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DPSS Amplifiers for High Energy, High Repetition Rate Applications

HEC-DPSSL

September 11-14, 2012

G. Jay Doster Ph.D.

Overview

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- Architecture
- Diode Laser Pumps
- Energetics
- Uniformity
- Laser Materials
- Performance
- Pulse Trains
- What's next?

Quasi-CW Gain Modules

- All modules are diode pumped solid state.
- Incorporate long life diode packages.
- Modules are available with rod sizes from 2mm to 25mm in diameter, 3cm to 12cm long, bar counts from 3 to 360, and pump energies up to 40 Joules.
- Modules use common parts to reduce costs and manufacturing times.

Gain Module Architecture

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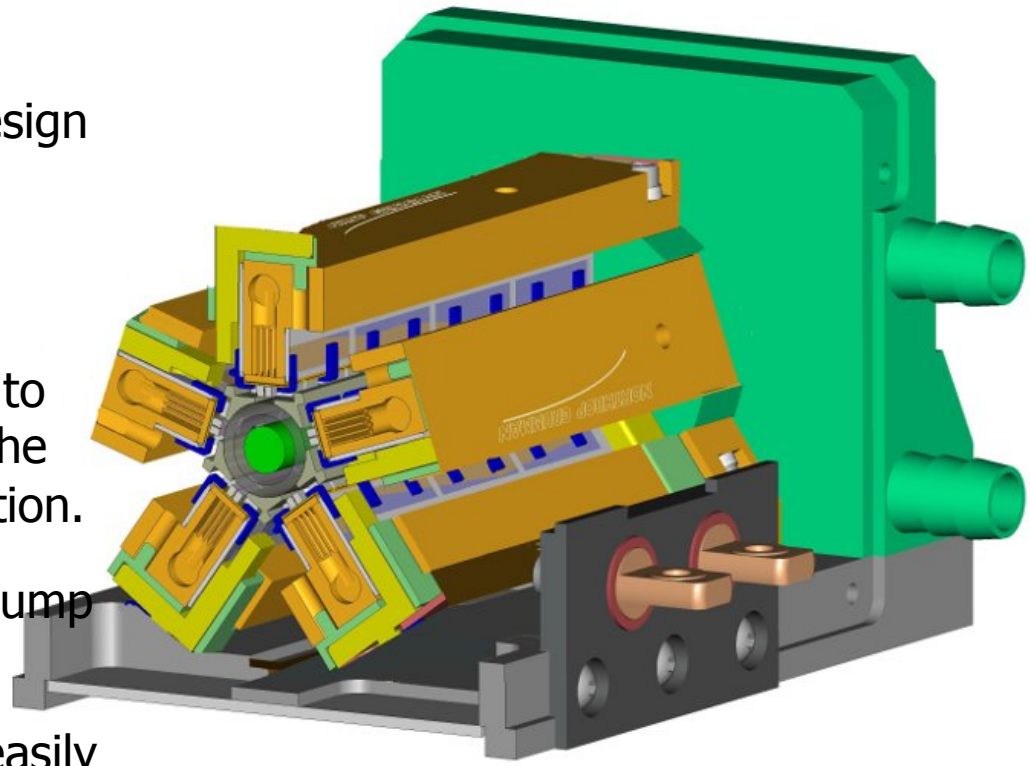
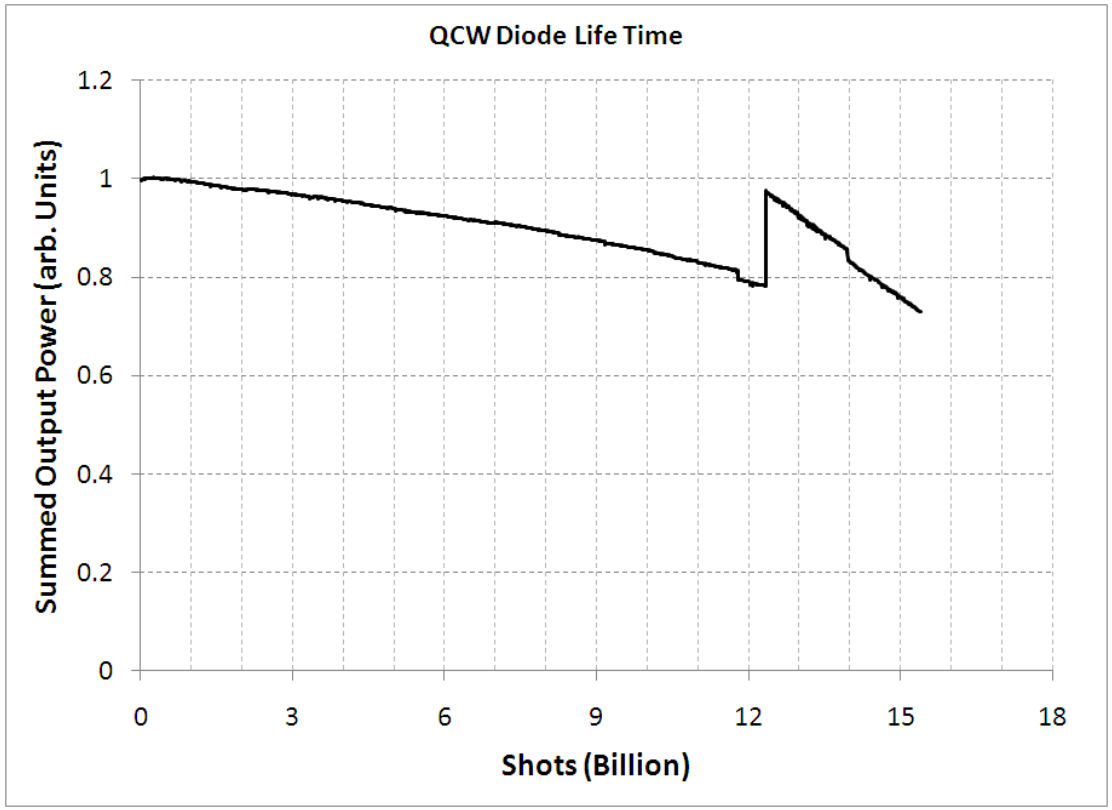
- The laser crystal is cooled by passing water over the rod at high Reynolds number.
- Five (or seven) around array design gives more uniform pump light distribution.
- Pump chamber includes a high reflector to increase the optical to optical coupling and increases the uniformity of the pump distribution.
- Design allows easily changing pump lengths and rod sizes.
- Coolant interface to module is easily modified to accommodate plumbing configuration of choice.

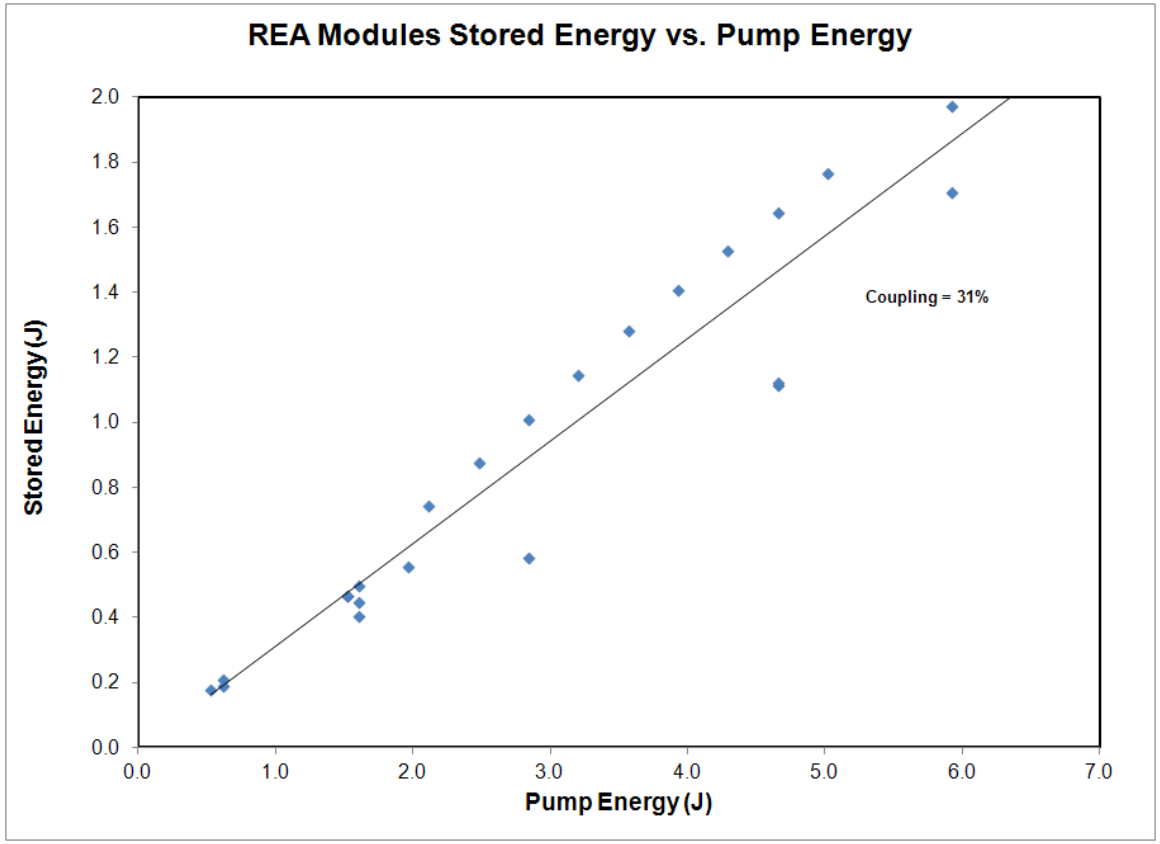


Diode Pump Life Time

- Diode are life tested under full operating conditions.
- 13 billion shot life times indicate 10,000 hour operation at 370 Hz.

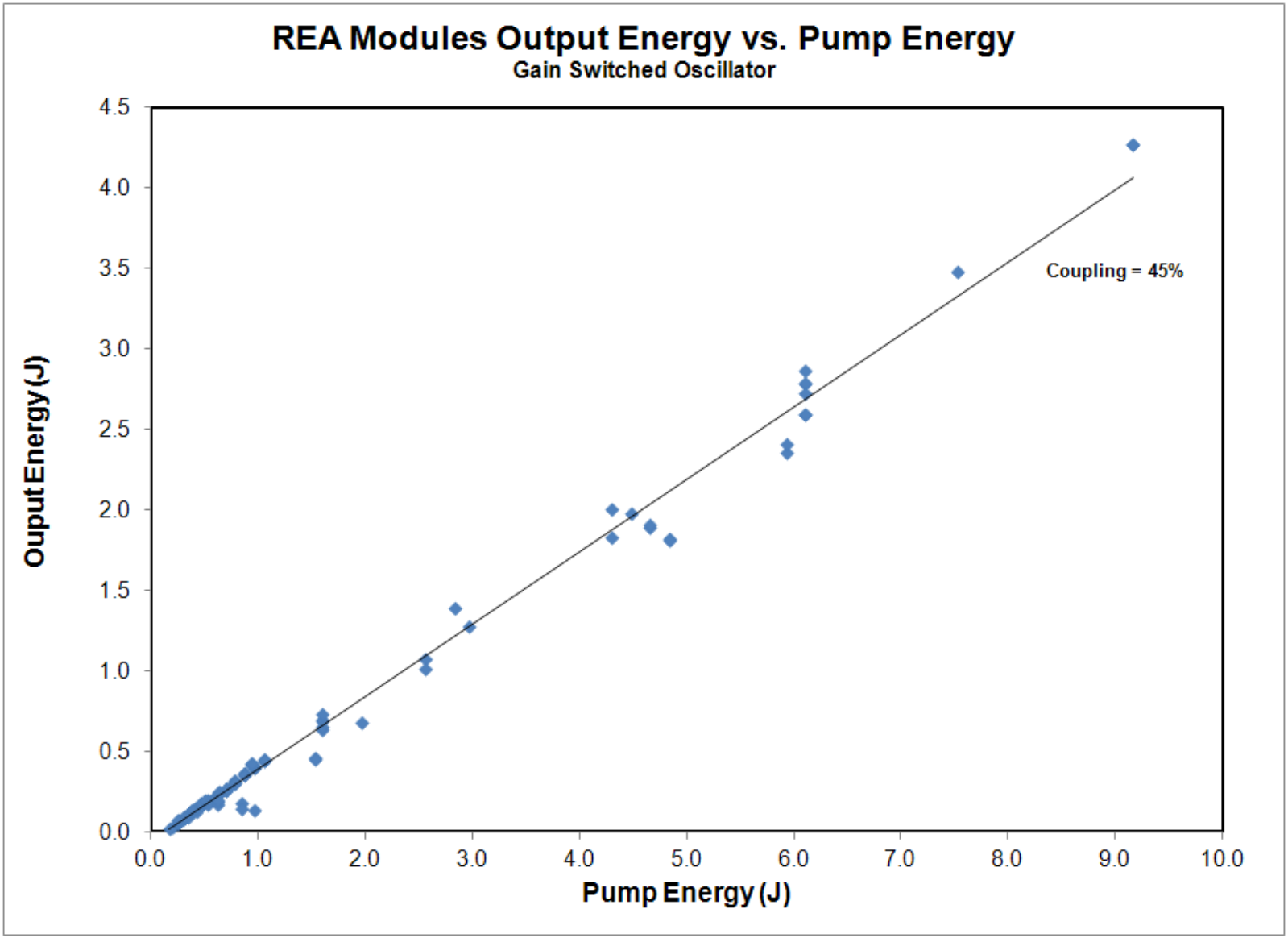


Gain Module Amplifier Performance

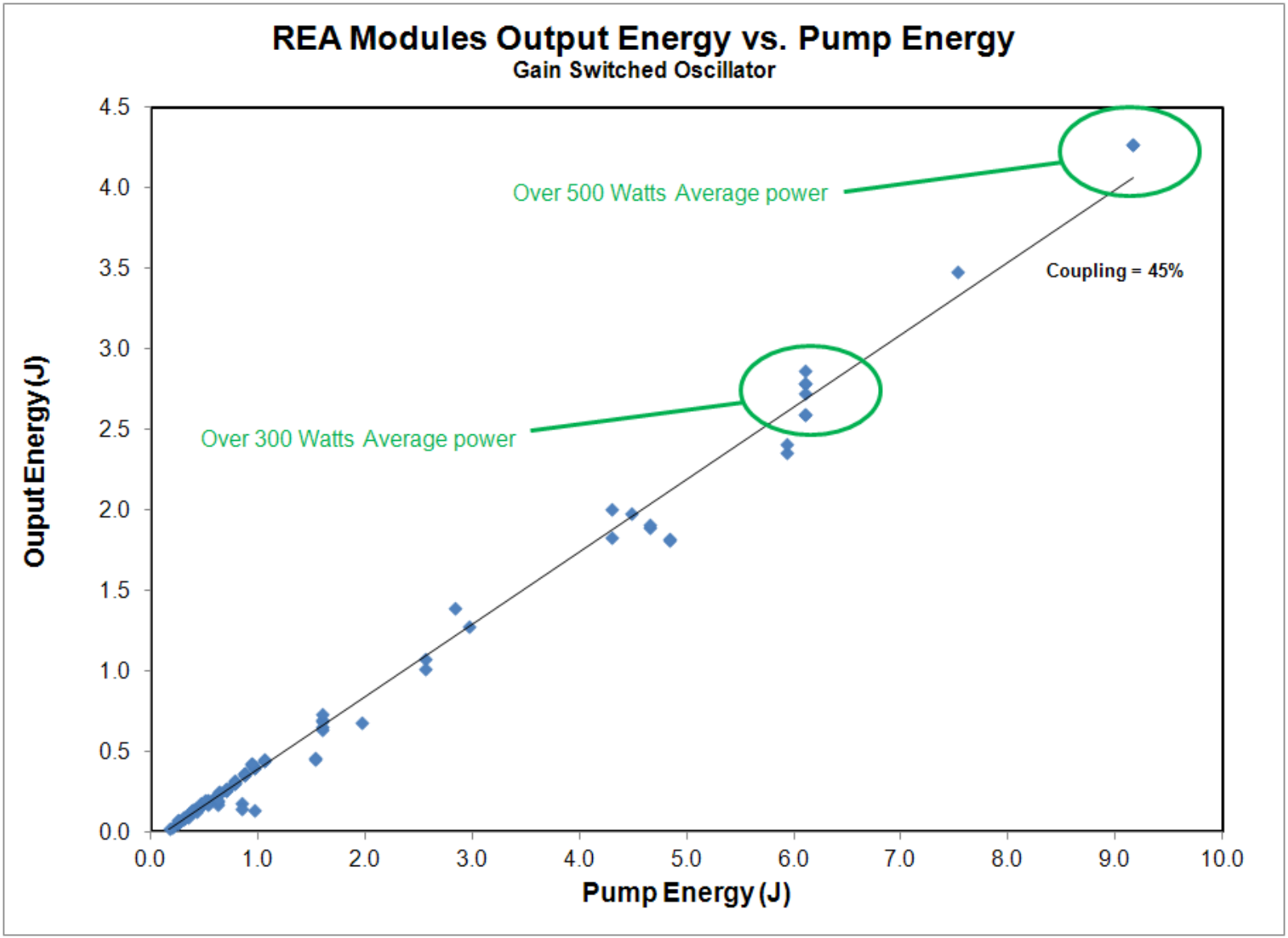


- Stored energy inferred from small signal gain measurements.
- 31% optical to optical coupling over entire product range.

REA Modules Output Energy

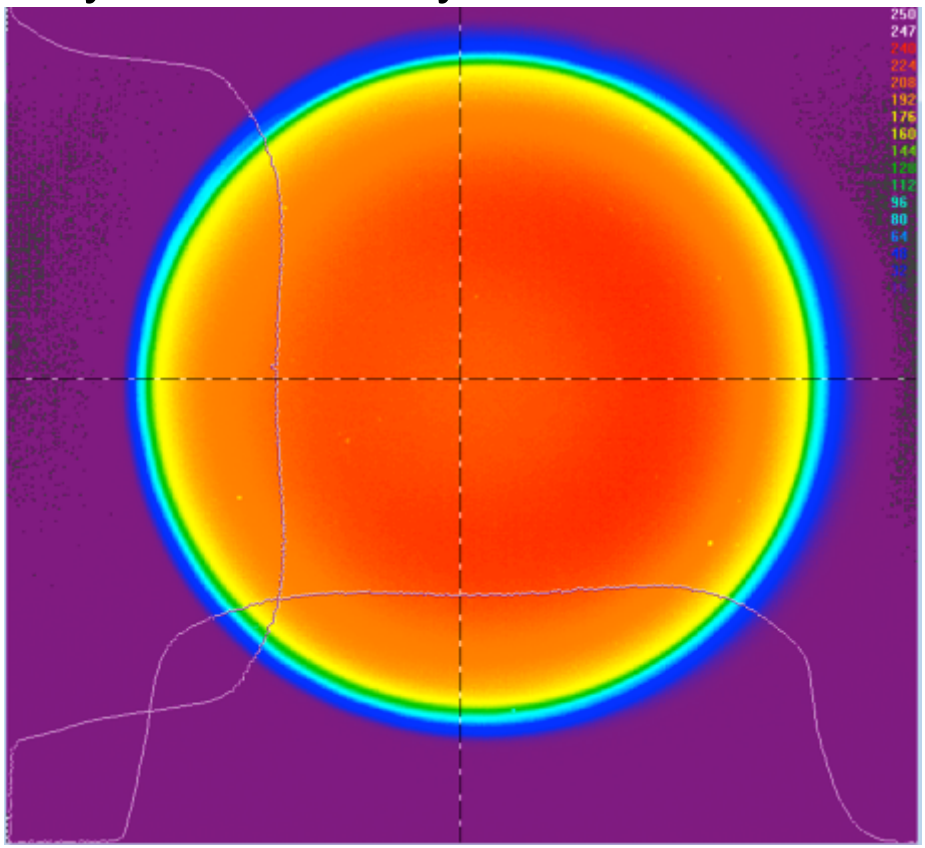


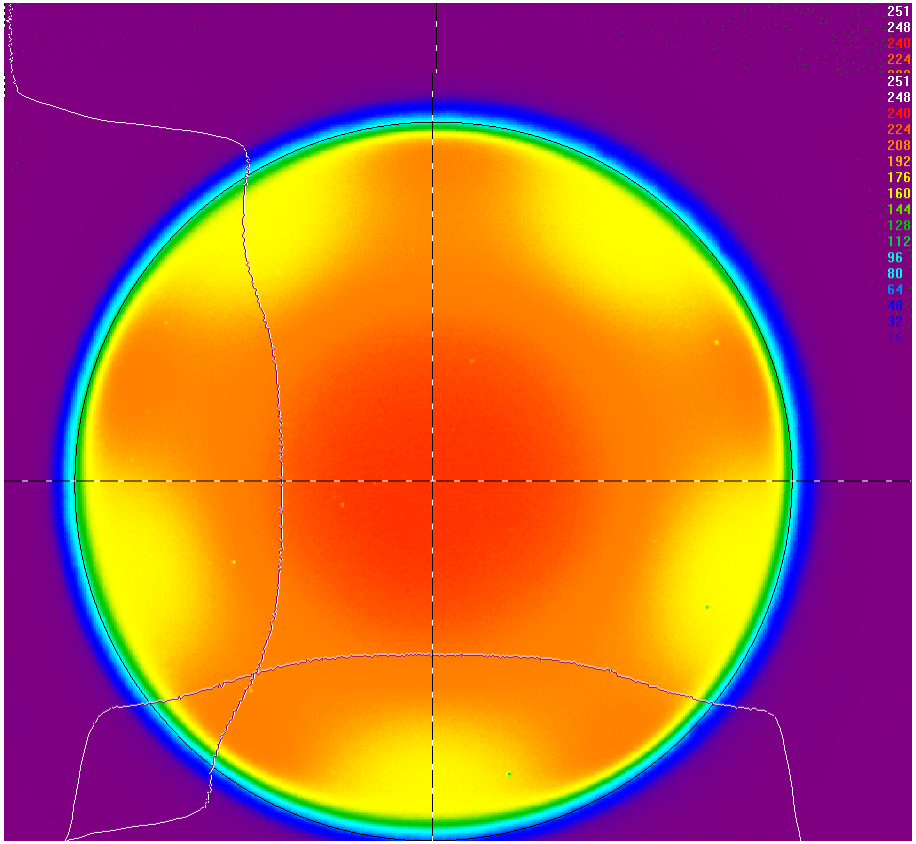
REA Modules Output Energy



Gain Uniformity

- Gain uniformity is an important performance parameter.
- Results in less beam distortion, more usable aperture area, and higher system efficiency.





Different Gain Materials: Nd:YLF, Yb:YAG

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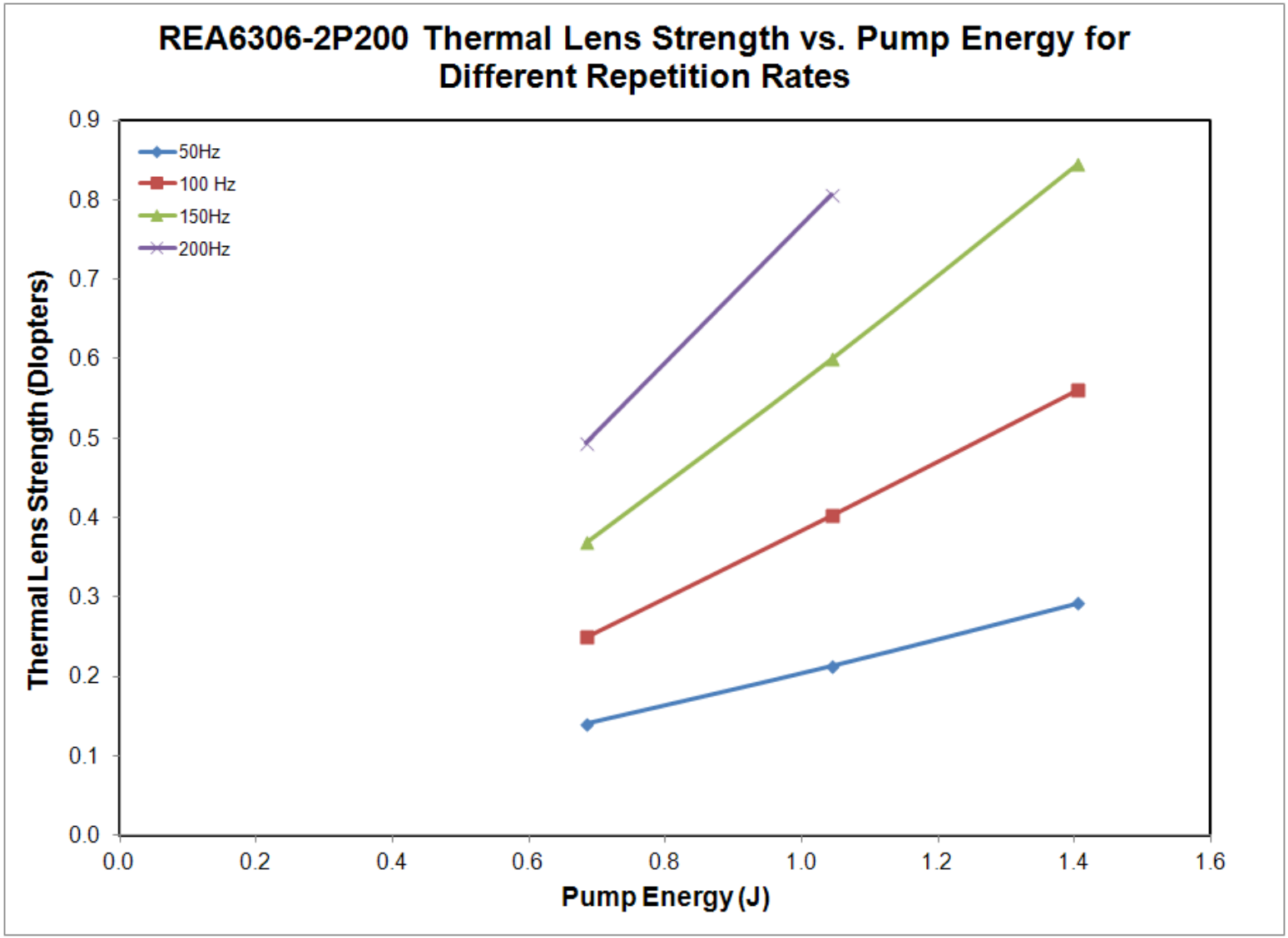
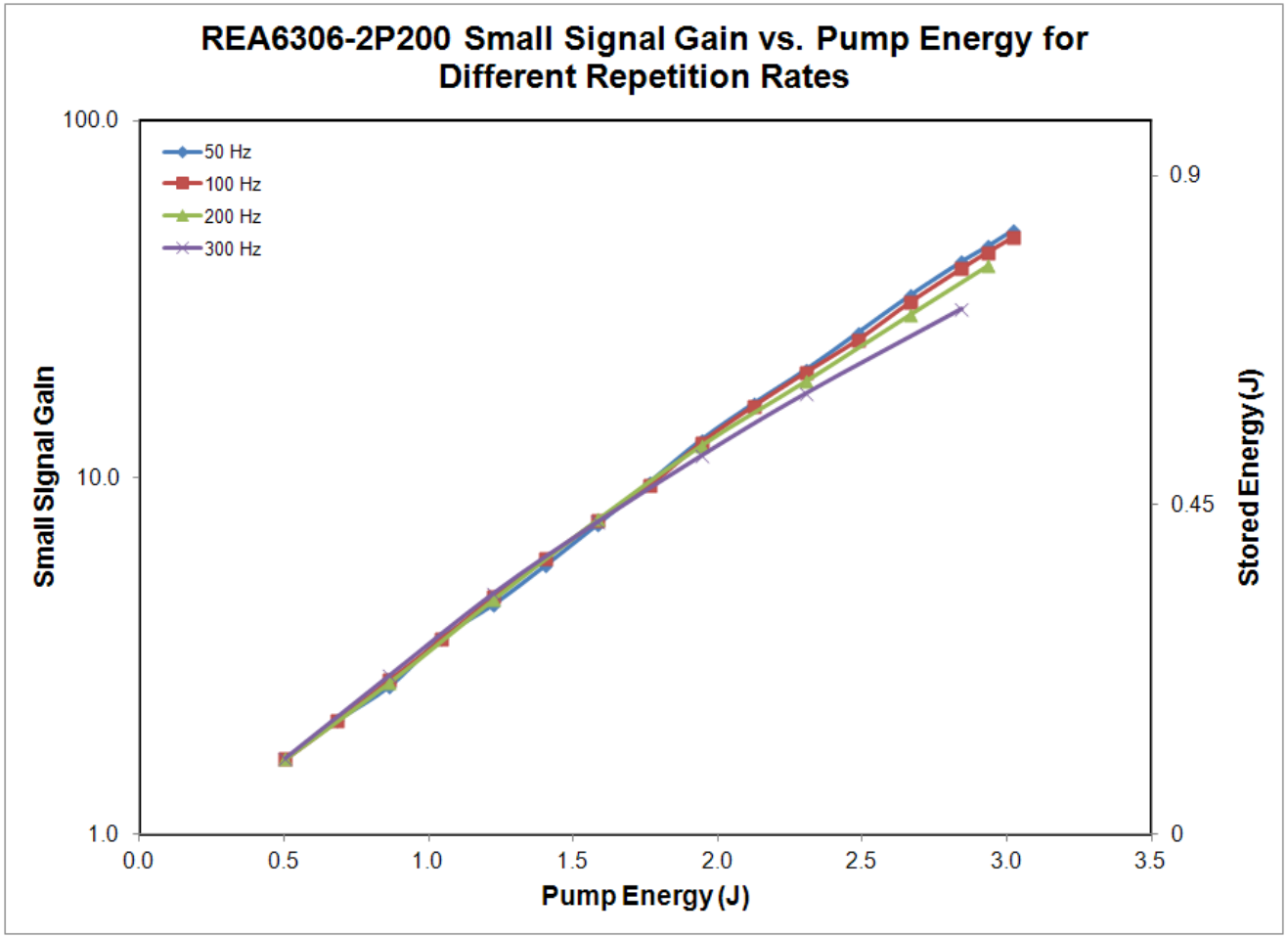
- Quasi-CW pump YLF gain modules are also available.
  - Higher saturation fluence, longer lifetime means higher energy storage.
  - Lower fracture limit vs. YAG reduces average power.
- Rod sizes up to 18mm.
- Uses same technology and parts as a standard Nd:YAG module.
- Long pulse energies over 1 Joule at 5Hz have been demonstrated.
  - 6.35 mm rod, 60 mm pumped length, 30 bars, 3 Joules pump energy.
  - 8 mm rod, 60 mm pumped length, 90 bars, 6.3 J pump, 3.5 J output energy.
  - 10mm rod, 60mm pumped length, 120 bars, 6.7J pump, 3.5 J stored energy.
- Yb Materials:
  - High pump thresholds
    - High Density stacks
  - Un-pumped region losses
    - Ceramic materials with undoped rod ends.

Typical Thermal Lens Strength Performance

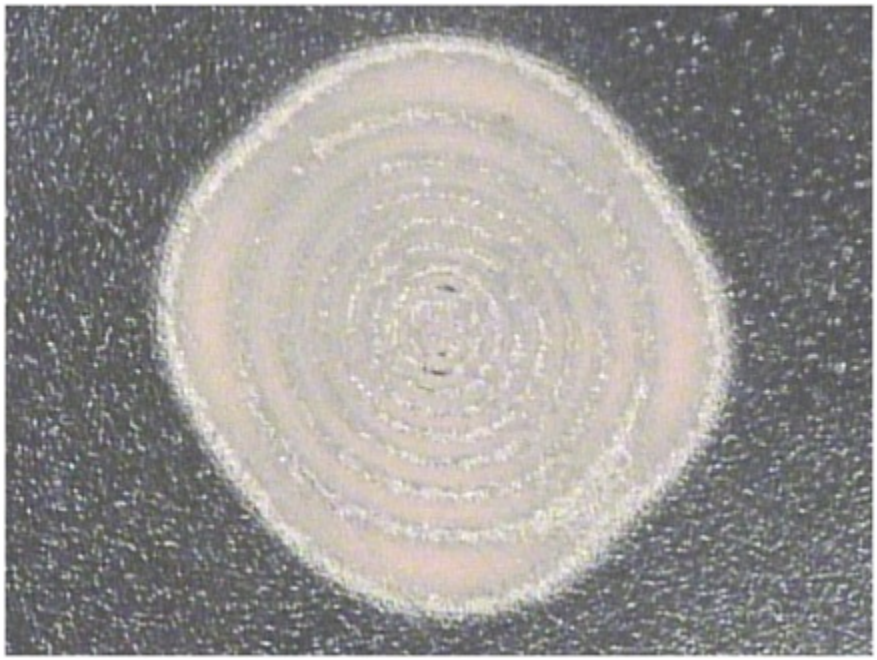


Small Signal Gain Performance



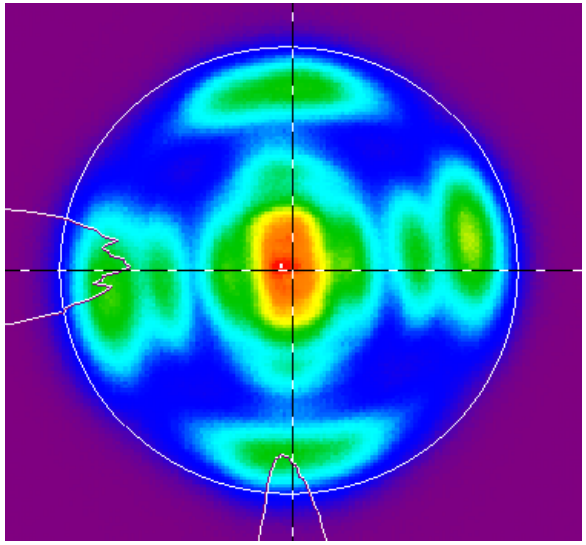
- Small signal gain is maintained as average power increases.

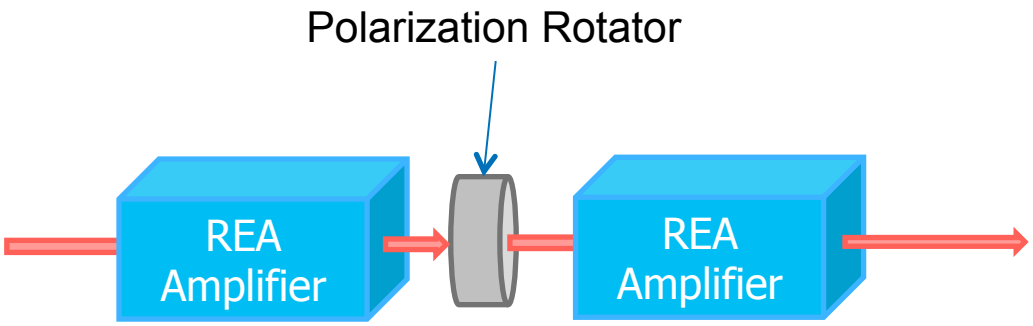
Beam Preservation



- Single head, single pass
  - Left is at 50Hz, right is at 100Hz.
- Degradation is due to thermally induced stress birefringence.

Use Compensation Scheme



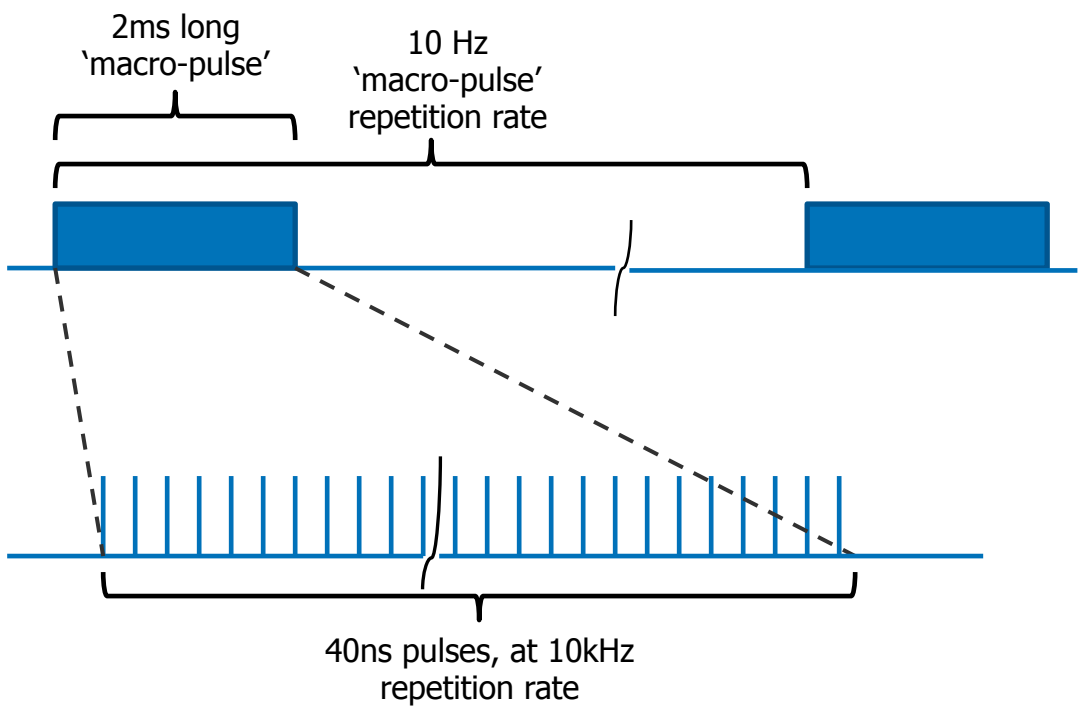


- By using two heads with a polarization rotator in between, much lower polarization losses can be obtained.
- Typically losses are reduced to 1-2%.

Pulse Trains

- What are pulse trains?
  - A series a short pulse width, closely spaced pulses, occurring in a series of bursts.
  - Pulse width 100ns or shorter.
  - Repetition rates of 5kHz or more.
  - Bursts of 100Hz or less.
  - The burst of pulses is called a ‘macro-pulse’.

- These are not hard limits, but guidelines.
  - Engineering trades to accommodate ‘unusual’ situations.



Examples of Modeling Output

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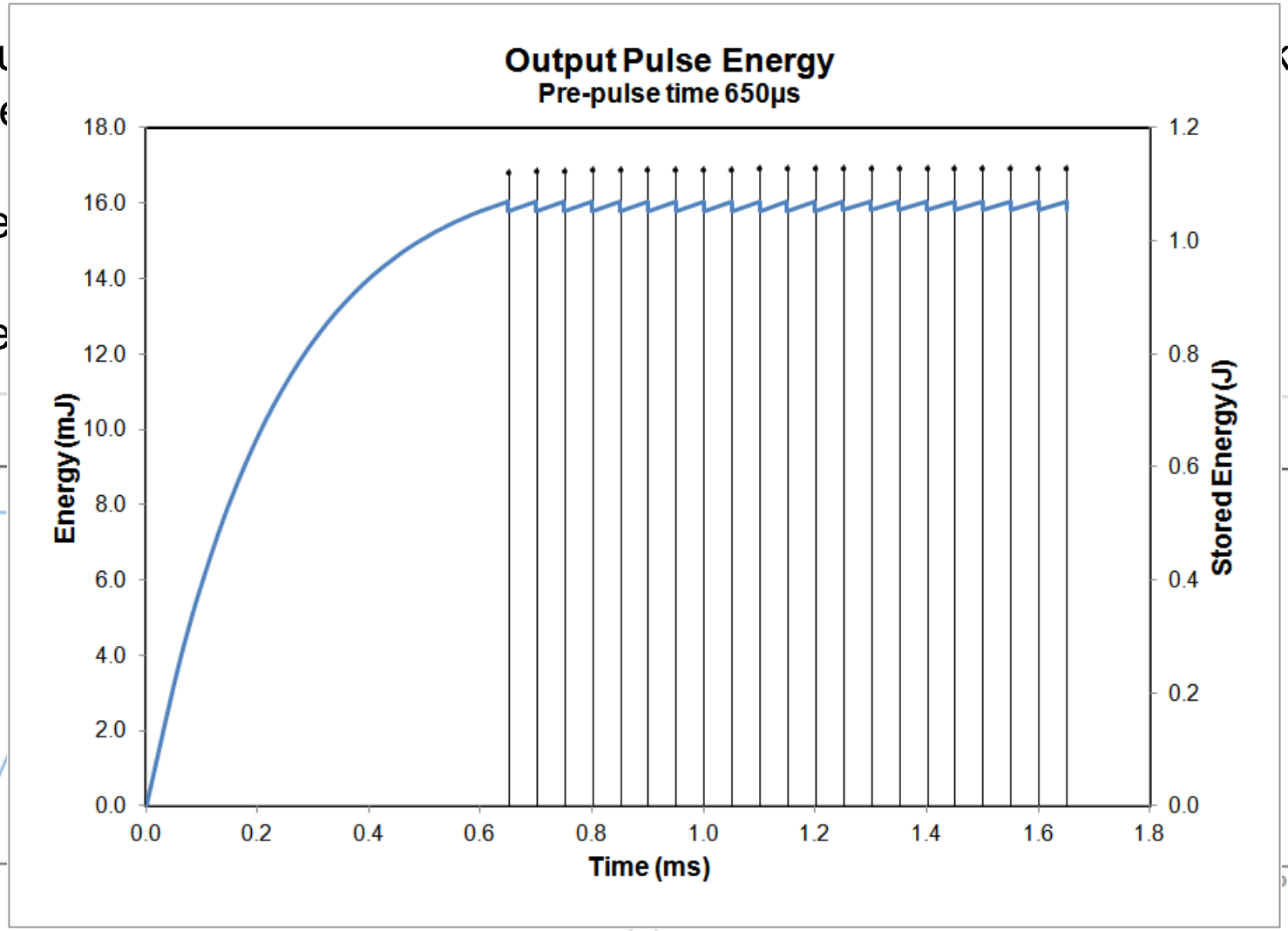
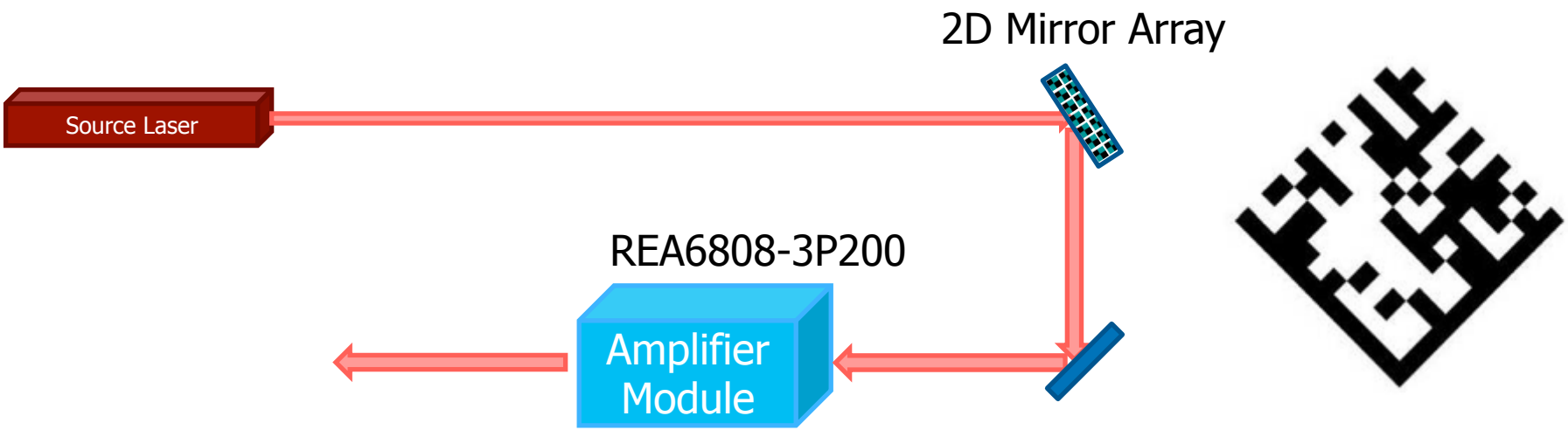
- The
- The



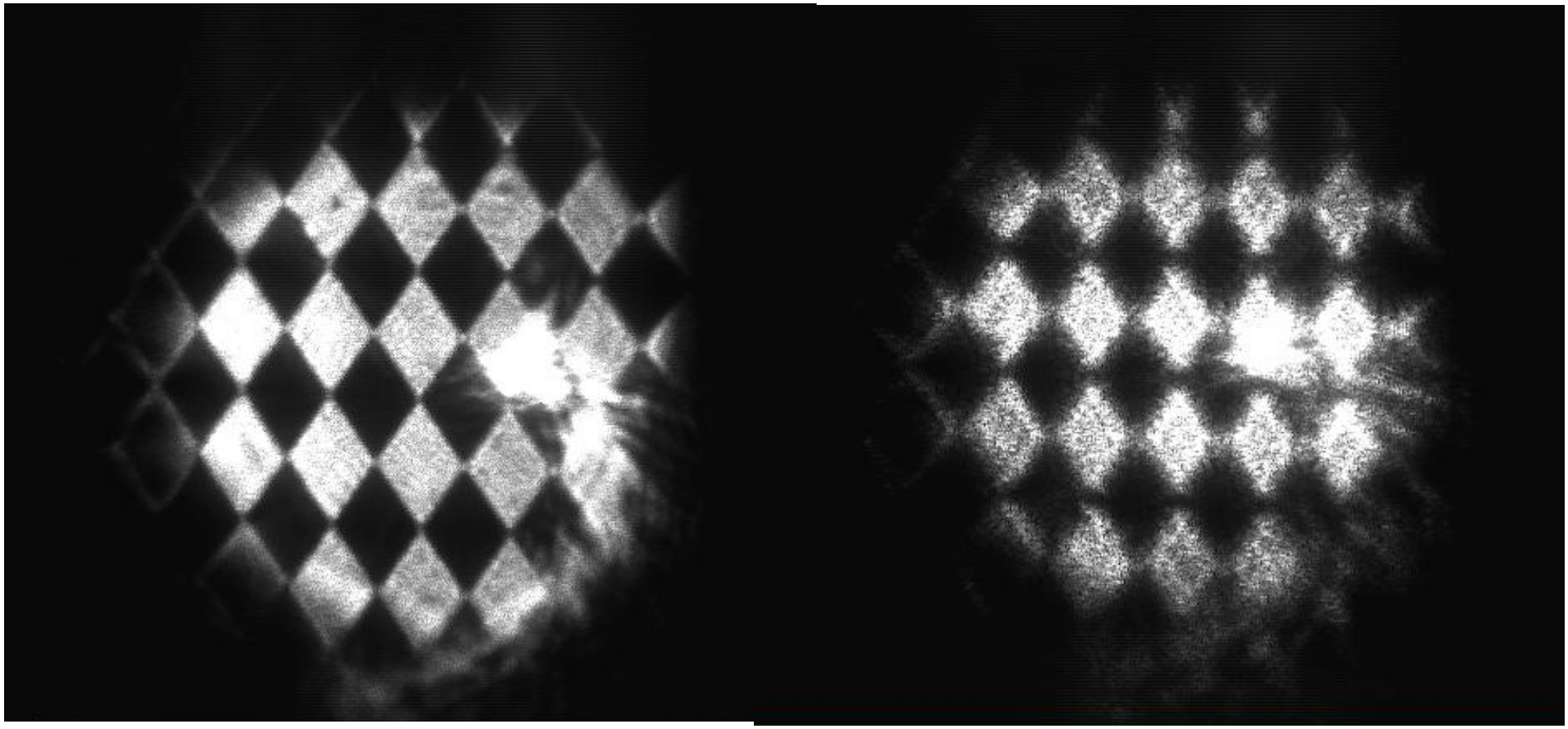
Application – Image Amplification

- Generation of 2D bar codes with a single pulse.
- Input image is generated by a 2D mirror array (DLP).
  - Mirror array has low damage threshold.
  - Input energy fluence < 1mJ/cm^2.
  - Too low to mark materials of interest
- One REA single pass results in ~140x amplification and good image quality.



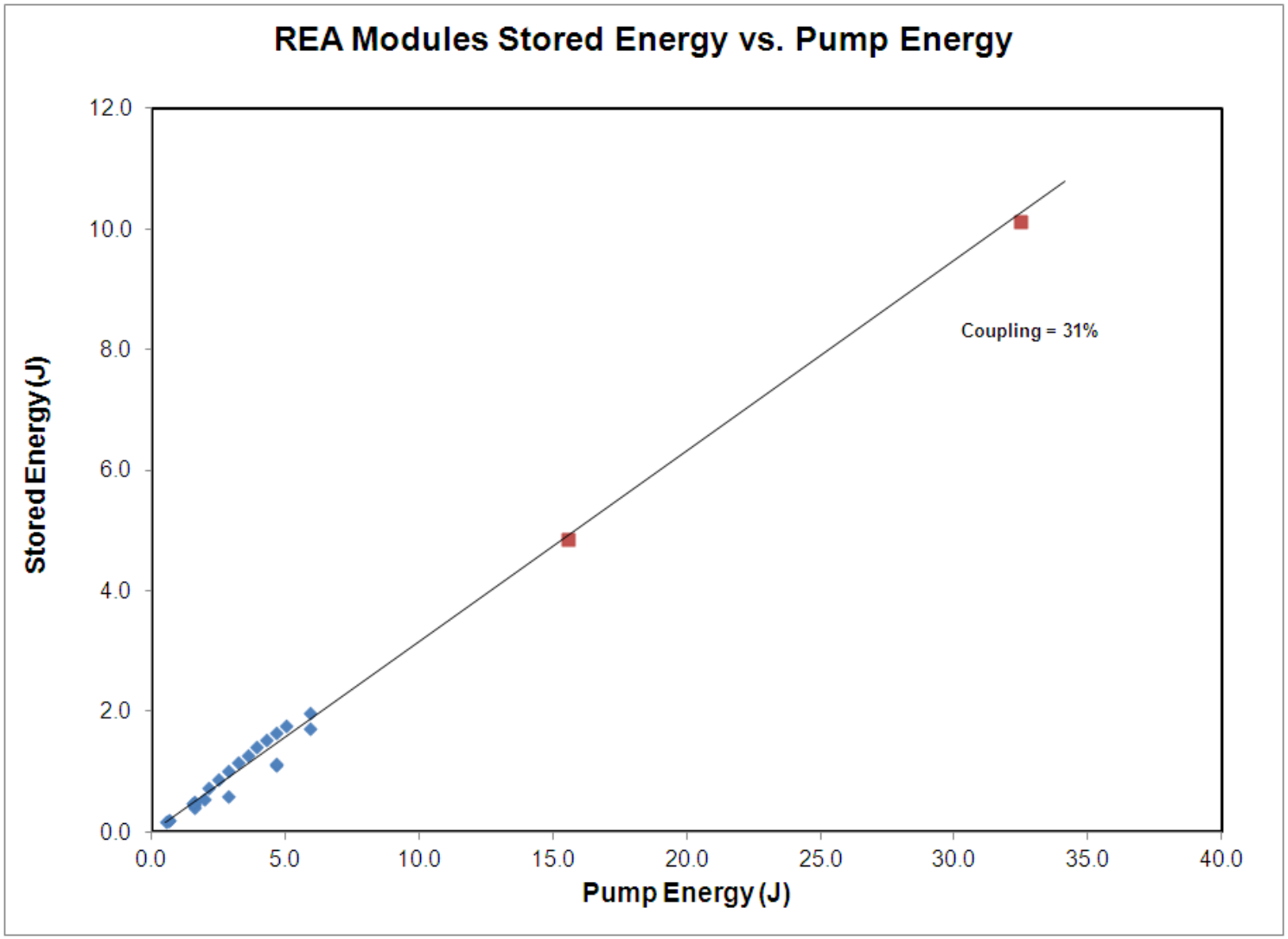
Images

- Before amplification on left, after amplification (120x) on right.
- Resultant 2D bar code meets industry standards for contrast, resolution, etc.



Images and data courtesy of Vardex Laser Solutions, Dr. Farzan Ghauri

What is possible?



Conclusions

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- NGCEO has a selection of 1J+ COTS amplifiers utilizing long life laser diodes.
- Repetition rates of 100Hz are easily obtainable.
- Very uniform spatial profile increases system performance.
- These amplifiers are building blocks, or engines, that pump OPCPAs for driving high energy laser systems.

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