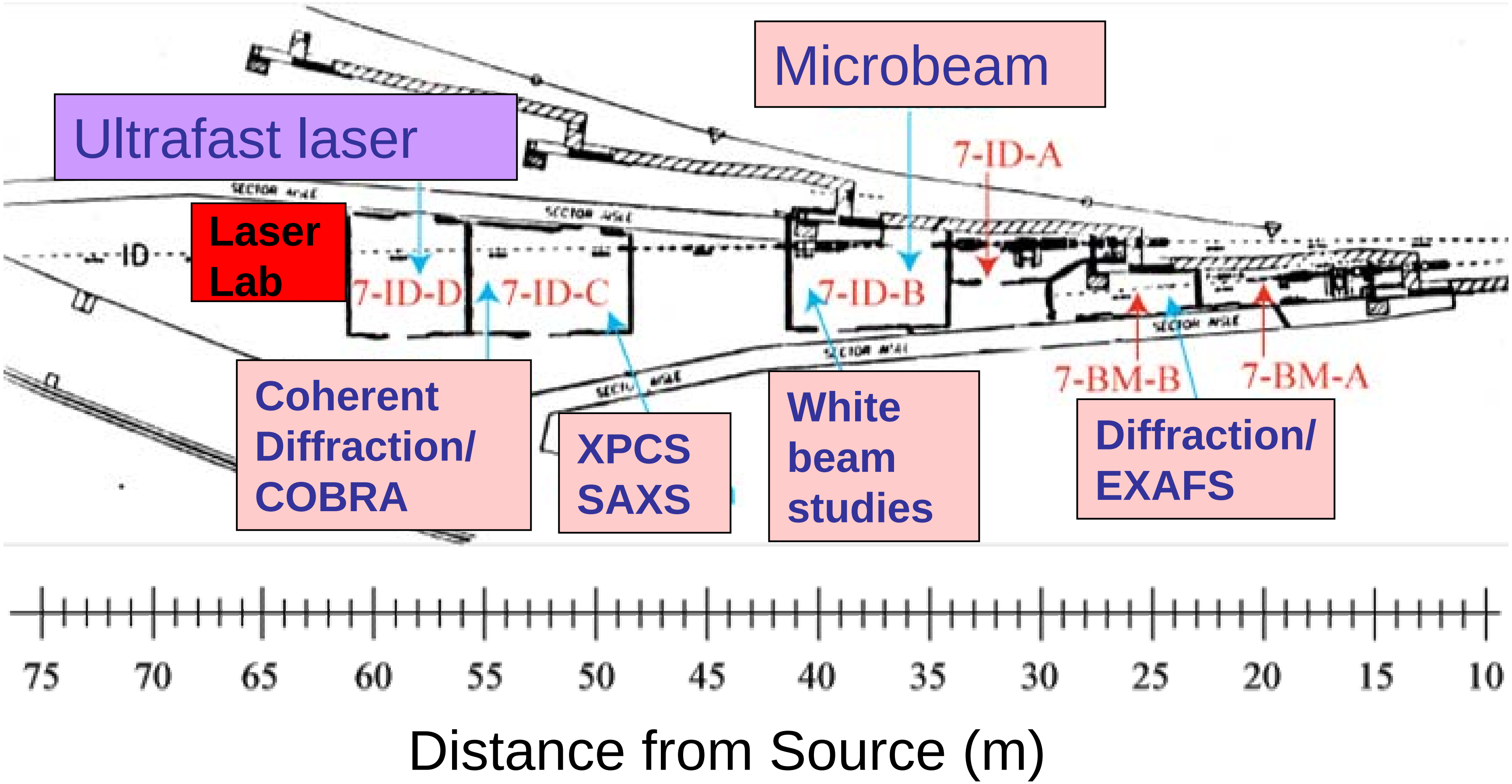
The New Ultrafast Laser Laboratory at Sector-7

Eric Landahl

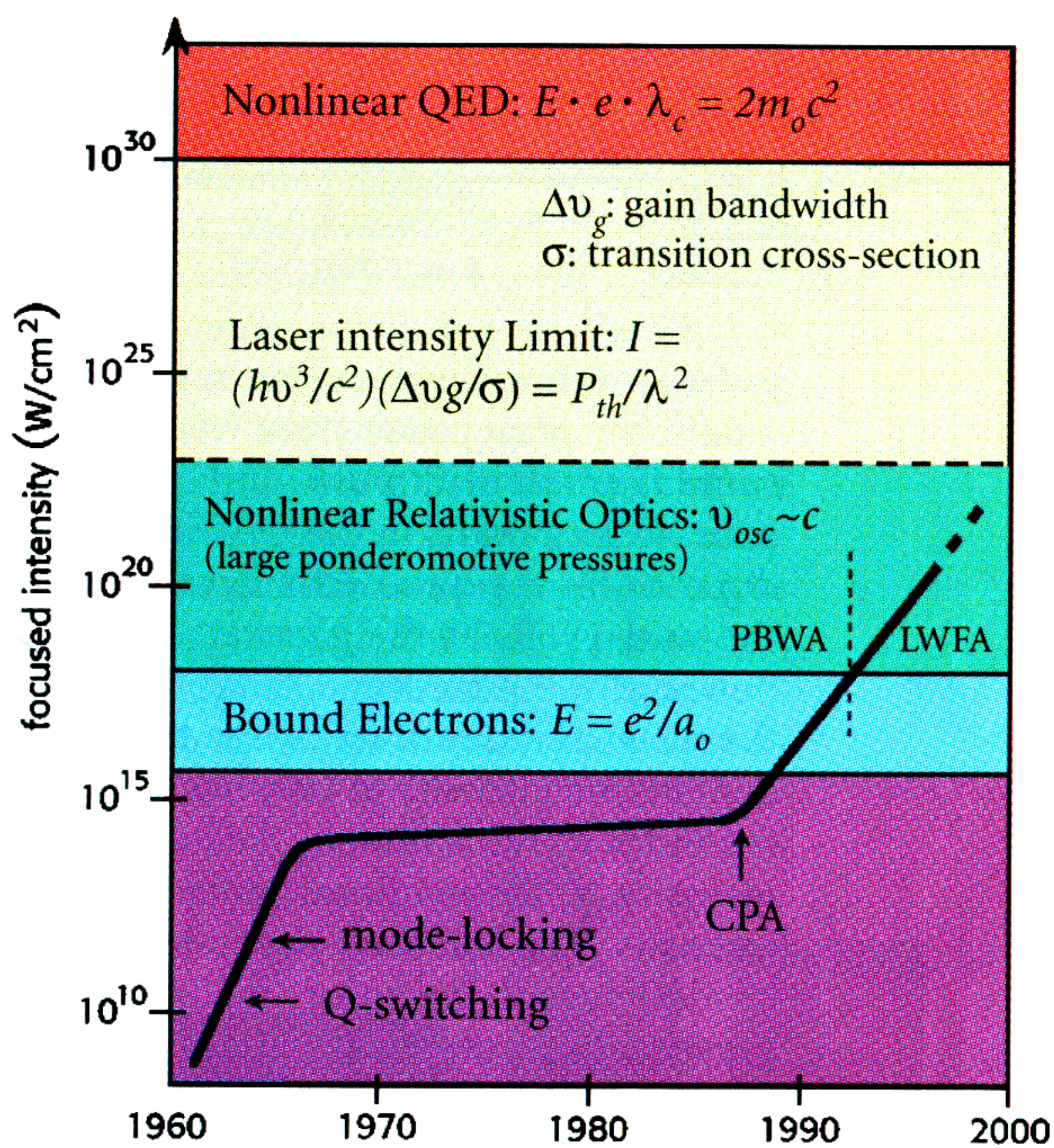
Time-Resolved Research Group

MHATT-CAT Sector 7 Floor Plan



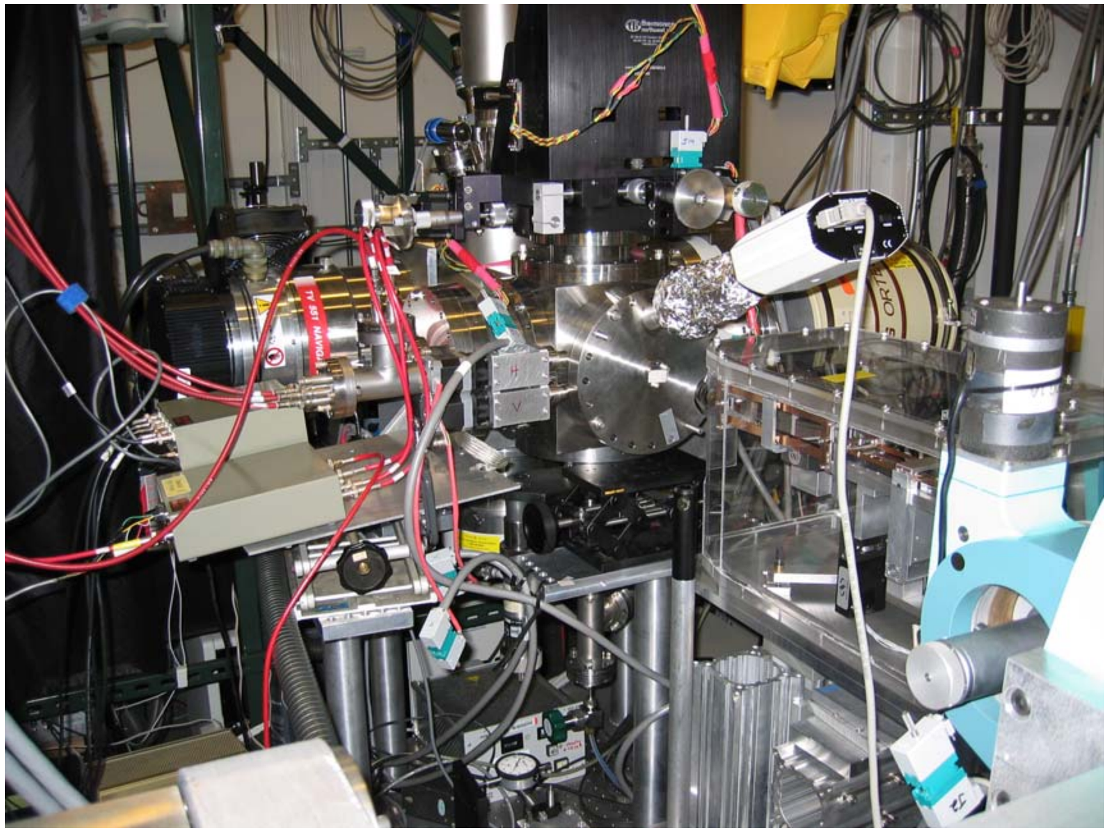
Why have femtosecond lasers at a picosecond x-ray source?

- High Field Strength Physics
  - GeV/m
  - MGauss
  - Mbar, 1000^{o}K, K~1, …
- Coherent Atomic Motion
  - meV X-ray science in the time domain
  - Coherent control of chemical reactions and excitations
- Understanding technological applications
  - Nonthermal drilling
  - Sub-wavelength materials processing
  - Isotope separation
  - Deposition



Courtesy U.Mich. FOCUS

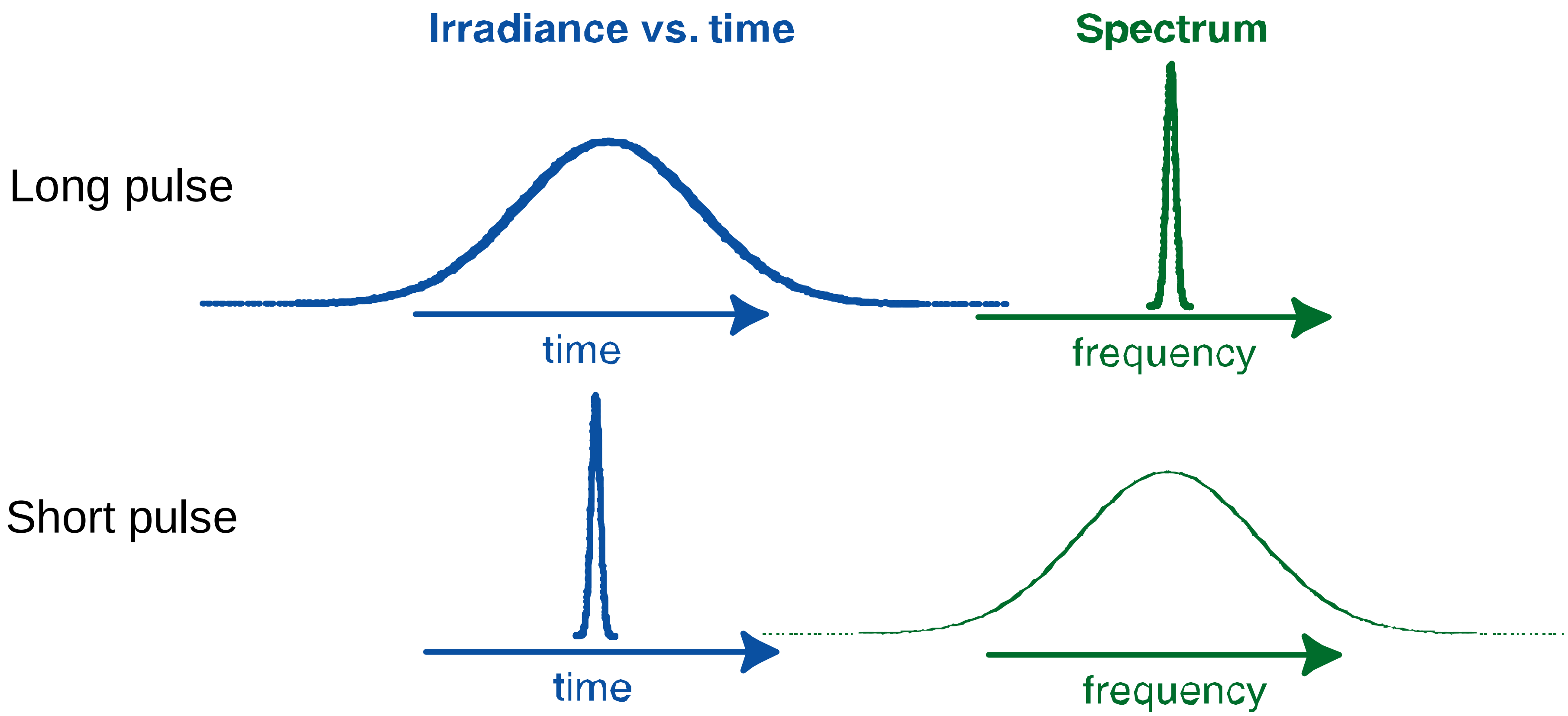
These are laser experiments that are done at synchrotrons…



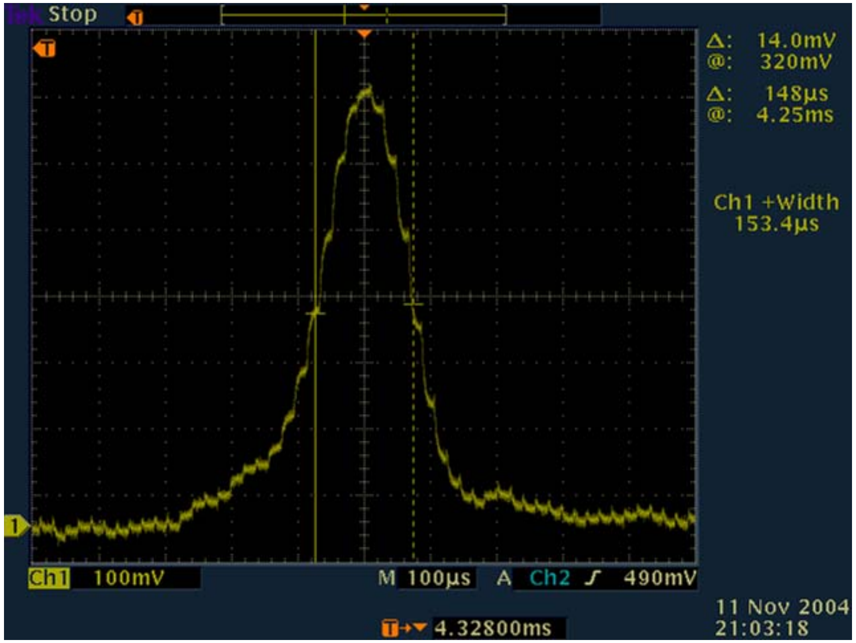
Not synchrotron experiments involving a laser!

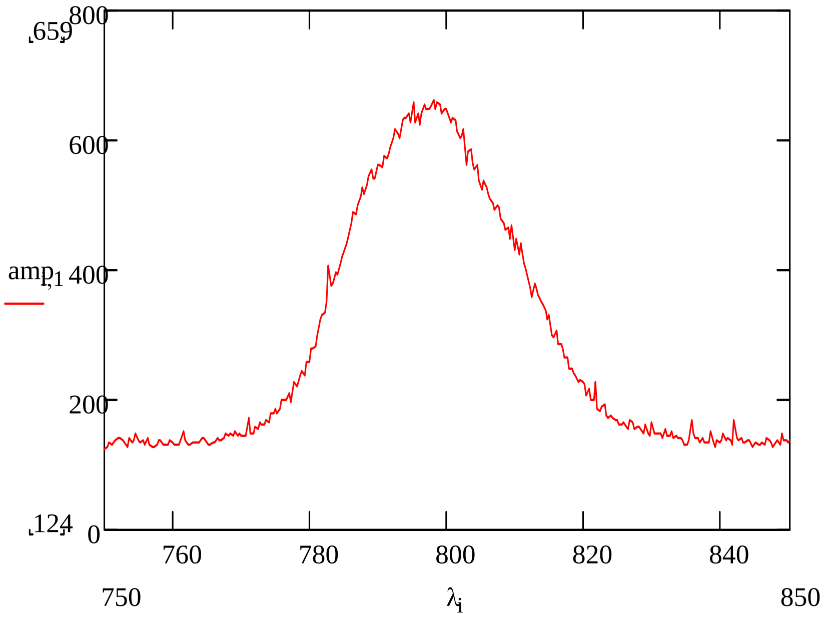
Long vs. short pulses of light

The uncertainty principle says that the product of the temporal and spectral pulse widths is greater than ~1.



New Laser Commissioning





45 fs FWHM

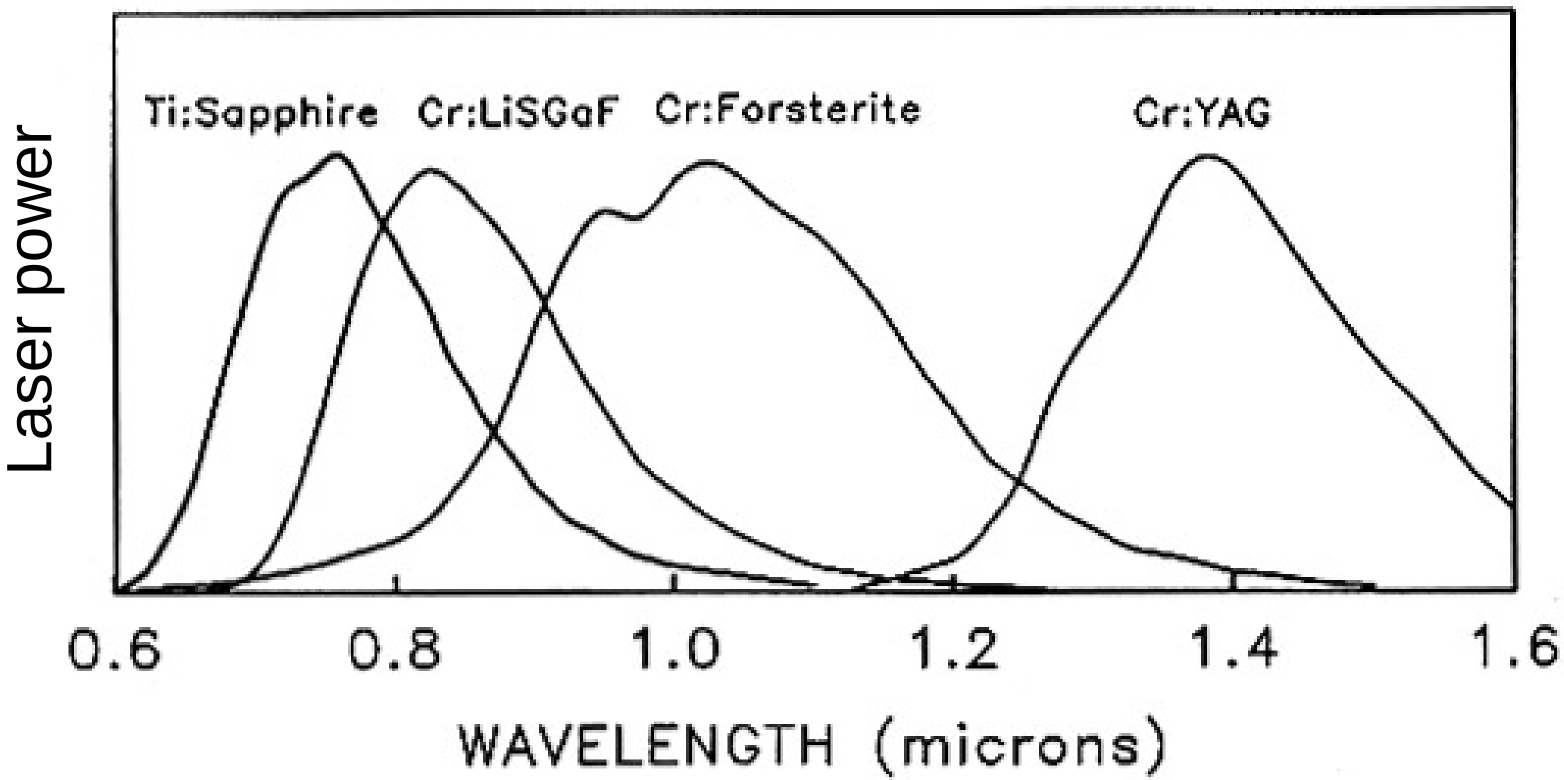
27 nm FWHM

(35 fs FWHM)

New laser

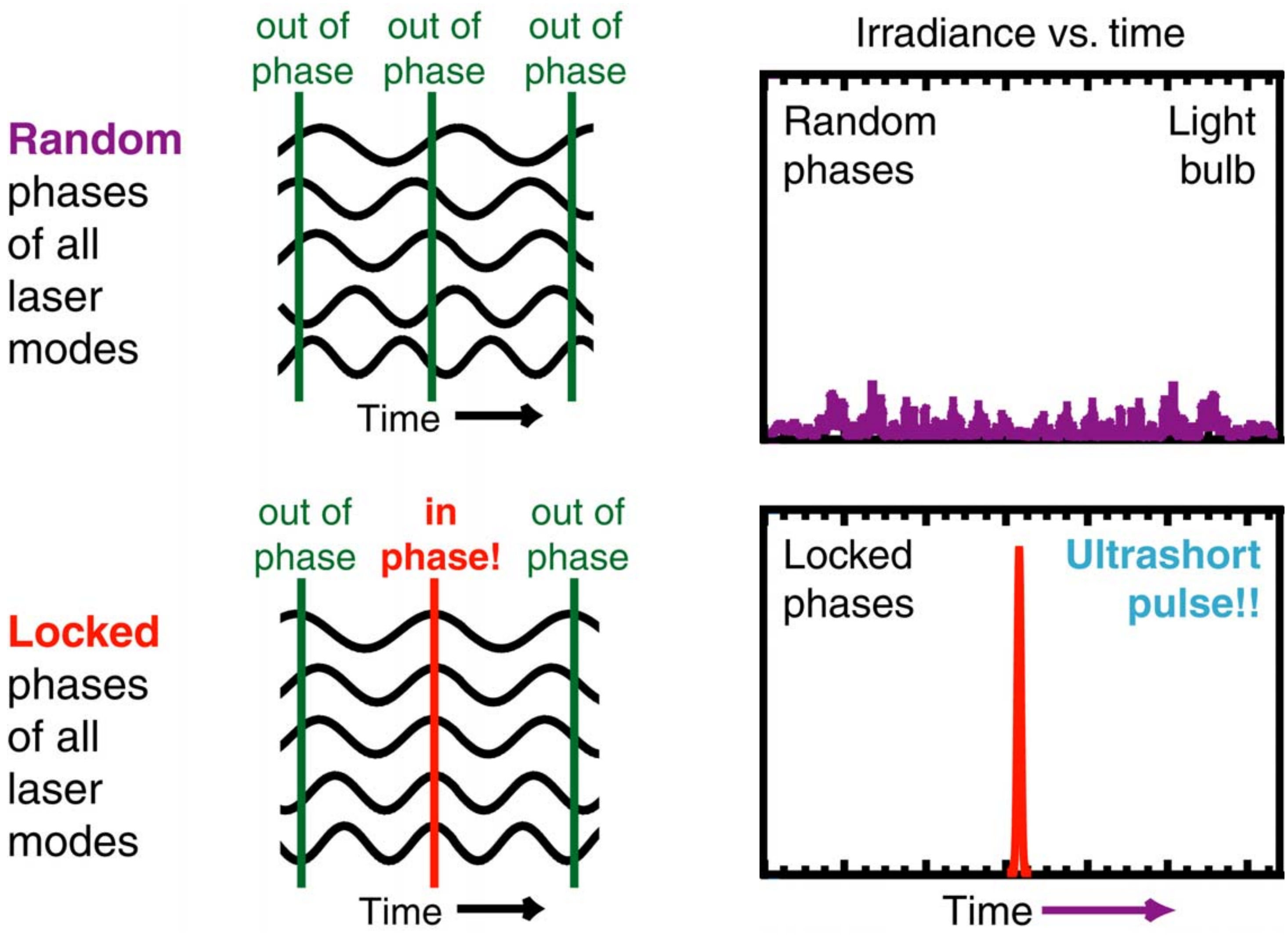
Ultrafast solid-state laser media have recently replaced dyes in most labs.

Solid-state laser media have broad bandwidths and are convenient.



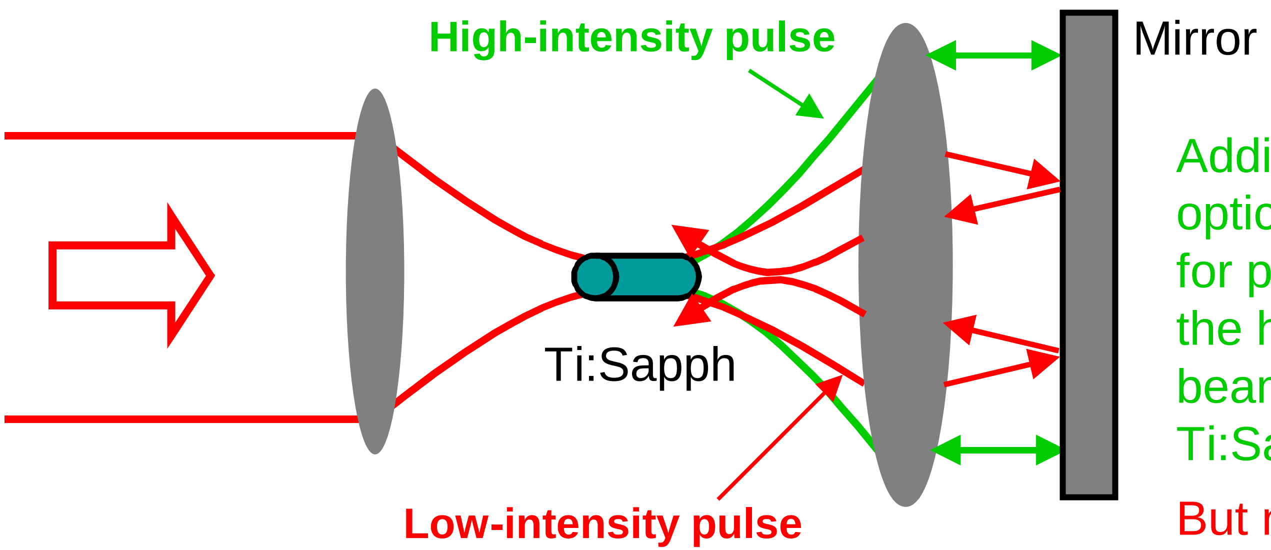
Generating short pulses = “mode-locking”

Locking the phases of the laser modes yields an ultrashort pulse.



Kerr-lensing is a type of saturable absorber.

If a pulse experiences additional focusing due to high intensity and the nonlinear refractive index, and we align the laser for this extra focusing, then a high-intensity beam will have better overlap with the gain medium.



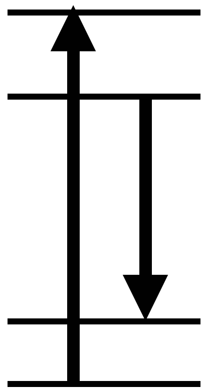
Additional focusing optics can arrange for perfect overlap of the high-intensity beam back in the Ti:Sapphire crystal.

But not the low-intensity beam!

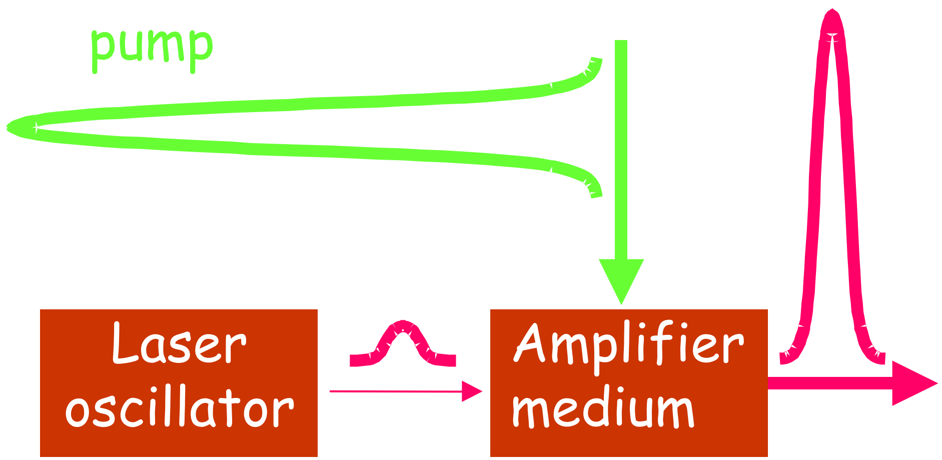
This is a type of saturable absorption.

Amplification of Laser Pulses, in General

Very simply, a powerful laser pulse at one color pumps an amplifier medium, creating an inversion, which amplifies another pulse.



Energy levels

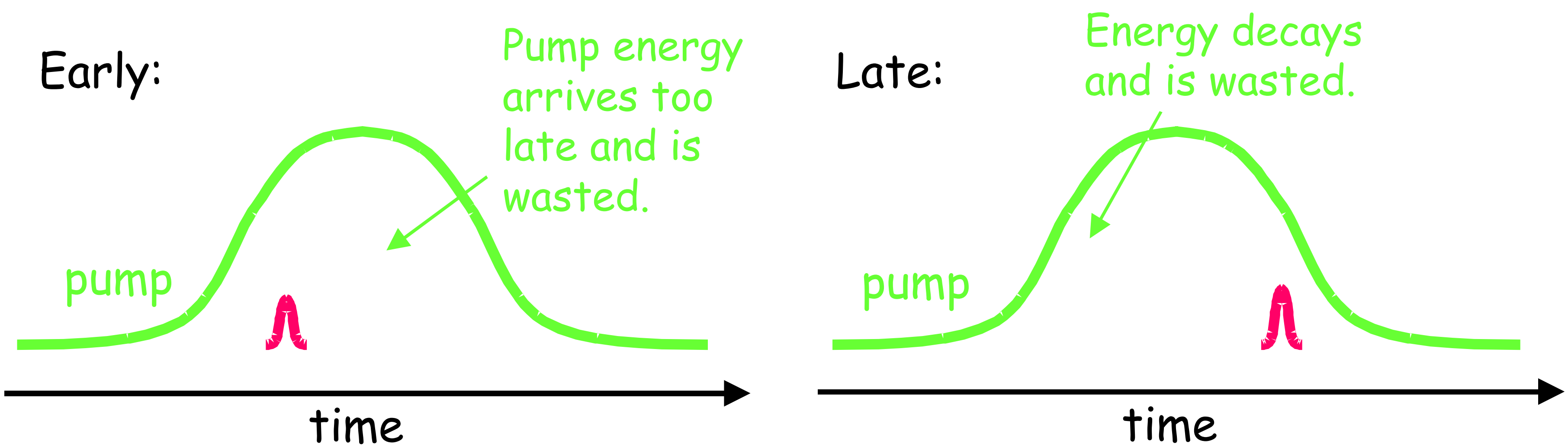


Nanosecond-pulse laser amplifiers pumped by other ns lasers are commonplace.

What's different about amplifying ultrashort laser pulses?

The first issue is that the ultrashort pulse is so much shorter than the (ns or μs) pump pulse that supplies the energy for amplification.

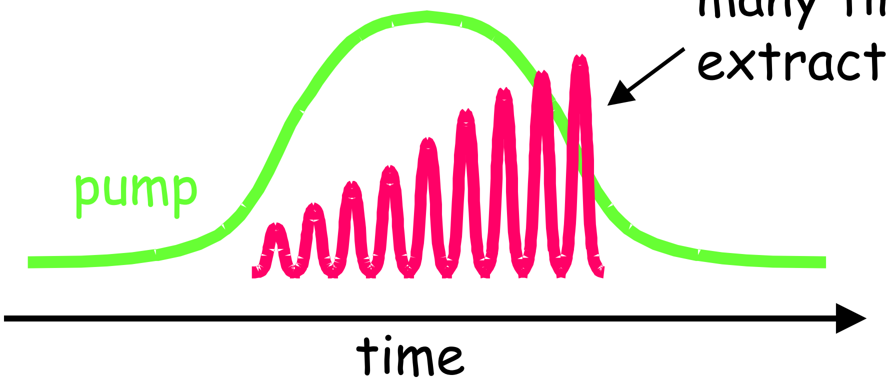
So should the ultrashort pulse arrive early or late?



In both cases, pump pulse energy is wasted, and amplification is poor.

So we need many passes.

All ultrashort-pulse amplifiers are multi-pass.

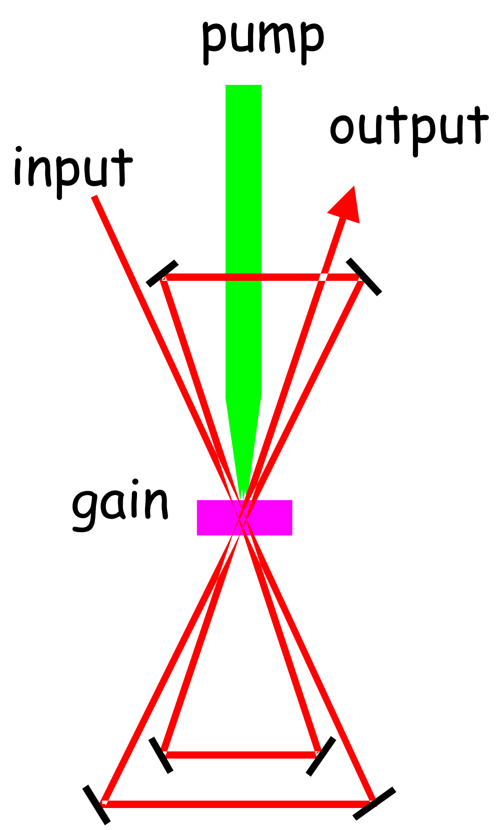


The ultrashort pulse returns many times to eventually extract most of the energy.

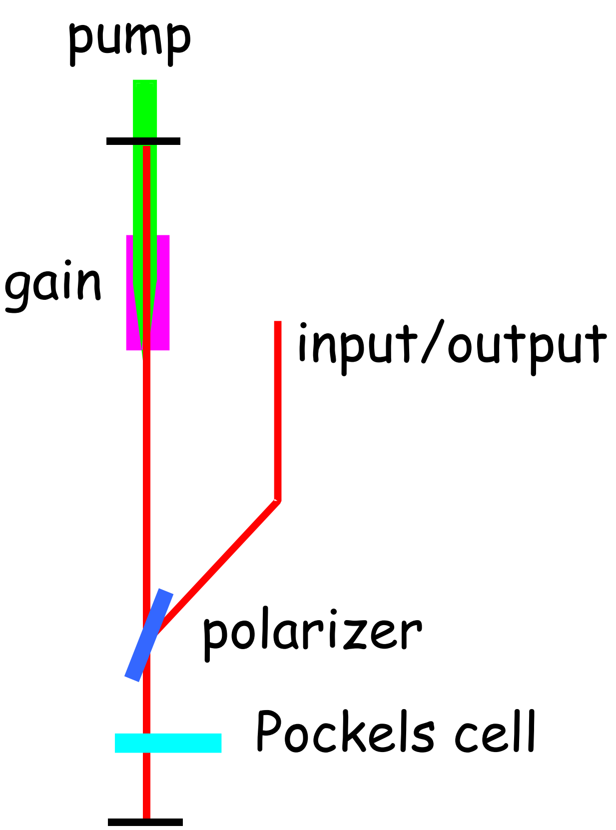
This approach achieves much greater efficiency.

Two Main Amplification Methods

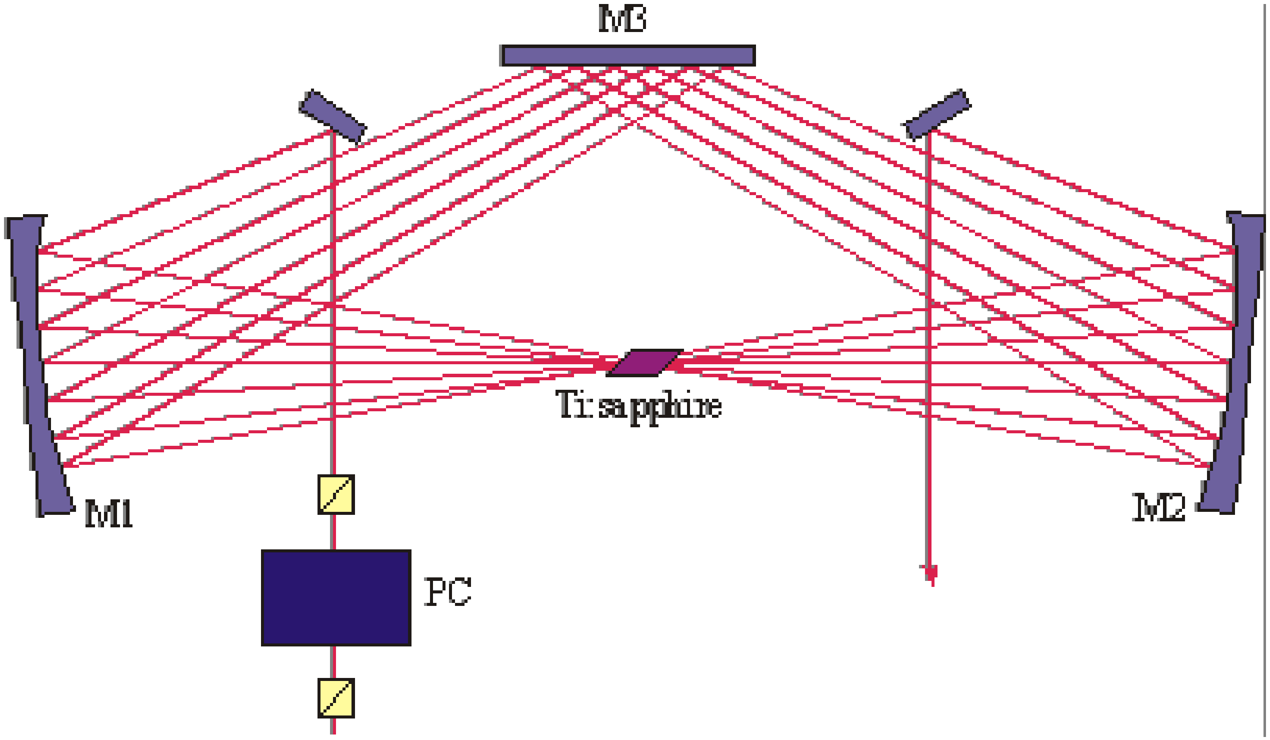
Multi-pass amplifier



Regenerative amplifier



A Multi-Pass Amplifier



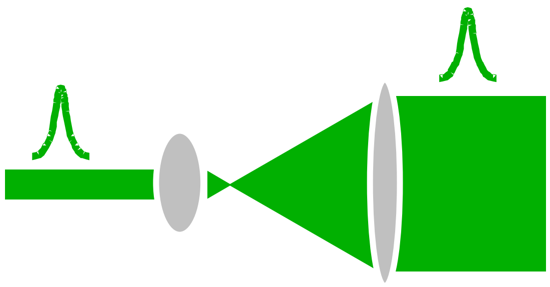
A Pockels cell (PC) and a pair of polarizers are used to inject a single pulse into the amplifier

Okay, so what next?

Pulse intensities inside an amplifier can become so high that **damage** (or at least small-scale self-focusing) occurs.

Solution:

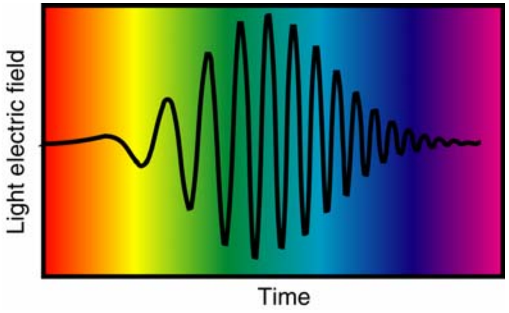
Expand the beam and use large amplifier media.



Okay, we did that. But that's still not enough.

Solution:

Expand the pulse **in time** , too.

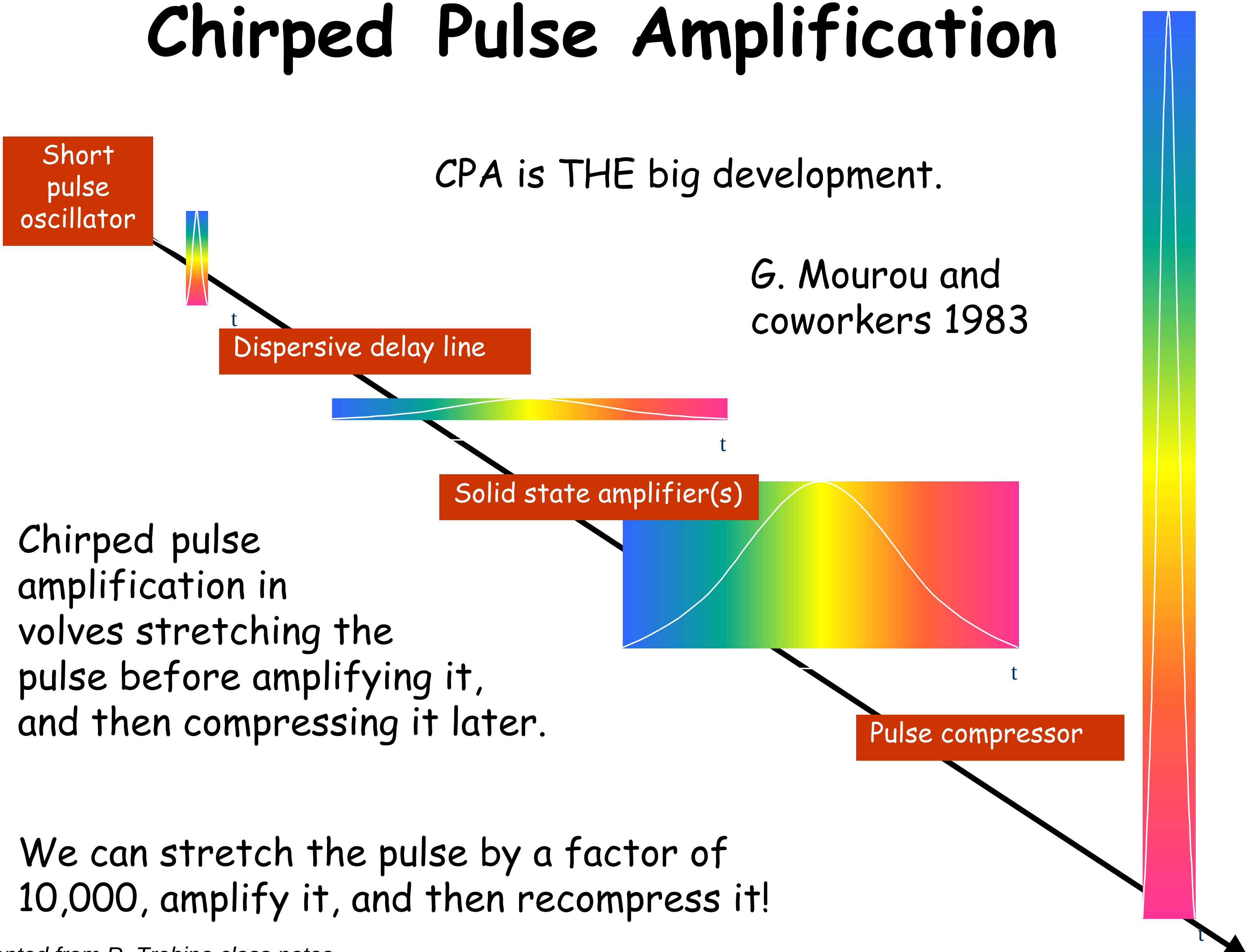


Adapted from R. Trebino class notes

Chirped Pulse Amplification

CPA is THE big development.

G. Mourou and coworkers 1983

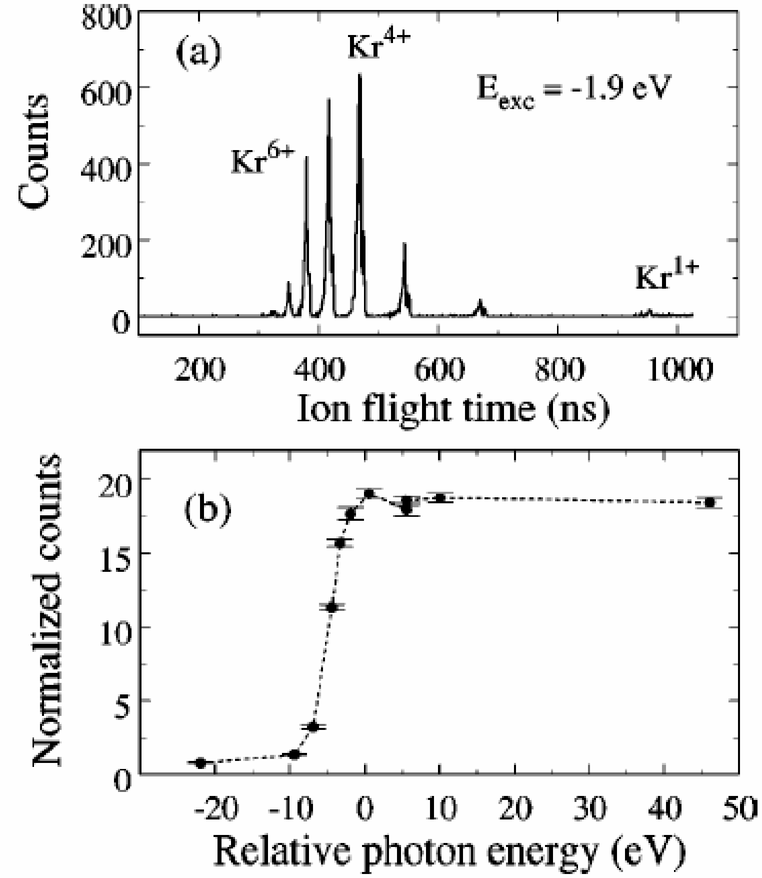


Chirped pulse amplification in volves stretching the pulse before amplifying it, and then compressing it later.

We can stretch the pulse by a factor of 10,000, amplify it, and then recompress it!

Adapted from R. Trebino class notes

Ionization of Kr



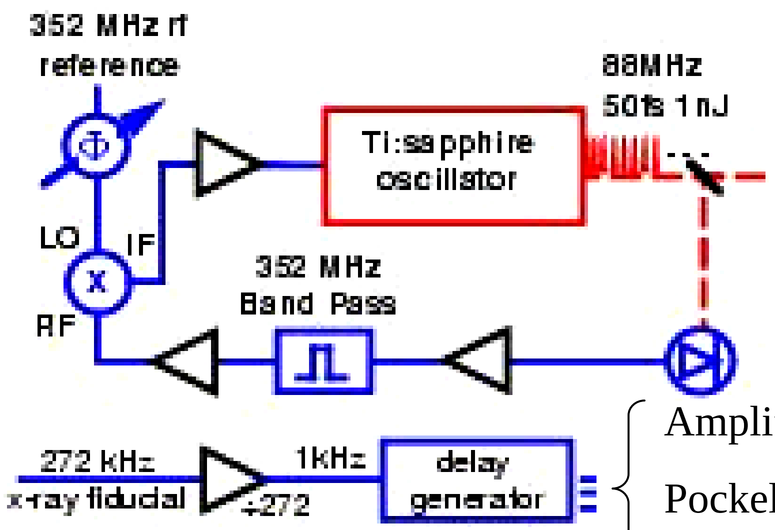
Courtesy

Linda Young, ANL

Phase Locking and Delay Scanning

Beam Derived

RF Drive Derived



P0

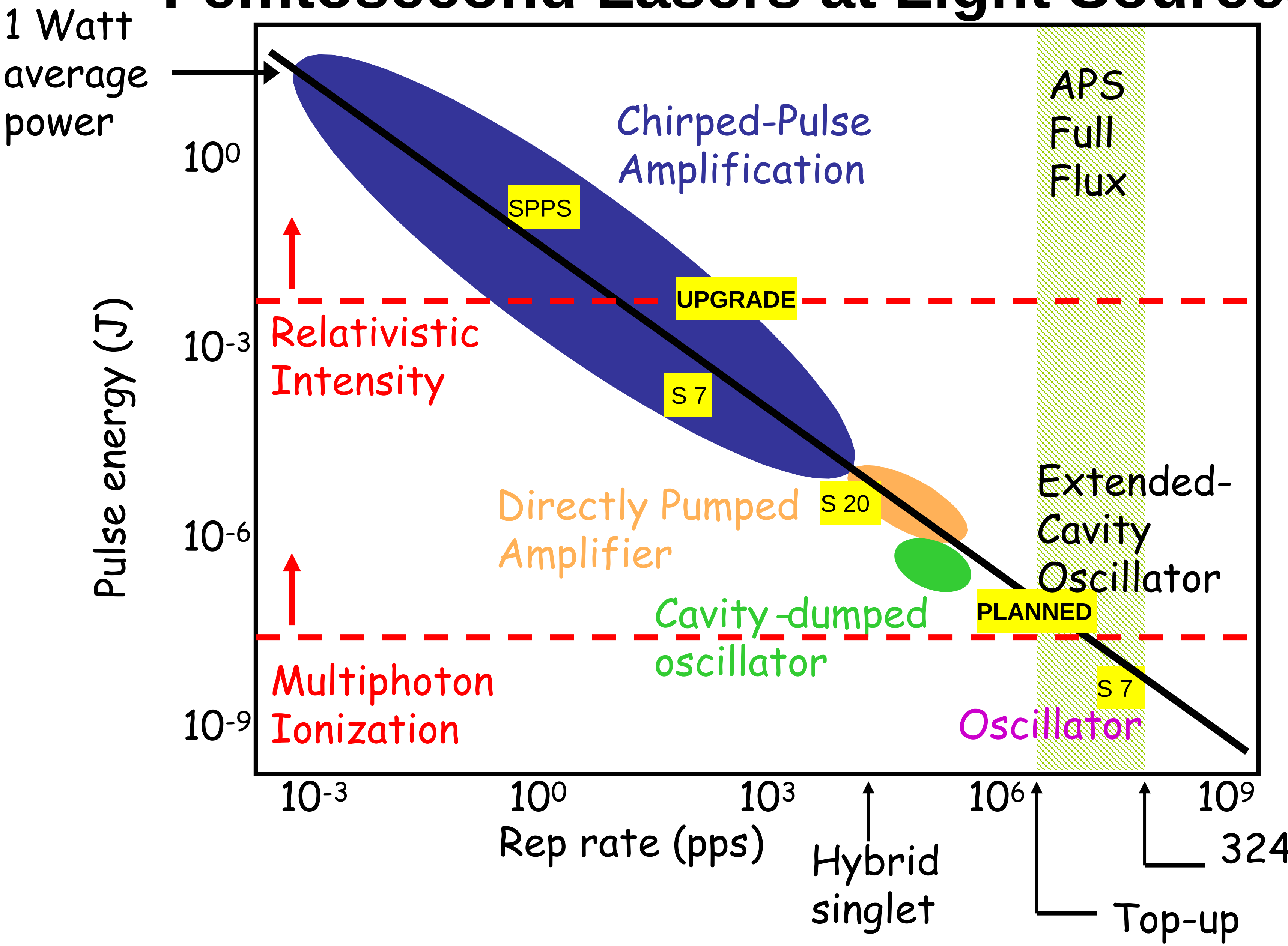
Amplifier Pump

Pockels Cell

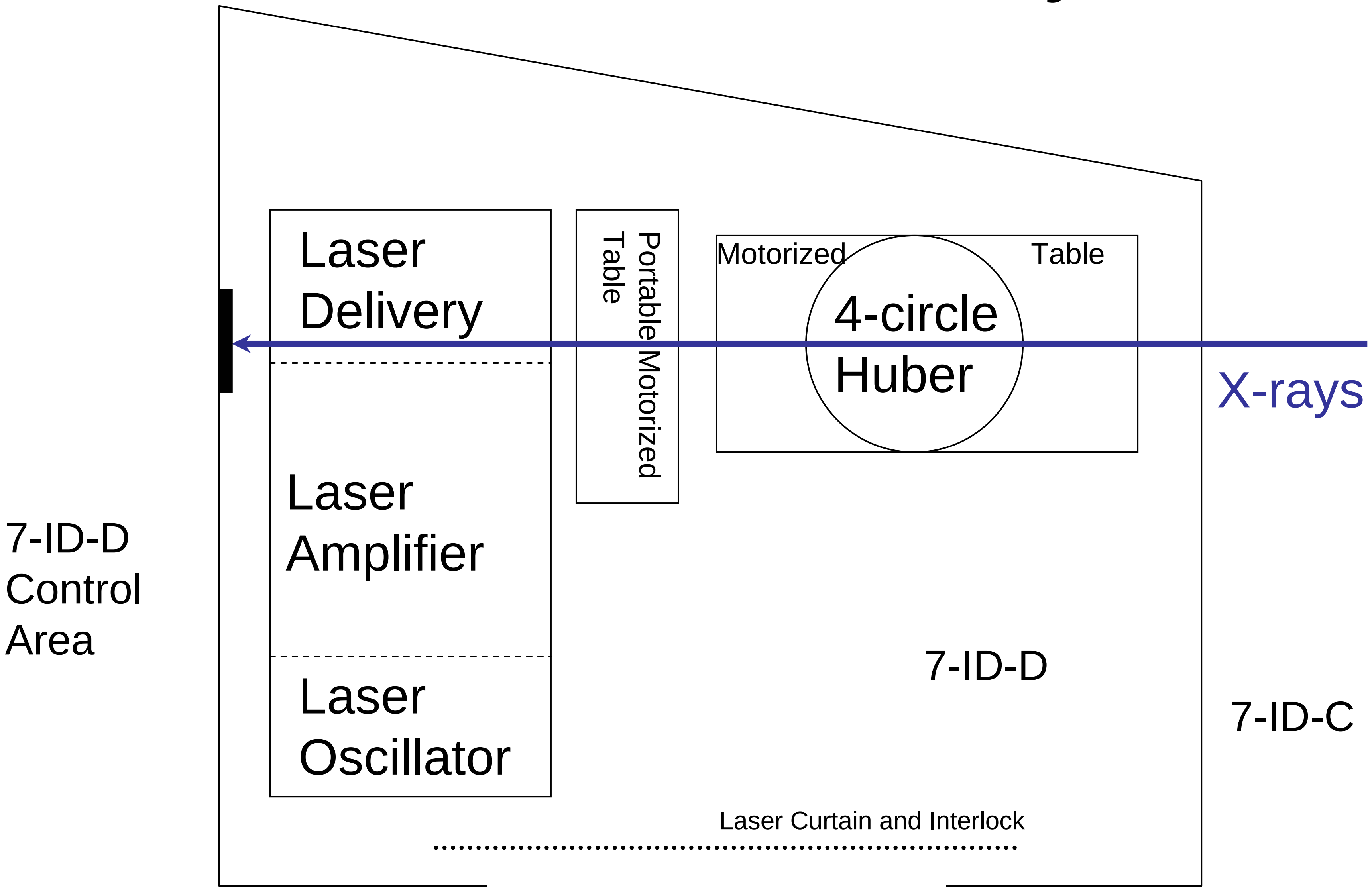
Triggers

EPICS

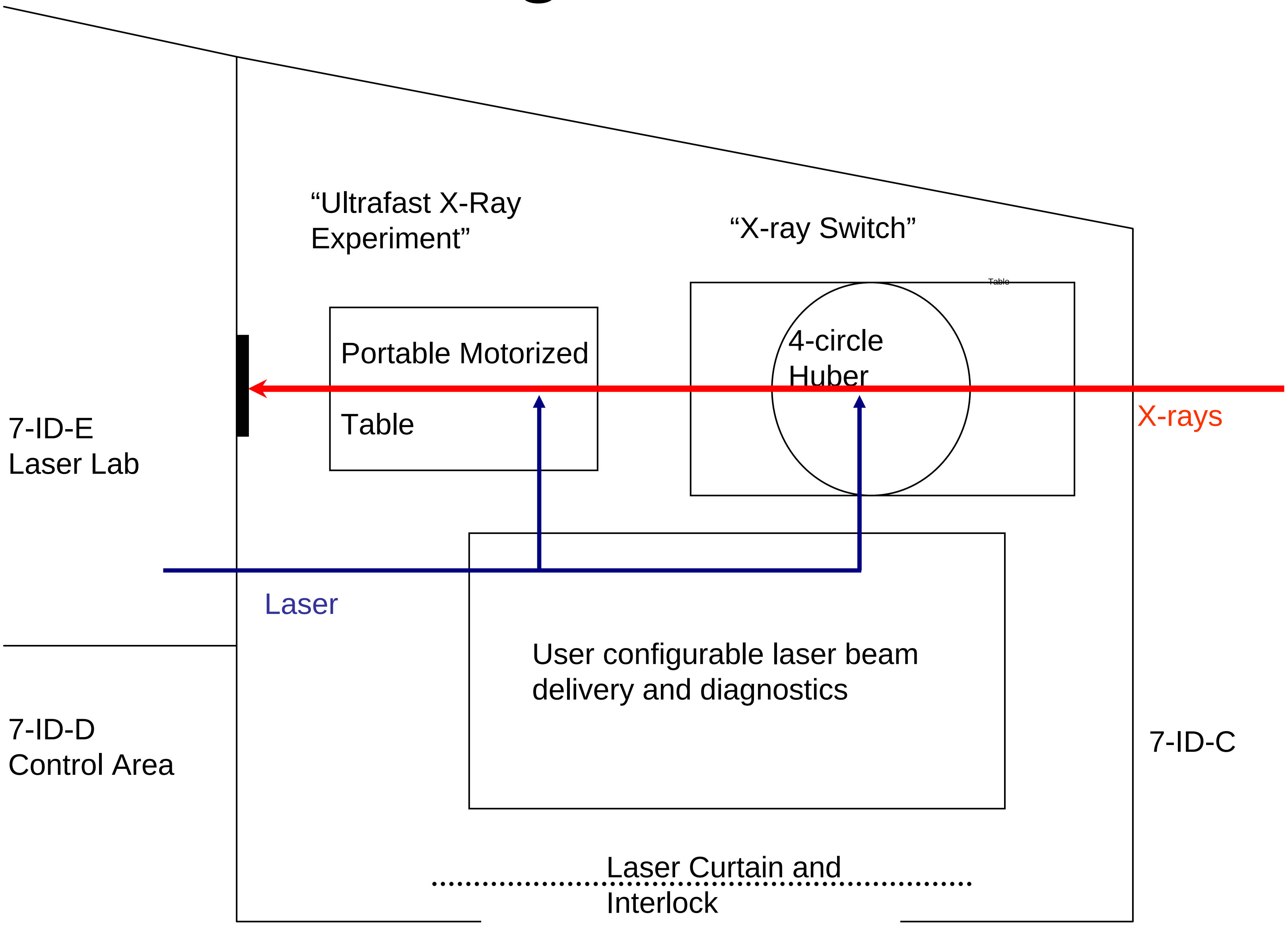
Pulse energy vs. Repetition rate: Femtosecond Lasers at Light Sources



TODAY: 7-ID-D Layout

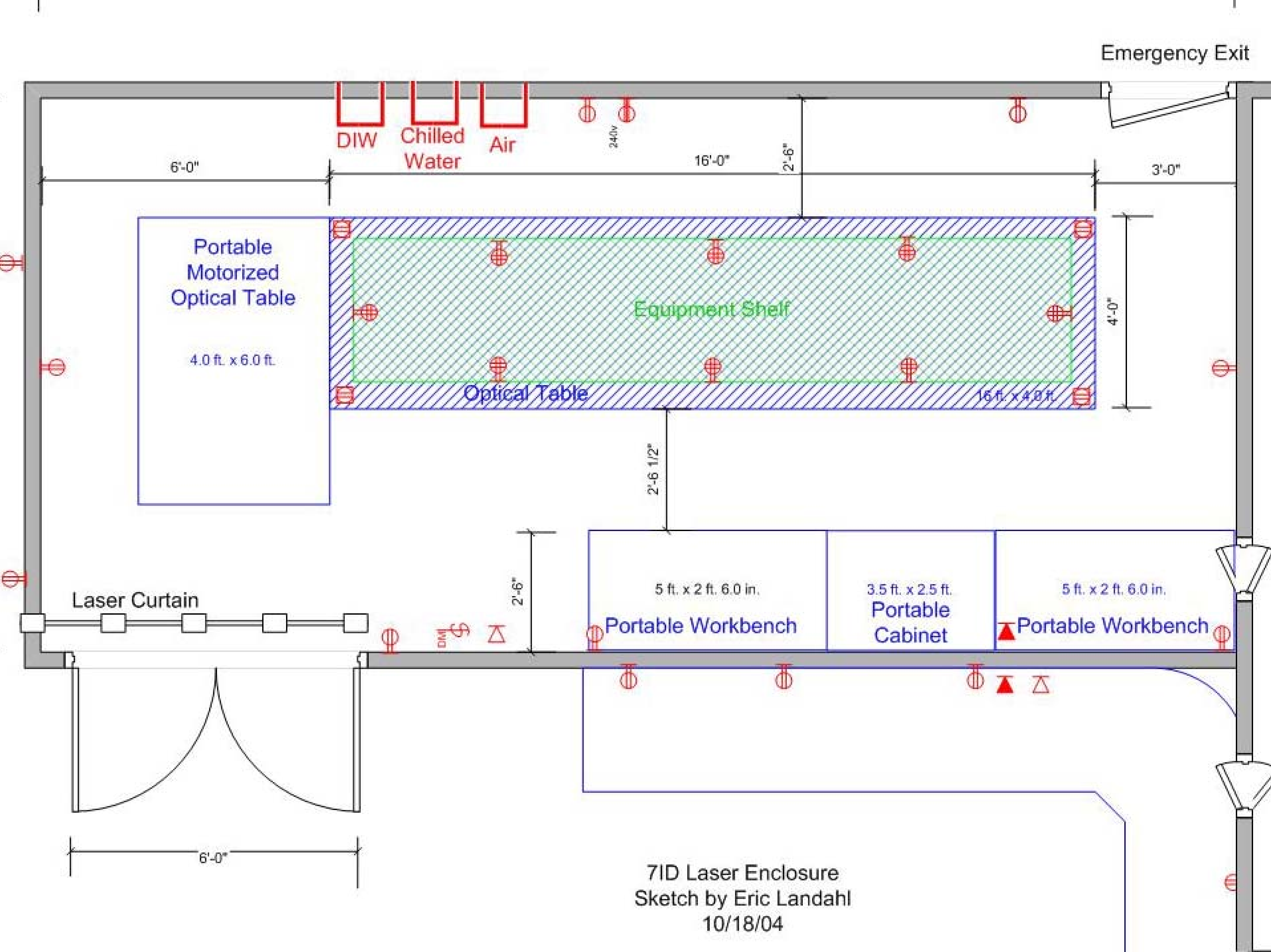


Future Configuration of 7-ID-D

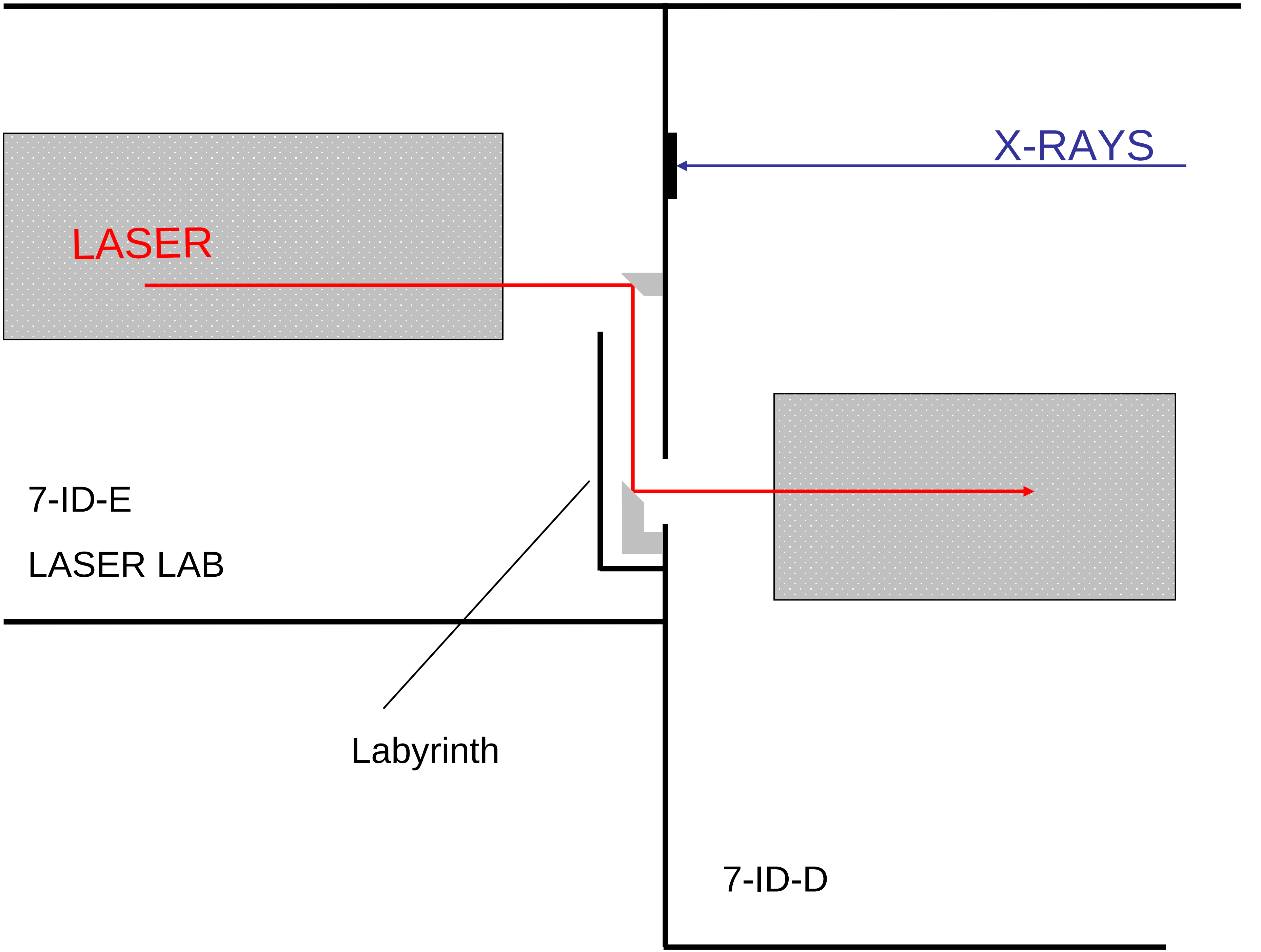


Justifications for a Laser Hutch

- Poor temperature stability degrades laser performance and delays data taking (wasting beamtime)
- Cleanroom-like environment quality necessary to ensure laser manufacturers meet specifications
- Laser safety
- Limiting access to the laser during the experiment will improve laser reliability and stability
- X-ray setup and non-laser experiments could be performed simultaneously alongside laser optimization



7ID Laser Enclosure
Sketch by Eric Landahl
10/18/04


X-RAYS
LASER
7-ID-E
LASER LAB
Labyrinth
7-ID-D