ATF Present Drive Laser & Replacement

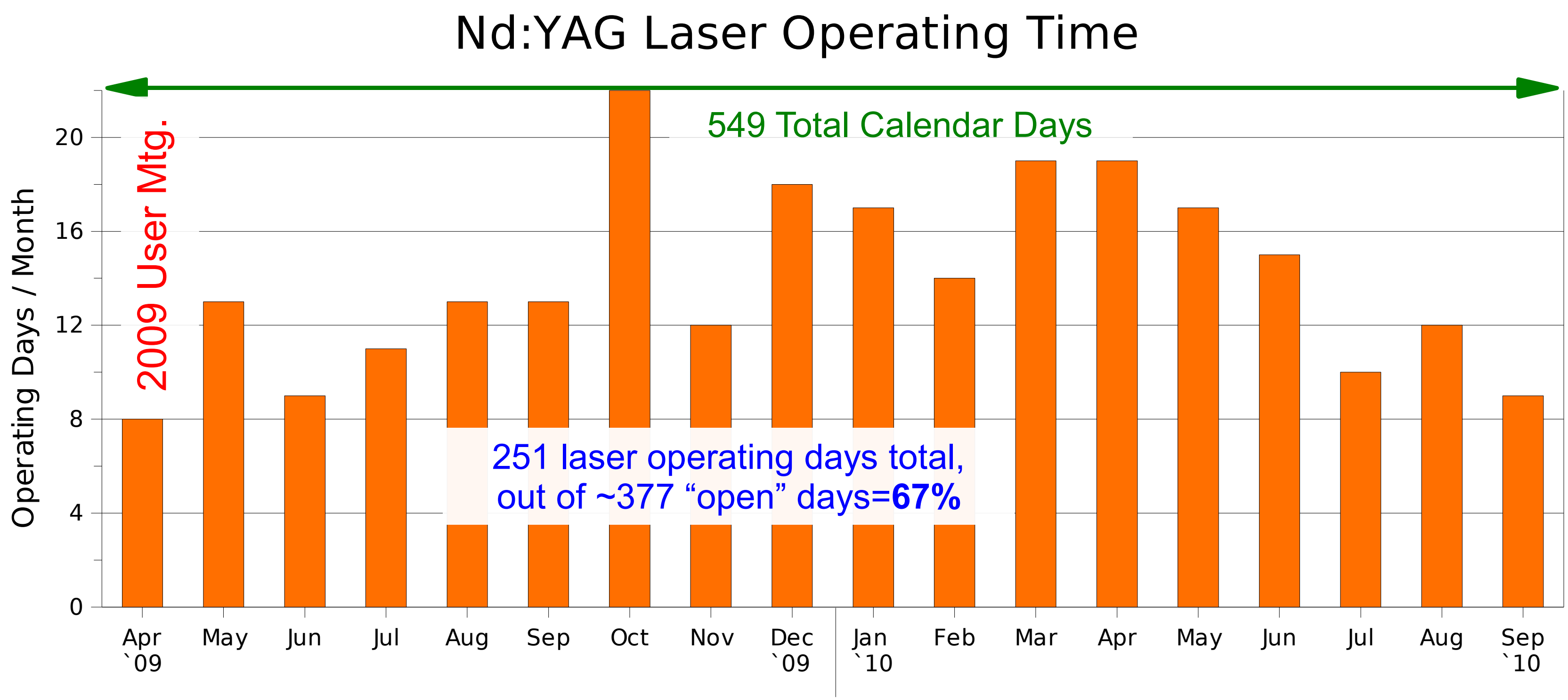
Igor Pogorelsky	*CO_2 laser and experimental support*
Mikhail Polyanskiy	*simulations, diagnostics, data acquisition*
Marcus Babzien	*YAG laser, general optical diagnostics*
Karl Kusche	*Laser safety, computer controls*

Current Nd:YAG Parameters

Energy: (dual pulse mode)	
UV on cathode	0-40 μJ
IR to CO_2 laser	10 mJ
Laser output: total IR	20 mJ
IR to gun	7 mJ
Green	2 mJ
UV	250 μJ
Energy: (pulse train mode) IR	~100 mJ / 20 pulses
Pulse duration (FWHM):	
Oscillator IR	7 ps
Amplified IR	14 ps
Green	10 ps
UV	8 ps

Transverse Distribution:	
Range of beam size on cathode (Ø)	0.2 - 3 mm
Top-Hat Beam Profile Modulation (P-P)	<20%
Repetition rate	1.5, 3 Hz
Shot-to-shot stability (rms):	
Timing	<0.2 ps
Energy	1 %
Pointing (fraction of beam Ø)	<0.3%
Drift (8 hour P-P)	
Timing	<2ps
Energy	<15%
Pointing (fraction of beam Ø)	<1%

Nd:YAG Running Time / Reliability



- No major failures or operating constraints
- Implemented new mode of green pulse delivery to FEL room: parasitically extract gun pulses when CO_2 laser fires →

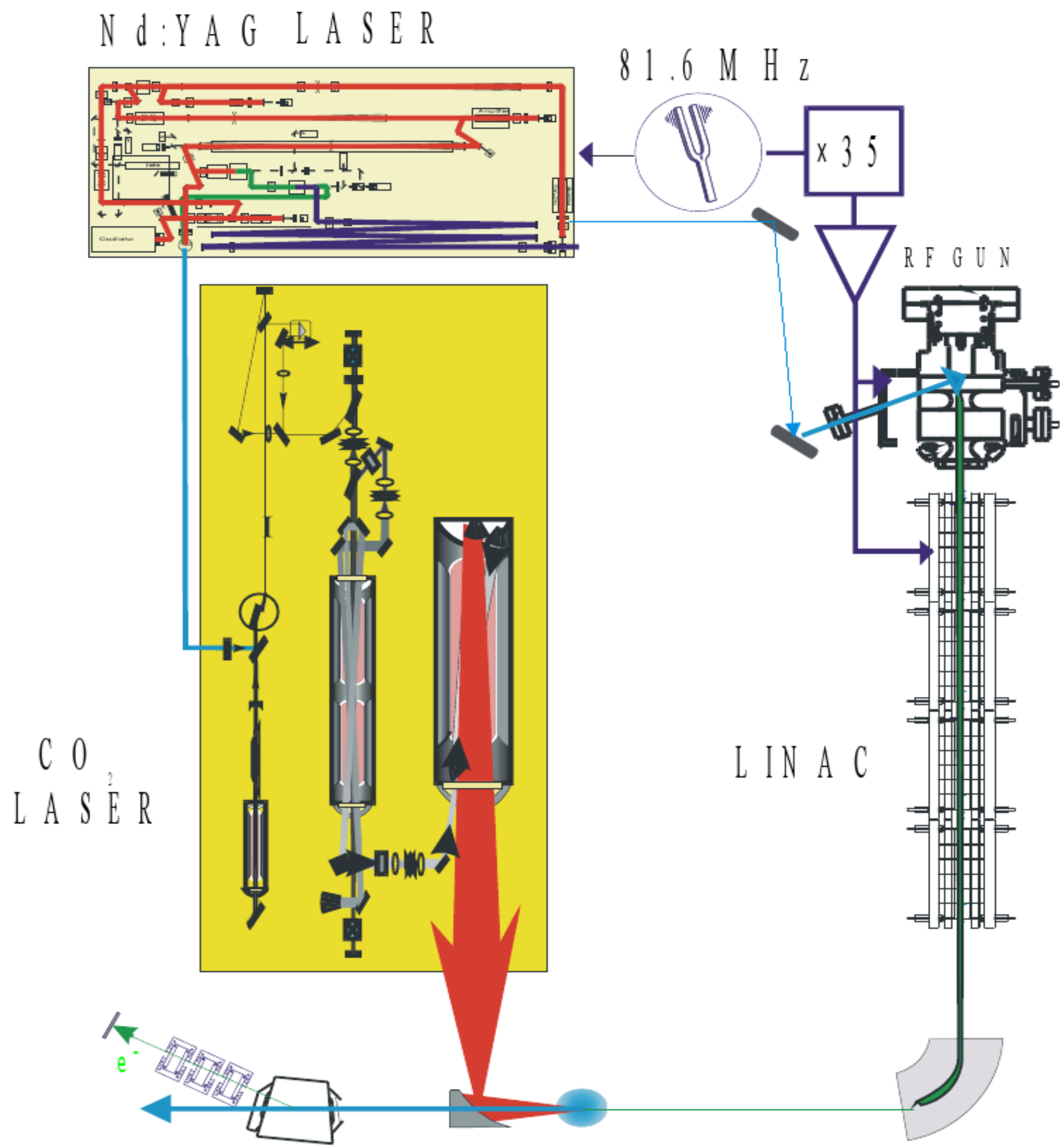
  e^- beam & green diagnostic operation no longer exclusive for most experiments

Nd:YAG Laser Evolution

- Stability, delivered energy, reliability always needed and compromise one another – the laser has a limited operating “parameter space”
- Capabilities and requirements introduced for new experiments may compromise other parameters
- However, the system now works better than any time in past decade because continuous learning and modification of weak points can somewhat increase capabilities
  Examples:
  - Routinely achieved energy stability <1% on cathode
  - Phase drift usually near 1 ps/day
  - Better symmetry of UV beam profile

Drive Laser Central Role

- Generates primary facility user resources:
  -high brightness electron beam
  -high power CO_2 laser pulses
- Timing:
  time structure & synchronization of above to one another and other facility equipment (i.e. delay generators, data acquisition, diagnostics)
- Diagnostics for experiments: e.g. Ion generation plasma density interferometry
- Cathode cleaning, detector characterization, optical timing fiducial, etc.



New Drive Laser Goals

- Phase 1: Replace current short pulse CO_2 slicing scheme to generate facility-synchronized ultrashort pulses at 10 μm wavelength
- Phase 2: Replace current Nd:YAG laser generation of UV pulses for photocathode operation
- Improve above two functions primarily in temporal domain - shorter duration, broader bandwidth, lower timing jitter & drift
- Maintain or improve reliability & high uptime – affects availability of both beam & staff

New Drive Laser Overview – Phase 1

FY 2010

Oscillator
30-300mW
81.6 MHz
<150 fs
$50k

→

Regen A
7 mJ
1 kHz
150 fs
$190k

→

Parametric Generator
Two-stage OPG
0.8->10.6μm ε~0.3%
<300 fs
$45k

→

Diagnostics
FROG
& Misc.
$40k

- Fiber oscillator seeding for best stability and environmental insensitivity
- Ti:Al_2O_3 regenerative & multipass amplifiers for broad bandwidth, high energy near IR generation
- All diode-pumped system – regulated supplies unlike most flashlamp pumped systems
- 1 kHz repetition rate removes seed timing limitation & enables more online monitoring & feedback
- Parametric generation for high MIR seed energy at shorter pulsewidth

New Drive Laser Phase 1 CO_2 Seeding

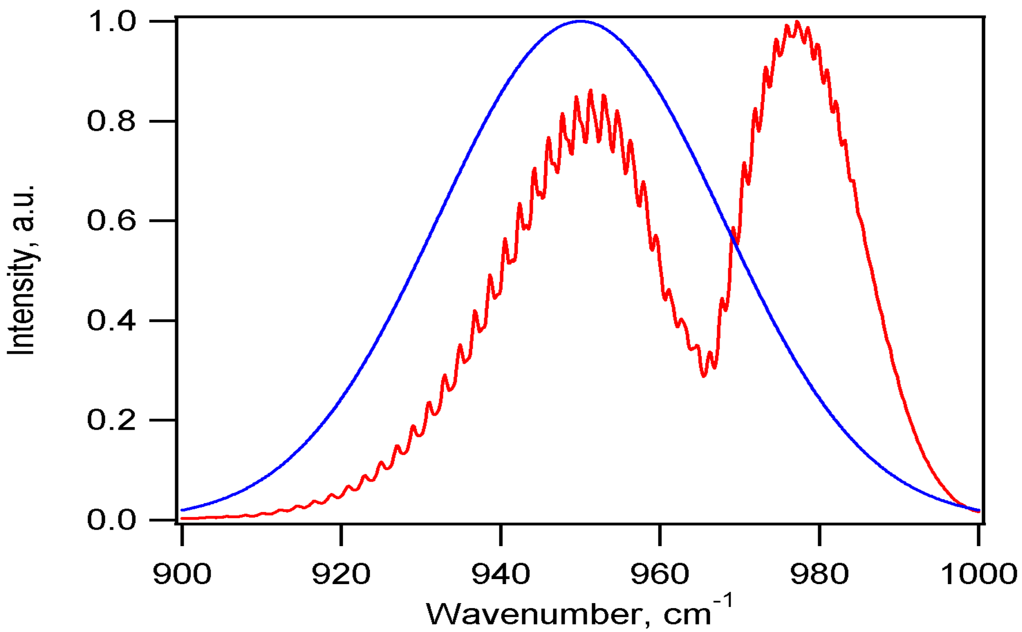
Pulse Duration	<350 fs
Pulse Energy	>40 μJ
Repetition Rate	1 kHz
Stability	<2% RMS
Beam profile	M^2<1.5

Amplifier footprint: 1x1.5 m^2

- State of the art has advanced to the level that Ti:Al_2O_3 ultrafast system can be more capable as well as smaller than the existing Nd:YAG system.
- Nearly all commercial system with standard products
- Vendor selected & order placed prior to end of FY2010

CO_2 Seeding Improvements

- Bandwidth/duration as needed for amplification over entire CO_2 rotational band



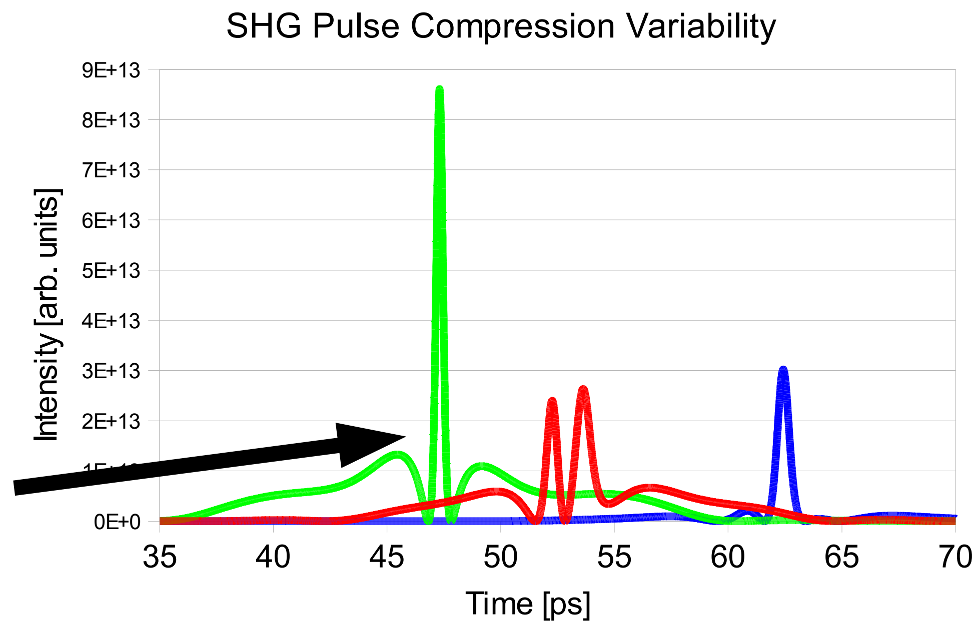
- Energy: 0.1 μJ/3 ps → 40 μJ/350 fs & significantly higher contrast
- Stability: ~20% → 2%
- Compactness means table more table space will be free after installation of new system

Benefits to Experimental Program

- Immediately (1 year) obtain 5x higher CO_2 power → higher a_0 e.g. ion beam energy increase
- Improved temporal resolution for PWFA interferometry, holography may be possible
- Ion beam generation experiment plasma density diagnostic pulses ~10x shorter, with lower jitter
- Higher gradient for IFEL

CO_2 Laser Operational Benefits

- Current short pulse generation scheme is complex & multi-staged
- SHG compression scheme effective but difficult to monitor & control



- Frequent alignment restricts availability of system
- New system has no flashlamps, warm-up, or gas circulation issues
- Should be close to turn-key, simpler to diagnose & adjust
- Higher seed energy will simplify CO_2 amplifier chain

Phase 2 Capabilities

Oscillator
30-300mW
81.6 MHz
<150 fs
$50k

→

Regen B
7 mJ
1 kHz
150 fs
$190k

→

Harmonic Generation
THG ε~10%
<200 fs
$20k

→

Shaping
Pulse Stacker
$65k

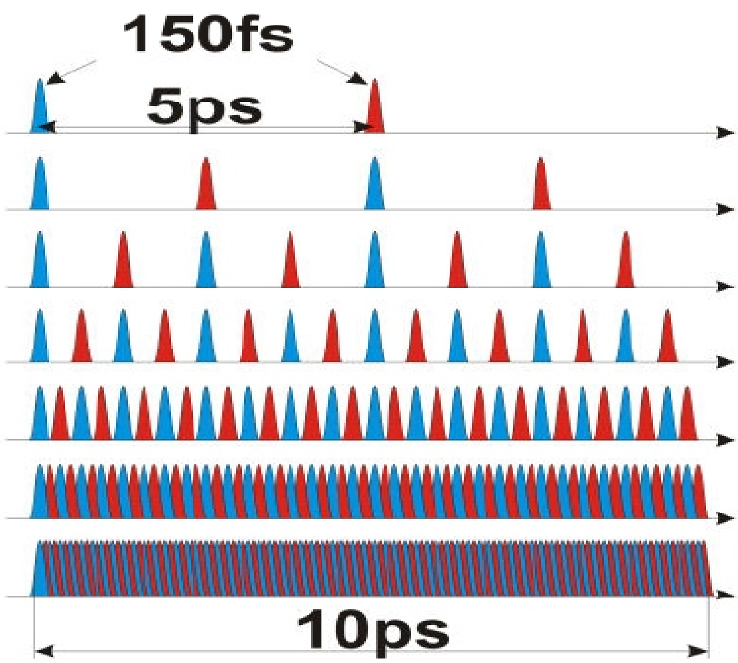
→

Diagnostics
FROG
Cross correlator
Misc.
$40k

- Common or duplicate components include oscillator, regenerative amplifier, diagnostics & controls.
- Much will be characterized from Phase 1
- Higher energy options exist if deemed necessary for photocathode dependent upon efficiency of harmonic generator & longitudinal pulse shaper

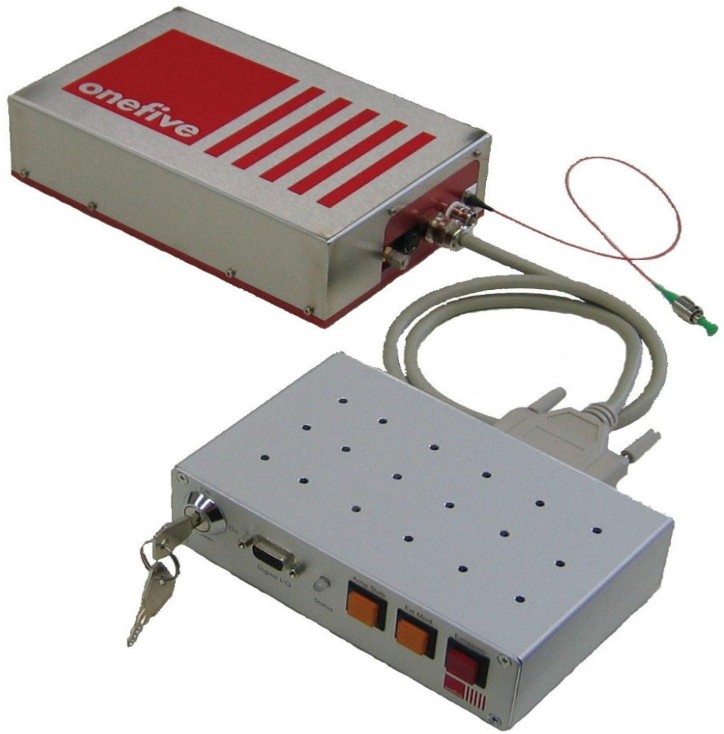
Photoinjector Benefit - Physics

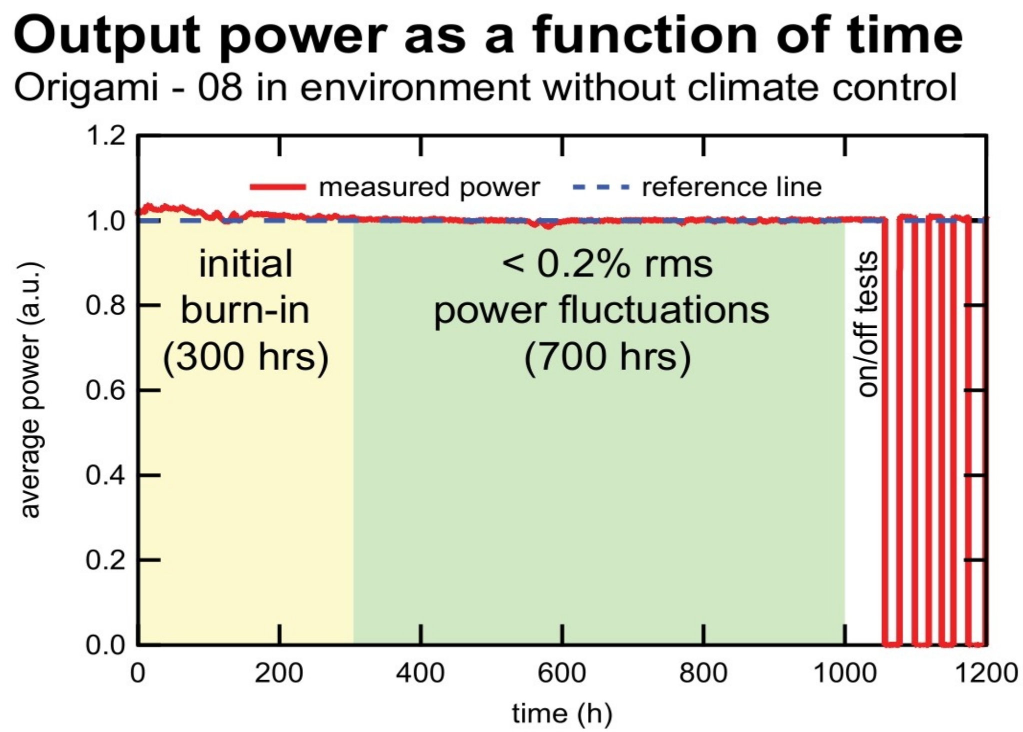
Pulse Duration	0.2 – 10 ps
Pulse Energy	>400 uJ
Repetition Rate	1 kHz
Stability	<2% RMS
Beam profile	M^2<1.5



- Short pulse: study 3D elliptical beam from photoinjector at low charges
- Stack pulses: achieve flat-top in time – Lower emittance in high charge regime
- May finally obtain sufficient energy to do spatial profile flattening!
- But, energy stability may be greatest challenge. May need to implement feedback on noise spectrum <1 kHz.

Operational Benefits





- Downtime expected to be comparable to present system because of NEW components, diode pumping, reduced component count
- Most subsystems will be temperature regulated → minimal warm-up
- Alignment drift, component degradation to be determined, but new system is smaller. Offline characterization possible before installation.

Integration Plan

- Phase 1 laser delivery in 5-6 months
- Infrastructure upgrades before delivery (clock, timing system, phase jitter diagnostic, mechanical utilities, control interface)
- Initial acceptance test within 1 month (vendor is local)
- Test CO_2 amplification with 10 μm transport line before disassembly of existing seed system
- Replace existing components on CO_2 table
- ~ 1 year to experimental running in new configuration
- Phase 2 as funding permits

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