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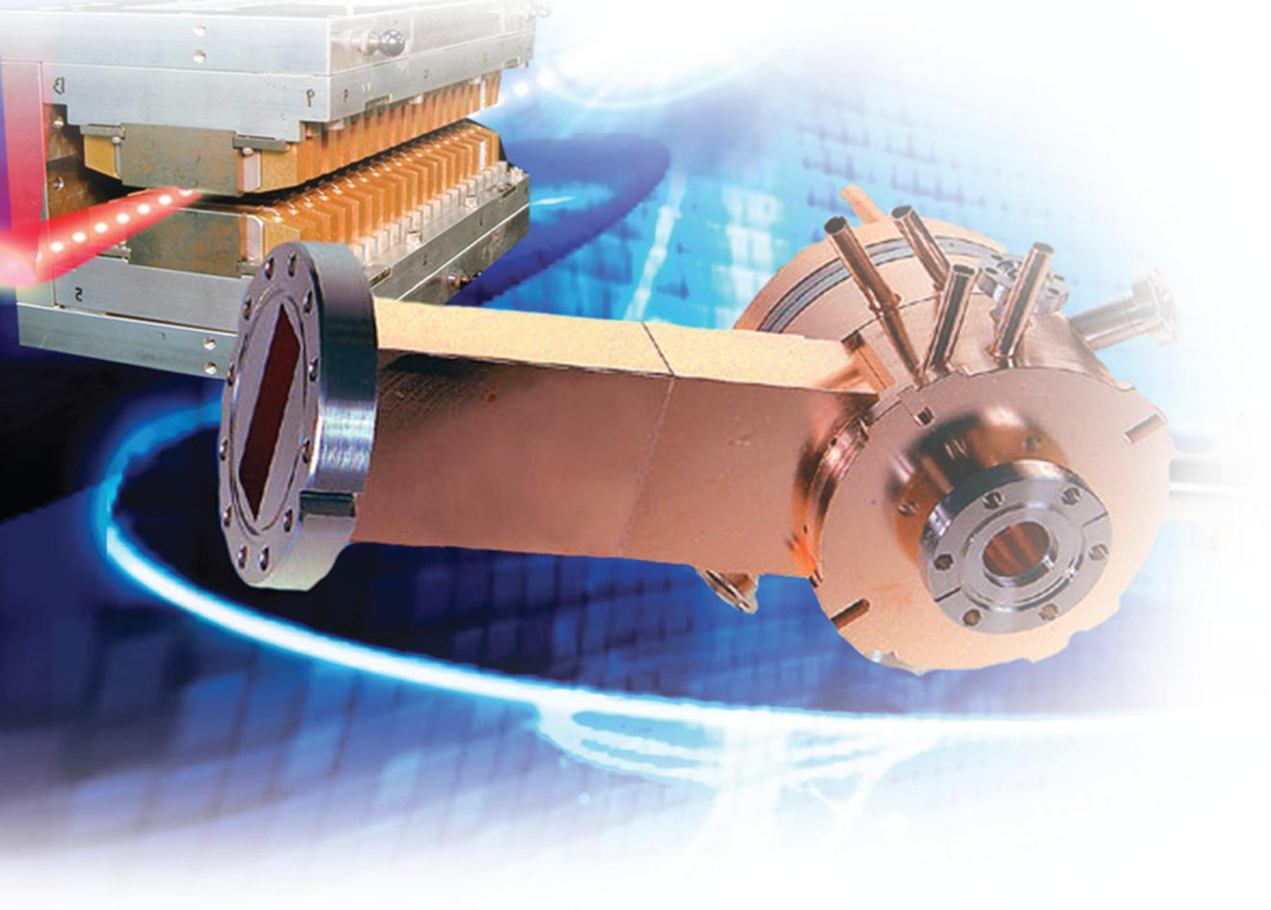

ATF-II Solid-State Laser Systems

Marcus Babzien, BNL-ATF

BROOKHAVEN NATIONAL LABORATORY
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U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

1. Laser systems & capabilities
2. Building 912 facilities
3. Example commissioning sequence

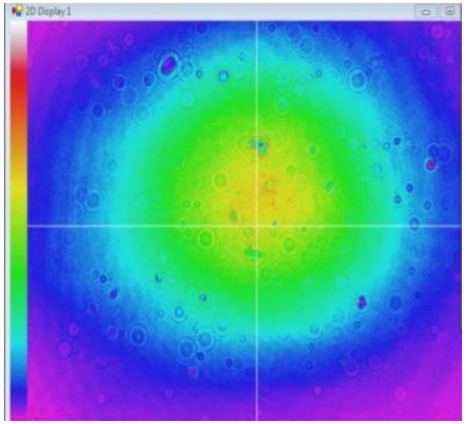
Overview of Lasers

- $Ti:Al_2O_3$ photocathode drive laser
  - High stability & uptime for serving multiple guns
- Nd:YAG pulsetrain/semiconductor switching system
  - Flexible pulse sequence generation
- $Ti:Al_2O_3$ strong field laser
  - TW high intensity pulses for experimental needs
- SDL drive laser
  - spare components for backup/upgrade of operating systems

ATF-II Photocathode Drive Laser

- Ti:Al_2O_3 regen -> single output pulse
- High repetition rate permits interleaved operation of multiple guns
- UV for linac & X-band test stand, IR for UED
- Pulse shaping improvements for photocathode operation enabled by extra bandwidth and higher energy
- Electronic synchronization will give advantages in experiment setup

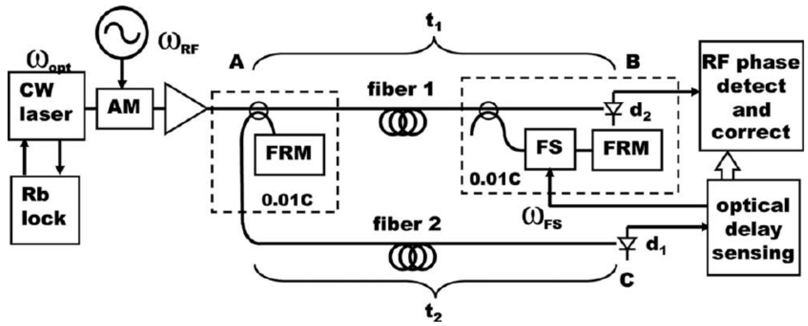
Amplifier footprint: 1x1.5 m2



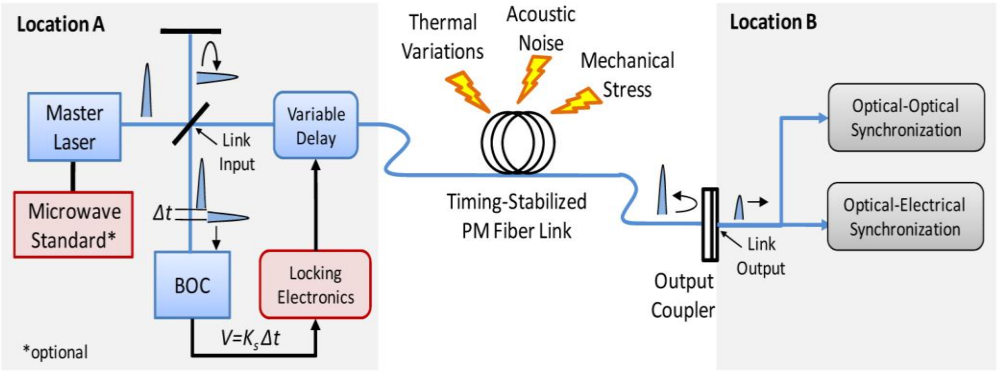
IR Pulse Duration	180 fs
Repetition Rate	240 Hz
Pulse Energy	7 mJ
Stability	<1% RMS
Beam profile	M^2<1.4

Synchronization

- 10 fs level synchronization is well within current laser technology, however …
- Environmental disturbances limiting existing RF phase-locking electronics need to be better characterized and mitigated
- No magic bullet, but ultimately stabilized optical timing distribution loops will be needed:



R. Wilcox, et al



Peng et al, "Long-term stable, sub-femtosecond timing distribution via a 1.2-km polarization-maintaining fiber link: approaching 10 link stability," Opt. Express **21,** 19982-19989 (2013); http://www.opticsinfobase.org/oe/abstract.cfm?uri=oe-21-17-19982

- Beam arrival monitors may be needed to measure e-beam jitter relative to NIR laser
- MIR to e-beam synchronization at 10 fs level is uncharted territory

ATF-I/II Nd:YAG System

- Electron/laser pulse trains are a distinguishing capability of ATF
- Used for interaction with optical cavities (e.g. Compton scattering) & raising linac average current

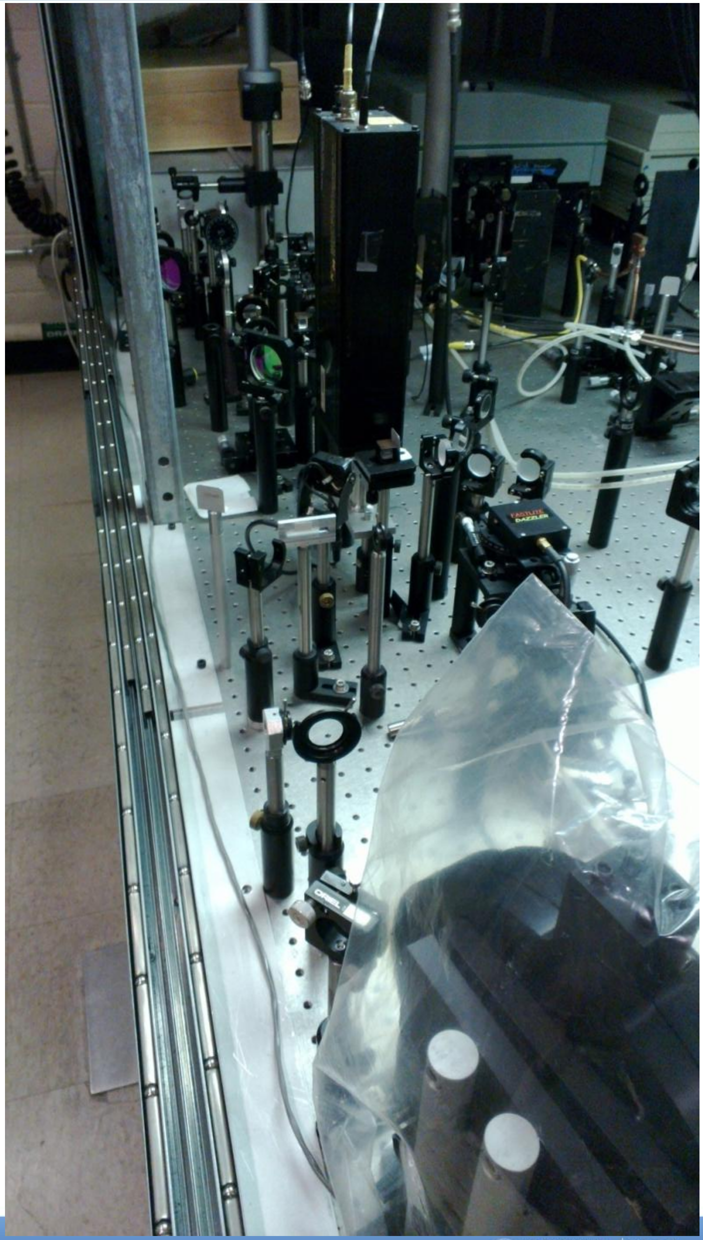
Energy: (dual pulse mode)		Transverse Distribution:	
UV on cathode	0-30 uJ x 1 pulse	Range of beam size on cathode (Ø)	0.2 - 3 mm
IR to CO2 laser	10 mJ x 2 pulses	Top-Hat Beam Profile Modulation (P-P)	<50%
Laser output: total IR	50 mJ		
IR to gun	7.5 mJ	Repetition rate	1.5, 3 Hz
Green	2.5 mJ		
UV	500 uJ	Shot-to-shot stability (rms):	
		Timing	<0.2 ps
Energy: (pulse train mode) IR	~500 mJ / 100 pulses	Energy	<0.7 %
		Pointing (fraction of beam Ø)	<0.3 %
Pulse duration (FWHM):			
Oscillator IR	7 ps	Drift (8 hour P-P)	
Amplified IR	14 ps	Timing	<3 ps
Green	10 ps	Energy	<5%
UV	8 ps	Pointing (fraction of beam Ø)	<1%

Nd:YAG Transition to ATF-II

- System is currently required for ATF-I experiments, no effective replacement is available
- Ties earliest CO_2 system move into Bldg 912 to end of ATF-I operations in Bldg 820
- Other CO_2 semiconductor switching options may be considered to decouple CO_2 transition from ATF-I linac operation

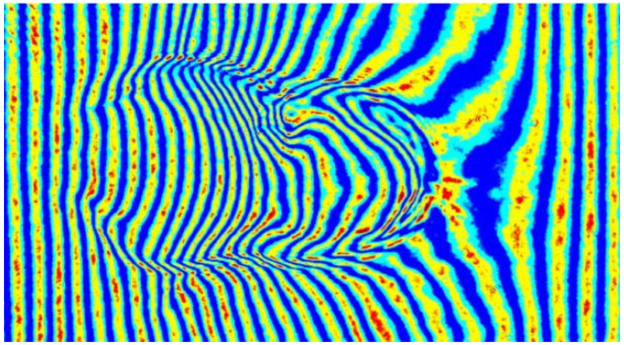
Strong Field System

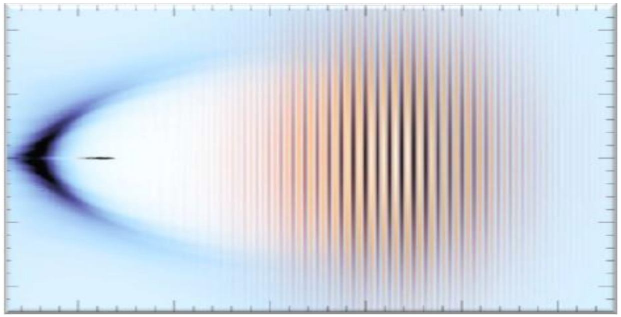
- Donated from BNL Instrumentation Division Laser Group
- Will be seeded by small pickoff from existing Ti:Sapphire drive laser (optical synchronization)
- Achieve contrast enhancement via XPW
- Inject into previously-tested flashlamp-pumped CPA amplifier chain
- Initially expect 150 mJ final output
- Pulsewidth is oscillator dependent: 50-180 fs $\Rightarrow \sim$1 TW initially
- Additional amplifier stage and grating compressor could allow 10 TW, if needed
- Transport to Exp. Hall 1 planned and accommodated in shielding design



Strong Field System

- Will provide NIR pulses for:
  - Ion generation plasma shaping (energetic NIR pulse)
  - Plasma wakefield holography (femtosecond, nm-bandwidth pulse)
  - Two-color Compton scattering (TW or greater peak power)
  - Two-color ionization injection LWA
  - FEL seeding (transform-limited pulse) VISA wiggler, etc.





- Independence from drive laser will bring greater flexibility for evolving experimental needs

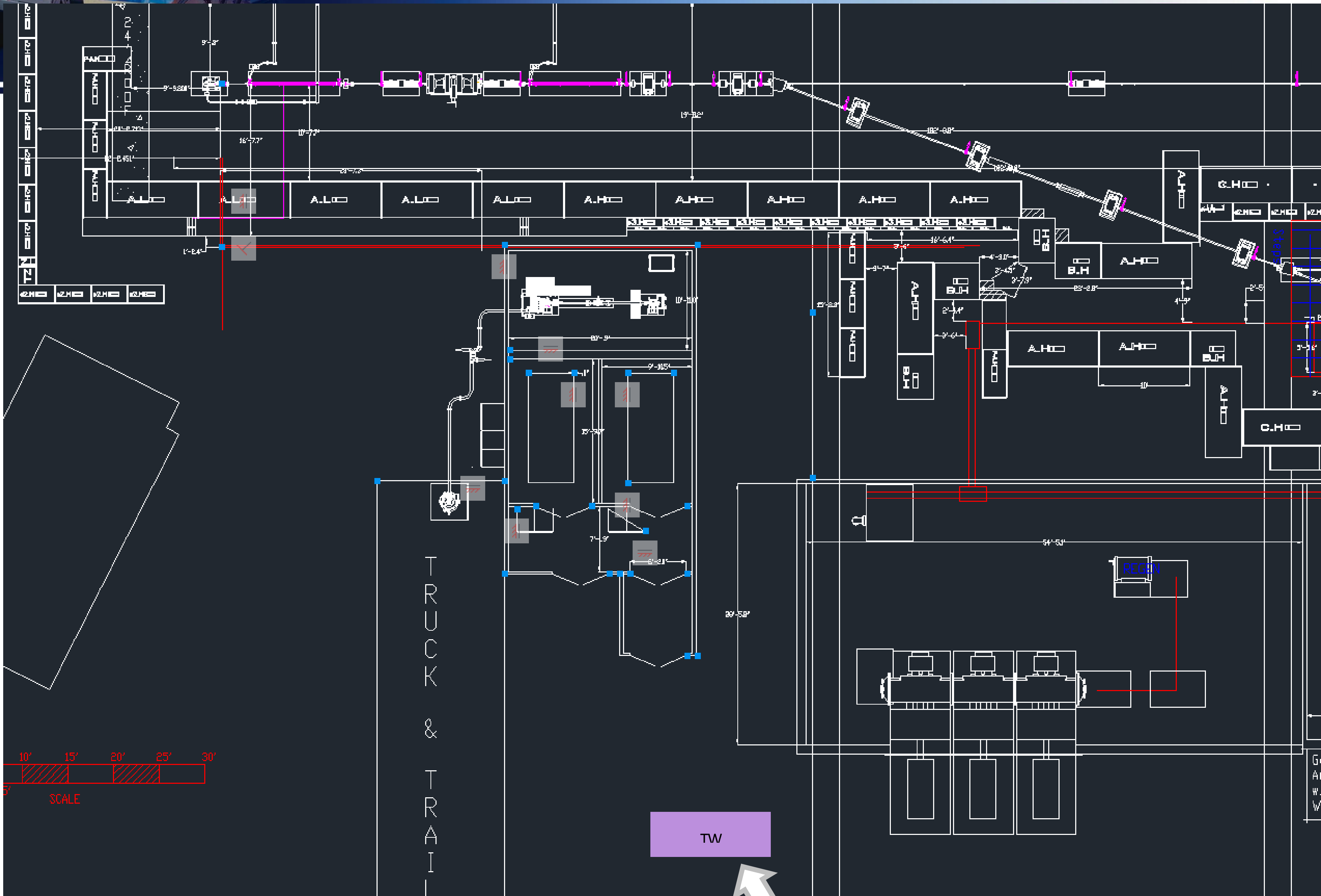
SDL Drive Laser

- UED experiment will start operations in 912 with ATF-II drive laser
- Old laser system from UED experiment in SDL will provide spare/upgrade components:
  - Shorter pulsewidth, 100 fs seed option (Femtolasers oscillator)
  - Amplifiers/pump lasers could be used to increase energy available to UED experiment for high energy OPA pumping
  - Stretcher/compressor/diagnostics may also find use in strong-field laser

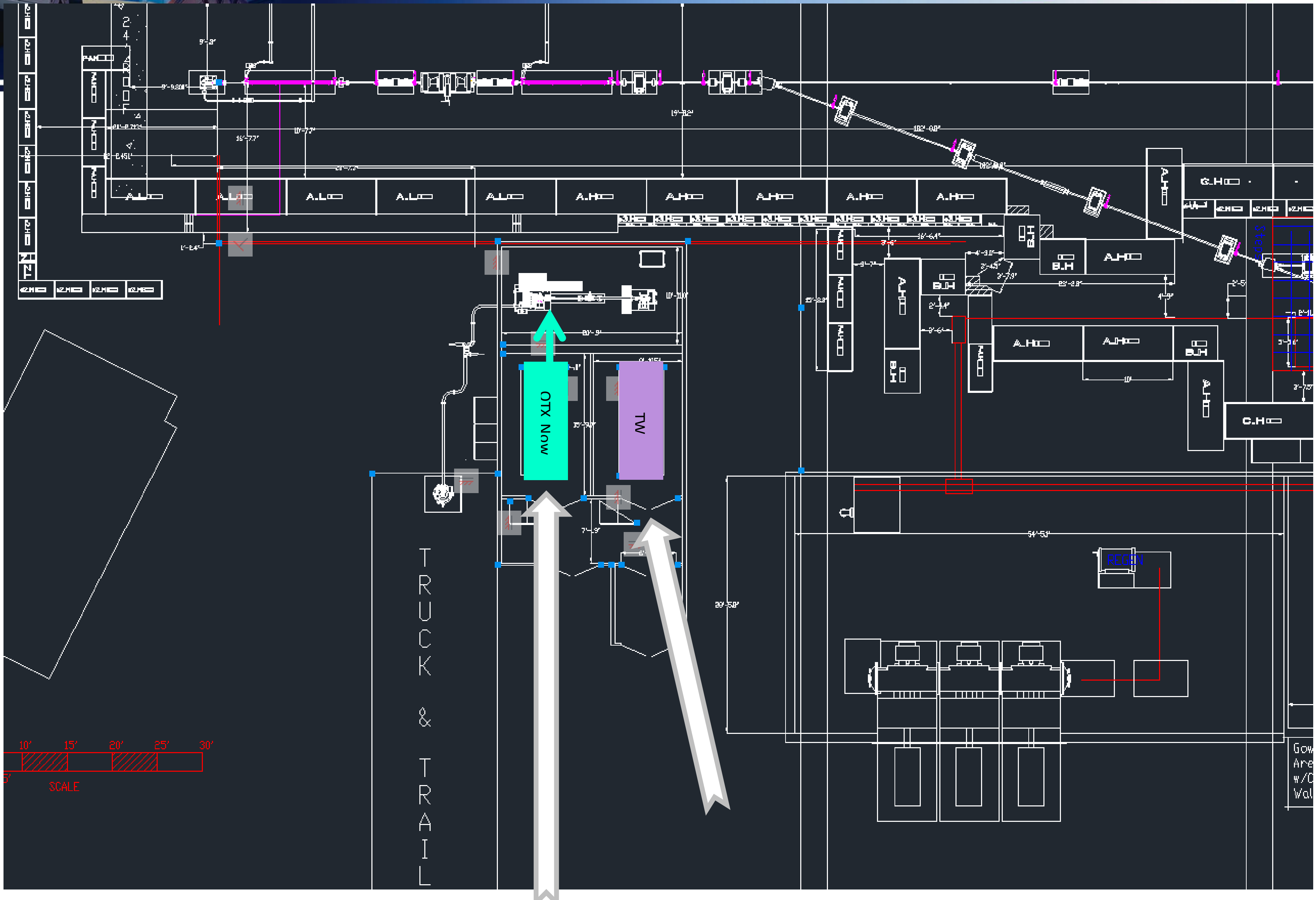
Building 912 Laser Infrastructure

- Laser clean room:
  - Space for UED experiment and two laser systems
  - Nominal temperature stability 0.05° C
  - Class 10000 air filtering
  - Laser power supply atrium
  - Separate UED and laser rooms entrances

- Independent vacuum transport lines to ATF-II gun, UED, & beamline #1
- Space constraints in 912 need to be reconciled with evolving experimental program



Solid state laser tentative installation sequence



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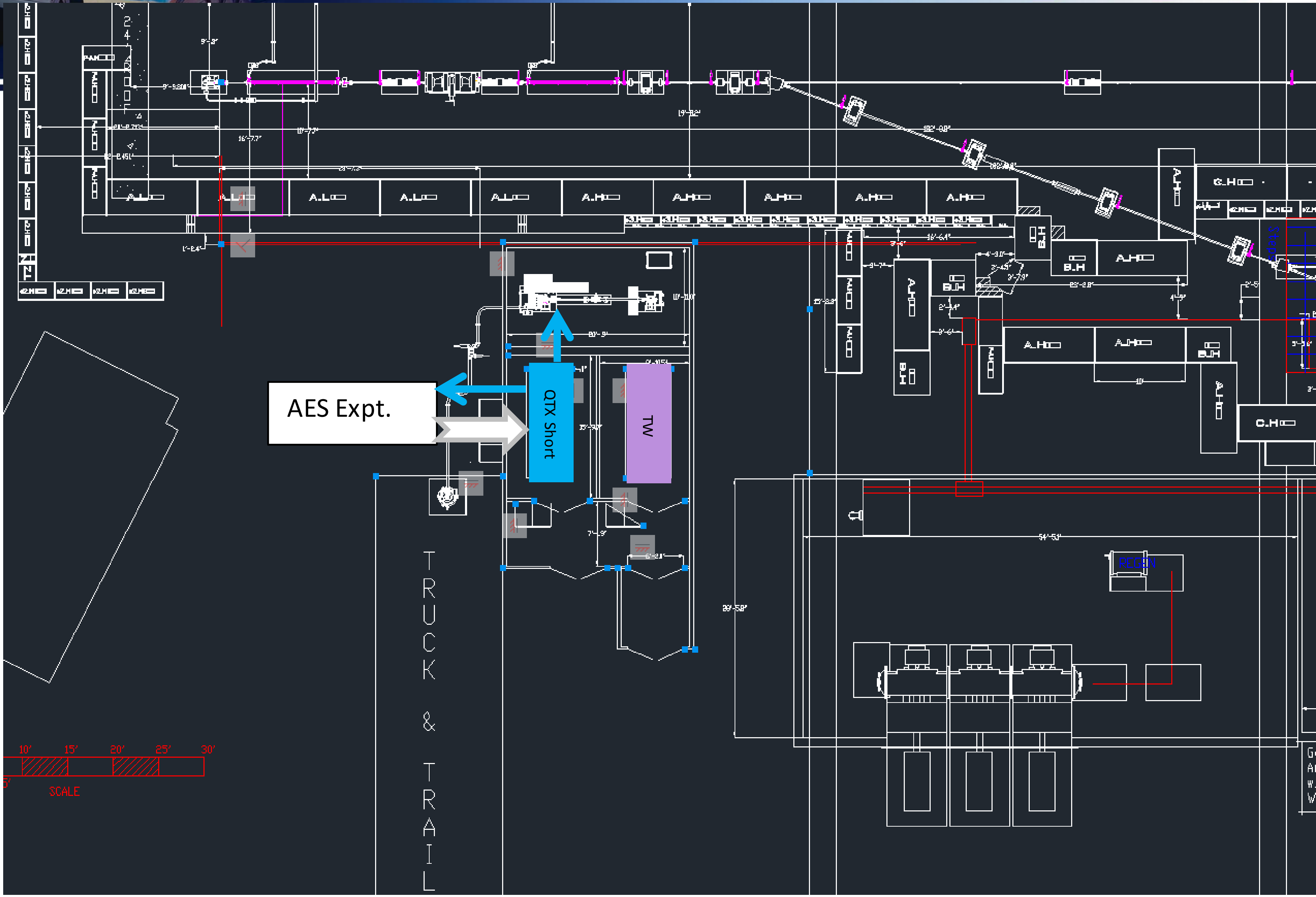

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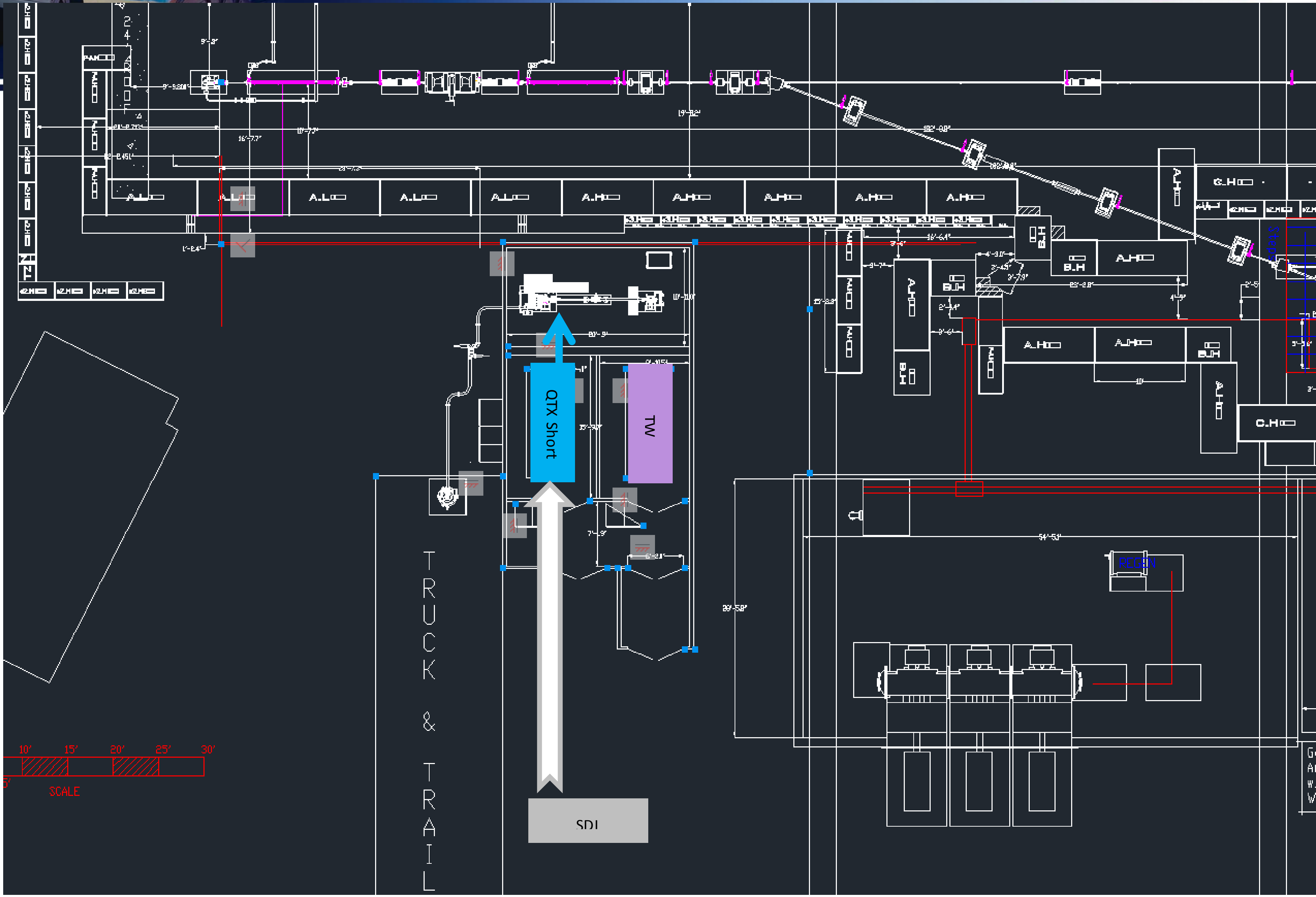

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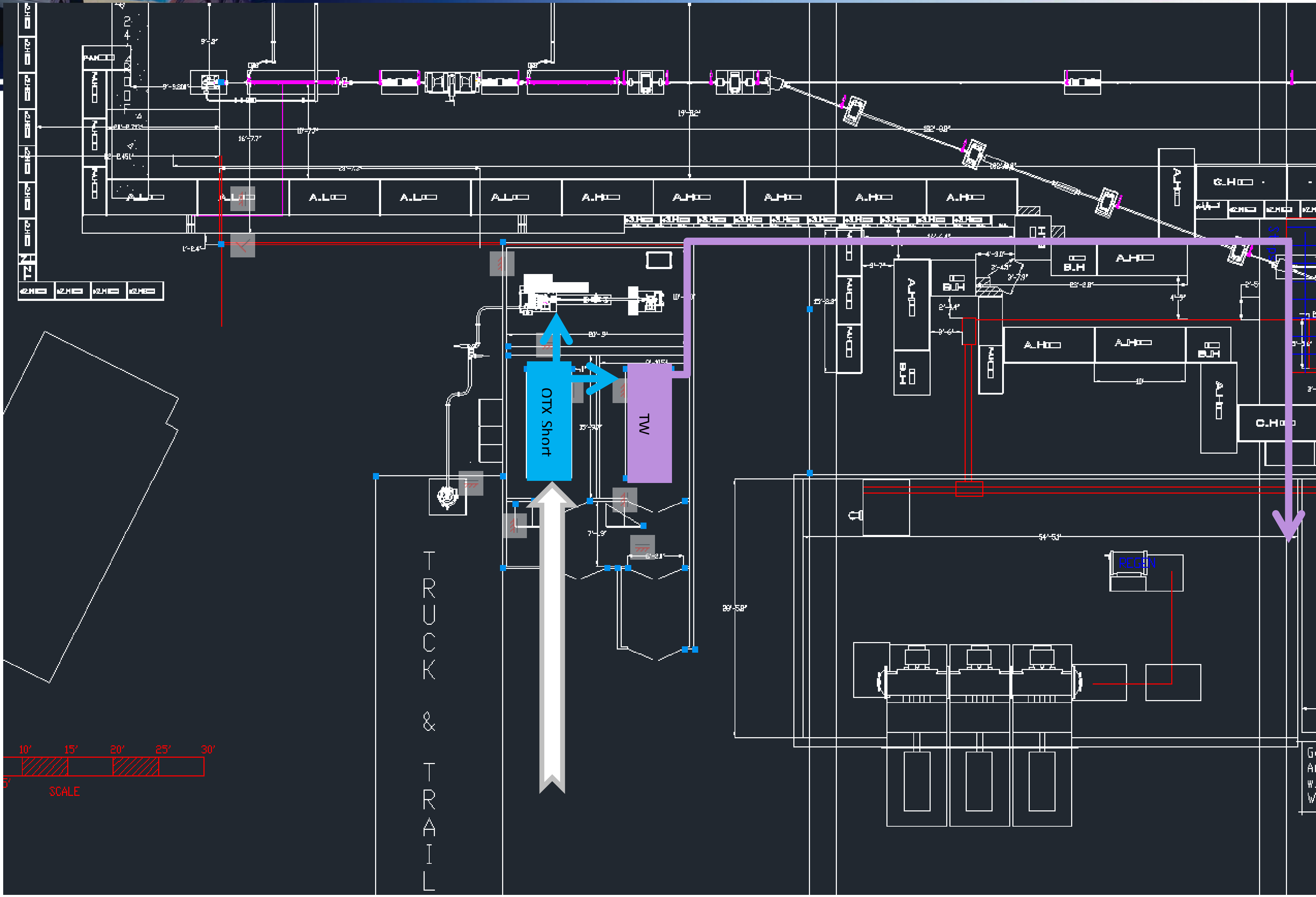

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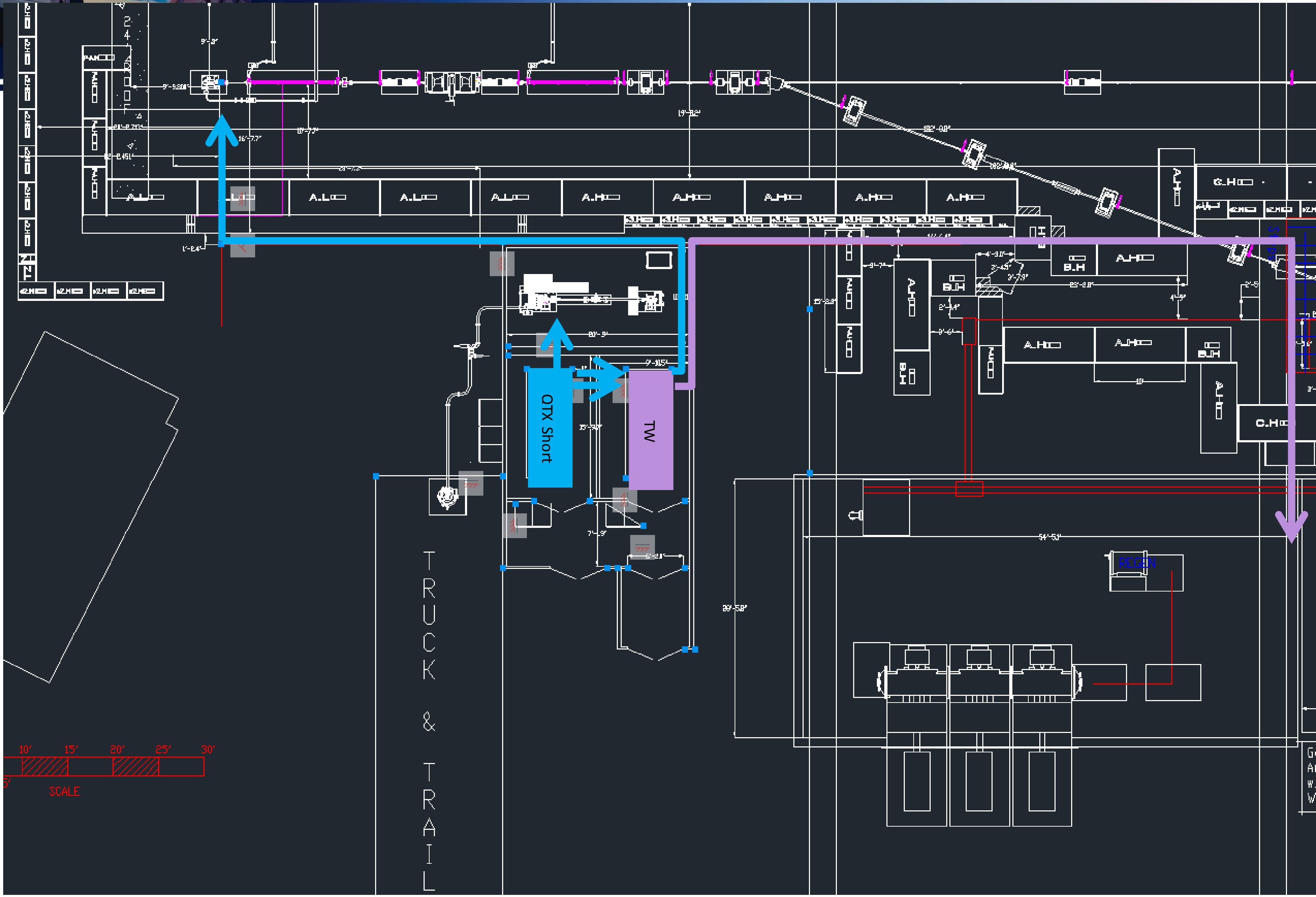

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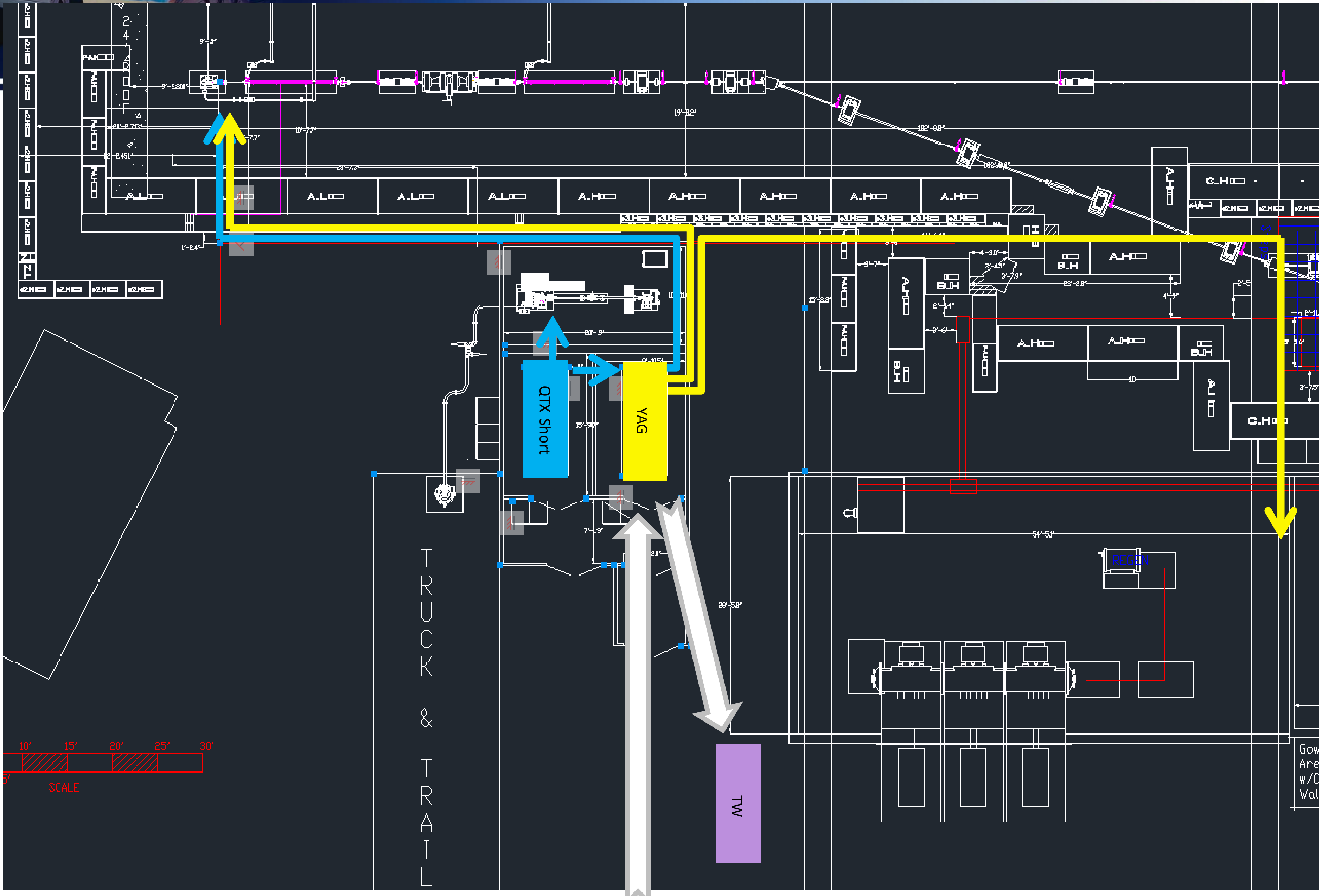

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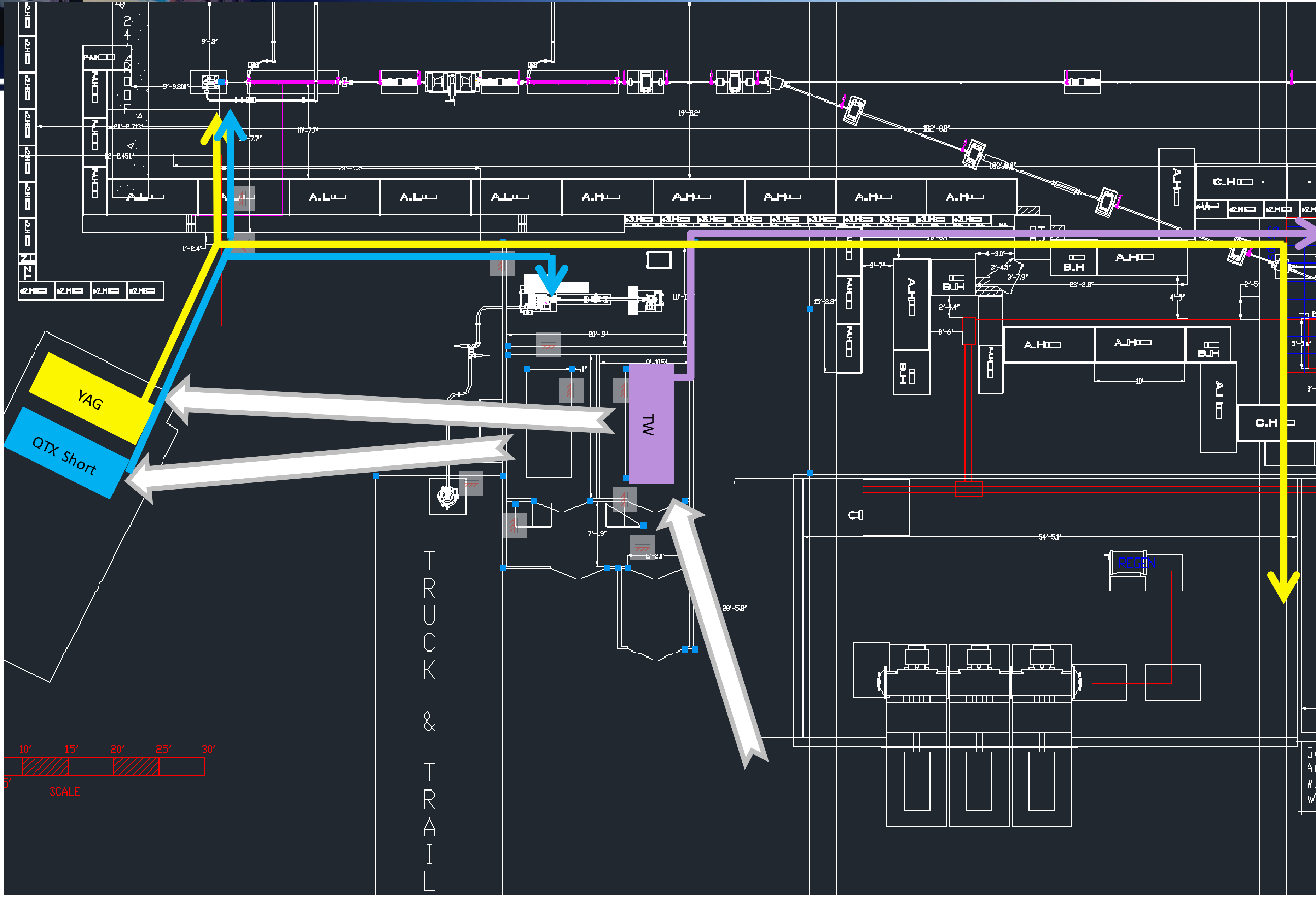

Solid state laser tentative installation sequence

Laser summary table

System	Wave-lengths	Temporal Format	Repetition Rate	Energy, Power	Examples Experimental Applications
Photocathode driver	785 (262) nm	1x 50-180 fs	240 Hz	7 mJ, 40 GW	Laser plasma shaping, Plasma interferometry, UED
Strong Field	785 nm	1x 50-180 fs	< 10 Hz	150 mJ, 1TW	Two-color Compton, Two-color Ionization Injection LWA
Nd:YAG Pulsetrain	1064, (532), (266) nm	1-100x 14 ps	< 10 Hz	20 mJ, 1.4 GW	Multiple pulse Compton scattering,

Thank You

Synchronization 2

- Phase-locking system assembled in-house from commercial hardware
- System has proven reliable at 1 ps level of jitter, few ps level of slow drift