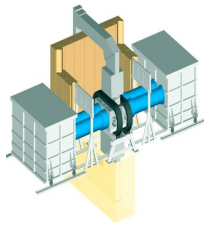

Overview of KrF Laser Development*

Plasma Physics Division

18th High Average Power Laser Program Workshop

presented by J. Giuliani

from contributed slides

Santa Fe, NM

April 8-9, 2008

*Supported by the Department of Energy/NNSA/DP

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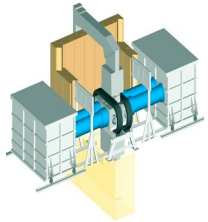

Key Components of a Krypton Fluoride (KrF) Laser

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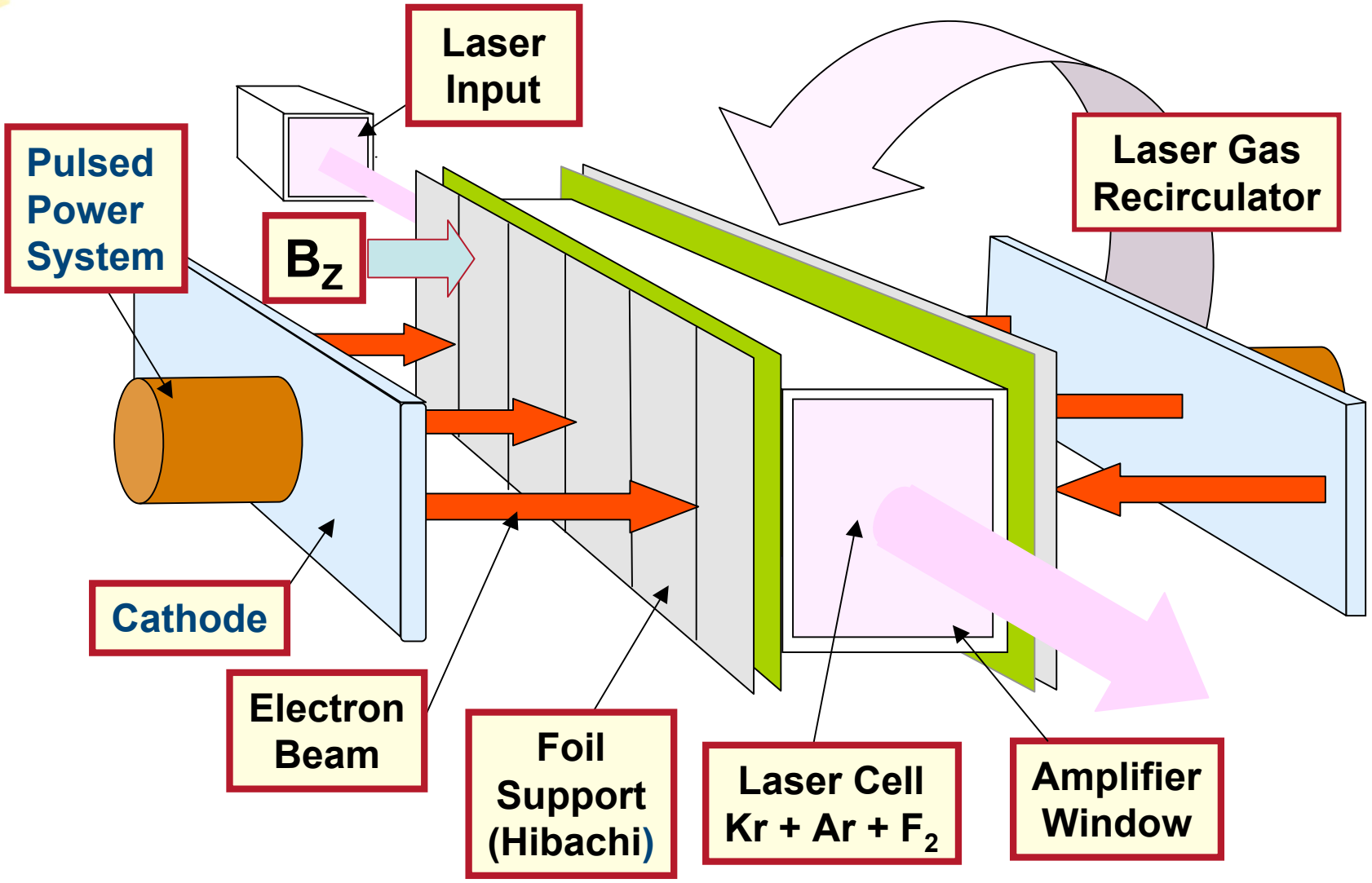
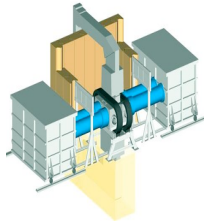




Outline

Plasma Physics Division

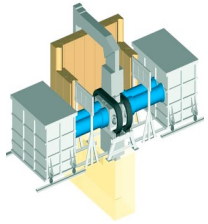
A. Main Amp
   - pulse power
   - oscillator single shot
   - recirculator
   - oscillator rep-rate
   - focal profile

B. Cathode Development
   - strip
   - ceramic honeycomb

C. Pre-Amp

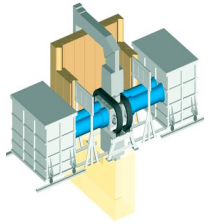
D. Laser System
   - multiplexing
   - rep-rate shots

E. Future
   - pre-amp recirculator
   - scalloped hibachi
   - Zirconia cathode
   - foil material



Main Amplifier

Plasma Physics Division



Long duration demonstrated for pulsed-power e-beam diode

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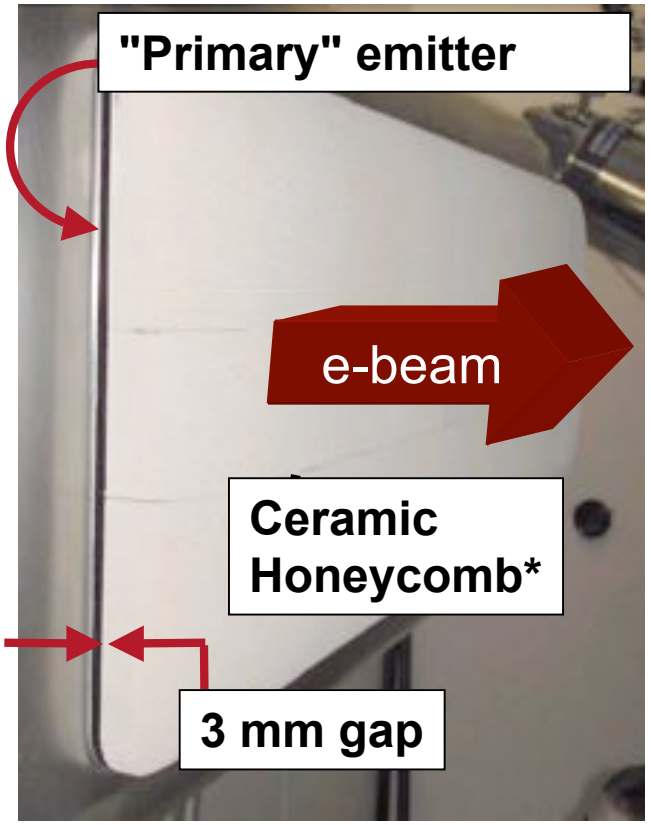
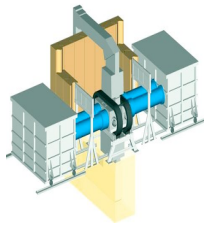
Five times10,000 continuous shots @ 1 Hz, into cooled anode plate, without breaking diode vacuum.

Cathode emission uniformity maintained throughout the whole run.
(=> laser pumping uniformity)





Intrinsic Efficiency 730 J Laser Shot of 9.6%

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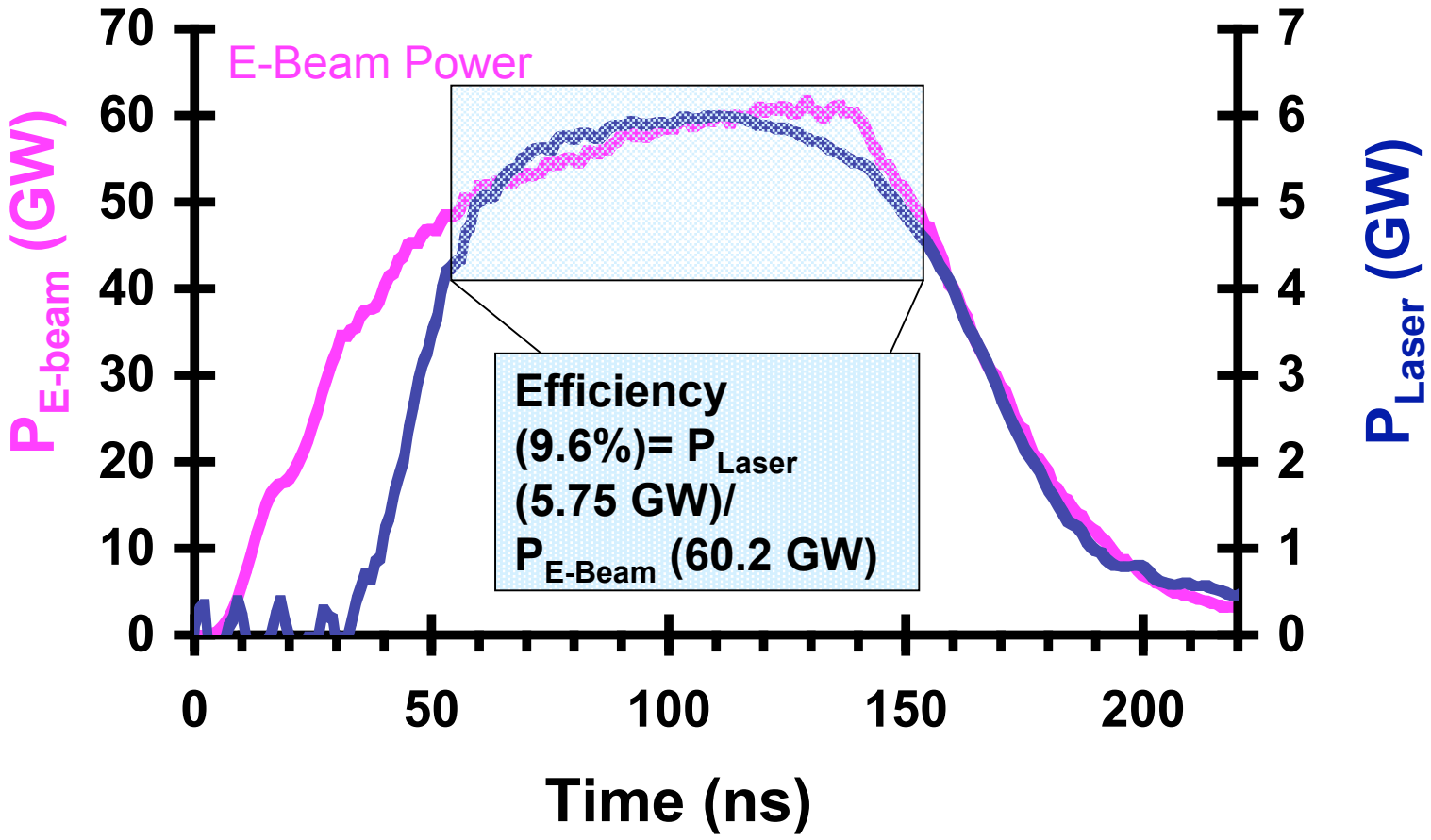
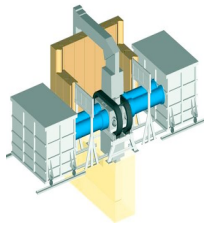


E-Beam Deposition Power
= (Pressure Rise (E)*Radiation Correction (105%)) + Laser Energy (E)
Distributed over the pulse width measured in the diode



Recirculator removes heat & calms flow.

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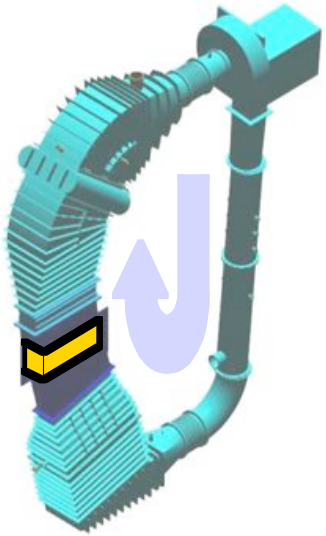
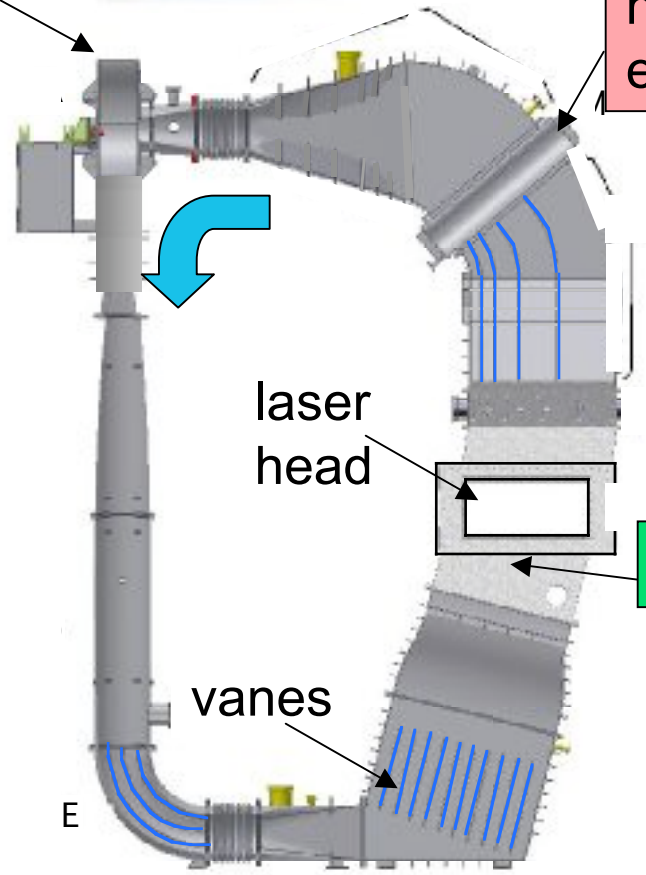
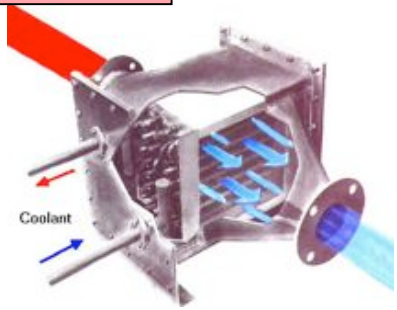


blower

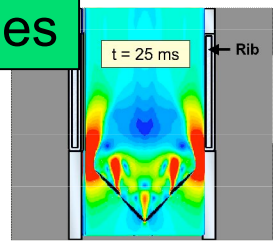
heat exchanger





laser head

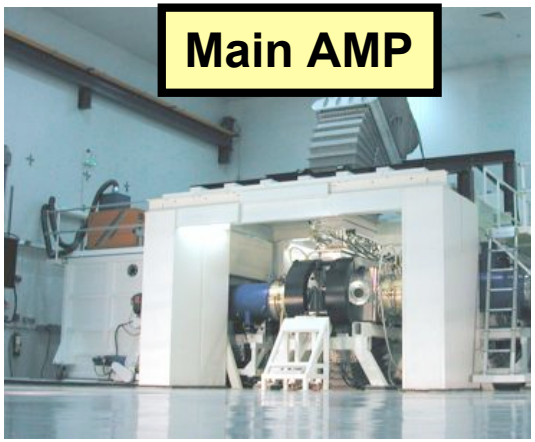
throttles

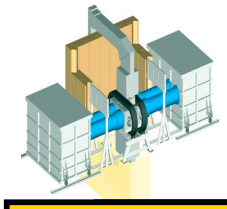


vanes

E

H

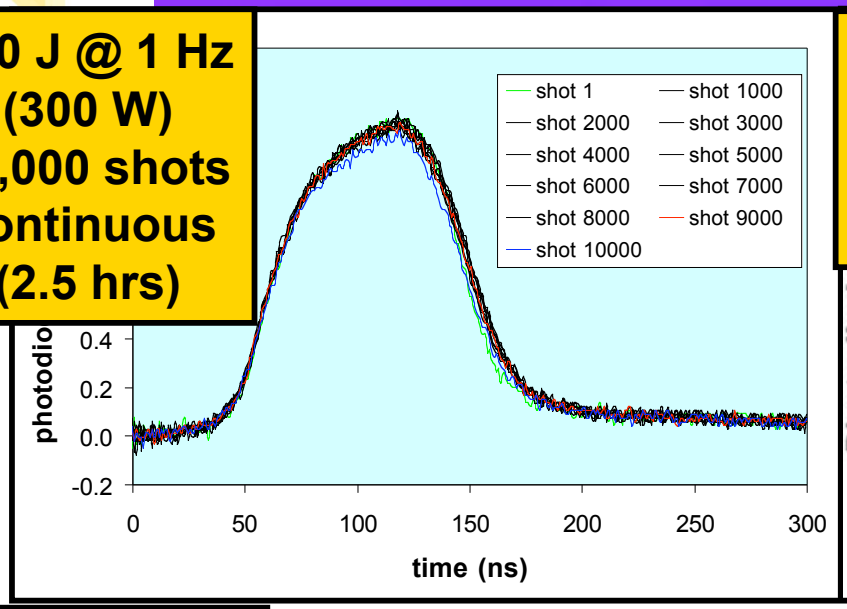




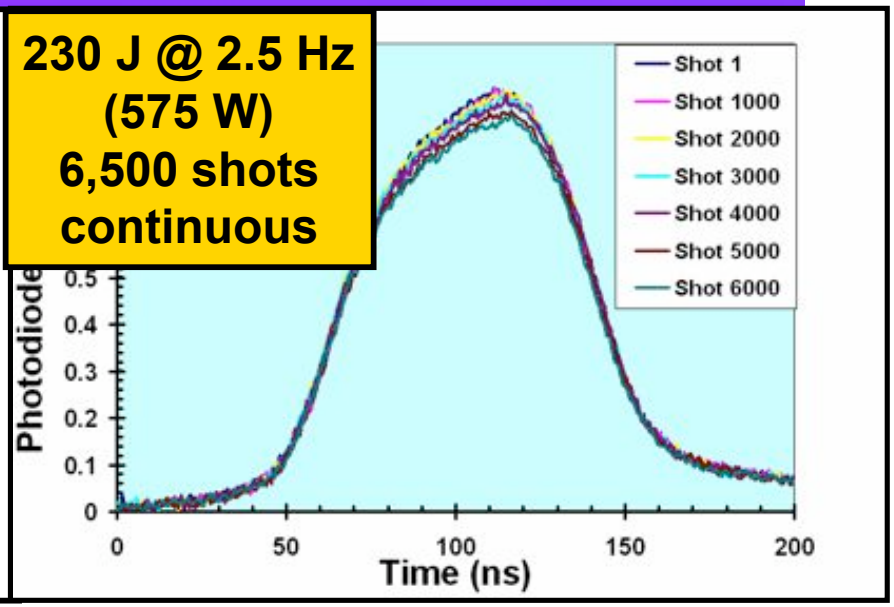
Consistent long duration, monolithic cathode, oscillator, double sided runs

Plasma Physics Division

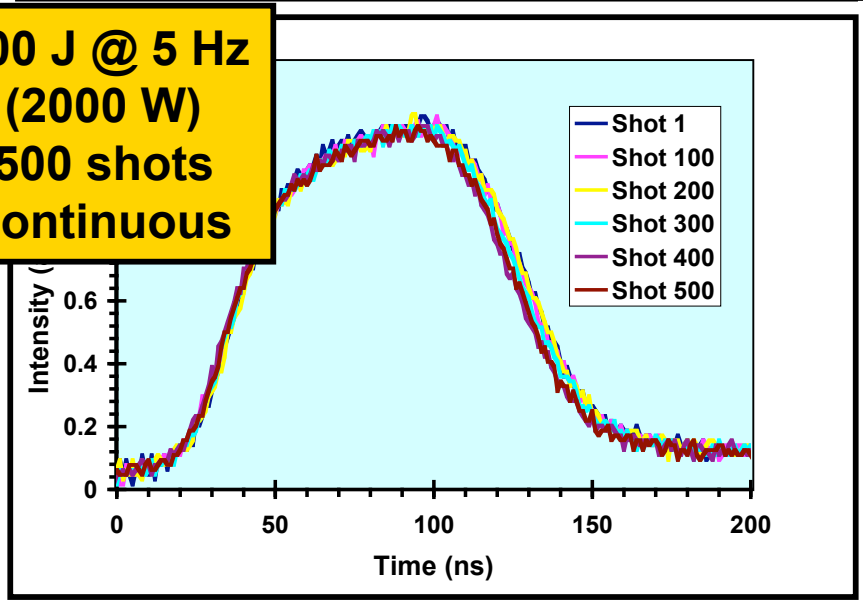
300 J @ 1 Hz (300 W) 10,000 shots continuous (2.5 hrs)



230 J @ 2.5 Hz (575 W) 6,500 shots continuous



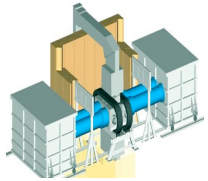
400 J @ 5 Hz (2000 W) 500 shots continuous



other notable results:

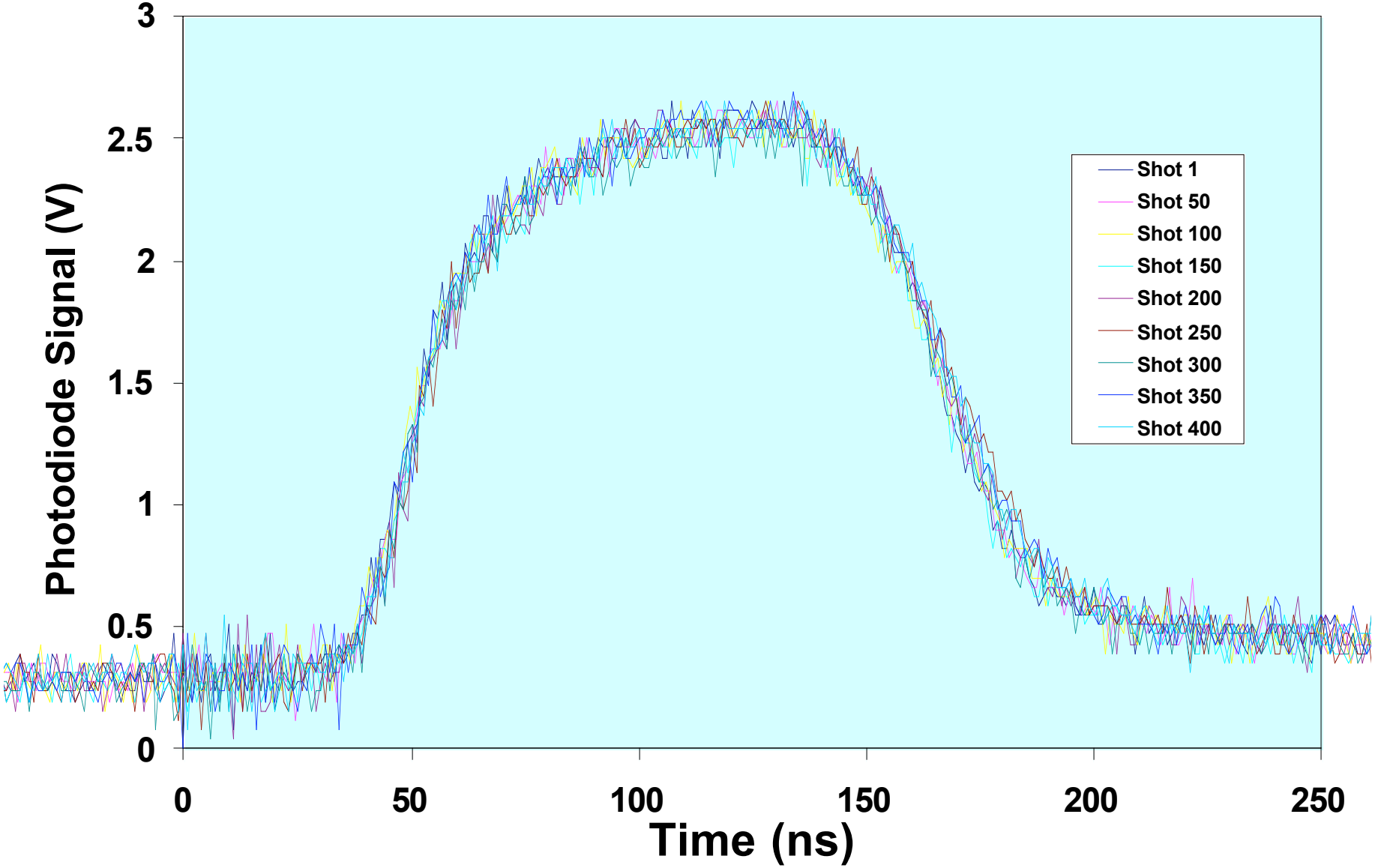
250 J @ 5 Hz (1,250 W), 7700 shots in four segmented run

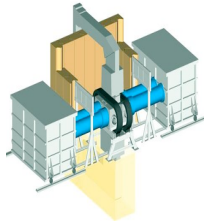
single sided @ 2.5 Hz 25,000 shot run.



700 J, 1 Hz Rep-Rate oscillator with strip cathode

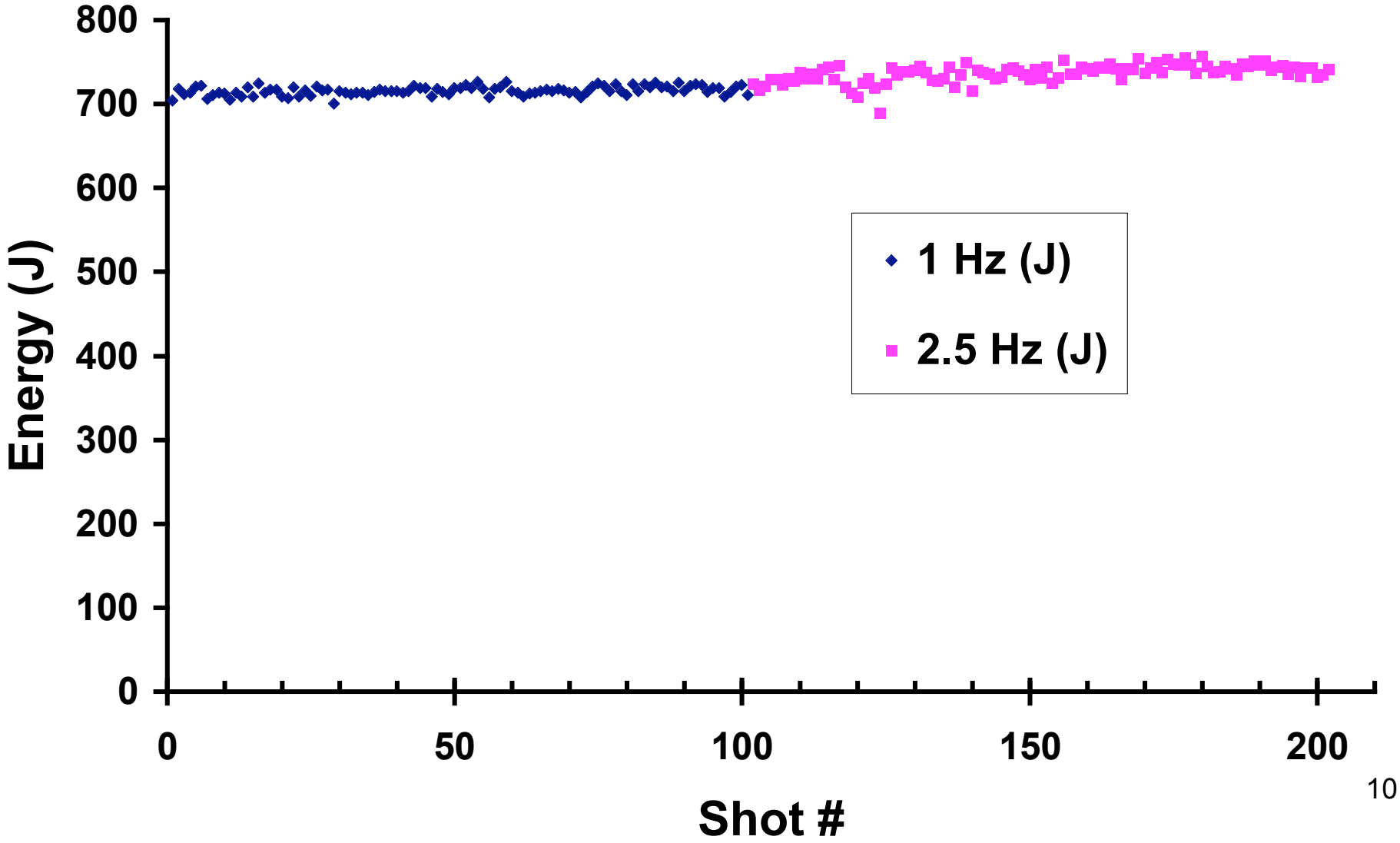
Plasma Physics Division

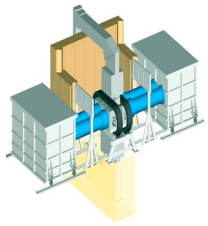




High efficiency oscillator maintained with strip cathode independent of rep-rate

Plasma Physics Division





30 shots 1 Hz Focal Profile Measurement ("Pseudo ISI")

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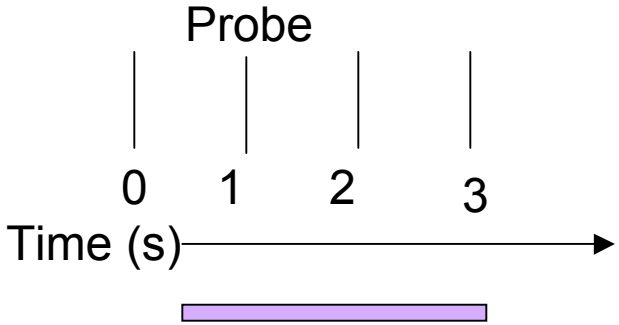
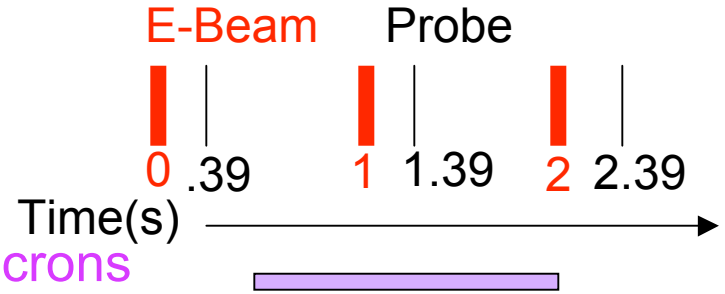
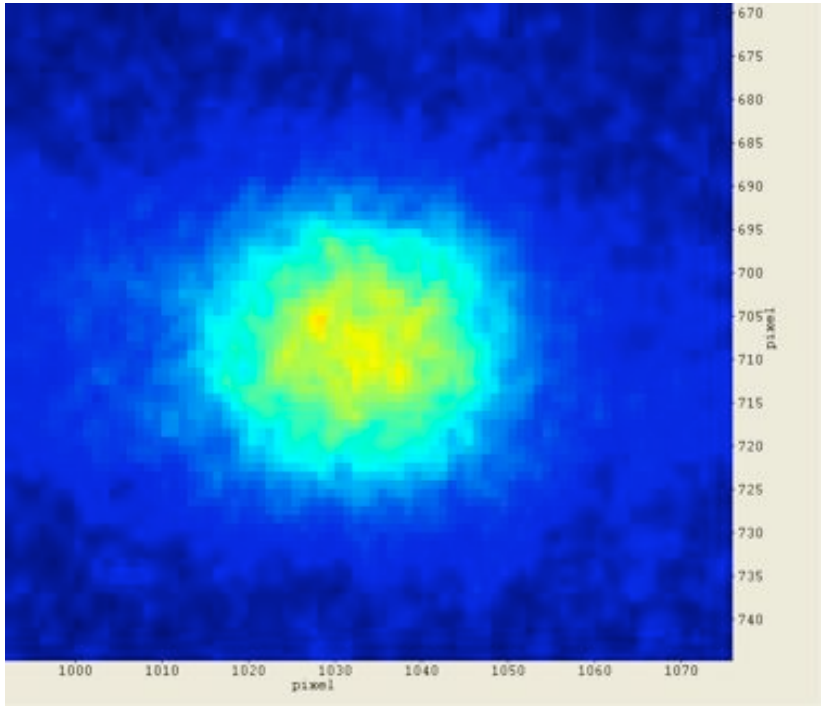
Probe Beam No E-Beam

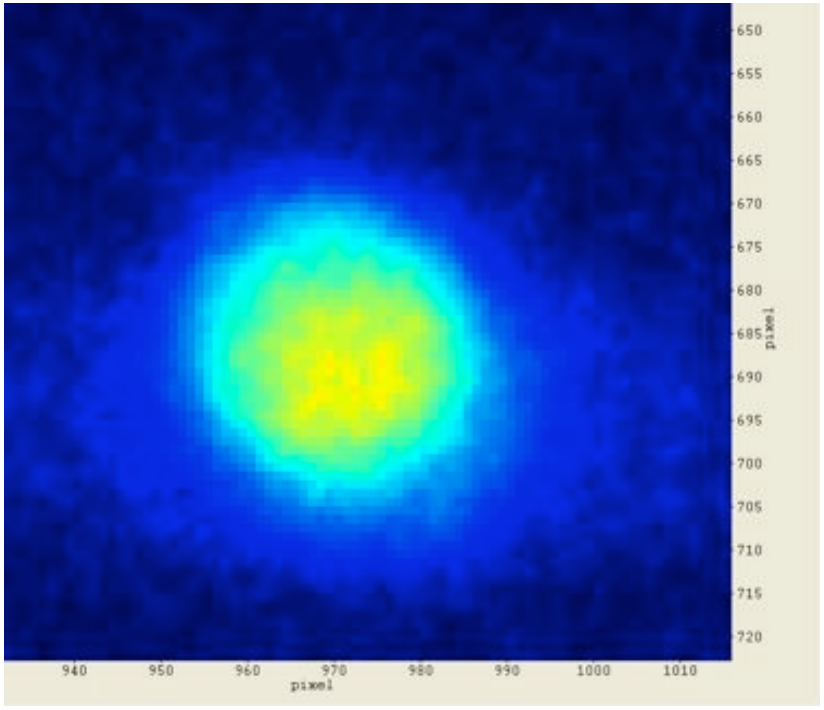


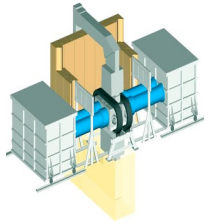
Probe Beam with E-Beam 1 Hz 390 ms after



500 microns







Hibachi/Cathode Development

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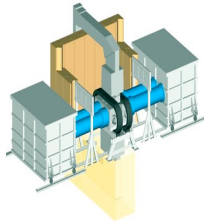

Strip cathode patterns e-beam to miss ribs, thereby enhancing deposition efficiency.

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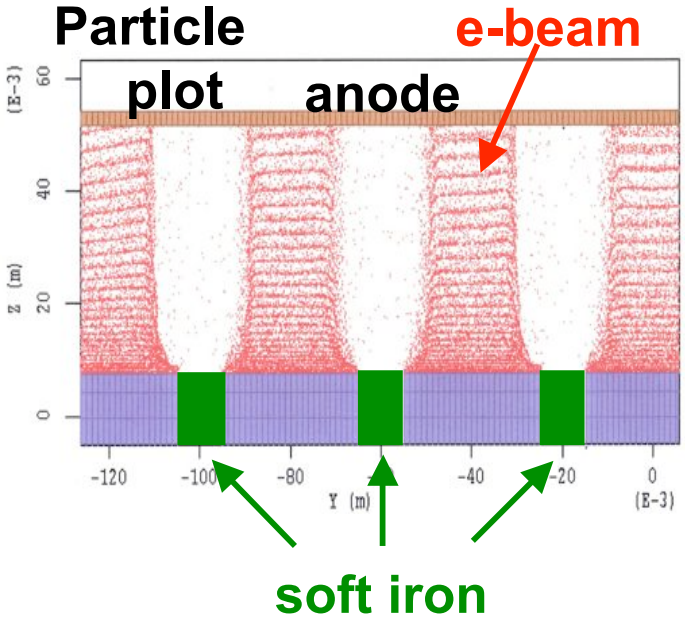
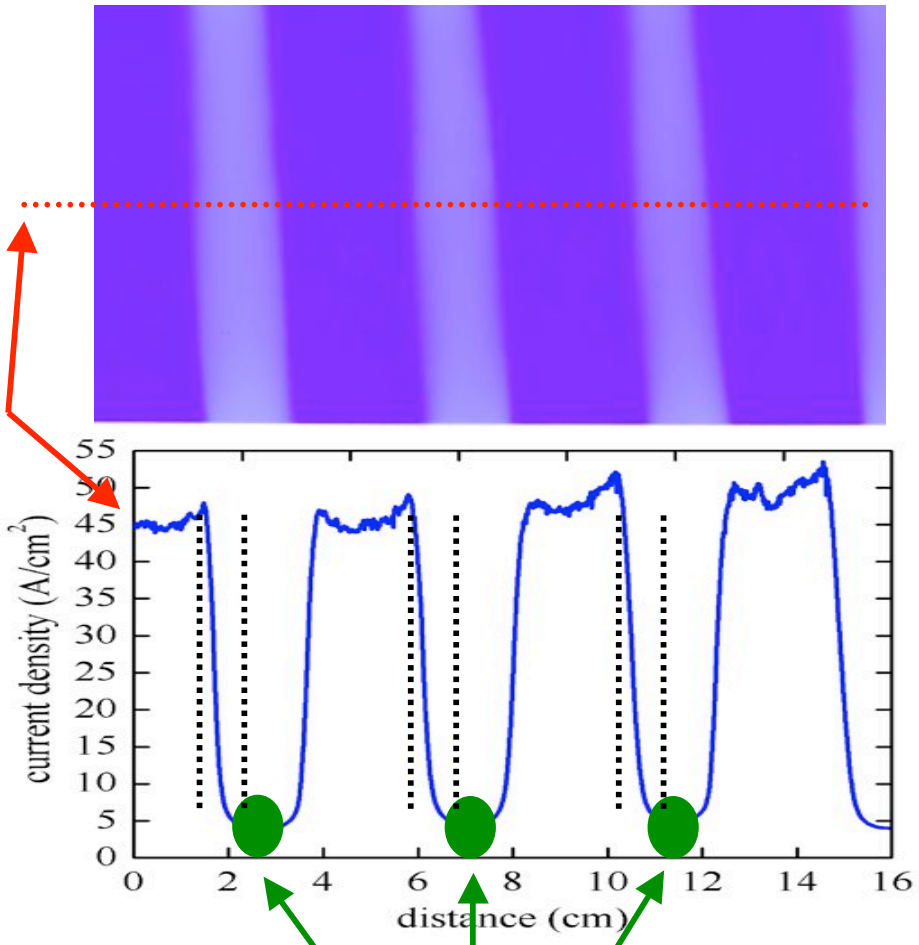
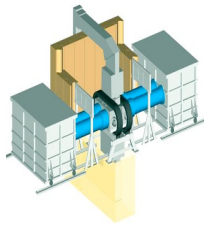
Particle-in-cell simulations



slanted strip cathode

Radiachromic film image (time-integrated)





Ceramic honeycomb Cordierite cathode overlies emitter to provide longevity

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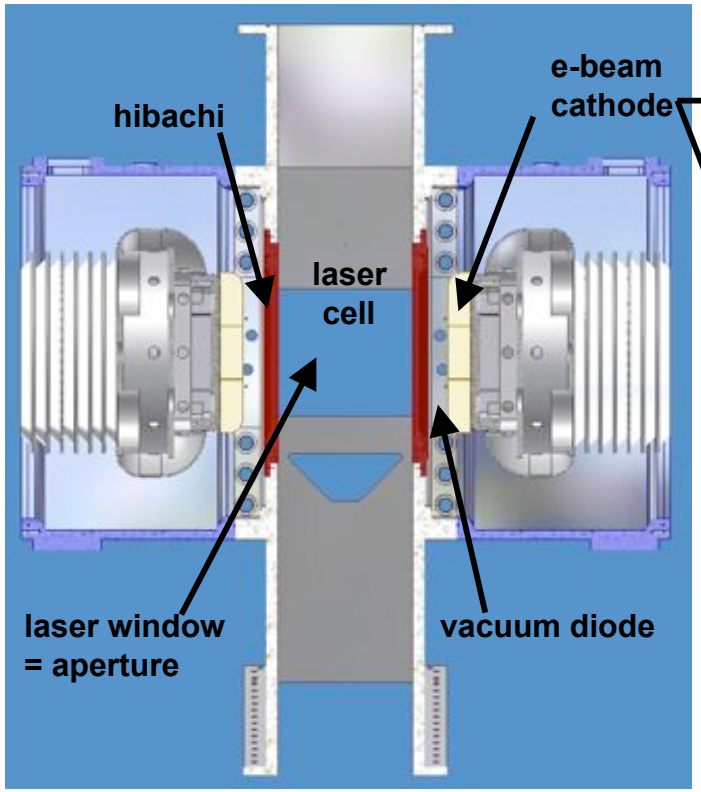
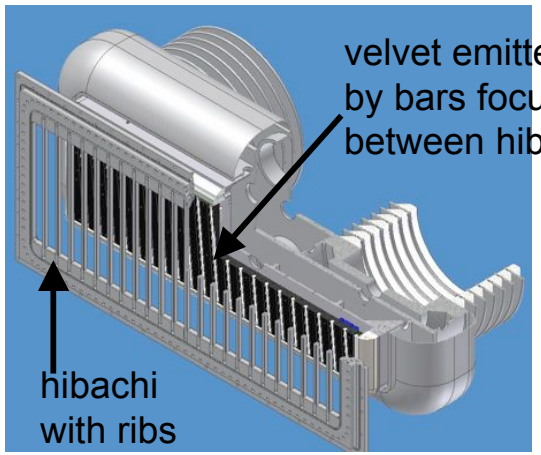
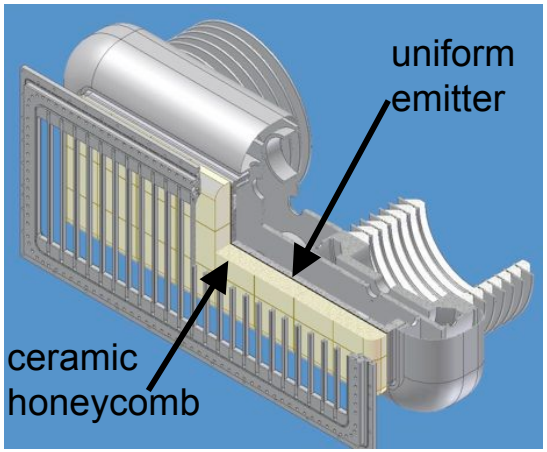


or

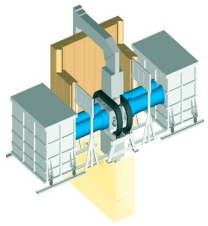
strip cathode
900 kW/cc gas deposition



monolithic cathode
550 kW/cc gas deposition



e-beam deposition into laser cell
for the two cathodes from
Hegeler, et al., POP, vol.11, p.5010 (2004)



Foil is lifetime sometimes limited by debris from Cordierite cathode

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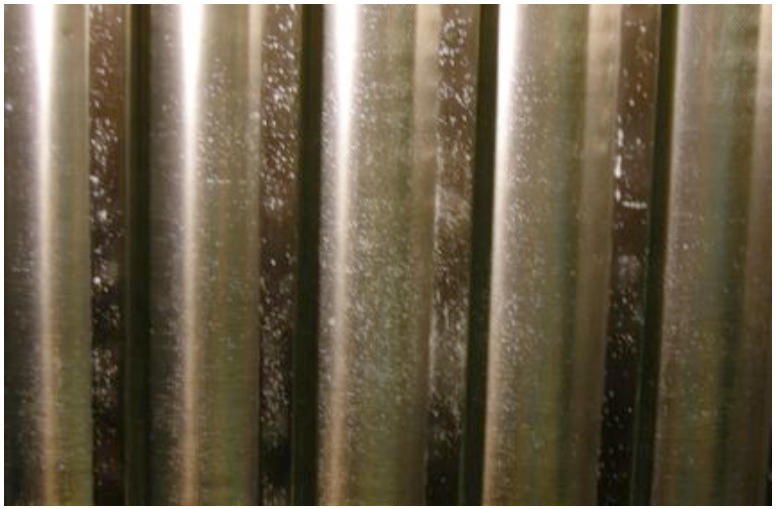

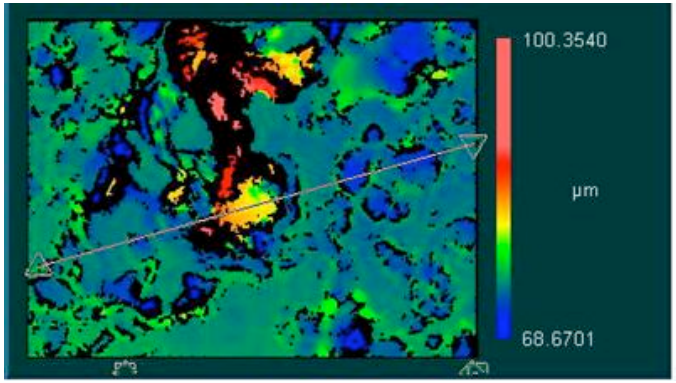

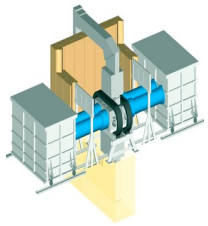

Silica coated reduces debris attack of hibachi foil.

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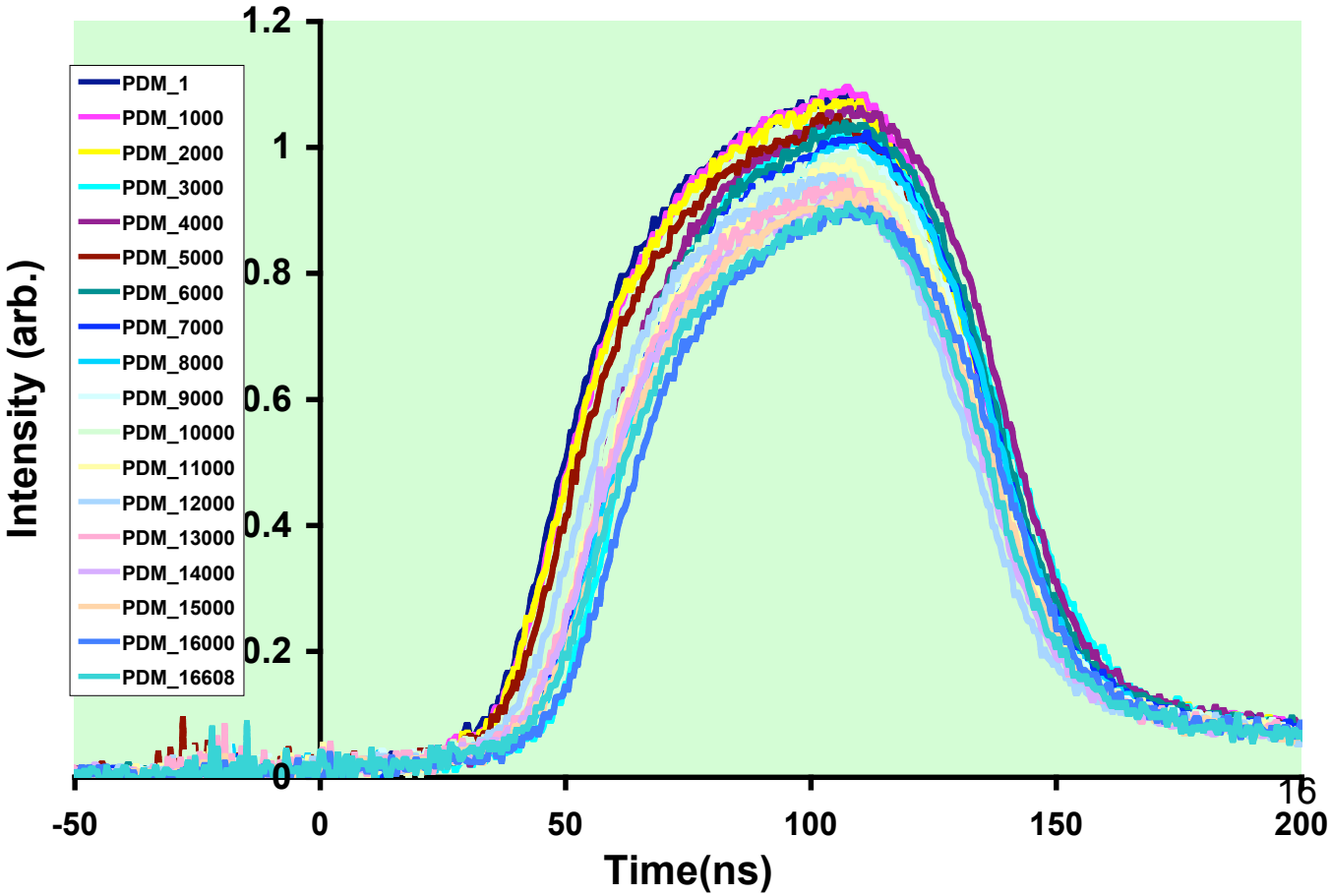
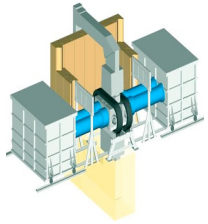
Average 270 J @ 2.5 Hz
Over Two Hour Time Period





Pre- Amp

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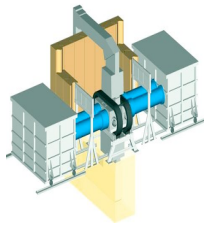

Preamp: measured laser energy output is consistent with Orestes simulations.

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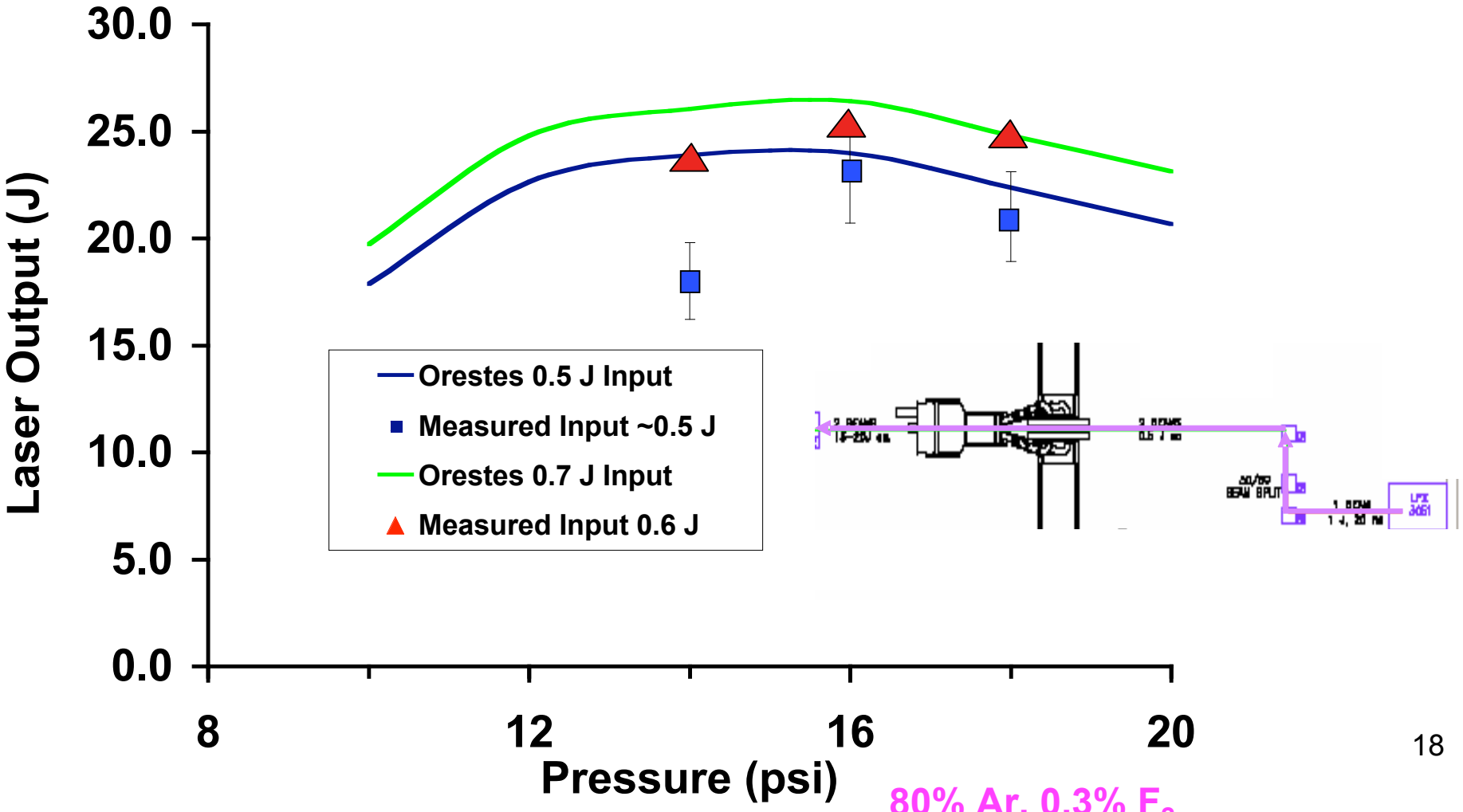
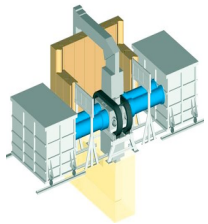
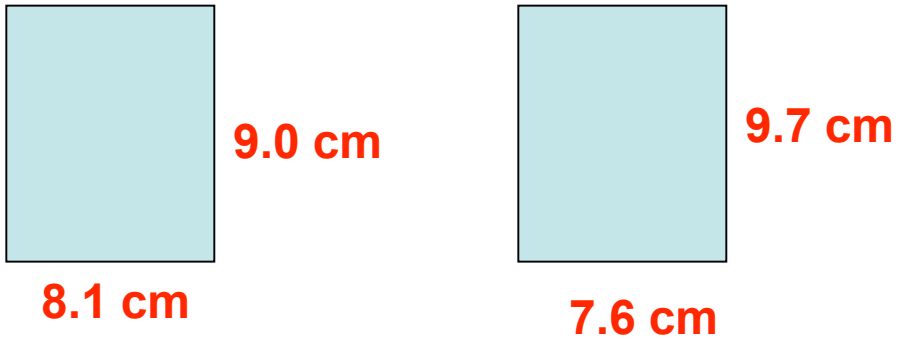


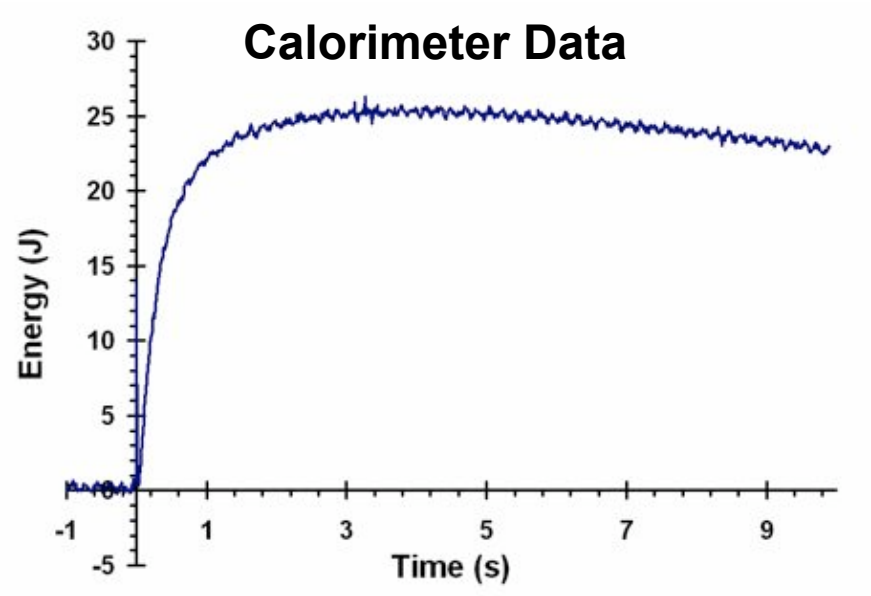


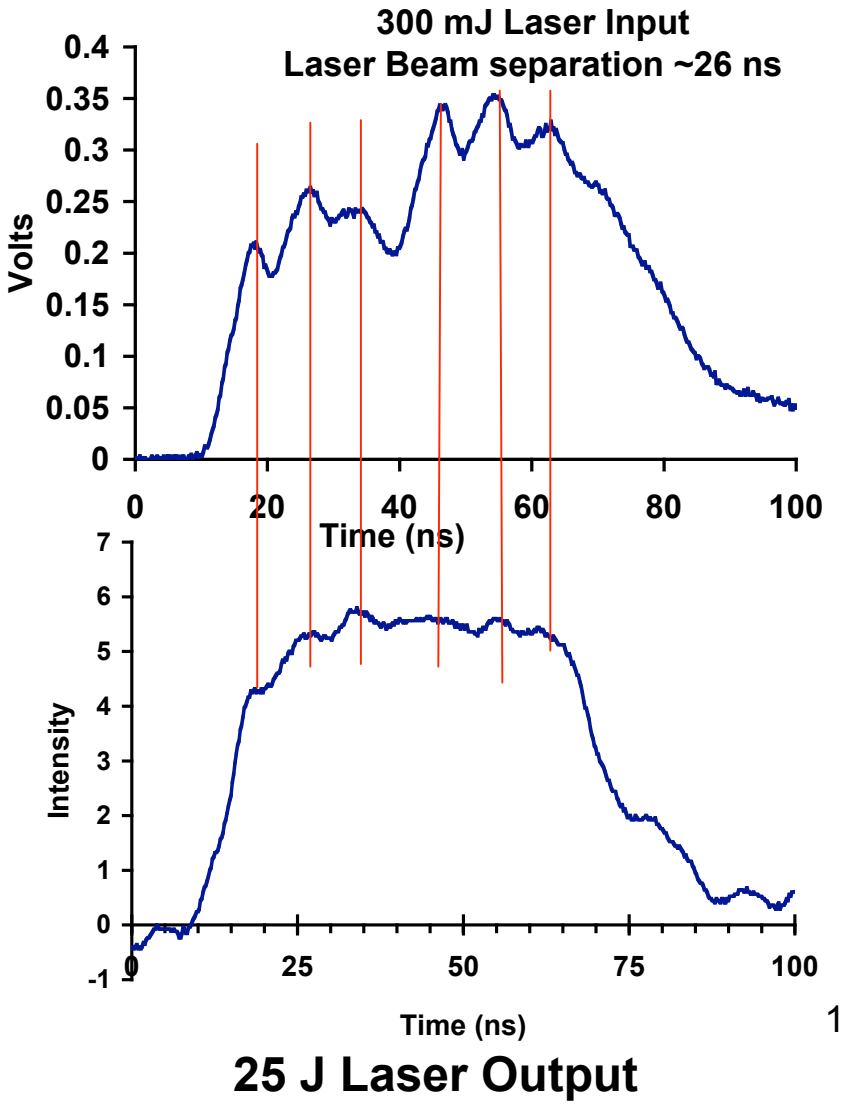
25 J Output of Two Beam Angularly Multiplex Preamplifier

Plasma Physics Division

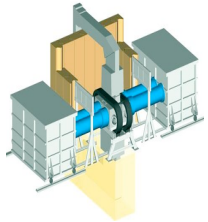
Beam 1 **Dimensions** Beam 2







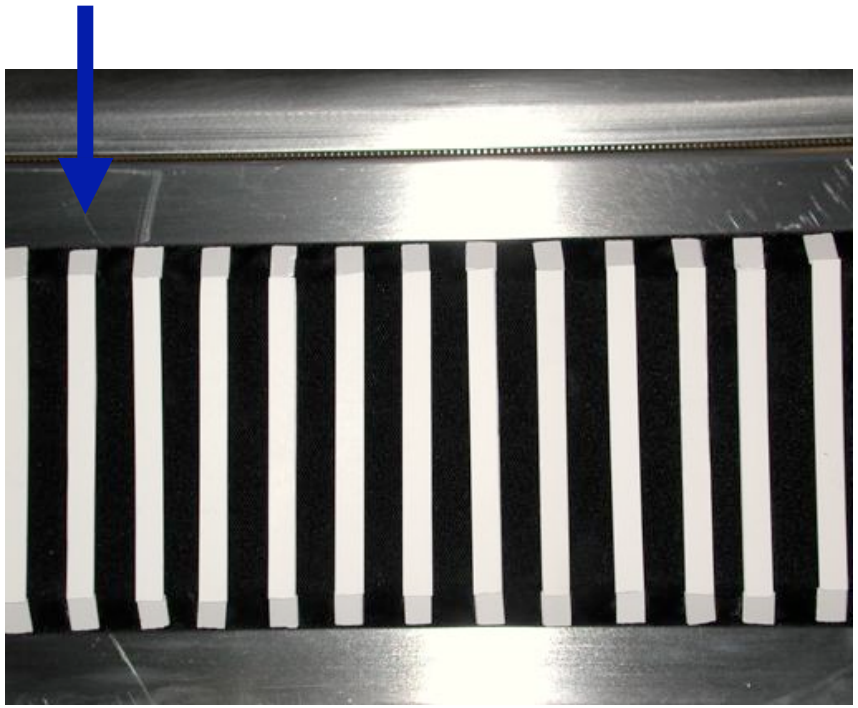
25 J Laser Output



Angularly multiplex 30 J preamplifier yield with strip cathodes

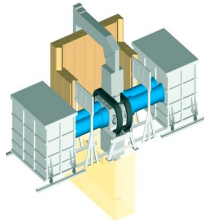
Plasma Physics Division

Preamplifier Strip Cathodes
Zircar to Suppress Electron Emission
Deposition 30% Larger than Monolithic



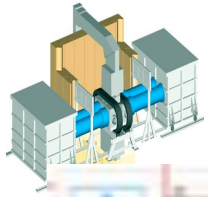
Gas Composition	Pressure	Laser Yield
82.2% Ar, 17.5% Kr, 0.3% F_2	18 psi	29.5 J
81.2% Ar, 18.5% Kr, 0.3% F_2	17 psi	30.3 J
80% Ar, 19.7% Kr, 0.3% F_2	16 psi	28.4 J
59.7% Ar, 40% Kr, 0.3% F_2	15 psi	29.8 J

Least stress on foils



Full Laser System

Plasma Physics Division



Electra KrF Laser Layout

Plasma Physics
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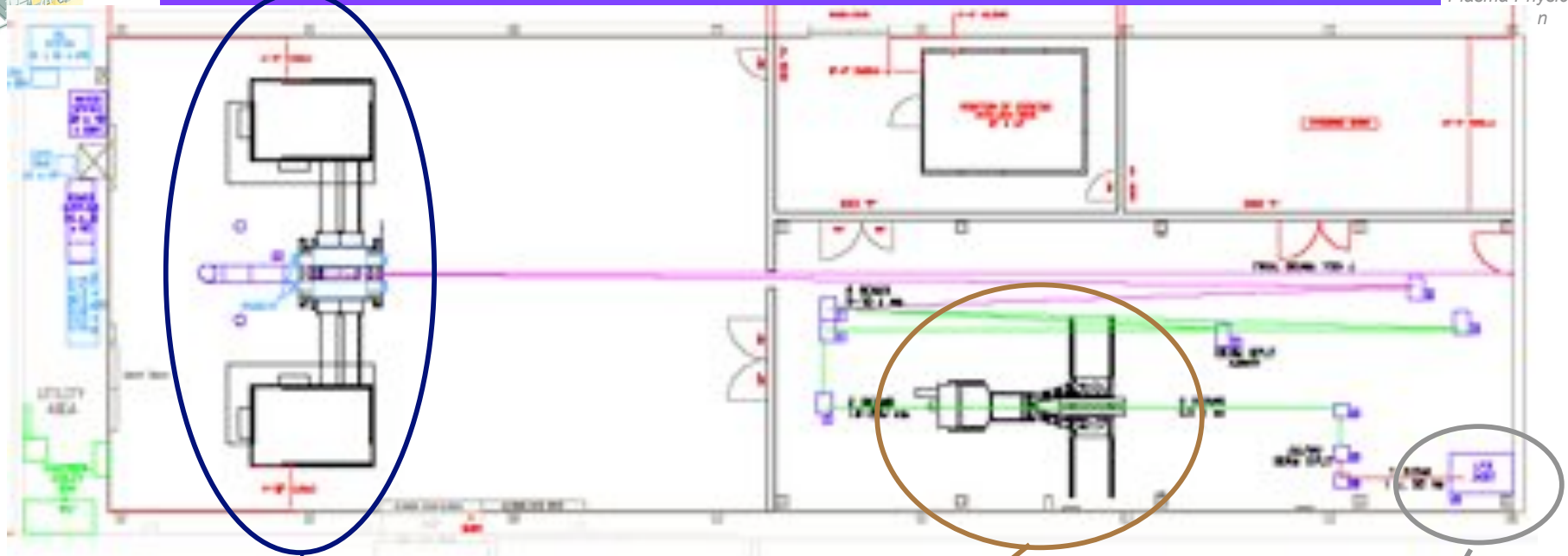
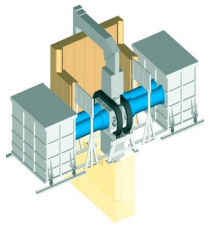


main amp 30 cm x 30 cm

pre-amp 10 cm x 10 cm

seed osc 1cm x 3 cm



Schematic of the laser beam multiplexing in full Electra system

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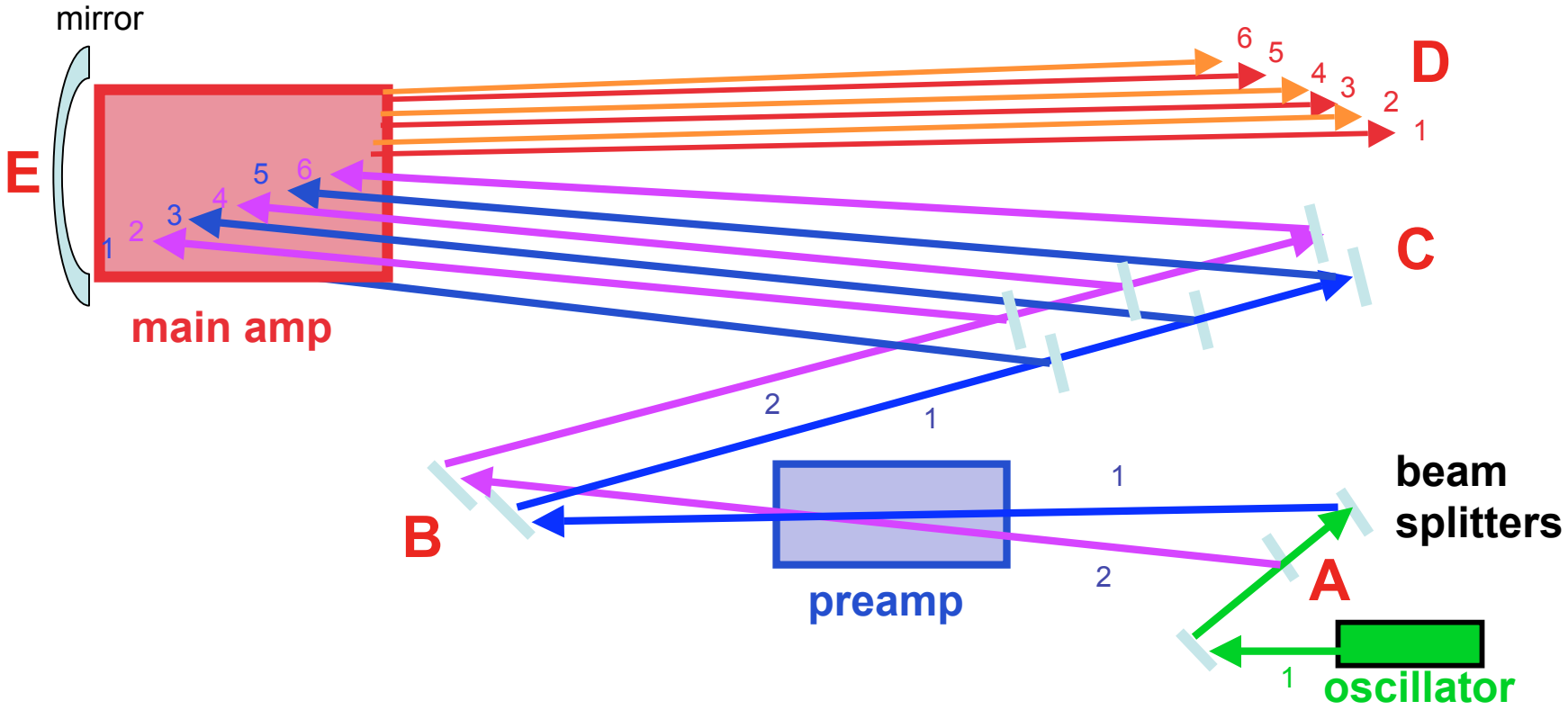
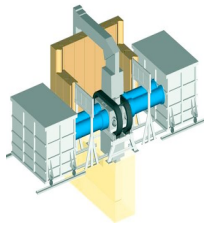
Beamlet #'s correspond to temporal sequencing



Note: This simplified sketch neglects two mirror arrays, including the main amp input array.
Labeled positions refer to following slides.



Photodiode signals of the multiplexed laser beam through the Electra system

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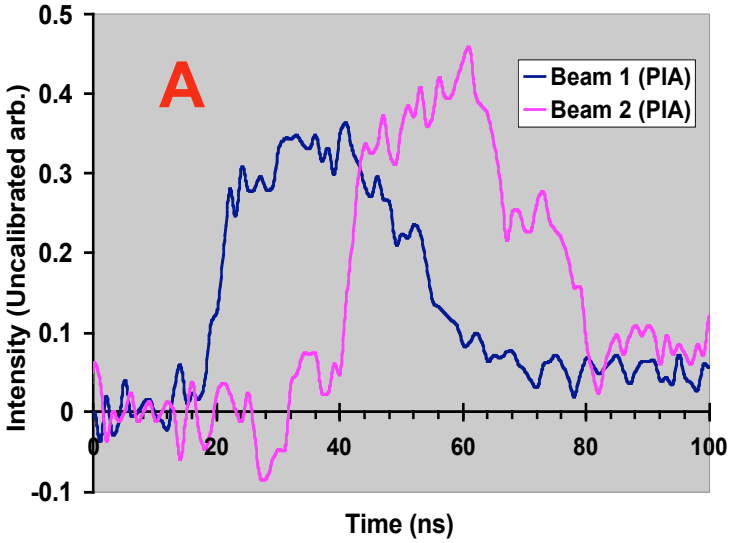

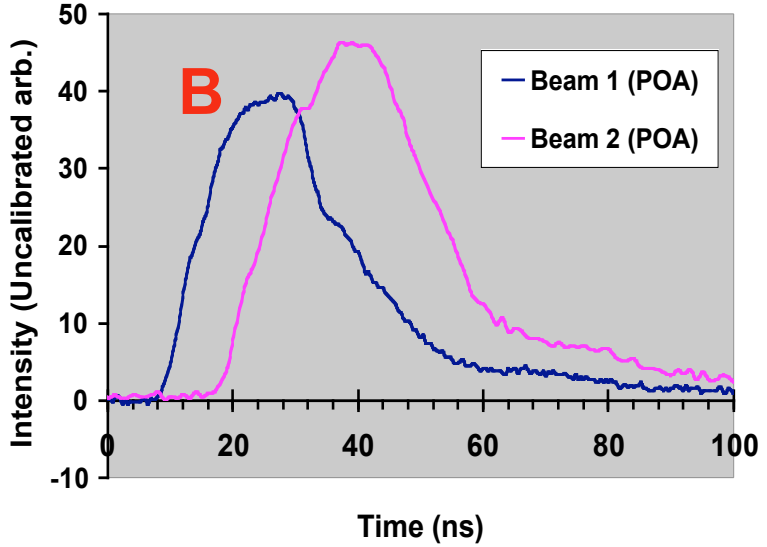

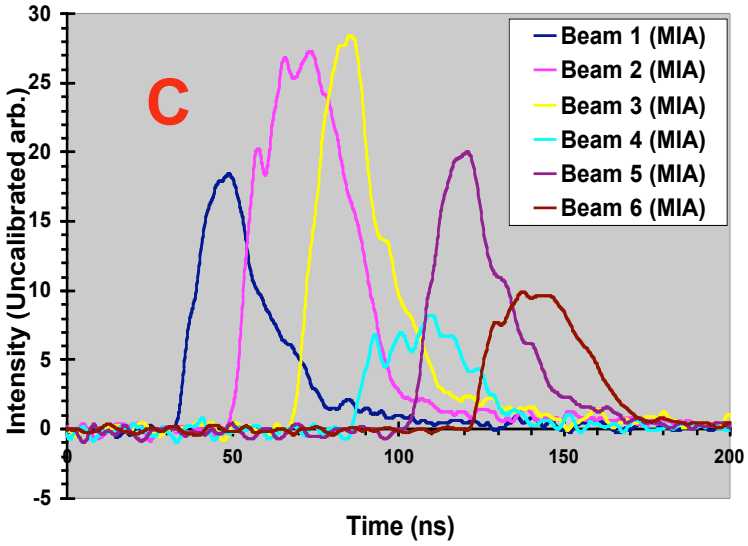

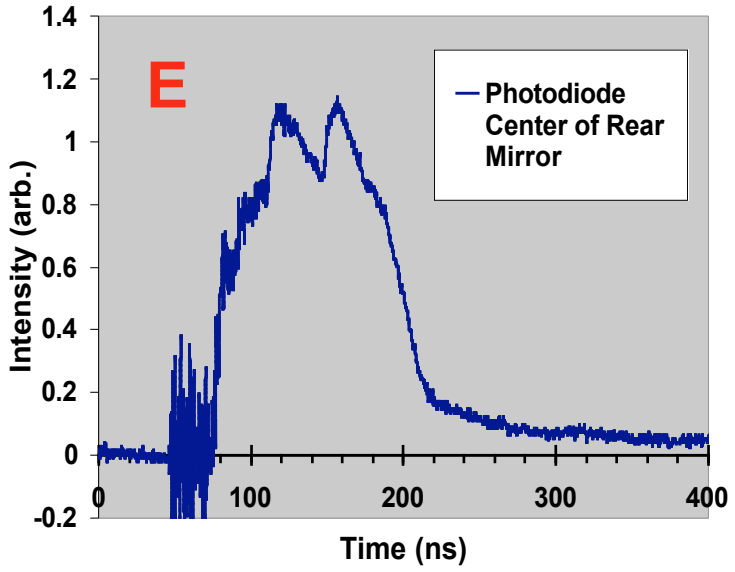

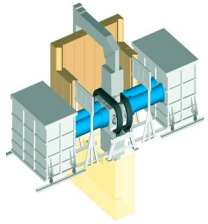

Final signals at the output array

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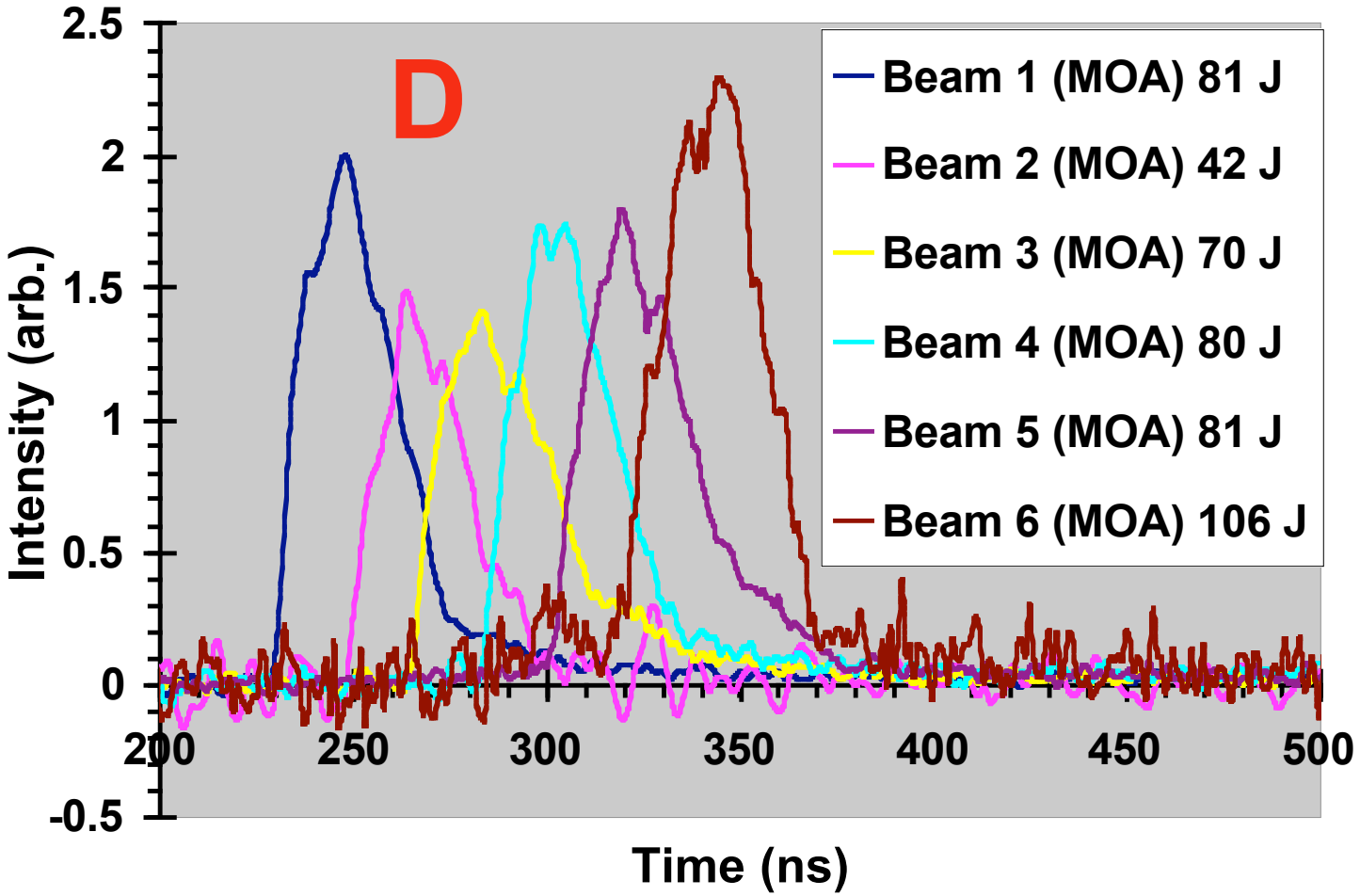
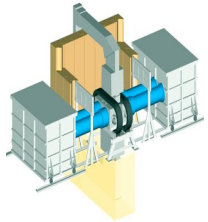


Photodiode Signal Sum is 460 J, Calorimeter on same shot measured 462 J



452 J single shot yield

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Split Beam

1 → 2

OSC

PRE AMP

Split Each Beam into 3

2 → 6

Main Amp
30 x 30 cm²

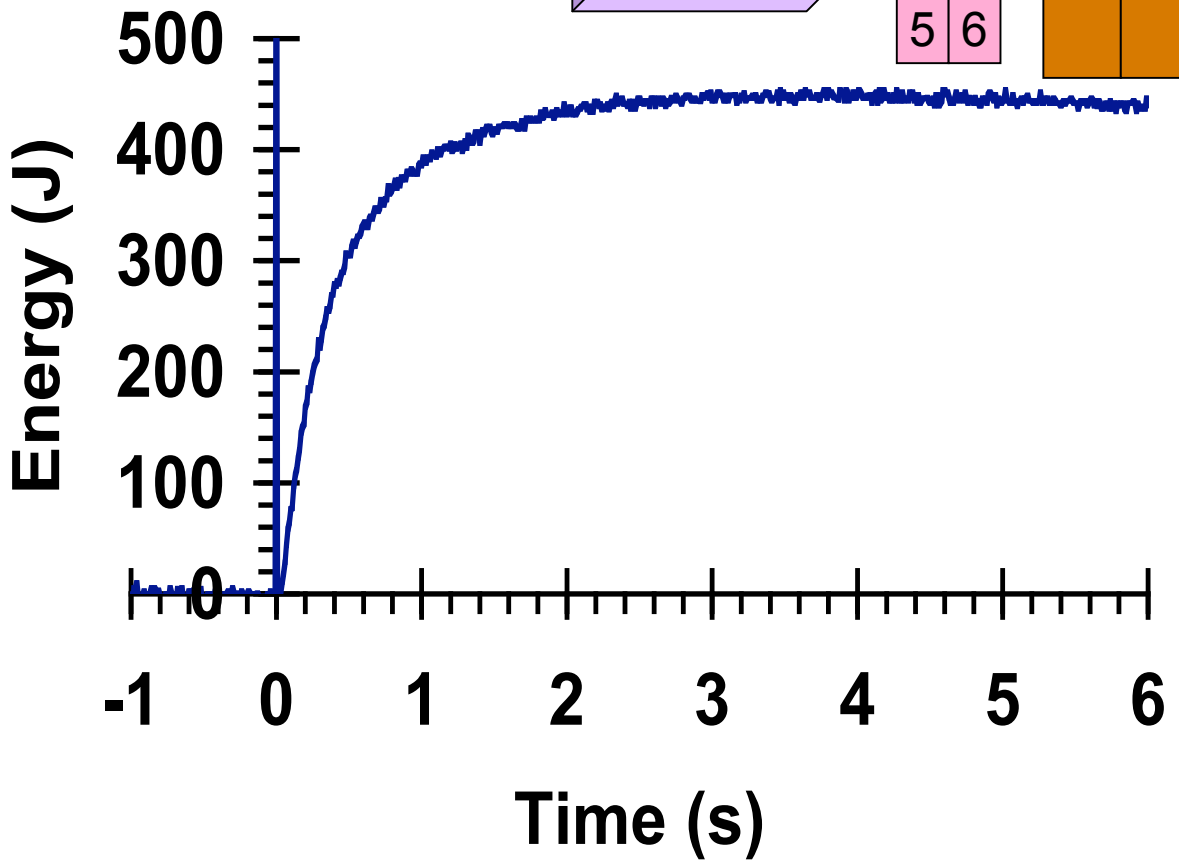
Output Beams
15 x 15 cm²

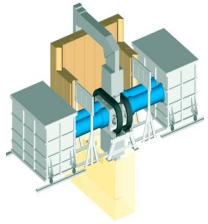
1 2
3 4
5 6

Calorimeter Array

Big
33 x 33 cm²

Small
18 x 18 cm²





Full laser system yield 1.585 kJ in one second 5 Hz burst

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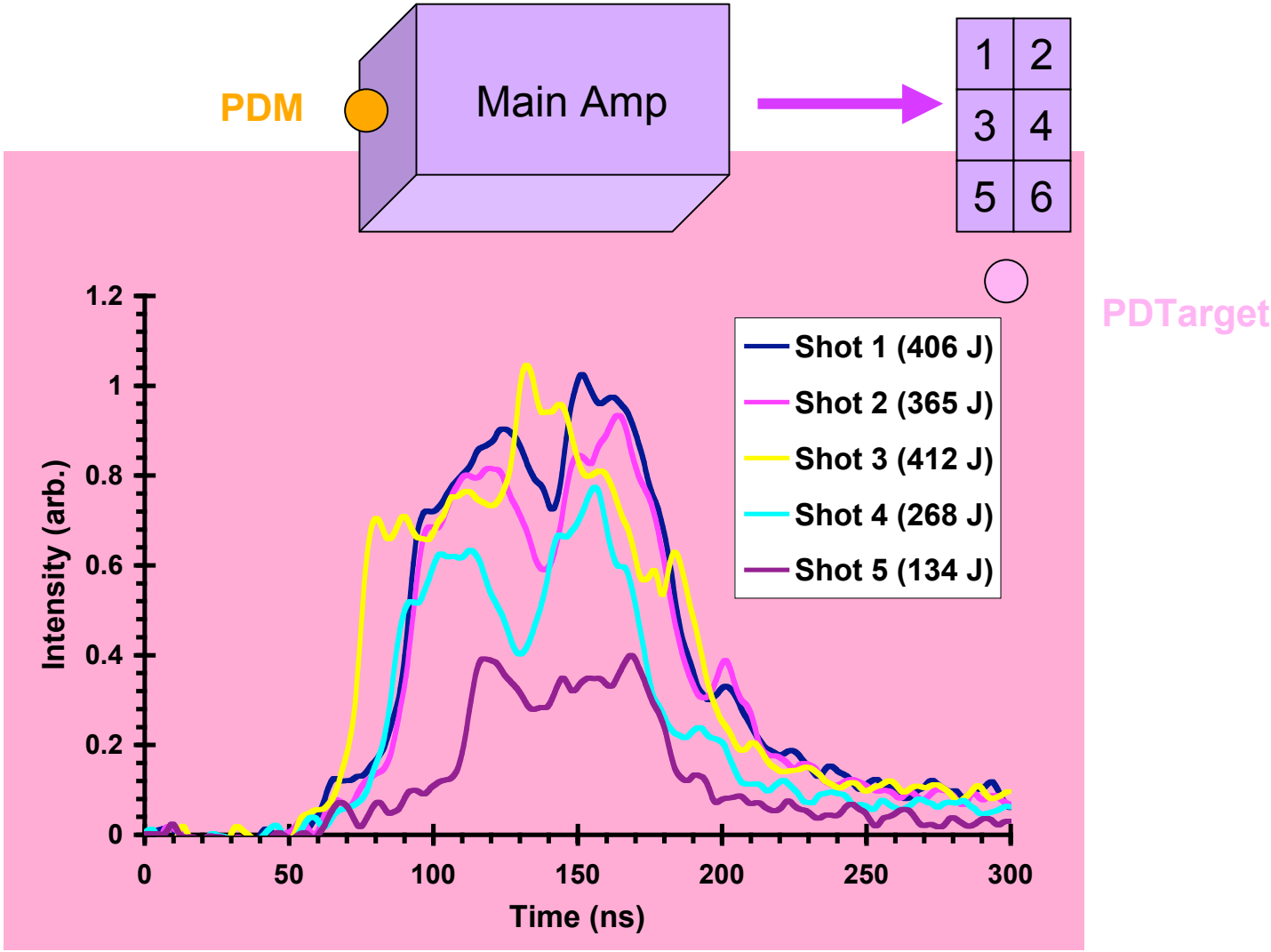

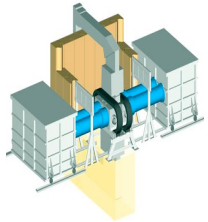

Pre-amp requires a recirculator for efficient rep-rate system operation

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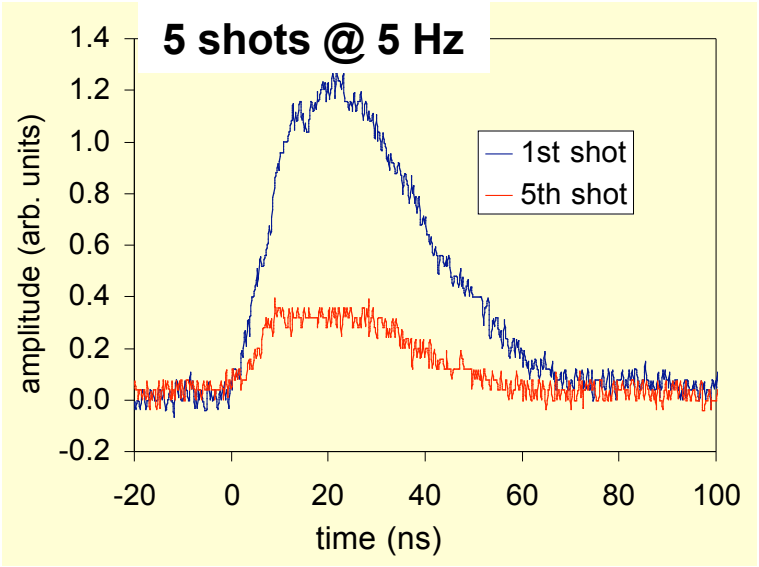
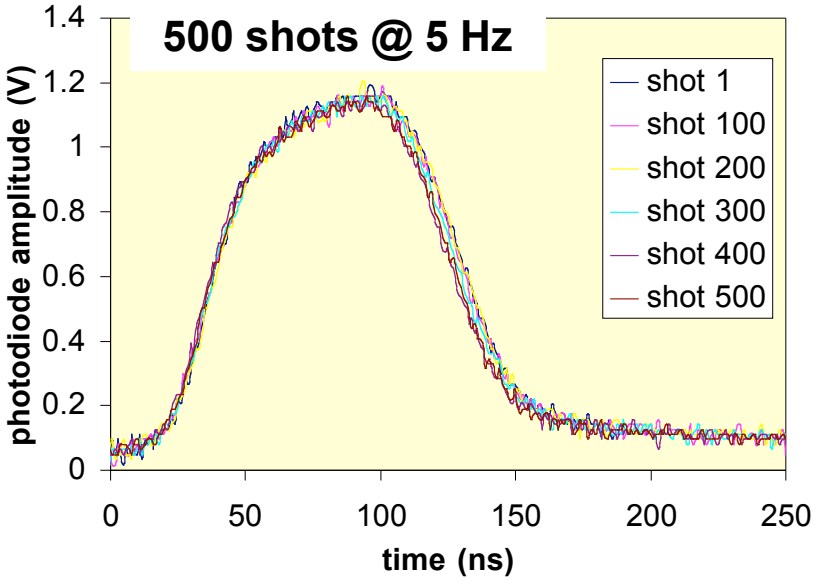
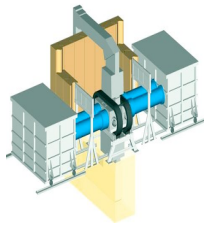


Pre-amp without gas recirculator



Main-amp with gas recirculator



Orestes predicts laser system output from ~350 J to ~800 J depending on cathode

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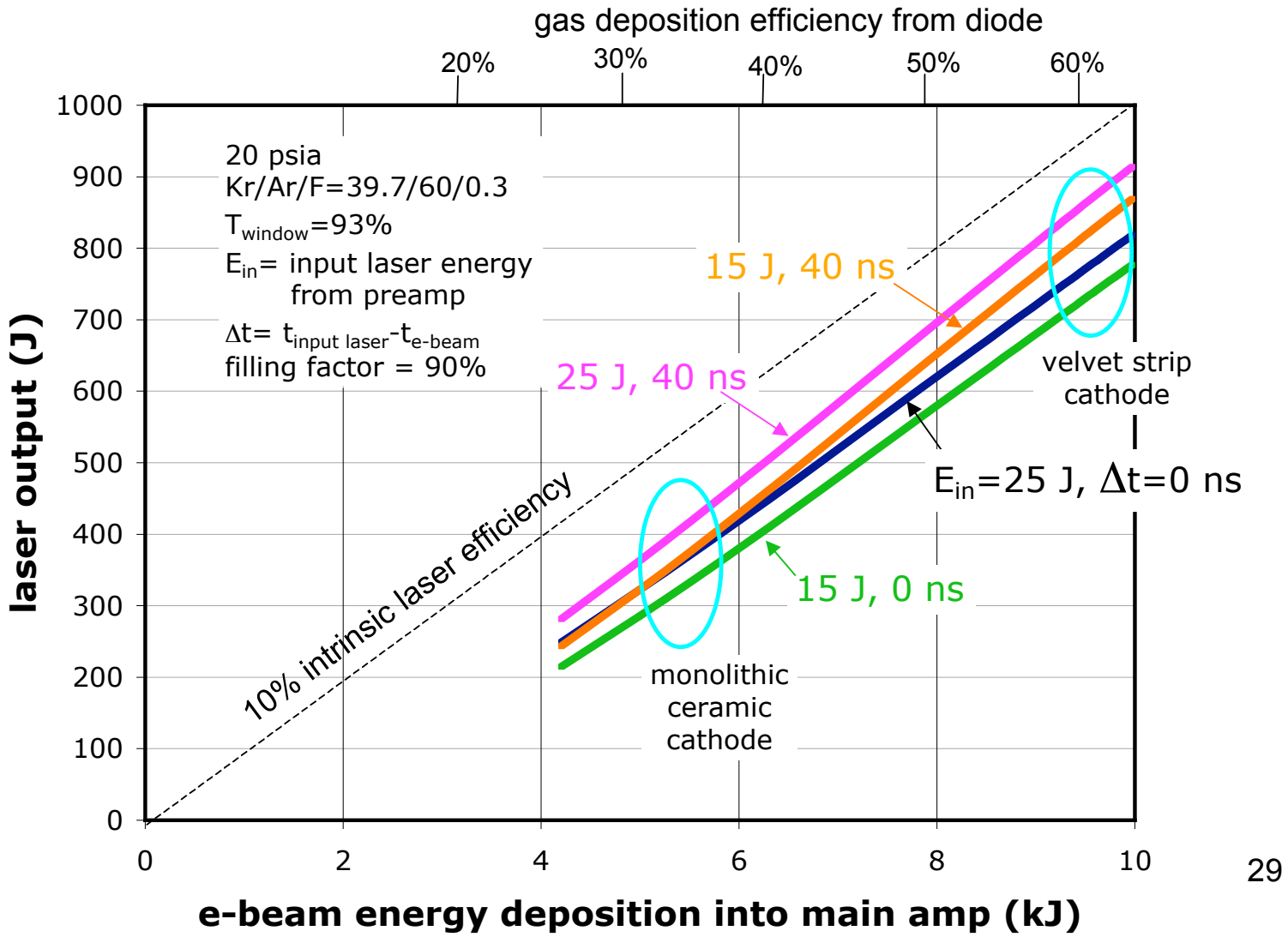
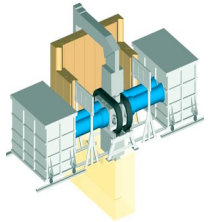
Efficiency includes rise and fall of e-beam.





Future

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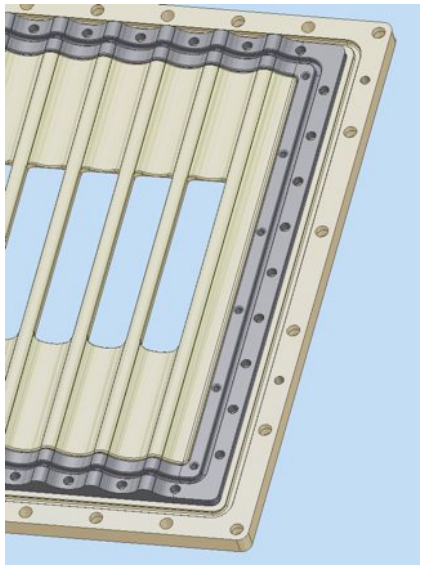
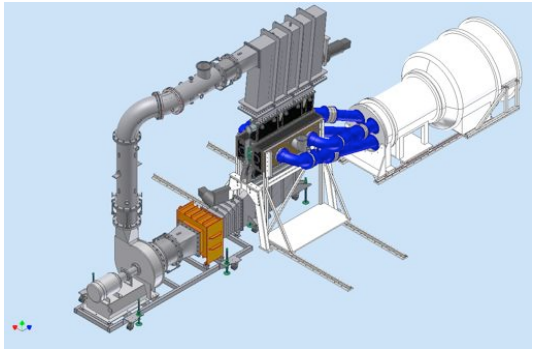
1) Zirconia has similar electrical properties to ceramic cordierite, but 5X mechanical strength. (July '08)



2) Scalloped hibachi significantly lowers mechanical stress on foil, even at elevated temperatures.

3) Pre-amp recirculator for full system rep-rate runs.



4) Monel or Inconel foils: more resistance to F_2, less grain structure which initiate mechanical failure modes.