Power Balance on a Multibeam Laser

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Summary

The 30-kJ OMEGA Laser System has been power balanced to 3% rms across 60 beams

- Maximizing inertial confinement fusion (ICF) target irradiation uniformity is a key requirement for successful target implosion
- ICF target-implosion simulations indicate <1% rms intensity balance over any 100-ps interval
- Power balance is assessed using a time-resolved and spatially integrated measurement of each of the 60 beamlines
- Dedicated campaigns have improved power balance from over 6% rms to less than 3% rms on cryogenic ICF experiments

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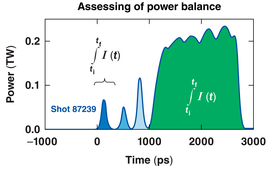
Conditions necessary to achieve power balance

- Equal gain at each amplification stage
- Equal losses at each amplification stage
- Equal frequency-conversion efficiency
- Equal beam timing



"Energy in feature"

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Passive losses are identified using calorimetric measurements

- Up to ten calorimeters are marched down each leg and each beamline of OMEGA
- A low-energy, low-power infrared (IR) pulse is used to measure transmission
- Stage-by-stage measurement of *passive* transmission is then calculated
- IR transmission of FCC's was also measured

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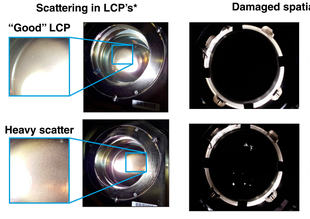
Other sources of incidental losses were also identified



Transmission losses of up to 3% were addressed.

*LCP: liquid crystal polarizer

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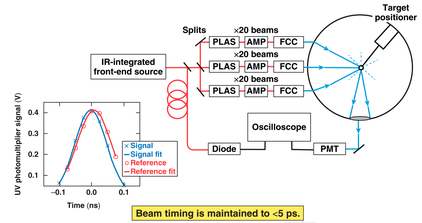
Beam timing is measured during routine maintenance periods



Beam timing is maintained to <5 ps.

PLAS: path-length adjustment system
PMT: photomultiplier tube
AMP: Nd:glass amplifier

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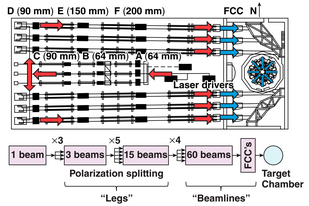
OMEGA's 60 beams are generated via splitting and subsequent amplification of a single seed beam

Stage	Amplifier Gain
A	10
B	10
C	5.8
D	5.5
E	3.4
F	2.9
FCC*	–



*FCC: frequency-conversion crystal

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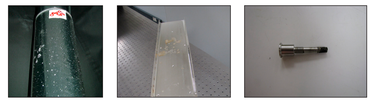
Small-signal gain (SSG) measurements are used to equalize gains at each stage

- Three consecutive iterations to optimize gain balance by stage
- Gain is measured *by stage* for each amplifier leg and beamline)
- Resulting data isolate poorly performing amplifiers
  - spotted rod jackets, dirty reflectors, corroded deionized water connectors
  - defective amplifiers are addressed after each SSG iteration

Stage	Goal rms (%)	Typical rms (%)
A	<0.5	0.3
B	<0.5	0.3
C	<0.5	0.3
D	<1.0	0.9
E	<1.0	0.9
F	<1.0	0.7



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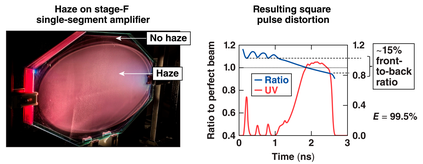
Compensating losses with amplifier gain results in poor power balance



Rough guide: 1% unbalanced loss results in 2% pulse tilt.

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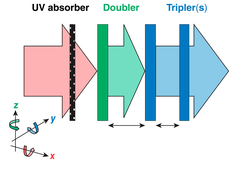
Frequency conversion performance equalization was improved by reducing the number of sensitive variables

- Conversion sensitivity to several variables: crystal tunings, thicknesses, transmissions, temperatures, separations (broadband operation), input polarizations, etc., for each crystal
- The 60 second-tripler crystals used for broad-bandwidth frequency conversion were removed to eliminate them as a source of imbalance
- A 60-beam tripler-tuning optimization was performed to reduce tripler-tuning variation to ±40-μrad rms



For shots with equal IR-input energy rms, the UV energy rms improved from 2.1% rms to 1.7% rms.

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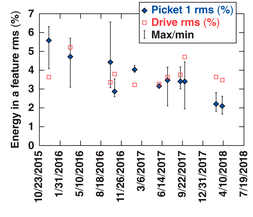
Dedicated campaigns demonstrate improved power balance

- Equal gain at each amplification stage
- Equal losses at each amplification stage
- Equal frequency-conversion efficiency
- Equal beam timing



Improvement in picket and drive balance from >6% to 3%.

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