An Integrated Research Experiment (IRE) for Diode-Pumped Solid State Lasers

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Diode-pumped solid-state laser drivers are an exciting new option for IFE that has materialized over the past few years

- Energy storage feature allows DPSSLs to benefit from extensive Nd: glass laser developments

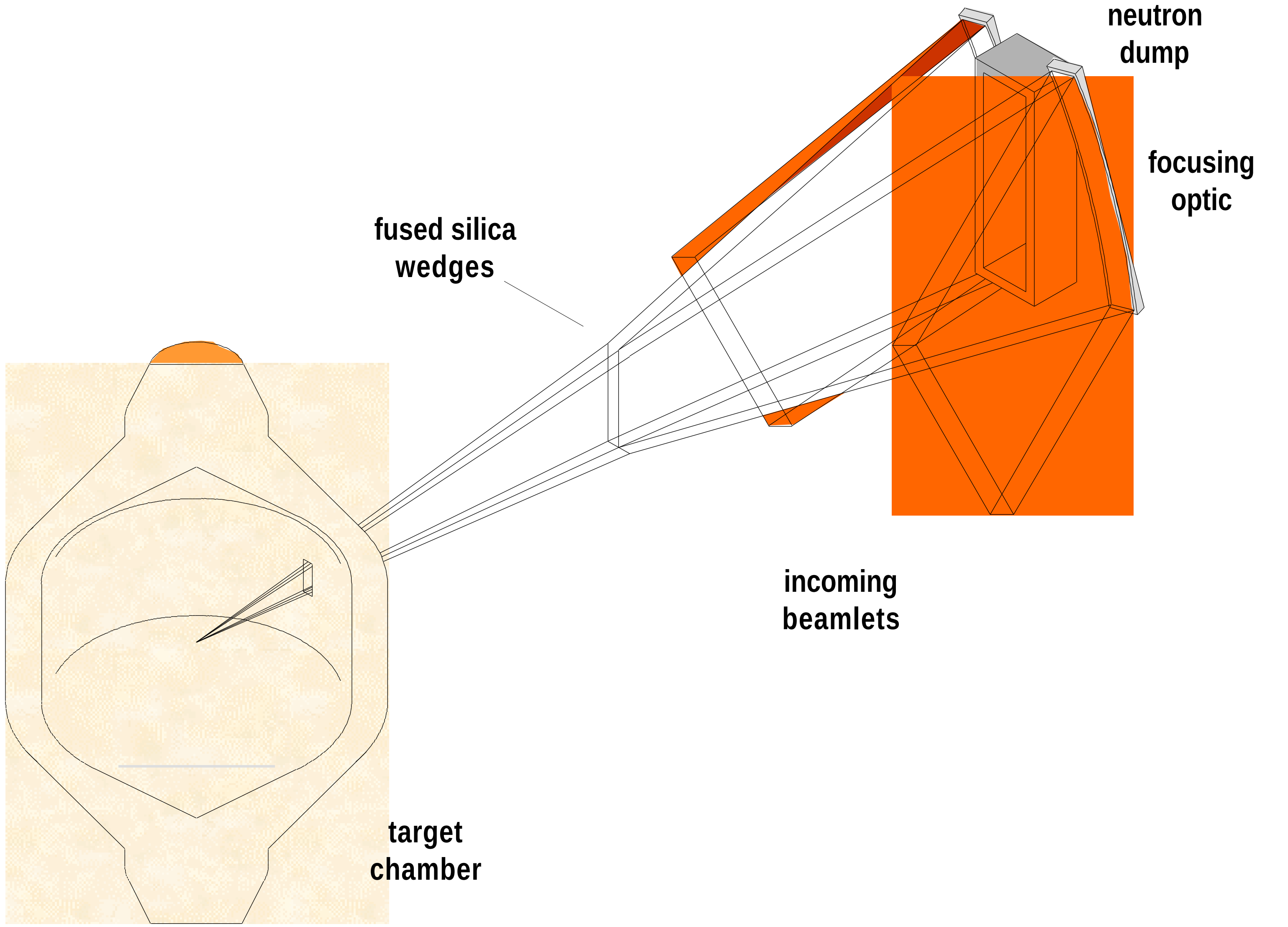
- Wavelength [1 mm (1ω), 0.5 mm (2ω), and 0.35 mm (3ω)] and target interaction features are equivalent to NIF

- Ultra-high brightness, high efficiency, and short pulse capability make DPSSLs potentially applicable to direct drive, indirect drive, fast ignition and a laser-based fusion neutron source

- We are currently constructing Mercury, a 100-J DPSSL testbed, under LLNL LDRD funding

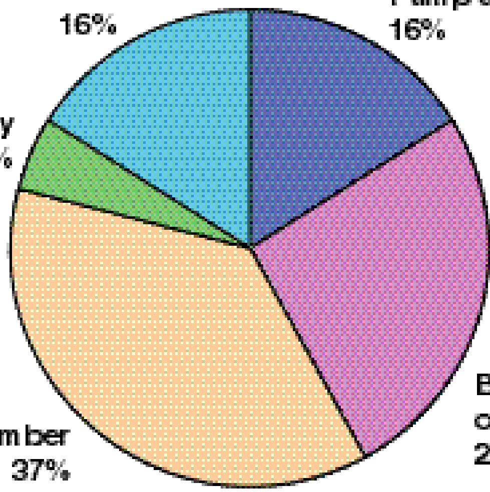
- We have proposed a 4-year $40 M phase I DPSSL Proof of Principle development program to precede a possible IRE

Two beamlines will be combined with fused silica wedges to form an 8 x 32 matrix of beamlets



The pump diodes account for only 16% of the cost of 1-GW$_e$ IFE plant

Cost breakout



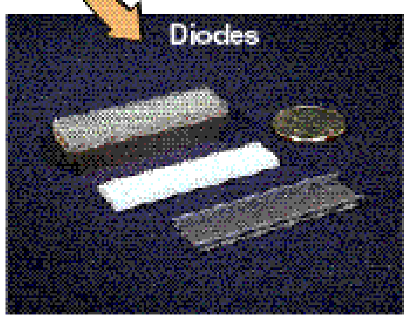
Detailed diode performance and cost

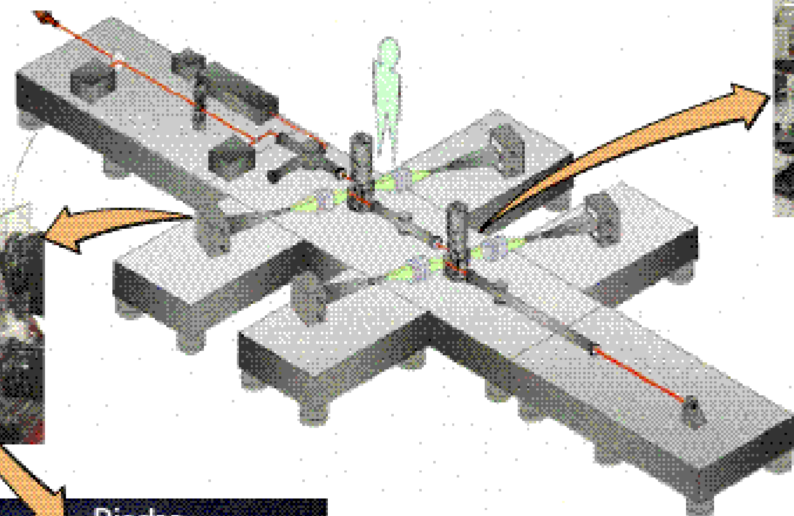
	1992 1 J GCS	2001 100 J Mercury	2010 4 kJ IRE	2030 2.3 MJ IFE
Efficiency	43%	45%	50%	60%
$/pk W	$20	$3	$0.50	$0.05
W/cm	100	100	100	200
# shots	10^6	10^8	10^9	10^{10}
Quantity	196	7000	200,000	60,000,000

- BOP, target factory, and chamber cost adopted from Sombrero study
- Most optics cost extrapolated from NIF experience
- Predicted direct capital cost of IFE driver is $900M for 1-GW$_e$ plant (diode pump arrays taken as commodity)

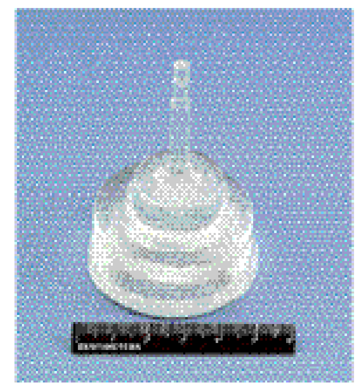
The Mercury laser: An example of an IFE-related activity over the next several years

Laser diode array





Gas-cooled amplifier

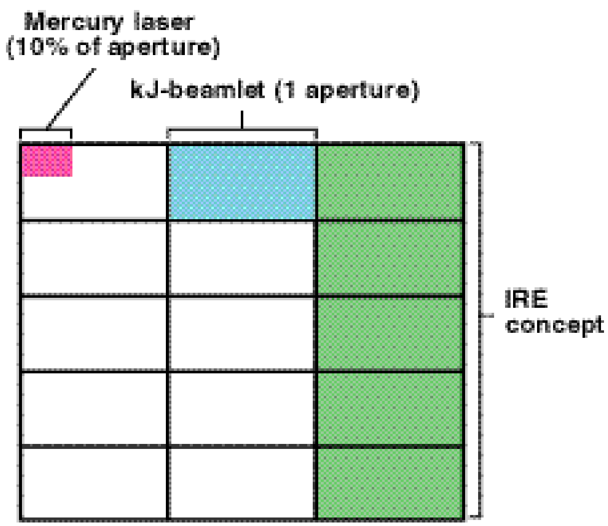


Strategic goals:

— 100 Joules (1.05 μm)
— 10% wall plug efficiency (1.05 μm)
— 10 Hz
→ Scalable to IFE drive

Mercury has technical overlap with future systems but at 10% of the aperture scale

15-kJ beamline



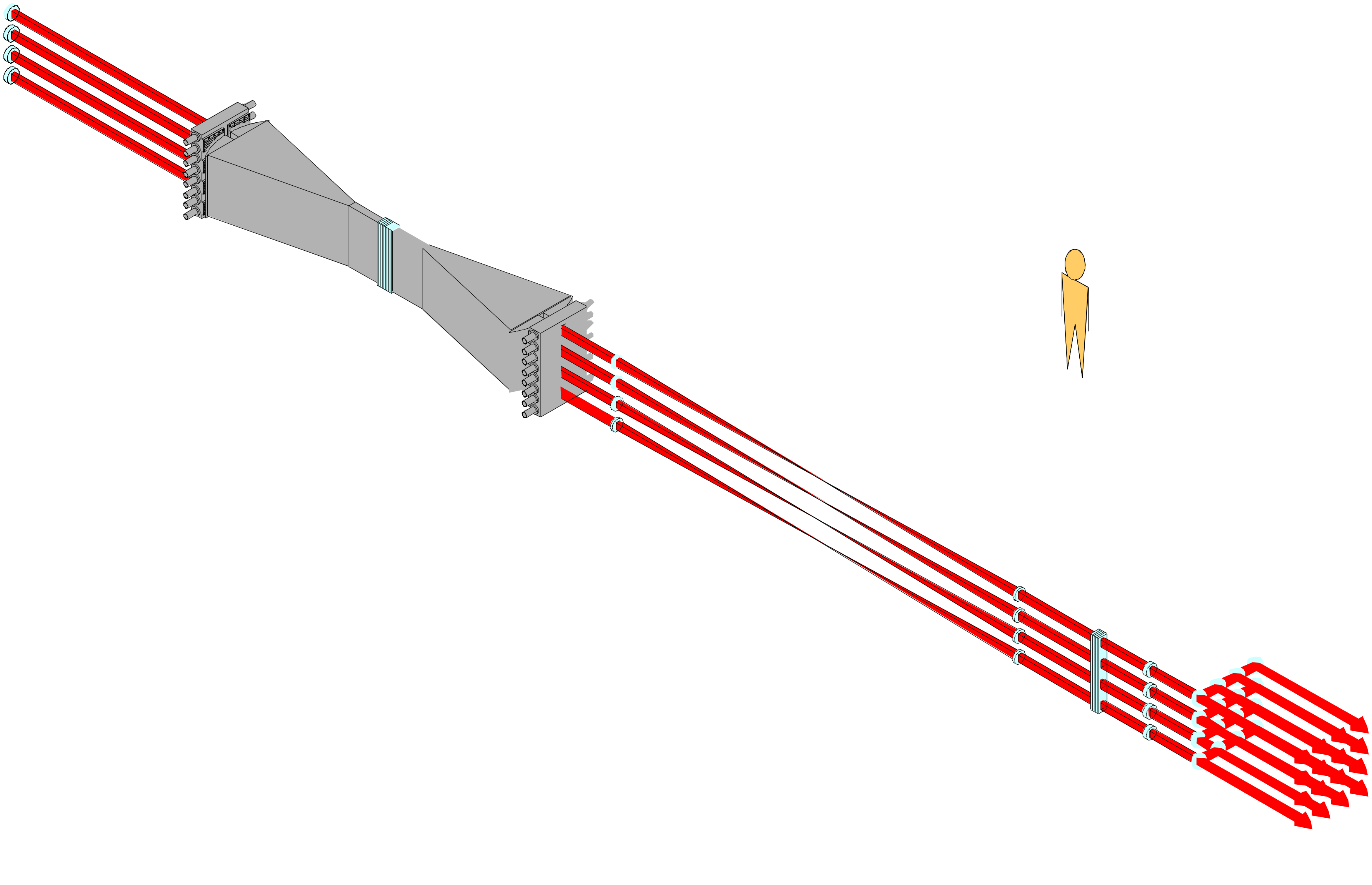
Parameter	100-J Mercury	1-kJ (beamlet)	15-kJ (beamline for IFE)	IFE driver (2 MJ, 130 beamlines)
Extraction fluence (J/cm^2)	8	8	8	8
Pump intensity (KW/cm^2)	10	10	10	10
Stored energy density (J/cm^3)	1.2	0.8	0.8	0.8
Crystal thickness (cm)	0.75	0.75	0.75	0.75
Repetition rate (Hz)	10	10	10	10
Diode cost ($/W)	2.50	1.0	0.50	<0.05
Aperture (cm × cm)	3 × 5	10 × 15	10 × 15 (15 segments)	10 × 15 (5000 segments)
Wall plug efficiency (%)	10 (1ω)	10 (3ω)	>10 (3ω)	>10 (3ω)

Modularity and similarity of laser parameters assure that testing subscale beamlets will cost-effectively address DPSSL physics and engineering issues

Four-year, phase I DPSSL developments ($40 M) will enable construction of an IRE and define pathway to an IFE driver

Phase I Goals/metrics

- Efficiency – validation of 10% overall system efficiency at 3ω with beam smoothing
- Beam smoothing – 1% smoothness on target (1 THz bandwidth with spectral sculpting)
- Gain media – High quality 20-cm Yb crystals
- Frequency conversion – > 75% efficiency at 10 Hz with 1 THz bandwidth (3 sets of crystals)
- Wavefront correction – < 5 x diffraction limited
- Technology integration – reliable Mercury operation for hours (> 106 shots)
- Scaling – optimized IRE laser design



A DPSSL IRE (~ 4 kJ) will provide the key demonstrations necessary for a powerplant driver

Beamlet performance:

- Integrated performance of a fundamental beamlet (~ 1 kJ)
  - Efficiency > 10%
  - Lifetime > 10^9 shots
  - Focusing performance on target including beam smoothing
  - Testing "foot" and "driver" beamlets and multiple color options

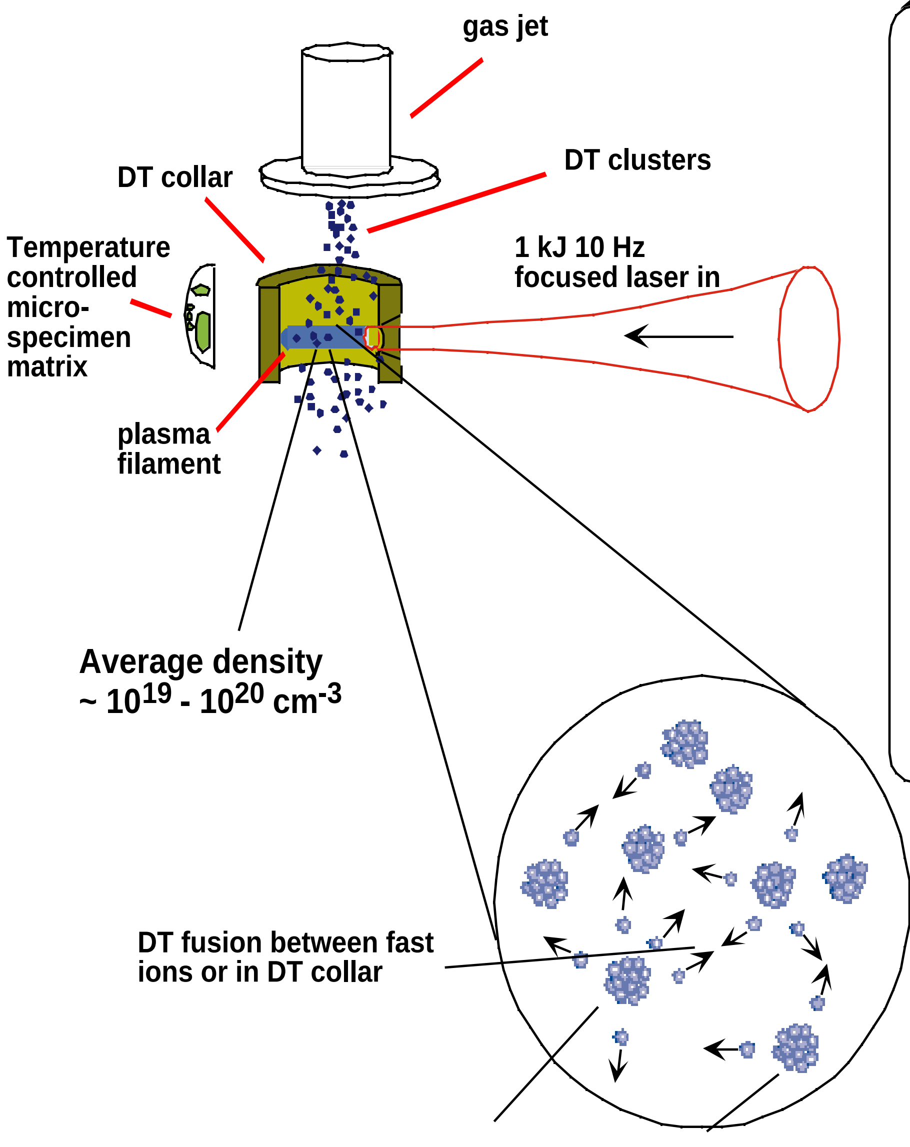
Segmentation:

- Integration of multiple beamlets to make a beam bundle (defining and testing shared functions such as pumping, cooling, beam transport, and focusing)

Vendor development:

- Ability to obtain the crucial parts of an IFE driver at the required performance and leading to required cost
  - Laser diode pump arrays (~ 25 MW at $0.50/$W_{peak}$)
  - Gain crystal plates (~ 35)
  - Frequency conversion plates (~ 30)

An efficient, compact laser driven fusion neutron source could be used to perform wall materials studies for future fusion reactors



- 14.1 MeV, pure DT fusion neutron spectrum
- High neutron flux on materials samples to simulate end-of-life irradiance (>200 dpa) in one yr

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Source must produce $>10^{14}$ - 10^{15} n/cm^2/sec for > 1 yr

DPSSL requirements ~ 1 kJ @ 10 Hz

Low total facility cost (< $100M)

Diode Pumped Solid State Laser Roadmap for IFE