Laser Facilities and Upgrades

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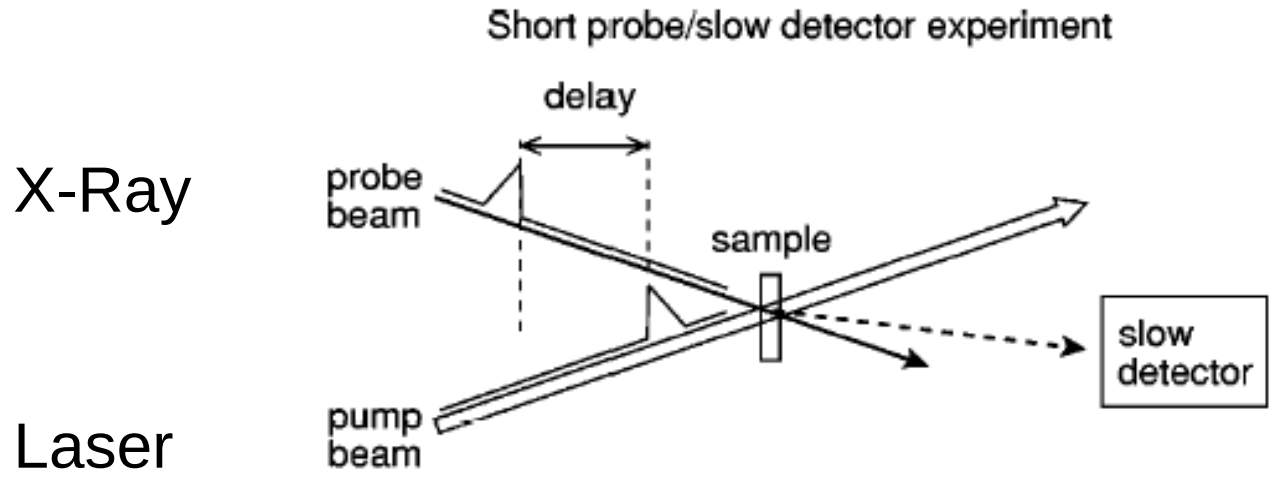
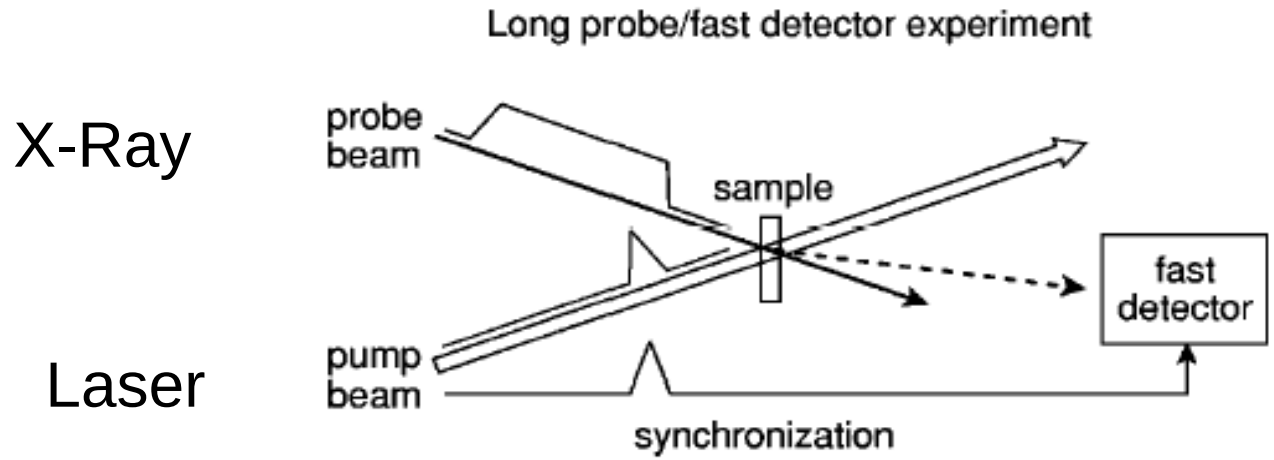
Sector 7

Two types of pump/probe experiments



Time resolution limited by probe duration; X-ray chopper may be required



Time resolution limited by detector; poor sensitivity

Jitter is an issue with both types of experiment.

Rousse et al., RMP 73, 17 (2001).

X-RAY VISIONS: TODAY'S SYNCHROTRONS AND BEYOND

Machine	Photons per pulse	Pulse length	Pulses per second	Estimated cost
3rd-Generation Synchrotron	10^2–10^4	~10–160 ps	5.4 million	>$1 billion
Slicing Source	10^3–10^4	~100 fs	10–10,000	$5 million
Short-Pulse Photon Source	10^8	~100 fs	10	$0.1 million to ?
Recirculating Linac	10^4–10^7	~100 fs	1000–10,000	$300 million to $500 million
Free Electron Laser (LCLS)	10^{11}–10^{12}	~200 fs	60–360	$250 million

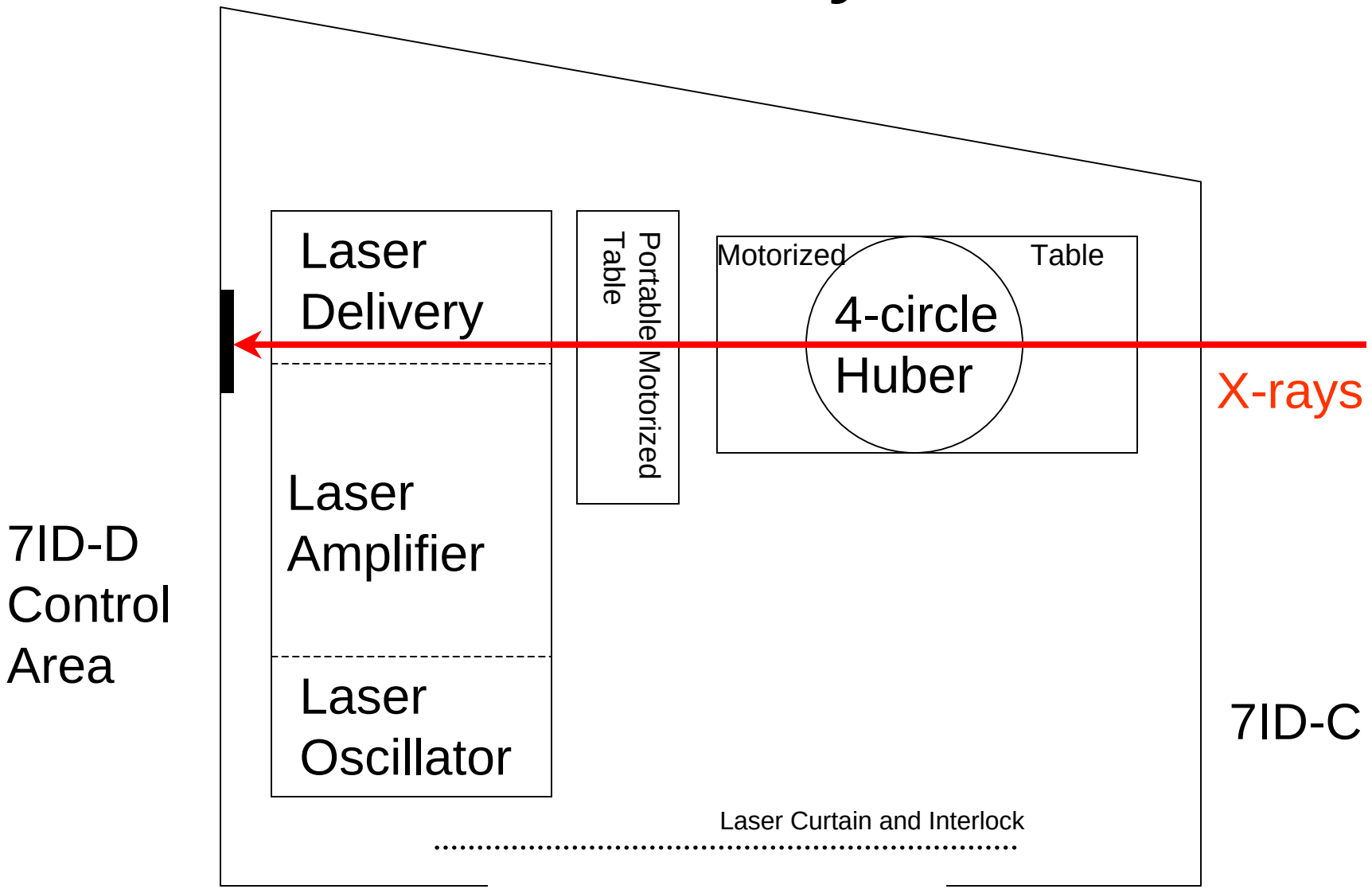
ps = picoseconds, or 10^{-12} seconds

fs = femtoseconds, or 10^{-15} seconds

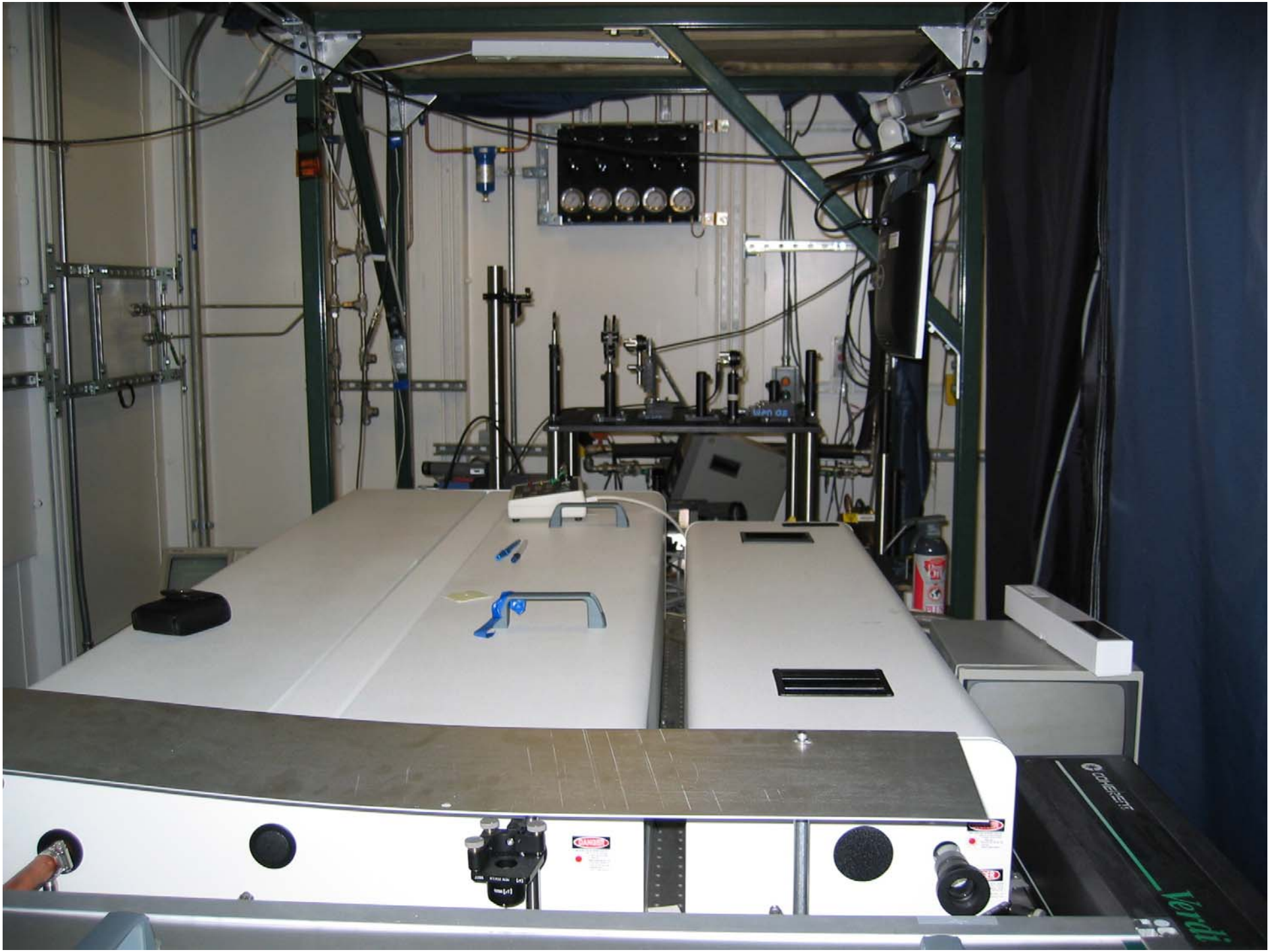
Battle to Become the Next-Generation X-ray Source

15 NOVEMBER 2002 VOL 298 SCIENCE

7ID-D Layout


Laser
Delivery
Laser
Amplifier
Laser
Oscillator
Portable Motorized
Table
Motorized
Table
4-circle
Huber
X-rays
7ID-D
Control
Area
7ID-C
Laser Curtain and Interlock


QUANTRONIX
COHERENT
Verdi
9/18/1999 2:52pm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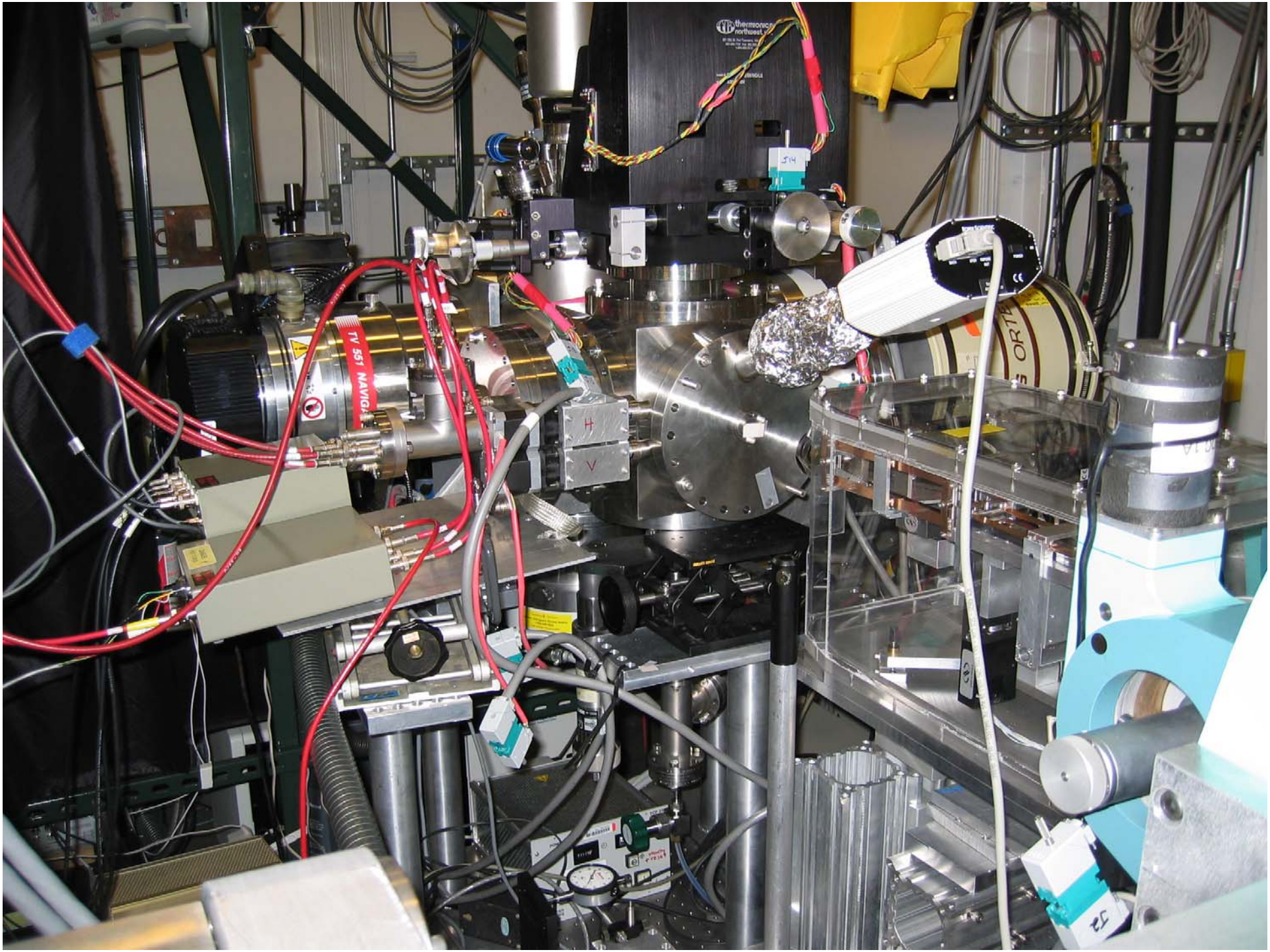
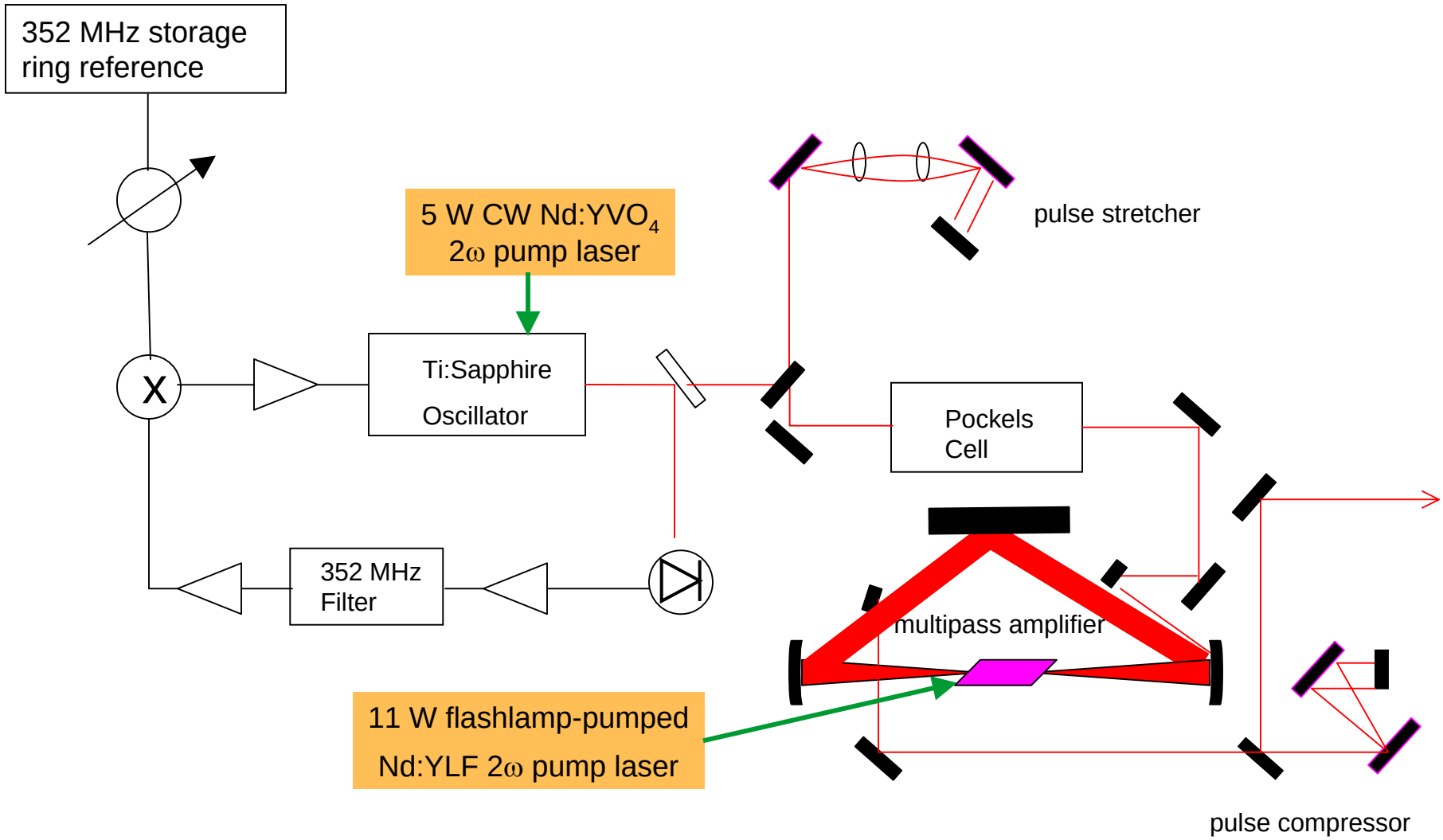

TV 551 NAVIGA
H
V

Sector 7 Ti:Sapphire CPA system



Oscillator: 88 MHz, 1nJ, 20 fs

Amplifier: 1 kHz, 0.6 mJ, 80 fs

S7 Ultrafast Laser Current Users & Laser Requirements

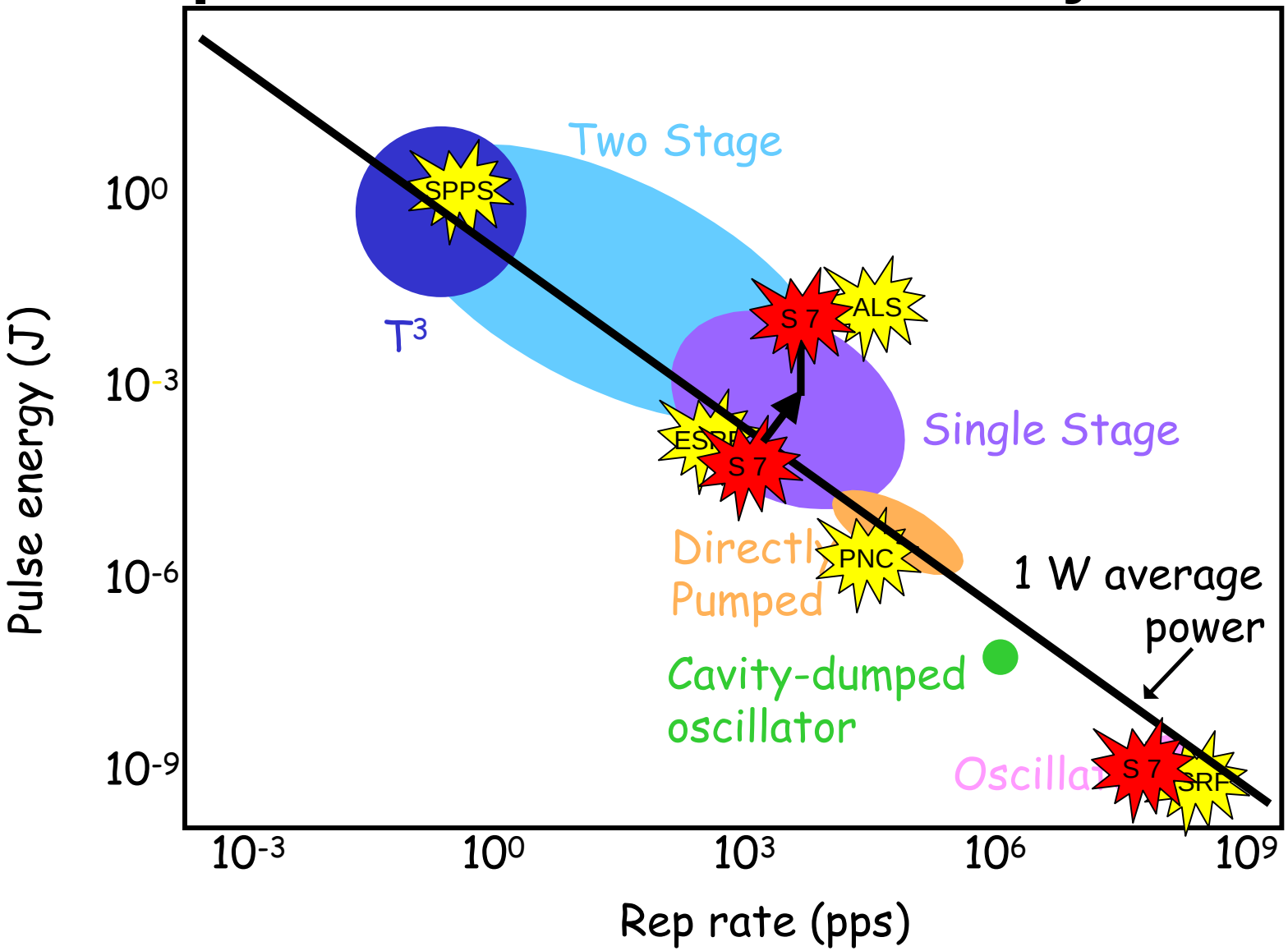
- U. Michigan (P.H.Bucksbaum, D.Reis)
  - Bragg switch — 100 μJ, 100 fs
  - Molecular orientation — 1 mJ, 100 fs
  - Compact streak camera development — 100 μJ, 100 fs
- ANL AMO Physics (L.Young)
  - Threshold shifts in photoionization → 10^{13} W/cm^2, 100 ps
  - X-ray probing of laser-excited atoms → 10^{15} W/cm^2, 50 fs
- APS XFD (B.Adams)
  - Laser pump, X-ray probe spectroscopy on GaAs — 2ω, 100 μJ, ps
  - Coherent optical phonons — < 50 fs, 88 MHz
- APS XFD (J. Wang)
  - Low jitter streak camera development → 1 mJ, 100 fs
- ANL Radiation Chemistry (R. Crowell) — 3ω, 100 μJ, 500 fs
  - XAS with ultrafast and UV pump lasers
- Ultrafast PUP, XTRA Collaboration, …

Laser stability is critical

Need for a New Laser Amplifier

- Existing laser oscillator and University of Michigan developed timing system continue to perform very well
- Amplifier pump laser (Quantronix, Inc.) is outdated, partially damaged, and operates well below specifications
- Beamtime is sometimes lost and data is sometimes compromised by laser failures and inadequacies
- All solid-state commercial femtosecond laser systems are now available with drastic improvements in average power, reliability, stability, and beam quality / intensity
- These improvements are critical to several experiments
- Higher average power is directly related to faster data acquisition
- Reliable operation will be expected by new General Users

Average Power:
Sub-picosecond Lasers at X-ray Sources



Adapted from R. Trebino class notes

Proposed Two-Phase Laser Upgrade

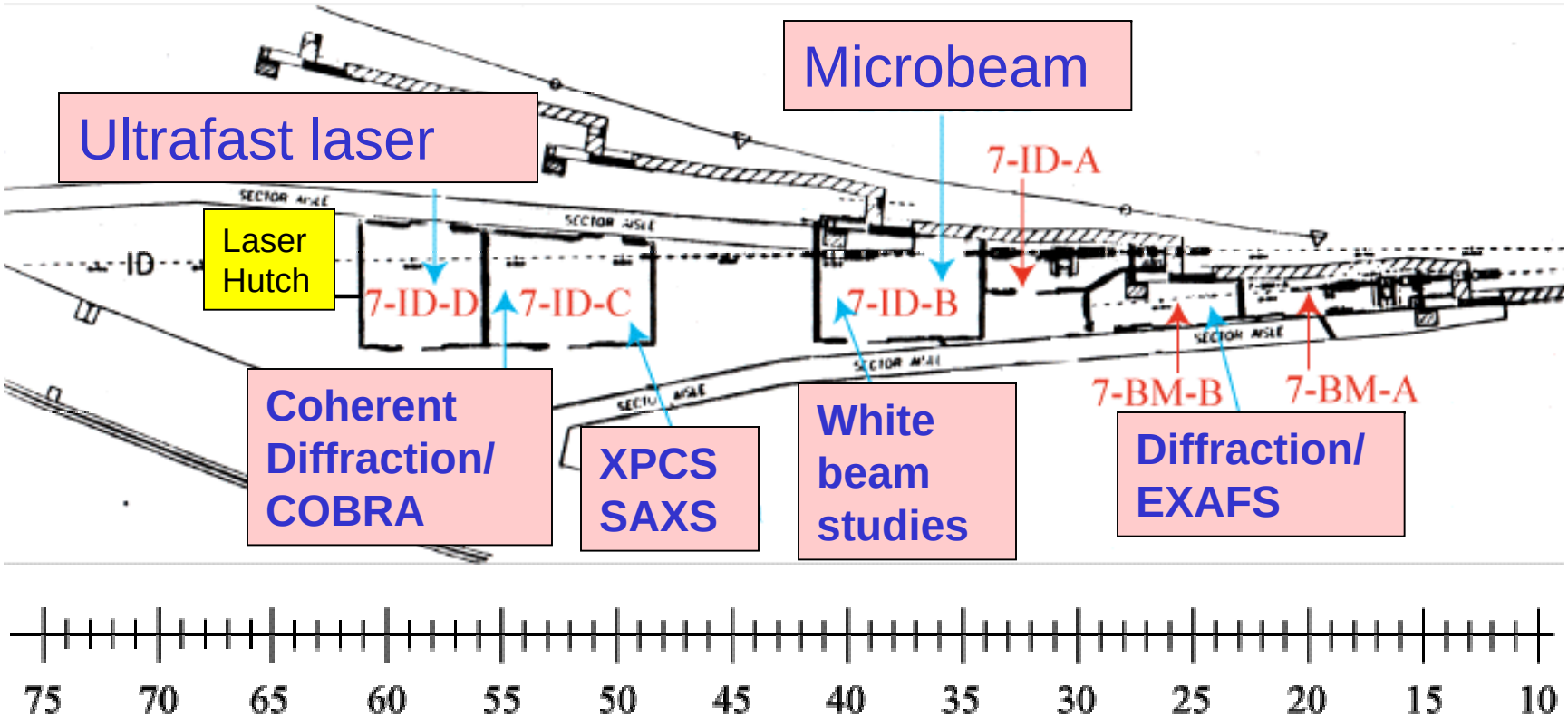
	Today [1]	Specified [2]	Upgrade Phase I	Upgrade Phase II
Cost	$10,000 [4]	$70,000	$255,000[3]	$130,000[3]
Output Power [5]	0.6 W	1 W	2.5 W	6.5 W
Duration FWHM	80 fs / 20 ps	50 fs / 30 ps	< 35 fs / 180 ps	< 35 fs / 180 ps
Pump Power	11 W	14 W	90W (30W used)	90 W
Pump Type	Arclamp-pumped	Arclamp-pumped	Diode-pumped	Diode-pumped
Repetition Rate	1 kHz [6]	1 kHz	1 - 10 kHz	1 - 10 kHz
Design	Multipass	Multipass	Regen	Regen + LN_2 cooled Multipass
Energy Stability (rms)	5% 1 hour > 25% 24 hour	2%	< 1% 24 hr	< 1% 24 hr
Pointing Stability	Poor long-term	100 μrad	-- [7]	-- [8]
M^2	> 5	1.5	1.3	1.5
Contrast Ratio pre- / post- pulse	~ 100:1 / ~ 100:1	100:1 / 100:1	1000:1 / 100:1	1000:1 / 100:1

Notes: [1] Performance shown is following a 3-day U. Michigan tune-up [2] Including service, equipment, and supplies [3] Vendor: Coherent, Inc. (not the only option) [4] Spent to-date [5] Compressed pulse; add ~40% for uncompressed [6] 887 Hz used in hybrid singlet mode [7] Negligible contribution from the laser; instability is environment dependent [8] Field data not yet available

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

Proposed Laser-only Hutch Location



Appendix
Other lasers at APS

- BESSRC
  - 1W @ 1 kHz, few ps, time-resolved x-ray spectroscopy
- PNC-CAT
  - 1 W @ 272 kHz, sub-ps, laser melting studies
- ChemMatCARS
  - 9W @ 20 kHz, 35 ns, Nd:YAG + harmonics
  - 1.4W @ 5 kHz, 50 ns, Nd:YAG + harmonics
- BIOCARS
  - ps and ns low power lasers for protein crystallography
- UNICAT
  - laser deposition studies
- APS ASD
  - 1 mJ @ 6 Hz, 10 ps, photocathode-driven FEL operations
- NanoCAT
  - No laser yet; likely required for nano-photonics mission