Ultrafast Optics

Physics 7810

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

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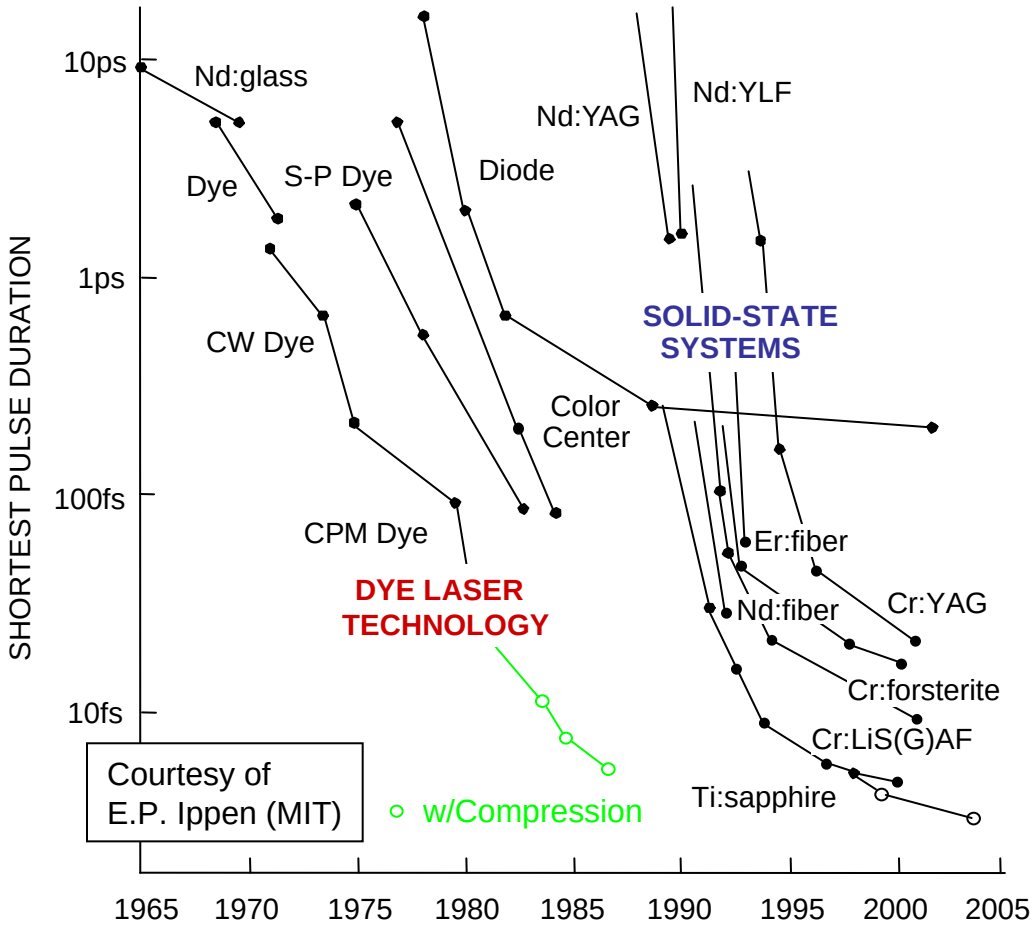
Office hours: Wednesdays 2-3 pm or by appointment

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 μm	1 THz	mm waves
femtosecond (fs)	10^{-15}	0.3 μm	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


SHORTEST PULSE DURATION
10ps
1ps
100fs
10fs
1965
1970
1975
1980
1985
1990
1995
2000
2005
Nd:glass
Dye
S-P Dye
Diode
Nd:YAG
Nd:YLF
CW Dye
SOLID-STATE
SYSTEMS
Color
Center
CPM Dye
DYE LASER
TECHNOLOGY
Er:fiber
Cr:YAG
Nd:fiber
Cr:forsterite
Cr:LiS(G)AF
Ti:sapphire
Courtesy of
E.P. Ippen (MIT)
w/Compression

Texts

- **Primary:**
  - Diels and Rudolph “Ultrashort Laser Pulse Phenomena, 2nd ed.”
    Academic Press, ISBN 978-0122154935
  - Draft of sections from book by A.M. Weiner
    I will hand out copies of sections we use
    A copy of the entire book is available for check out if you wish make a full copy
  - 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 16th

Calendar

- I will try to minimize cancellation of classes, but will have some.
- I know of two so far (hopefully that's all):
  - January 15th (This Thursday!)
  - March 12th
- 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

- Disabilties: 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
  - Regnerative, 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