# Auto/cross-correlation of Green Picosecond Pulses Based on Two-photon Photodiodes

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# Ultrashort Pulses

- Electromagnetic Pulses whose time duration is in the femtosecond (fs = $10^{-15}$ s) to picosecond (ps = $10^{-12}$ s) range
- In time domain:

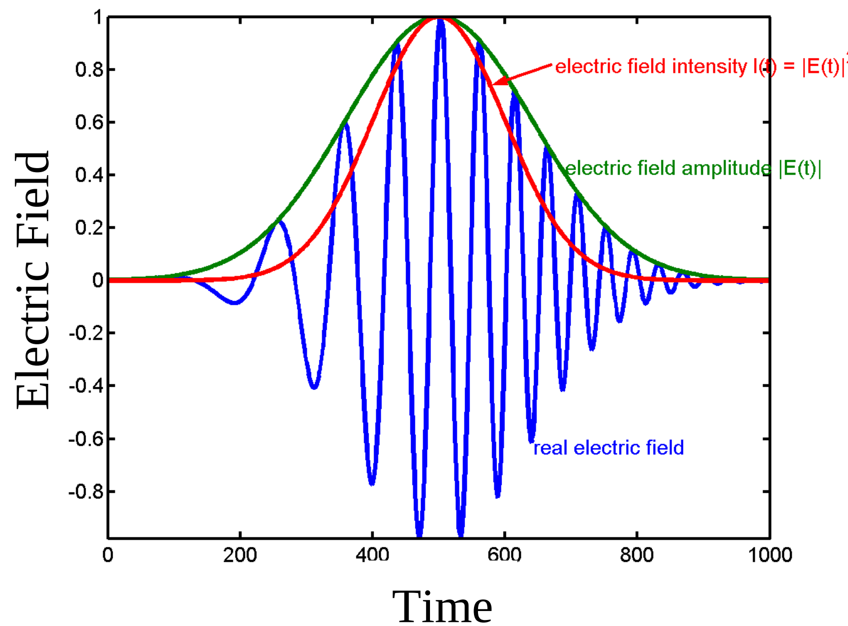
$$E(t) = \xi(t) e^{i\varphi(t)} e^{i\omega_l t} = \sqrt{I(t)}\, e^{i\varphi(t)} e^{i\omega_l t}$$

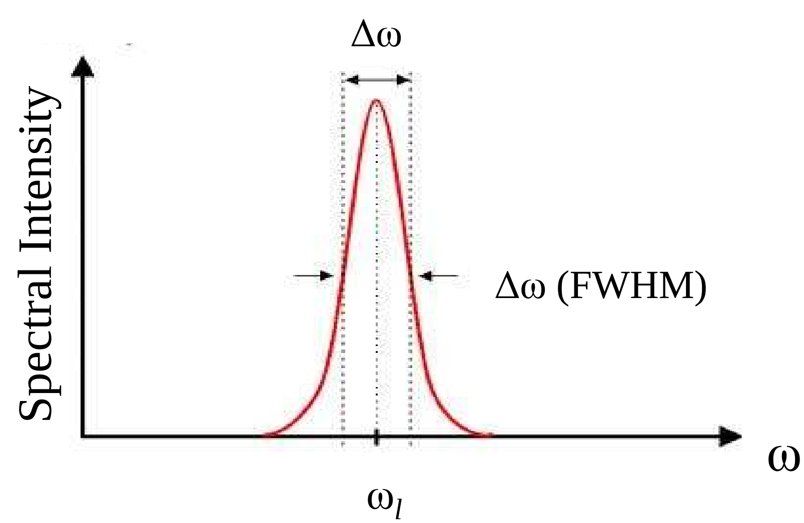
- In frequency domain:

$$E(\omega) = F\{E(t)\} = \sqrt{S(\omega)}\, e^{i\Phi(\omega)}$$

- Spectral Phase Function $\Phi(\omega)$:
  - constant → Bandwidth-limited pulses
  - others → chirped pulses → due to dispersion or other processes
- Minimum duration-bandwidth product:

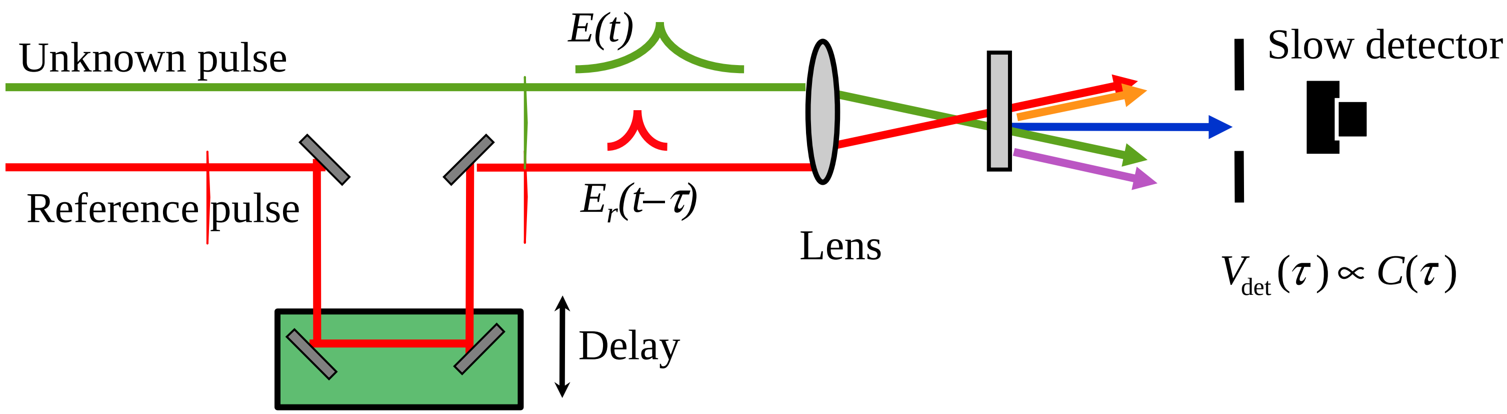
$$\Delta\omega_p \tau_p = 2\pi \Delta\upsilon_p \tau_p \geq 2\pi c_B$$



# Intensity Auto/Cross-correlation

- Electronics devices (diodes, oscilloscopes, etc) are not fast enough to allow direct measurement of picosecond and femtosecond pulses.



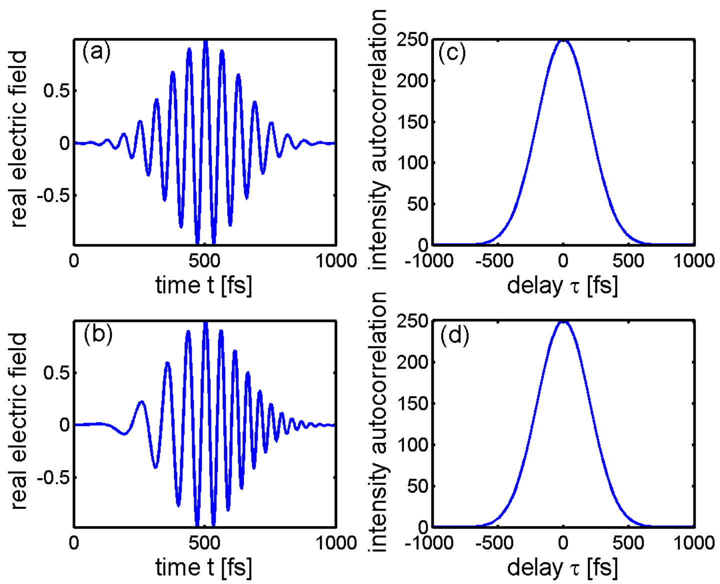

- Intensity Cross-correlation →

The temporal profile $I_s(t)$ of a signal can be determined if a shorter (reference) pulse of known shape $I_r(t)$ is available.

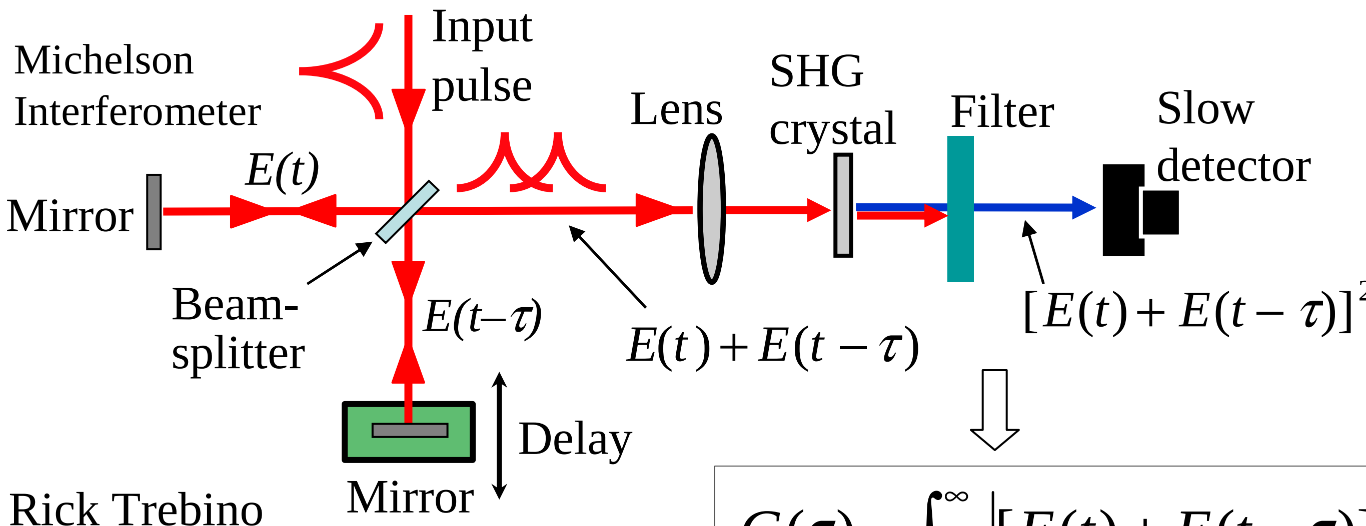
$$A_c(\tau) = \int_{-\infty}^{\infty} I_s(t) I_r(t-\tau) dt$$

- Intensity Autocorrelation: $I_s(t) = I_r(t) = I(t)$

- Autocorrelation is a symmetric function → contain little information on the pulse shape and pulse chirp.

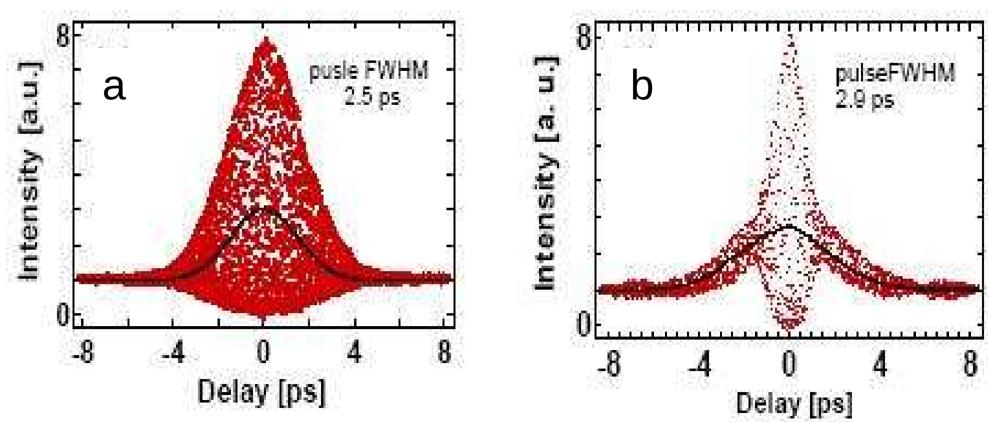


# Interferometric Autocorrelation

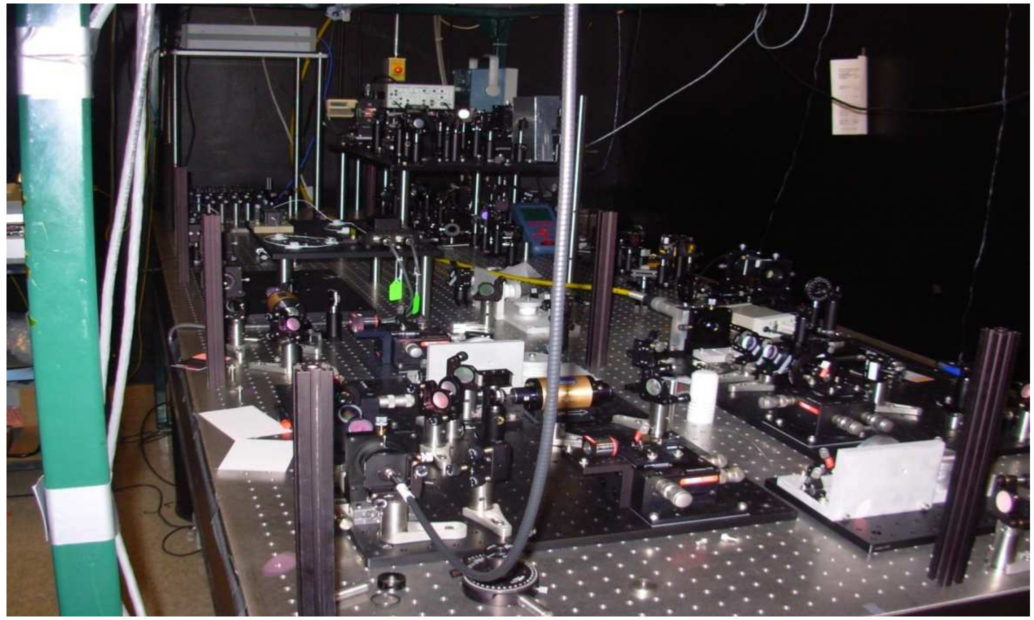



$$G(\tau) = \int_{-\infty}^{\infty} \left| [E(t) + E(t-\tau)]^2 \right|^2 dt$$

- Interferometric Autocorrelation is a symmetric function. However, it contains information about the pulse chirp.
- In the case of a phase modulated (chirped) pulse (b), the interference pattern is much narrower than the pulse intensity autocorrelation.

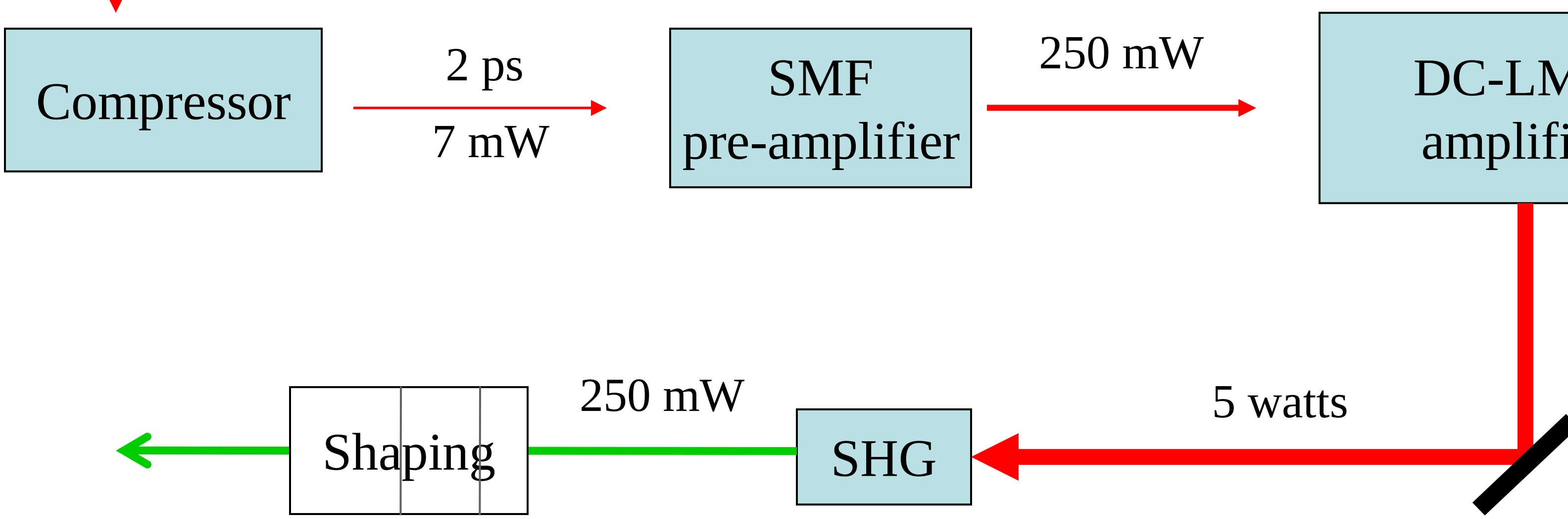


# First Stage of 1.3 GHz System

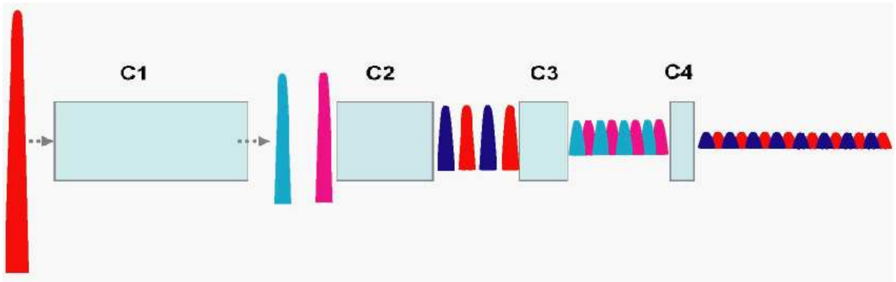


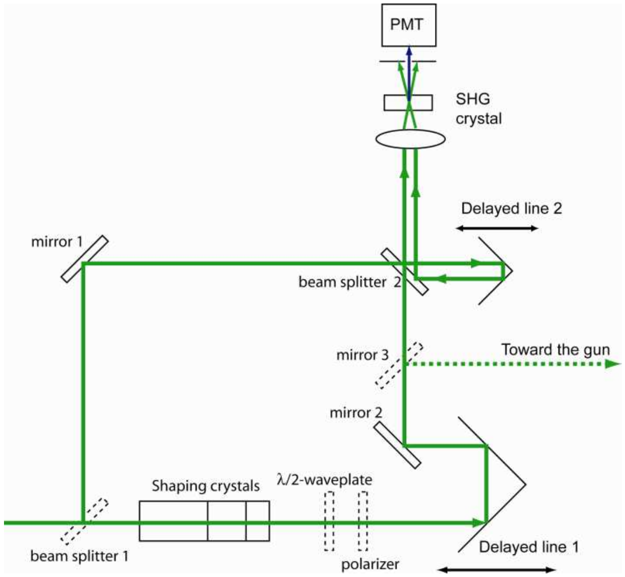
1.3 GHz
oscillator

20 ps
14 mW

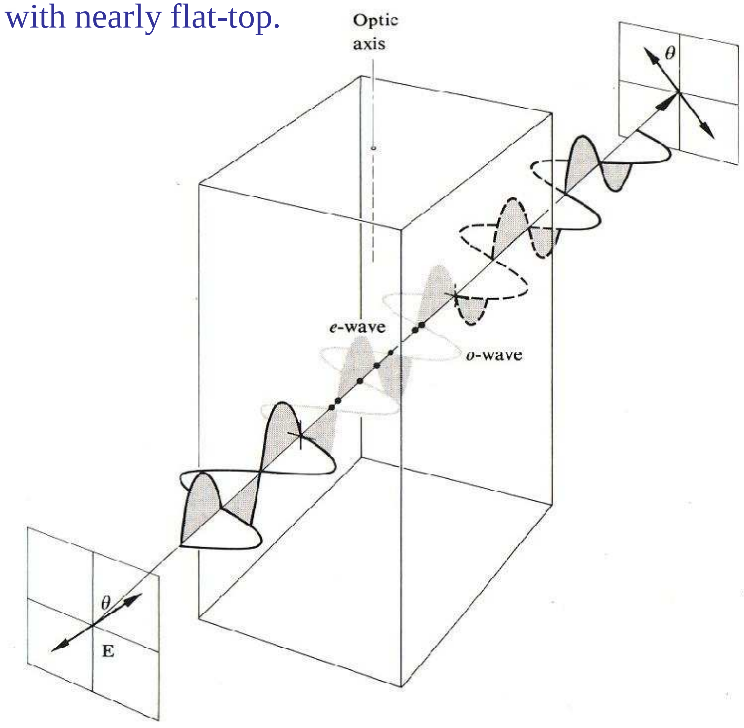


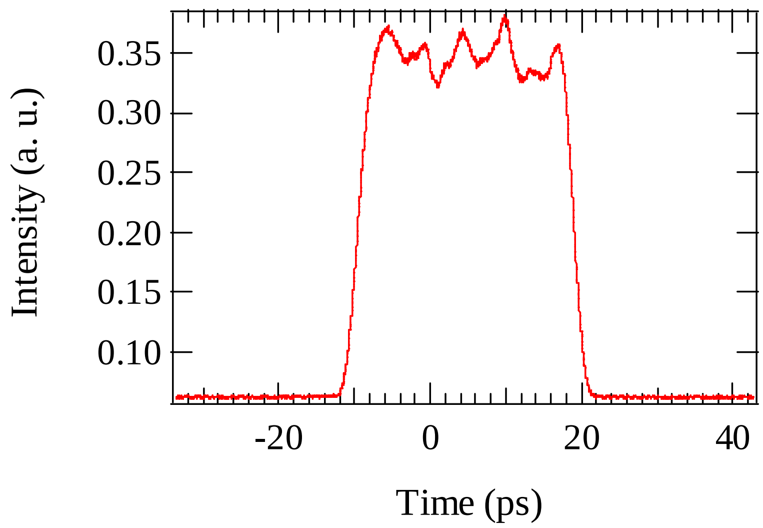
# Longitudinal Shaping




- Birefringent material: refractive index depends on polarization direction. Pulse with orthogonal polarization travel with different velocities.
- We stack 2-ps pulses through a sequence of 3 birefringent crystals to produce pulse with nearly flat-top.



# Two-photon Photo-diode

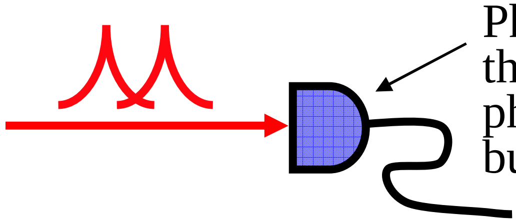
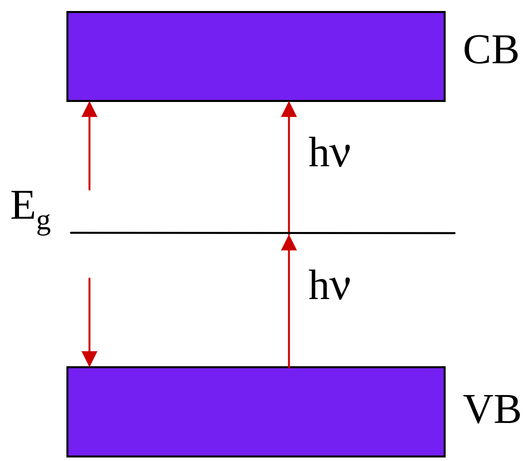
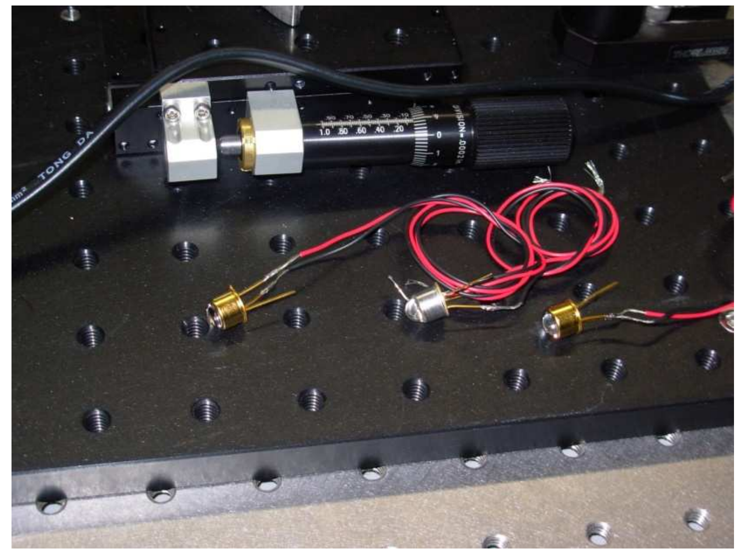
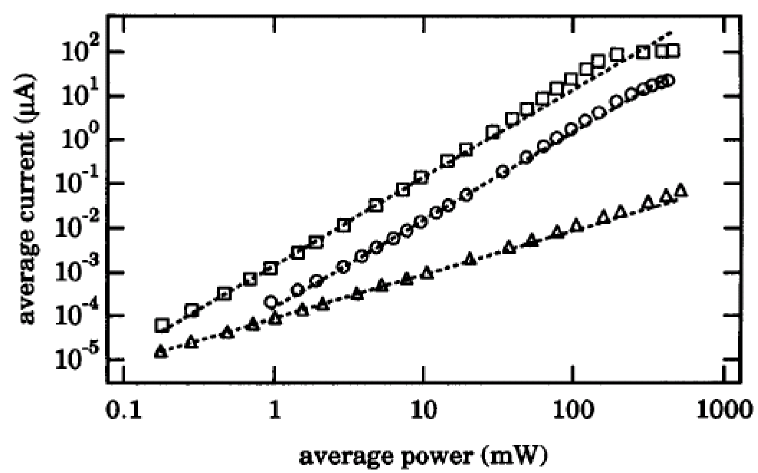


Photo-detector that absorbs two photons of ω each, but not one at ω.



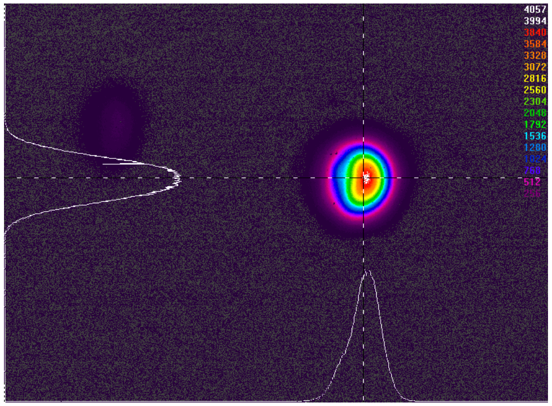

- $h\nu < E_g < 2h\nu$
- Two-photon induced photocurrent ~ $I^2$
- Vary the spot size of the focused beam to optimize the output signal

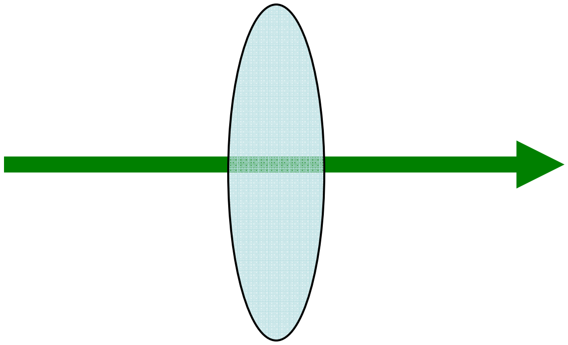


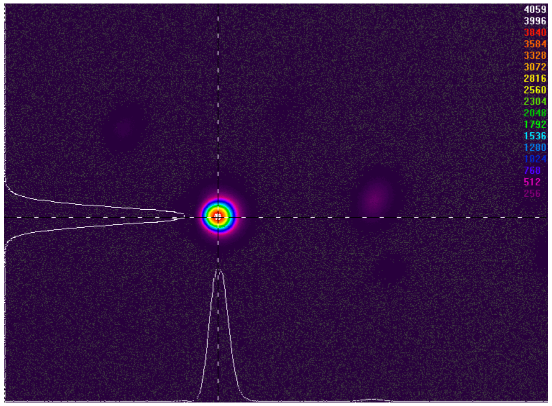


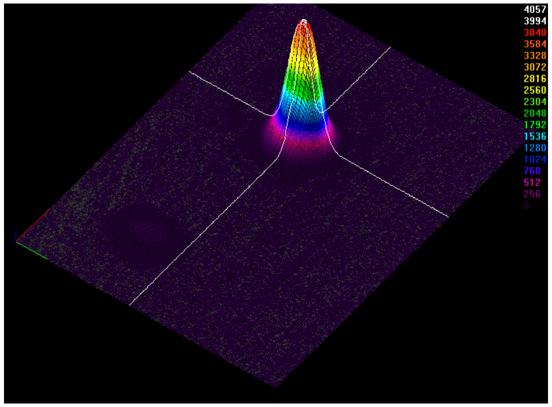

GaAsP diode works at 1 um Ranka et al, 1997

# Laser Focus Spot Size



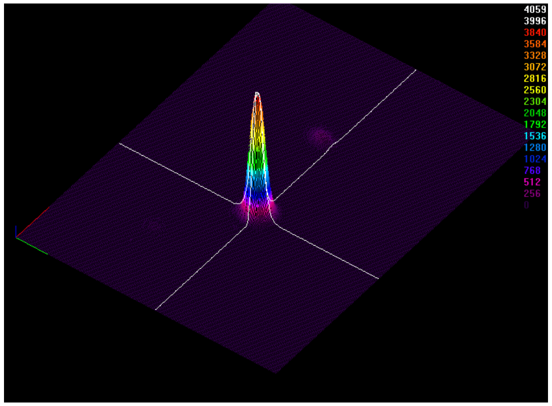






$$w_{spot} \approx \frac{\lambda f}{\pi w_0}$$

**Error: by a factor of 2**



# Project Goals

1. Be familiar with the ERL laser system.
2. Measure the photo-current as function of the laser beam power for three commercially available laser diodes using the first stage of the ERL 1.3 GHz laser system.
3. Repeat the measurements in (2) for different sizes of the focused laser spot.
4. Identify which diode, if any, has a quadratic response.
5. Use the diode from (4) to build an auto/cross-correlator.
6. Identify and quantify errors in autocorrelation measurements.