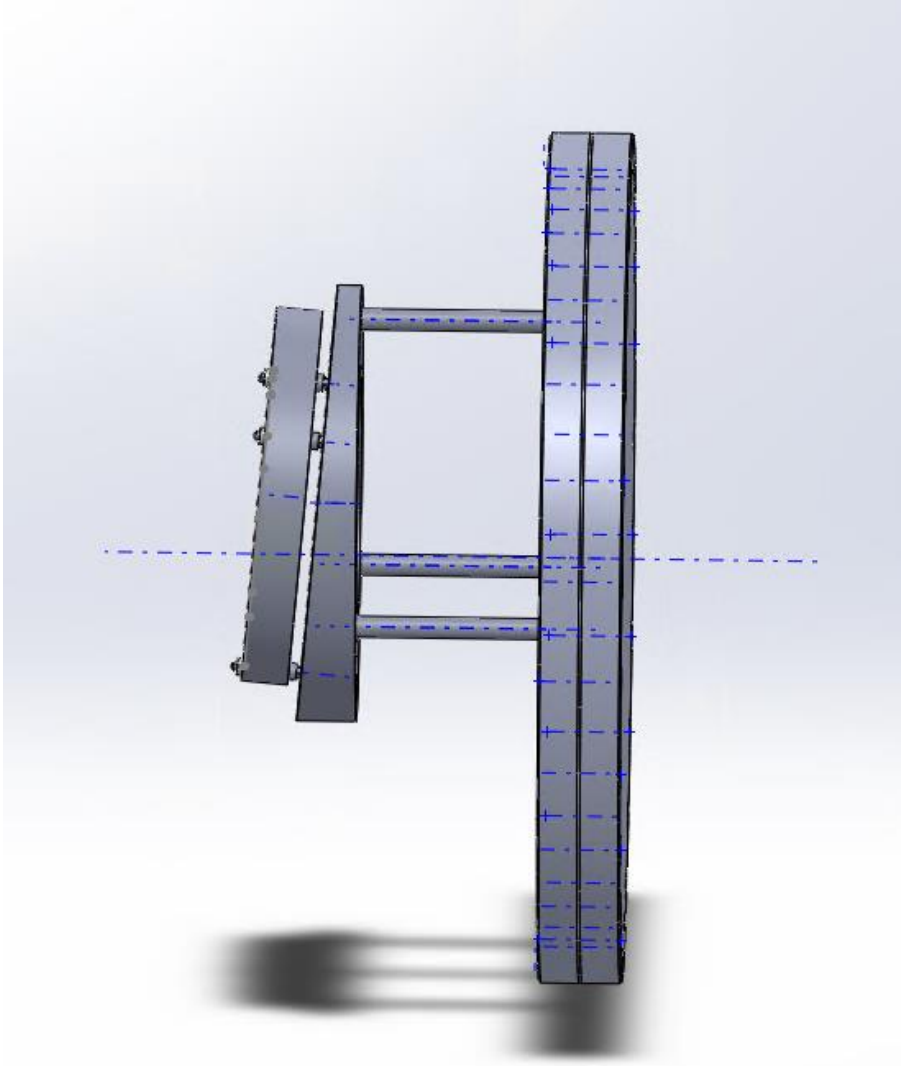
With E_0, I, and λ being the strength, intensity, and wavelength of the driving field, respectively.

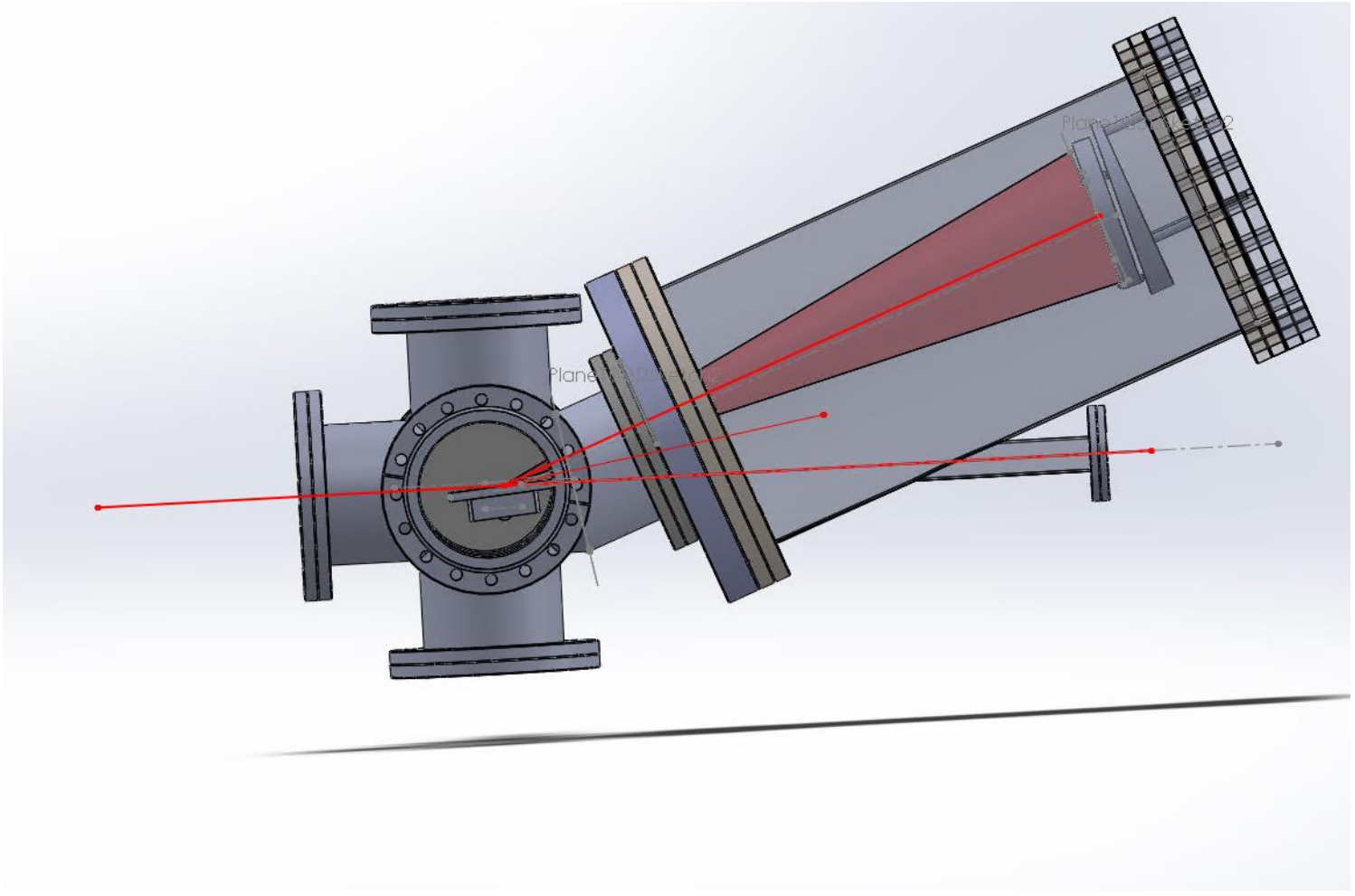
Ren, X. (2013) Laser Driven Rotational Dynamics of Gas-Phase Molecules: Control and Applications Manhattan, KS Kansas State University


Turbo Pumps
Optical Grating
MCP
Initial Frequency = ω₀
Harmonic Frequency = n*ω₀
Where n is an interger, n > 9
Differential Pumping Walls
Super Sonic
Jet


Differential Pumping
Stage 1
Gas Chamber
Differential Pumping
Stage 3
Differential Pumping
Stage 2
MCP Detector Tube
Connectors

High Harmonic Chamber 3D design



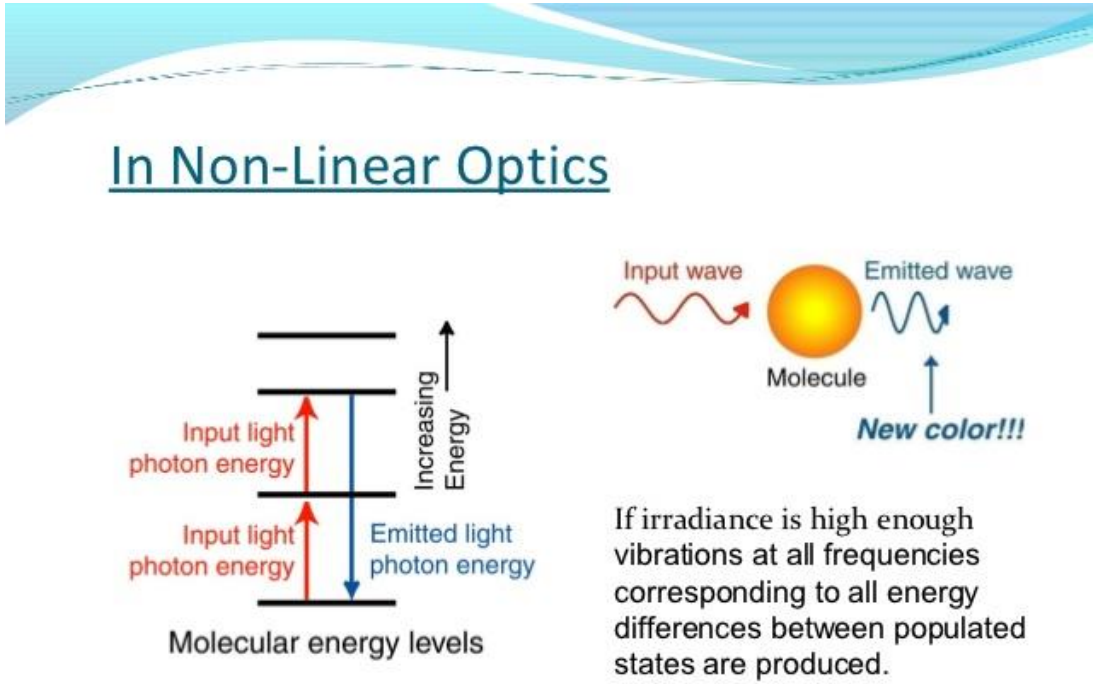


Low Harmonic Generation

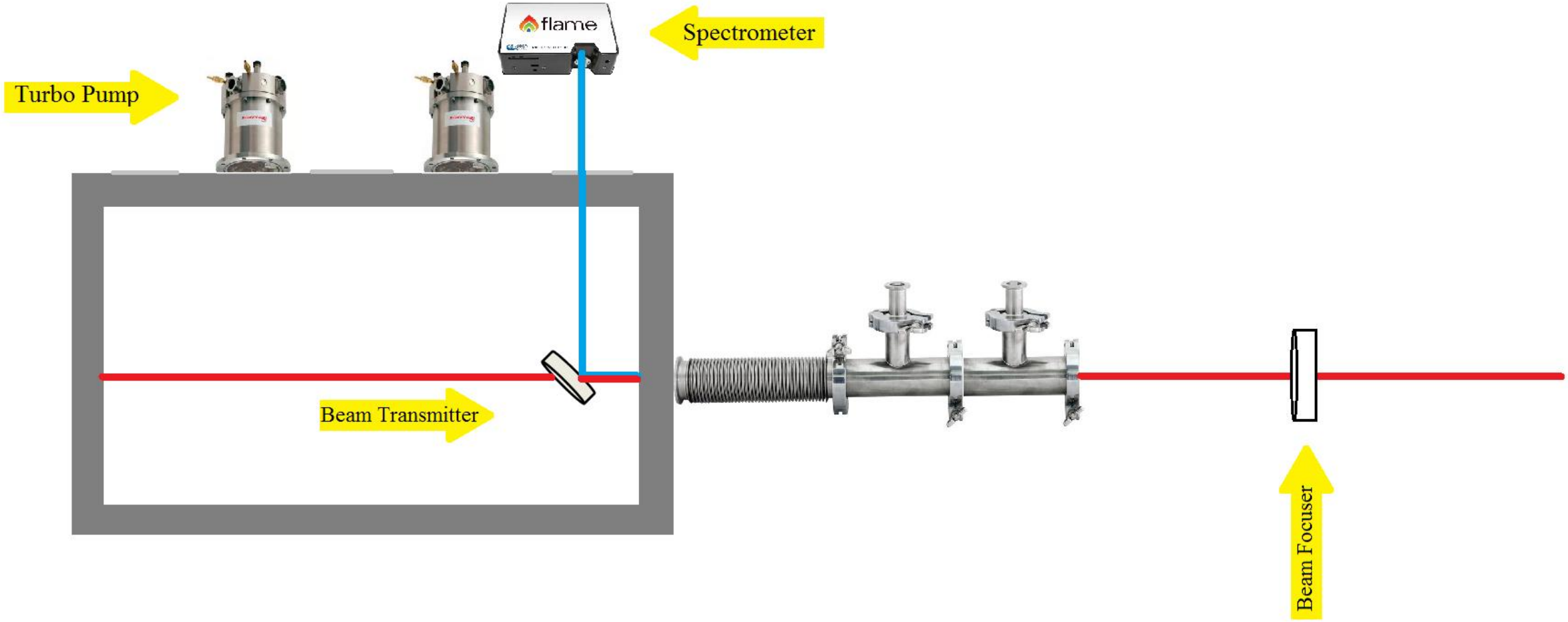
- Parametric and "instantaneous“ nonlinear optical phenomena, in which the optical fields are not too large, can be described by a Taylor series expansion of the dielectric polarization density (dipole moment per unit volume) P(t) at time t in terms of the electrical field E(t):

$$\mathbf{P}(t) = \varepsilon_0(\chi^{(1)}\mathbf{E}(t) + \chi^{(2)}\mathbf{E}^2(t) + \chi^{(3)}\mathbf{E}^3(t) + \ldots),$$

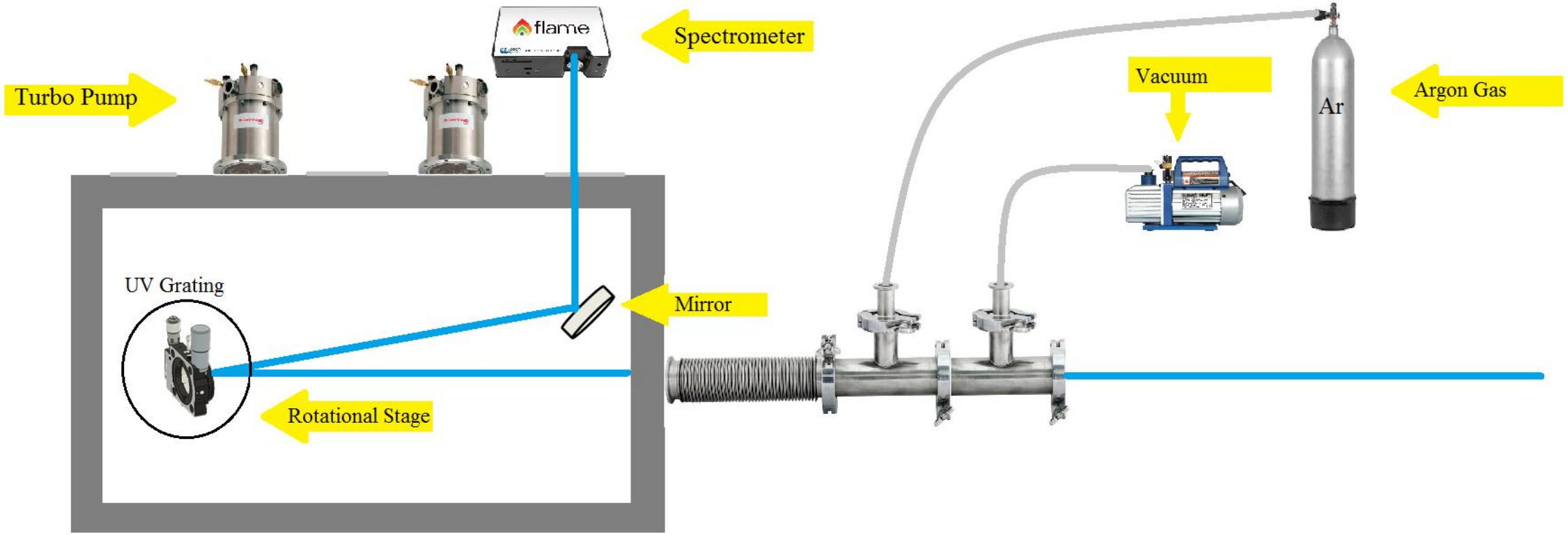
- Nonlinear optics (NLO) is the branch of optics that describes the behavior of light in nonlinear media, that is, media in which the dielectric polarization P responds nonlinearly to the electric field E of the light. The nonlinearity is typically observed only at very high light intensities (values of atomic electric fields, typically 108 V/m) such as those provided by lasers.



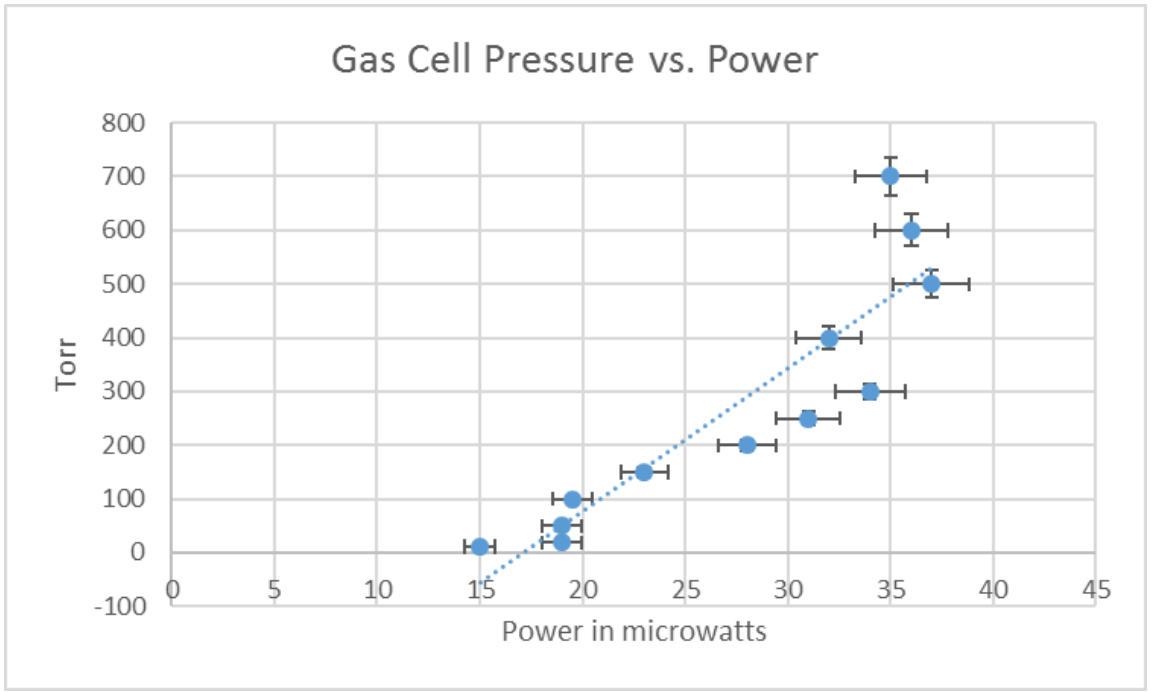
3rd Harmonic Setup

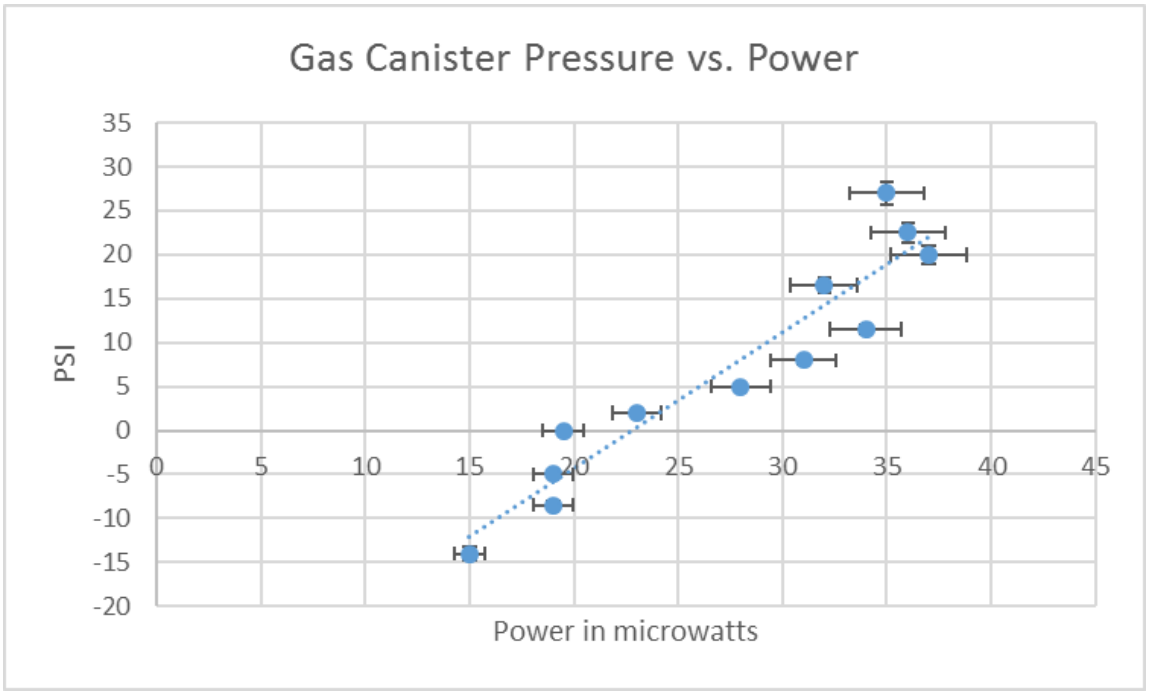


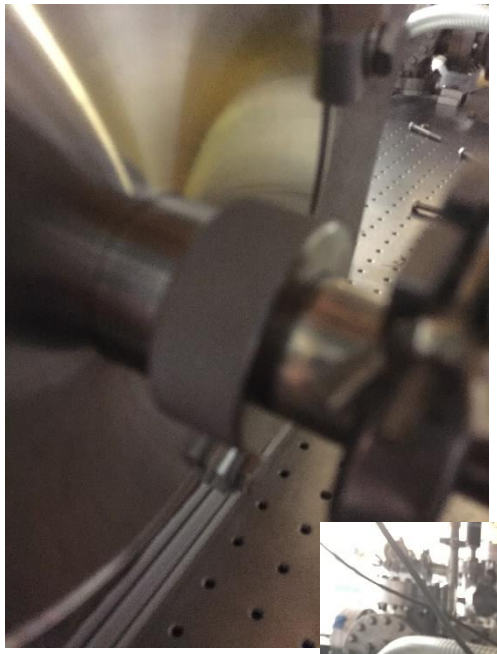
5th Harmonic Setup



Third Harmonic Generation In Argon Gas







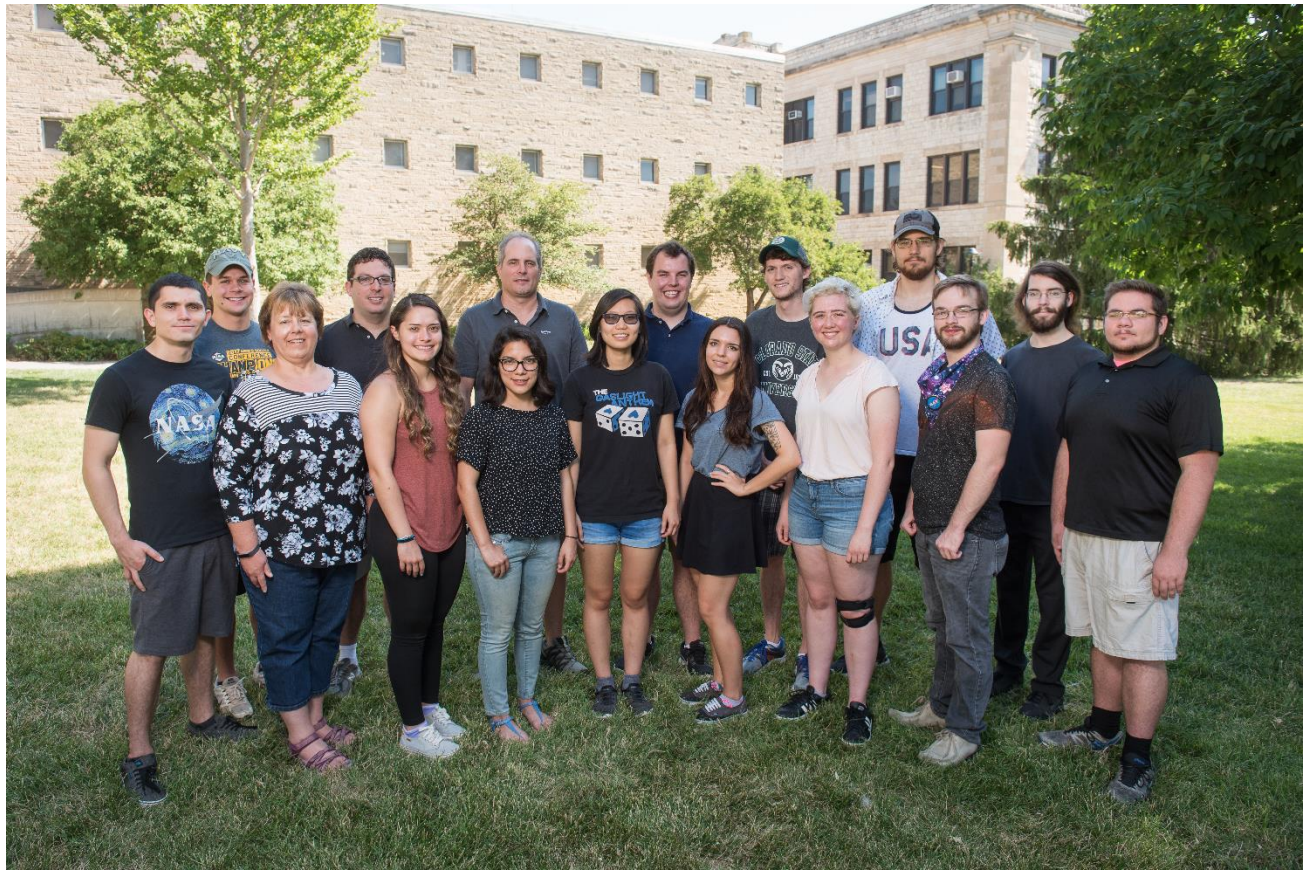

TEXAS

Future Steps:

Refurbish the vacuum chamber that will allow me to create high harmonics.

Several step process

- Alignment
- Vacuum Differential
- Electronic testing



The next goal would then to mount the MCP/HH Chamber

Acknowledgements:

Vinod Kumarappan

Tomthin Nganba Wangjam

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Miller. D (1988) Atomic and Molecular Beam Methods (Volume one) New York, NY: Oxford University Press, Inc.

Hillenkamp. M, Keinan. S, Even. U (2003). Condensation limited cooling in supersonic expansions. Journal of Chemical Physics, 118(19), 8699-8705