

# Ultrafast Optics

Physics 7810

<http://jilawww.colorado.edu/phys7810/>

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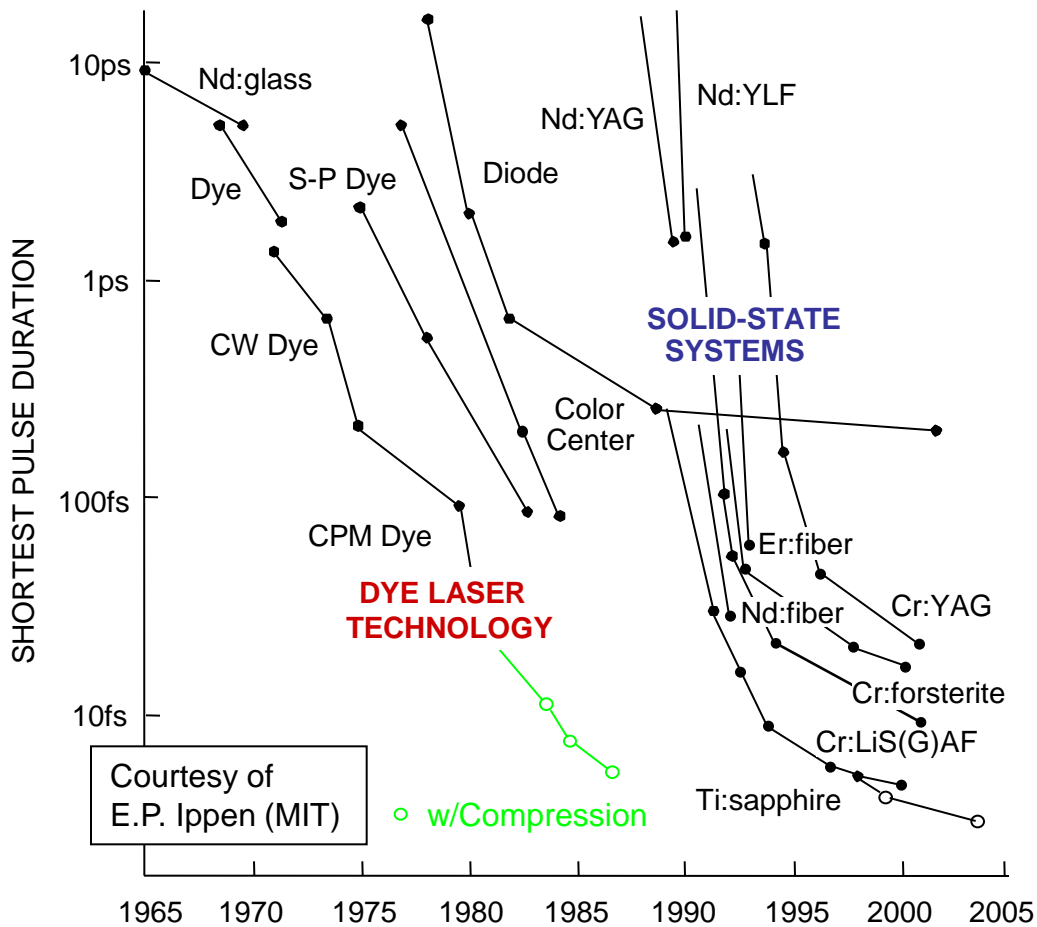
Office hours: Wednesdays 2-3 pm or by appointment

# Time & Frequency scales

	$t$ (sec)	$\Delta L=ct$	Frequency	
microsecond (ms)	$10^{-6}$	300 m	1 MHz	radio waves
nanosecond (ns)	$10^{-9}$	0.3 m	1 GHz	micro waves
picosecond (ps)	$10^{-12}$	300 $\mu\text{m}$	1 THz	mm waves
femtosecond (fs)	$10^{-15}$	0.3 $\mu\text{m}$	1000 THz	light waves

Ultrafast: 1 minute is the geometric mean between 1 femtosecond and the age of the universe

Ultrashort optical pulses are the fast man-made “technological” event



# Texts

- **Primary:**

- A.M. Weiner, “Ultrafast Optics”  
John Wiley and Sons, ISBN 978-0-471-41539-8

- **Secondary**

- Diels and Rudolph “Ultrashort Laser Pulse Phenomena, 2<sup>nd</sup> ed.”  
Academic Press, ISBN 978-0122154935
- Draft chapters from book edited by Trebino and Squier  
Available on web: <http://www.physics.gatech.edu/gcuo/ultratext.html>

- **Also useful:**

- Trebino, "Frequency Resolved Optical Gating"  
Springer, ISBN 1402070667
- Ye and Cundiff, "Femtosecond Optical Frequency Comb Technology" Springer,  
ISBN 0-387-23790-9

- **Plus:**

- Occasional review papers – links will be posted on web site
- I will post lecture vugraphs on web site (hopefully before class, but no promise)

# Boring stuff...

- Grading:
  - Homeworks sets (4-6 during semester)
    - Posted on Website
  - Project
  - Presentation (on project)
    - During last few class periods
    - “Conference” style → XX minute time slots
- Projects:
  - not directly related to your thesis
  - “review” paper
  - Simulation
  - “Lab”
    - In your research lab or using ti:sapphire laser in Keck Lab
    - Probably requires partner
    - One week time slots (to be assigned)
    - Must be doable with available equipment
      - See list or propose
  - Topic by Feb. 3
  - Due April 16<sup>th</sup>

# Calendar

- I will try to minimize cancellation of classes, but will have some.
- I know of two so far (hopefully that's all):
  - February 17<sup>th</sup>
  - April 5<sup>th</sup>
- I will evaluate our progress and decide if/what is needed for makeup

# Not so boring stuff...

- Possible lab project topics:
  - White light interferometry
  - Dispersion and compensation w/ fs pulses
    - Using FROG
    - Using spectral interferometry
  - Transient absorption spectroscopy (LT-GaAs)
  - Continuum generation
  - Combs:
    - Beat w/ CW laser
    - Self referencing? (only for the truly ambitious...)
  - Make a proposal...

# The fine print

- **Disabilities:** If you qualify for accommodations because of a disability, please submit a letter to me from Disability Services in a timely manner so that your needs may be addressed. Disability Services determines accommodations based on documented disabilities. Contact: 303-492-8671, Willard 322, or <http://www.Colorado.EDU/disabilityservices>
  - If you have a temporary medical condition or injury, see guidelines at <http://www.colorado.edu/disabilityservices/go.cgi?select=temporary.html>
- **Absences due to Religious observances:** Campus policy regarding religious observances requires that faculty make every effort to reasonably and fairly deal with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please notify me as soon as possible. I will provide you with lecture materials and be sure to schedule project laboratory time and presentations to avoid schedule conflicts.
- **Classroom Behavior:** Students and faculty each have responsibility for maintaining an appropriate learning environment. For full CU policy, see <http://www.colorado.edu/policies/classbehavior.html>
- **Honor Code:** All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. For further information see: <http://www.colorado.edu/policies/honor.html>

# Topics

- Review of laser basics
- Fundamentals
  - Description of pulse, temporal and spectral phase, chirp
  - Time-bandwidth product for various pulse shapes
  - Propagation
  - Nonlinearity
  - Numerical modeling of propagation
- Optics and dispersion
  - Phase velocity, group velocity, GVD, GDD, units thereof
  - Dispersion of materials, glass, air...
  - Measurement of dispersion
  - Dispersion compensation (prisms, gratings, negative dispersion mirrors)
- Sources
  - Modelocking (active, passive)
  - Saturable absorbers, types: real vs. effective
  - Time versus frequency domain descriptions, pulse trains (basics of combs)
  - Pulse propagation, “master” equation, dispersion management

# More Topics...

- Pulse shaping
  - Fourier
  - Space-to-time mapping
- Diagnostics and measurement
  - Autocorrelation
  - FROG
  - SPIDER
  - Spectral interferometry
- Amplification
  - Chirped pulse
  - Regenerative, multi-pass

# And even more Topics...

- Ultrafast Spectroscopy
  - Transient Absorption
  - Transient Grating
  - Coherent Phenomena: Optical Bloch Equations
  - Photon Echoes
  - Two-D
  - Faraday/Kerr rotation
- Ultrafast Processes in Matter
- High Harmonic/X-ray Generation
  - Carrier-envelope phase effects
- THz generation
  - Time-domain THz spectroscopy
  - Imaging
- Combs: absolute frequency metrology, optical atomic clocks

# Useful features of ultrashort pulses

- Time resolution
- Spatial Resolution
- Bandwidth
- Peak intensity
- Pulse-to-pulse coherence

# Uses of ultrafast pulses

- Ultrafast Spectroscopy
- Control of Chemical Reactions
- Laser-Plasma Interactions
- High speed electrical measurements and testing
- Short wavelength generation
- Optical Communications
- Biological/Medical Applications
- Microscopy
- Materials processing
- Optical frequency metrology/optical atomic clocks
- Timing/clock distribution