EVOLUTION OF THE LASER MEGAJOULE TIMING SYSTEM

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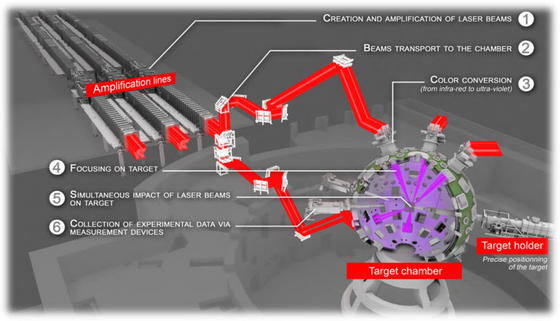
- LMJ dimensions : 300 m x 150 m x 50 m
- Operating since 2017
- 24/7/365 basis availability
- ~ 700 Equipment (Delay generators, Optical splitters, O-E converters)



- Jitter < 5 ps rms
- Drift < 5 ps peak-to-peak
- Precision ± 10 ps, Dynamic 100 µs/1 s
- 2500 Triggers and Fiducials
- 1500 Optical fibers for the timing system
- 7.10^{-3} Equipment failure/year

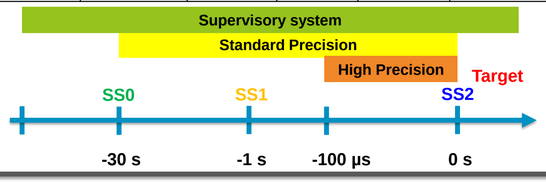
LMJ timing system

LMJ timeline and requirements.

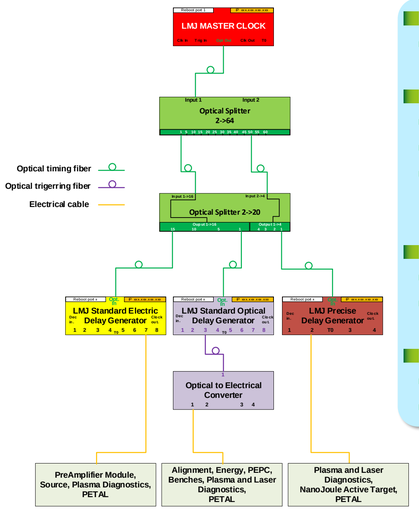
176 laser beams (22 laser bundles) + PETAL

- 40 ps rms on target
- Jitter < 5 ps rms
- Drift < ± 20 ps p-p
- Electrical and optical triggers
- 2 classes of precision, standard and high
- More than 2500 triggers and fiducial signals

Classes of performance Precision Delay generator	Jitter rms	Temporal Drift peak to peak			Precision	Range
		24 hours	7 days	1 month		
Standard	<100 ps	<200 ps	<500 ps	<1 ns	<±1 ns	1 s
High Specification Measurement	<5 ps 4 ps	<6 ps 4 ps	<10 ps 4 ps	<20 ps 4 ps	<±10 ps	100 µs



Timing system architecture



- Master Clock is the time reference
  - Time data information are sent with the reference clock
- Optical passive distribution network
  - Optical fibers measured
  - Passive optical splitters
  - Asymmetrical network : adapt optical power to each class of delay generator
- Two classes of delay generator
  - Standard precision (optical and electrical)
  - High precision (electrical only)
- Electrical and optical delayed signals
  - Triggers and fiducials
  - For laser beams and diagnostics

LMJ Master synchronization room

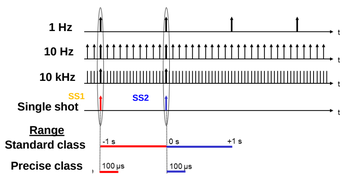
Front

Rear

Timing system Equipment

Master clock

The LMJ master clock (GFT3013), connected to a GPS/rubidium oscillator, converts stable 10 MHz signal to a standard optical frequency (155.52 MHz) within a single-mode optical fiber.



- λ = 1549.32 nm
- 12 dBm (≈ 16 mW) optical output
- 3 frequencies: 1 Hz, 10 Hz and 1 kHz (programmable)
- 3 time references: SS0 (-30 s to -2 s), SS1 (-1 s) and SS2 (0 s)

Passive Optical Splitter

- main splitter: 1 x 64 (first splitter)
- standard splitter: 1 x 32 (for standard delay generator)
- precise splitter: 2 x 8 (two 1 x 4 for precise delay gen.)
- asymmetrical splitter: 2 x 20 (1 x 16 + 1 x 4 for both delay gen.)

Optical/Electrical Converter

- single channel: COE 1 x 1
- 8 channels: COE 8 x 8
- Single to 4 split channels: COE 1 x 4

Delay generators

Fiducials and triggers signals are generated by two different delay generators:

- Standard precision delay generator (GFT1018):
  - Electrical: 8 electrical outputs (BNC connector)
  - Optical: 8 optical 1310 nm outputs (SC/PC)

  The optical delay generator can be used in conjunction with an optical to electrical converter.

- High precision delay generator (GFT1012):
  - 2 BNC outputs (EP2V)
  - 4 BNC outputs (EP4V)

Rise Time
Elec. < 1.2 ns
Opt. < 5 ns

Amplitude
Elec. 10 V ± 0.5 V
Opt. > 300 µW

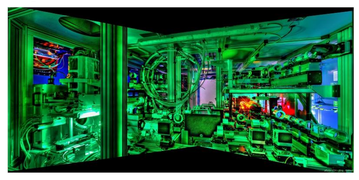
Width

Elec./Opt. 1 µs ± 0.1 µs
Opt. (COE) 10 µs ± 0.5 µs

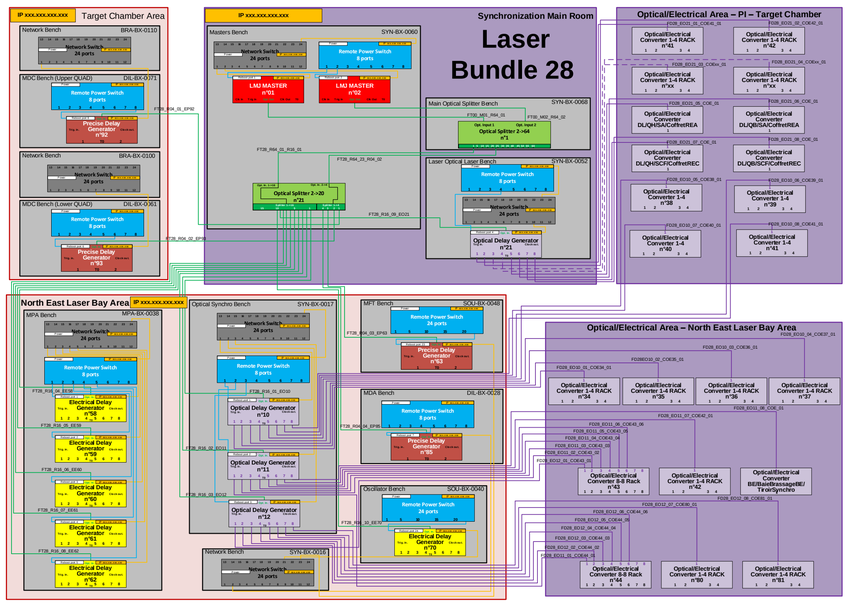
- Signal specifications: Delay generator and optical to electrical converter

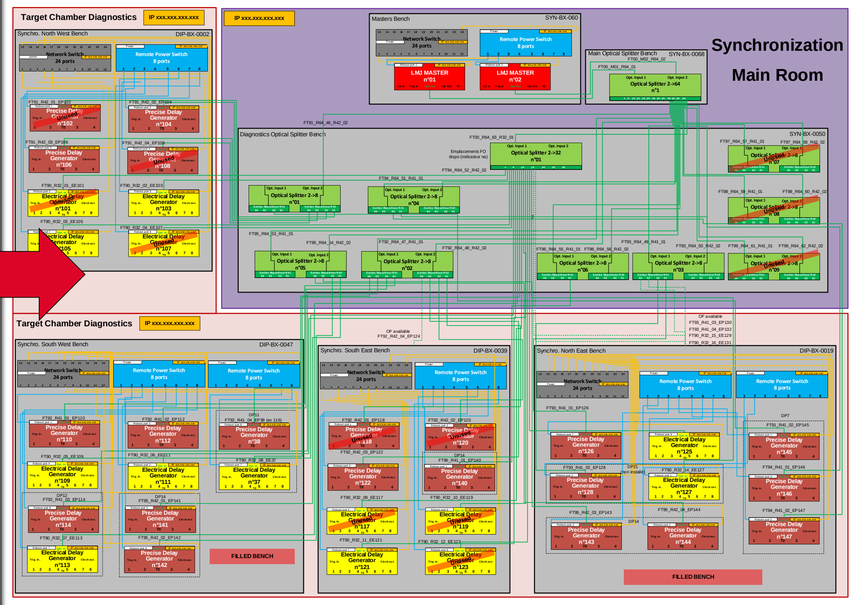
Timing system: Lasers and Diagnostics

1/22 Laser Bundle

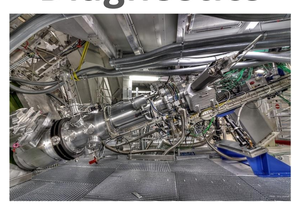


- 14 delay generators
  - 10 standard precision
  - 4 high precision
- 50 optical fibers (2 m to 300 m)
- 14 optical to electrical converters
- 1 passive optical splitter
- …and 22 Laser bundles !





Diagnostics

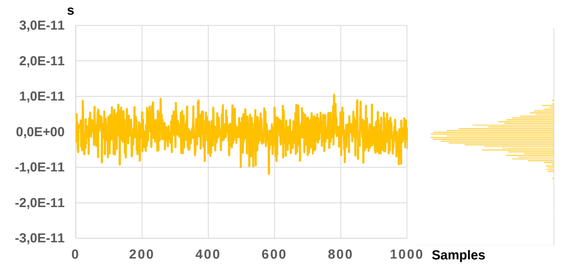


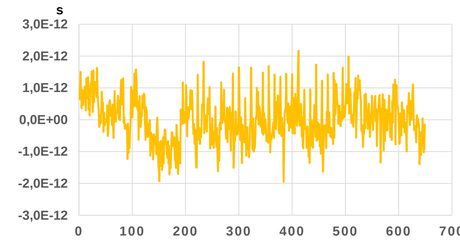
- 57 delay generators
  - 21 standard precision
  - 36 high precision
- 52 optical fibers (2 m to 300 m)
- 27 optical to electrical converters
- 10 passive optical splitter
- …and increasing with each new diagnostic !

Measurements: Current and updated

Current vs updated precise delay generator (old[1,2] vs new delay generator chip[3])
First measurements results on prototype delay generator

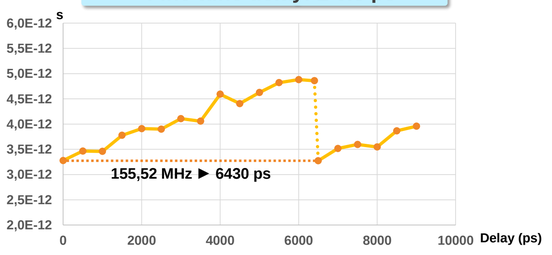
- Jitter (rms): Between 2 outputs / 2 delay generators
  - Current: 4.0 ps ± 1 ps
  - New (proto.): 4.0 ps ± 0.8 ps



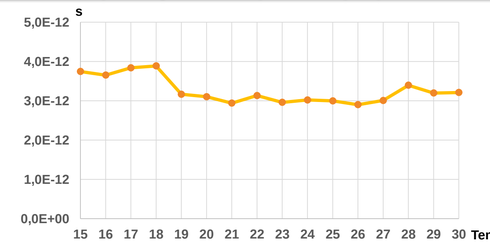


- Temporal drift (peak-to-peak): 1 month
  - Current: 4.0 ps ± 1 ps
  - New (proto): 4.0 ps ± 1 ps

- New measurements:
  - Fine tune delay: ± 0.8 ps



- New measurements:
  - Temps vs jitter: 3.0 ps ± 0.2 ps (20°C - 25°C)

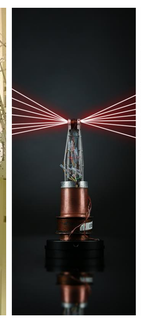


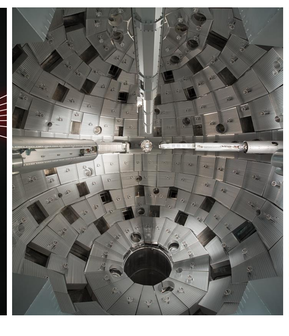
[1] Somerlinck, T.; Falgon T.; Bazoge, N.; Hocquet, S.; Monnier-Bourdin, D.; "Laser Megajoule Timing System"; TUBPR06; ICALEPCS 2019.
[2] Hocquet, S; Hours, P.; Bazoge, N., Monnier-Bourdin, D; Somerlinck, T; Falgon, T.; "Ultra-High Precision Timing System for the CEA – Laser Megajoule"; MOPHA059, ICALEPCS 2019.
[3] Badets, F.; Billiot, G.; Bouquet, S.; Spataro, A.; Fustier, A.; Lepin, F.; Caillat, B.; Magnier, C.; "A 4-channel, 7ns delay tuning range, 400 fs step, 1,8ps rms jitter Delay generator implemented in a 180nm CMOS technology", TUBPR02, ICALEPCS 2019.

And the future…

New master clock, new delay generators and new architecture are under development with new specifications:

- Mix old and new synchronization
- Higher frequencies and new time references
- Optical driver output (optional wavelength)
- Automatic fiber measurement (timing, attenuation…)
- Improved performances (jitter and drift)
- New features (Gaussian output, variable level, auto calibration…)





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