Electra KrF Laser Development

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Naval Research Laboratory
Plasma Physics Division
Washington, DC

Presented by Frank Hegeler

Work supported by *DOE/NNSA/DP*

NRL
J. Sethian **M. Wolford**
S. Obenschain **J. Giuliani**
M. Myers **J. Dubinger**

Commonwealth Tech
F. Hegeler **M. Friedman**
T. Albert **J. Parish**
R. Jones **P. Howard**

RSI
P. Burns **R. Lehmberg**
S. Searles **W. Webster**

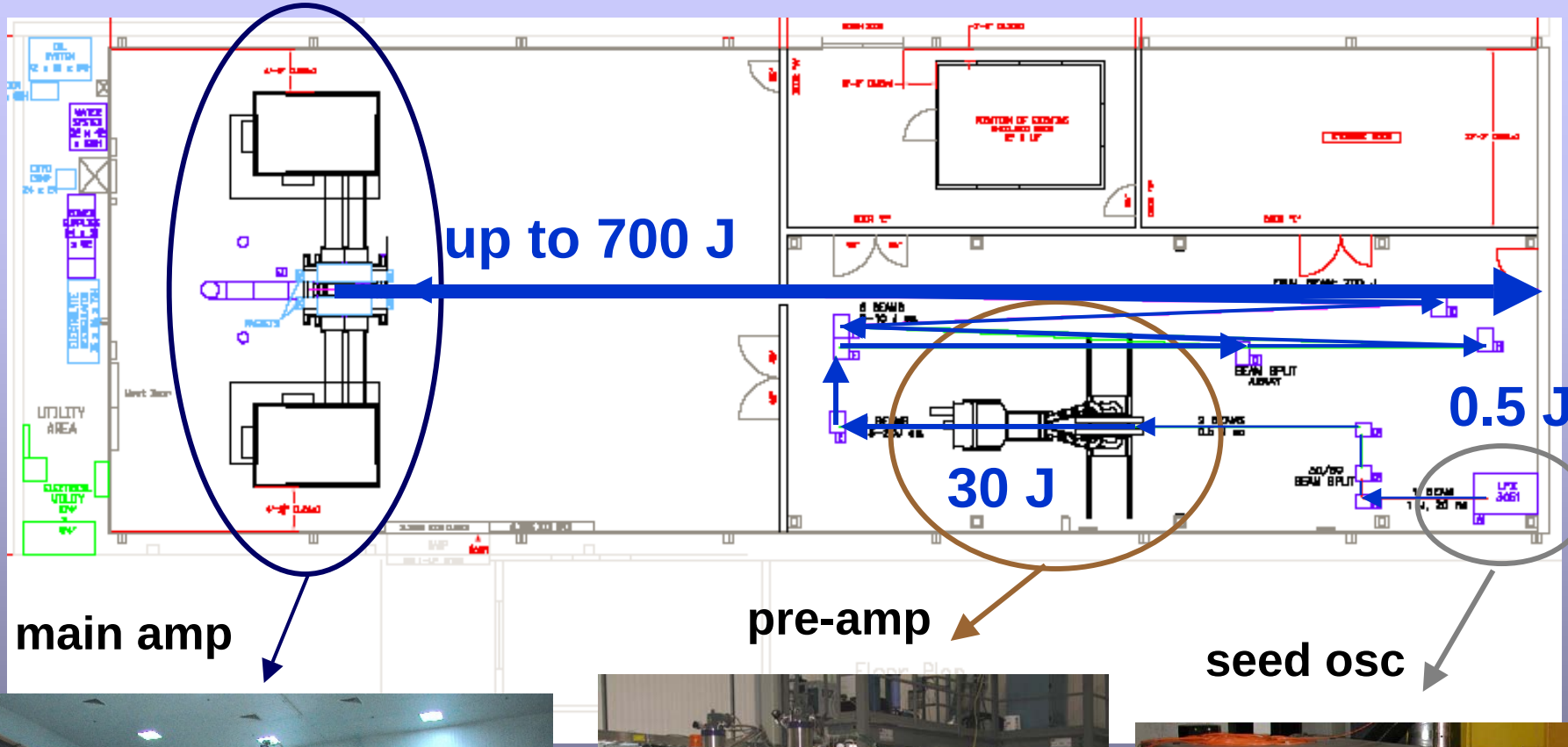
SAIC
R. Jaynes
A. Mangassarian

Applied Pulsed Power
S. Glidden **H. Sanders**

PLEX LLC
M. McGeoch

Georgia Tech
S. Abdel-Khalik **D. Sadowski**
K. Schoonover

The Electra KrF Laser System



Strip Cathode on Pre-Amplifier Increases Pump Efficiency to Achieve 30 J Laser Yield

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

Preamplifier Strip Cathodes
Zircar to suppress electron emission
Deposition 30% larger than monolithic

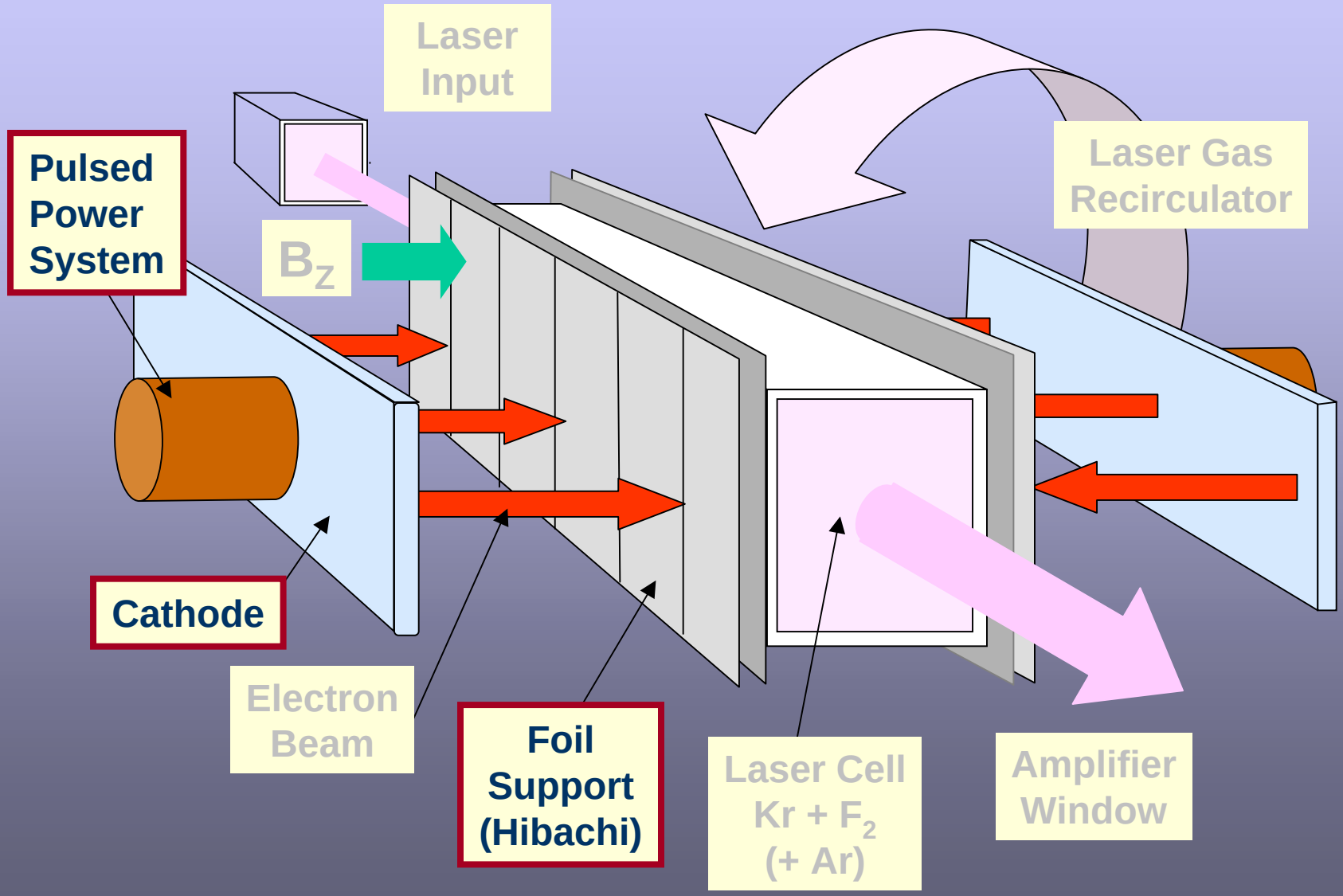
Full Electra Laser System has been Tested for Single Shots and Short Bursts

Achieved 460 J for single shot experiments.

5 shot burst @ 5 Hz resulted in a total laser power of 1.6 kW or an average laser energy of ~320 J per shot

- **Future laser gas recirculator on pre-amplifier will allow constant output energies at high laser powers.**

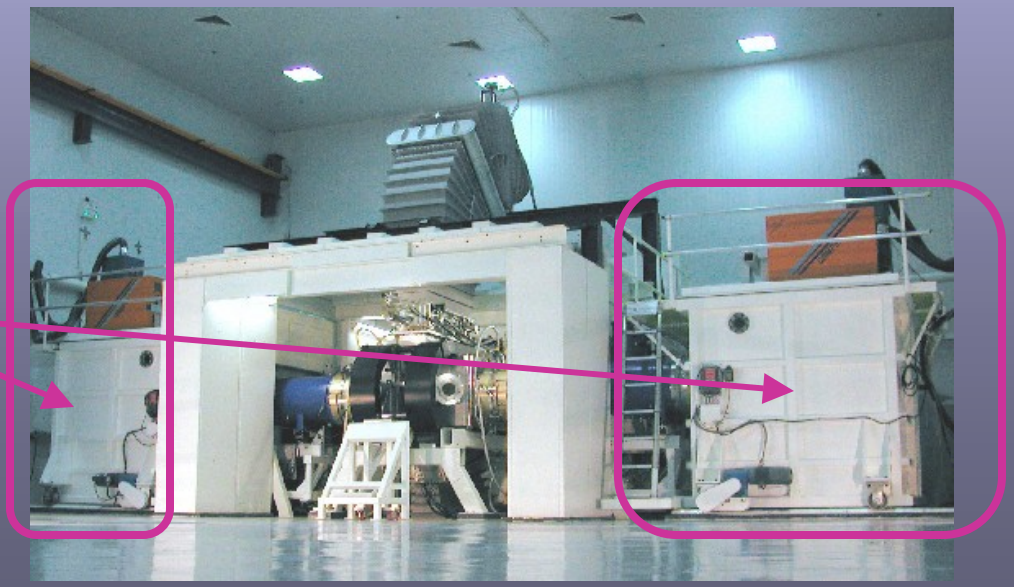
Key Components of a Krypton Fluoride (KrF) Laser



Pulsed Power System

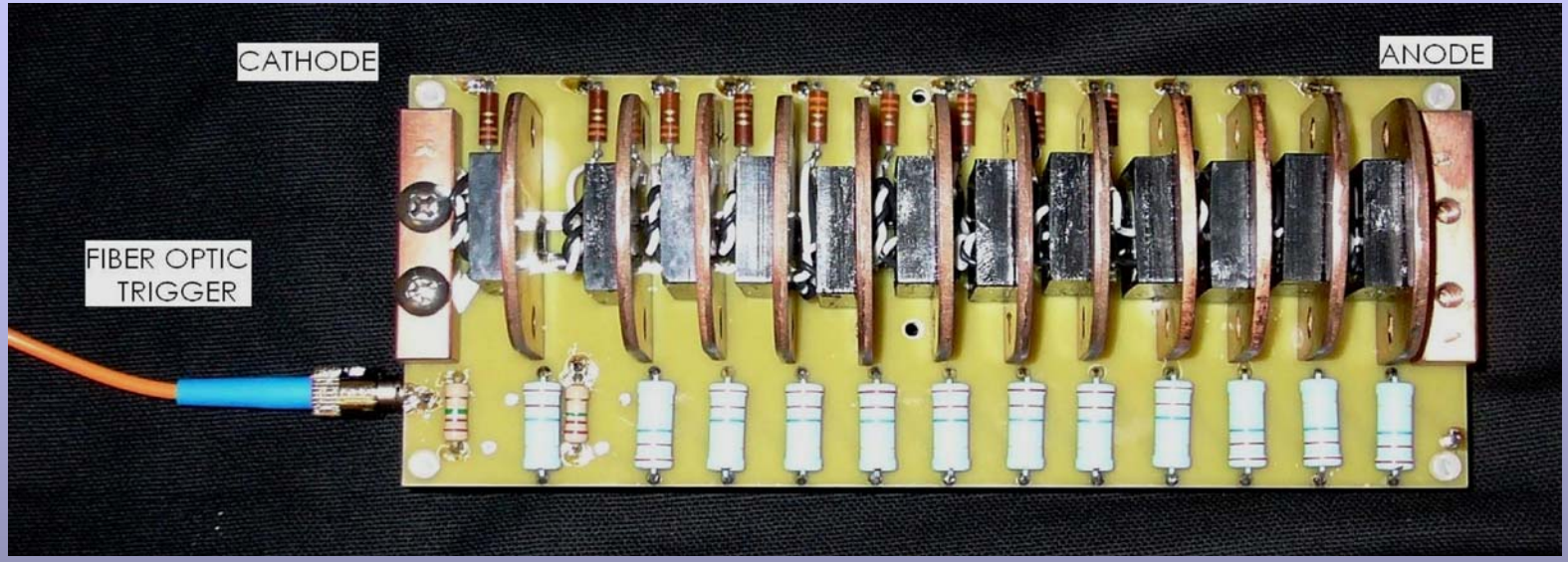
- **Solid State Switch Development**
  - **Switch lifetime tests**
- **Small Scale (250 kV, 7 kA) Solid State Pulser**
  - **Cathode durability tester for >10^6 shots**
  - **Verify durability of solid state pulser**

Solid state switch to be used for upgrade of existing pulsed power systems



Development of an all Solid State Pulsed Power System

48kV Solid State Switch Development (with Multiple Silicon Thyristors)

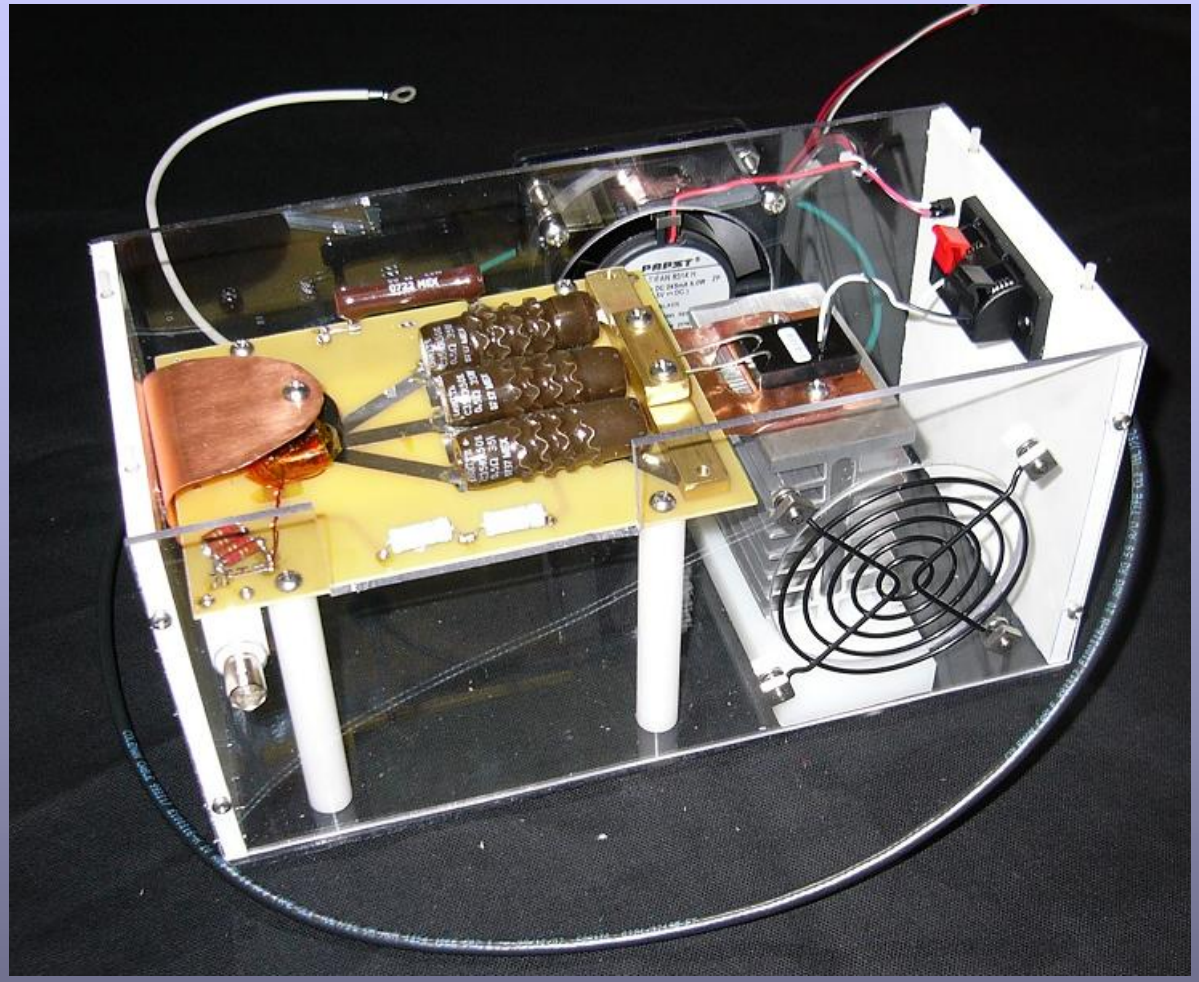


Commercially available switch for $4,000 (list price for one 48kV switch)

Switch is being used for bio/medical applications (very reliable)

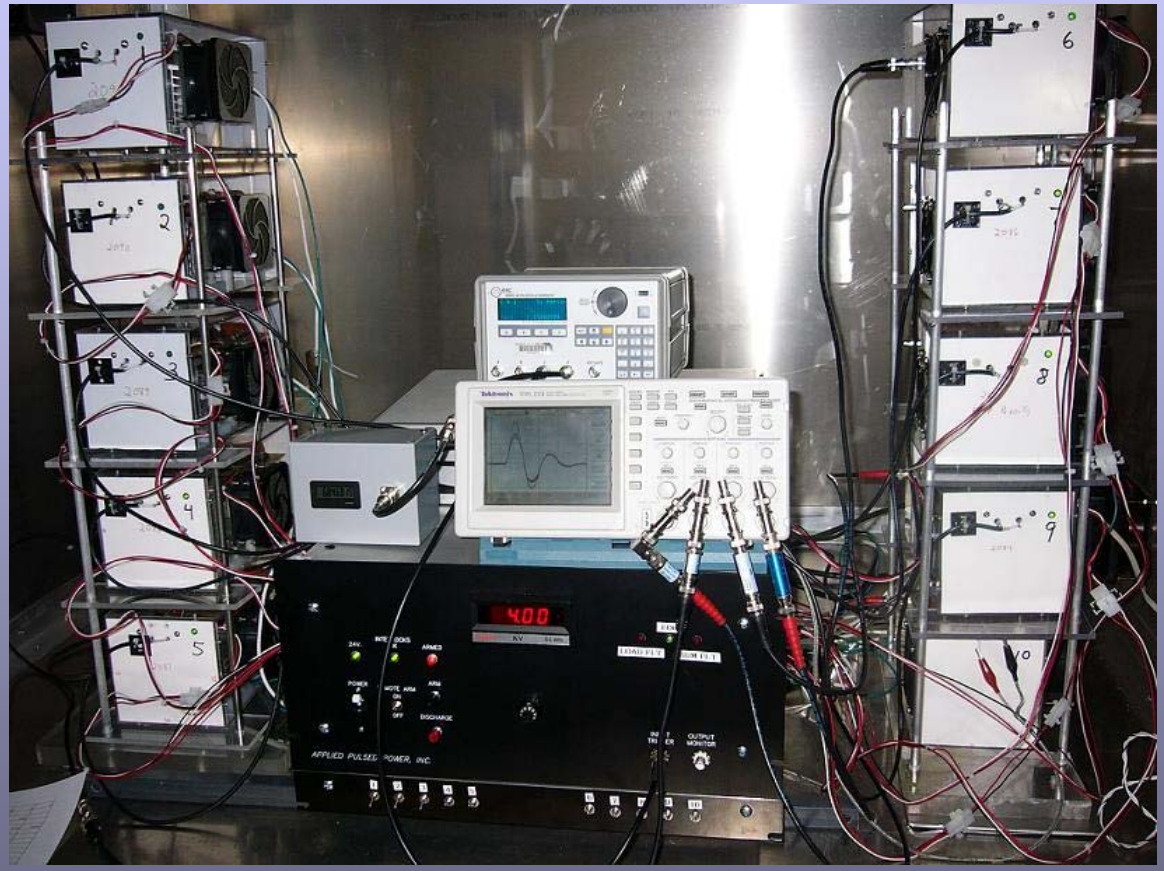
Pulsed power upgrade of Electra's main amplifier require 2*x*48 switches ($384,000 for switches not including quantity discount)

Thyristor Lifetime to be Tested for 10^8 pulses



- One of 10 lifetime testers. Each operates at 4kV, 7 kA, 400 ns FWHM.
- All lifetime testers are charged by single 1.5 kJ/s power supply.
- Thyristor is tested for 1.7 M pulses per day (10^8 pulses in 2 months).

No Thyristor has failed in the Lifetime Test Stand (as of April 1, 2008)



Station	# of shots (as of 04-01-08)
1	7 Million
2	7 Million
3	7 Million
4	6.9 Million
5	7 Million
6	70 Million
7	10.1 Million
8	9.2 Million
9	10.1 Million
10	43 Million

As of today, each station should have 12 Million additional shots

Small-Scale Solid-State System Under Construction

Picture shows the 12 stage Marx, which uses *APP* Thyristors. Magnetic switch and transit time isolator will be added to the system soon.

250 kV, 7.0 kA, 270 ns pulser with rep rate of 14 Hz

Expected life: >10^8 pulses

3 stage Marx was tested for >10^6 pulses at 5, 10, and 14 Hz

System will be used to test cathode durability and solid state Marx lifetime.

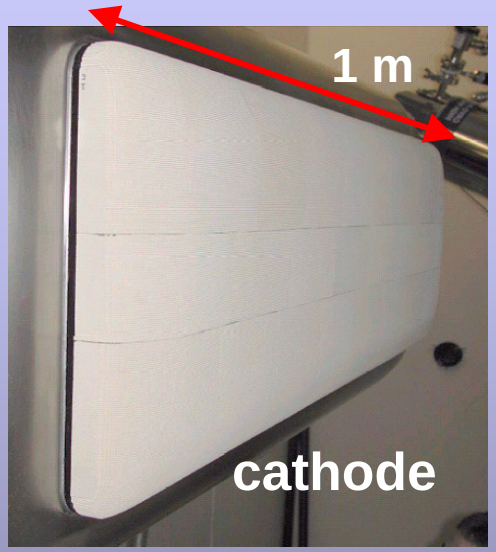
PLEX LLC

Cathodes

- **Development of Zirconia cathode**

Zirconia will Replace Cordierite as Cathode Material

- Cordierite ceramic honeycomb cathode has been successfully operated continuously for 25,000 shots at 2.5 Hz, and 10,000 shots at 5 Hz.
- Zirconia has very similar cathode properties (electrical) but its mechanical strength is 5 times of cordierite.
- Full size zirconia cathode experiments are scheduled for June/July 2008.

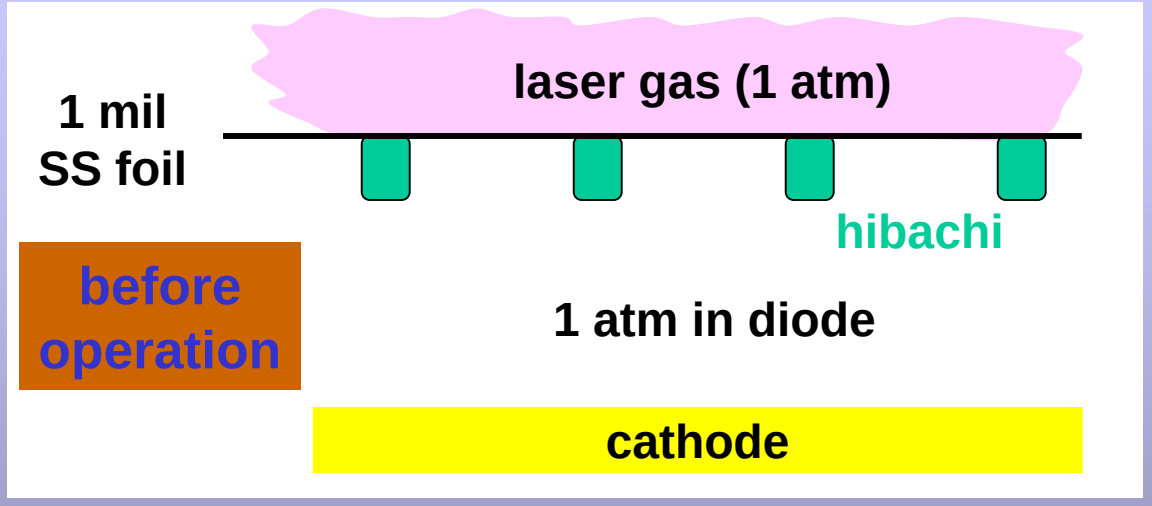


Properties	*Cordierite*	*Zirconia*
Compressive Strength	350 MPa	1700 MPa
Modulus of Elasticity	70 GPa	351 GPa
Flexural strength	117 MPa	545 MPa @ 20 C 351 MPa @ 800 C
Poisson's Ratio	0.21	0.31

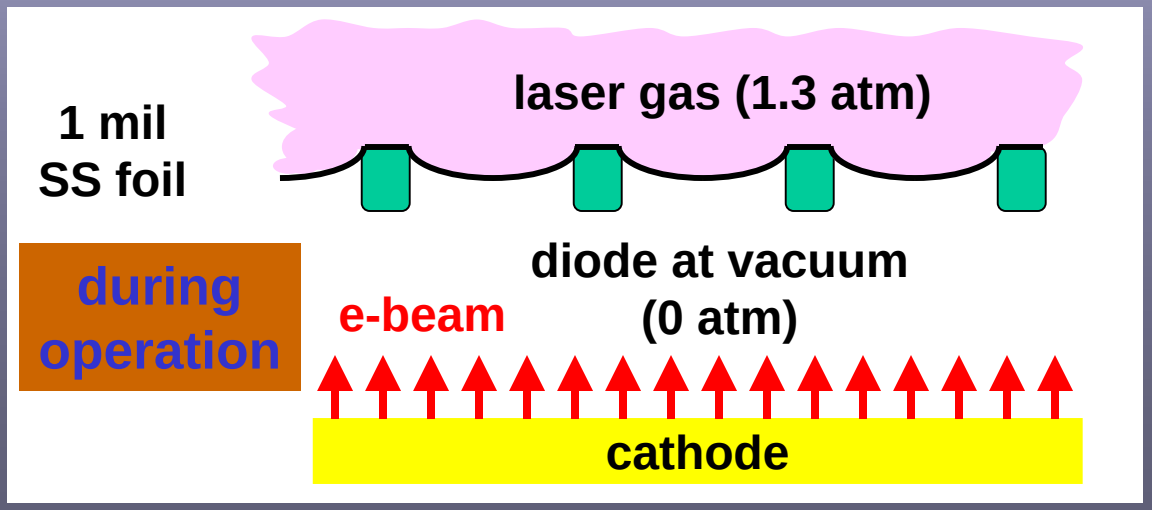
Hibachi and Foils

- Scalloped Hibachi
- Foil Materials
- Foil Pressure Tester
- Foil Cooling

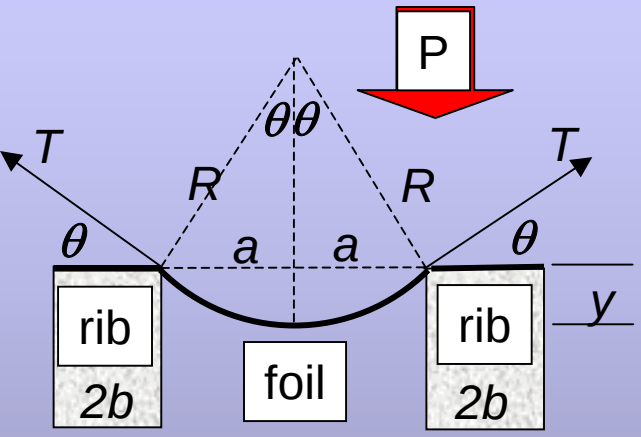
Thin Metal Foil Separating Diode Vacuum from Laser Gas Presently Operates in the Plastic Regime



Stress is above yield point of foil (causes plastic deformation)



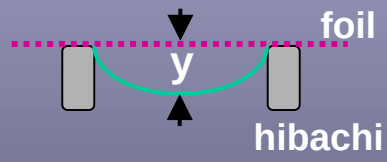
Scalloped Hibachi will Significantly Reduce Stresses on Foil

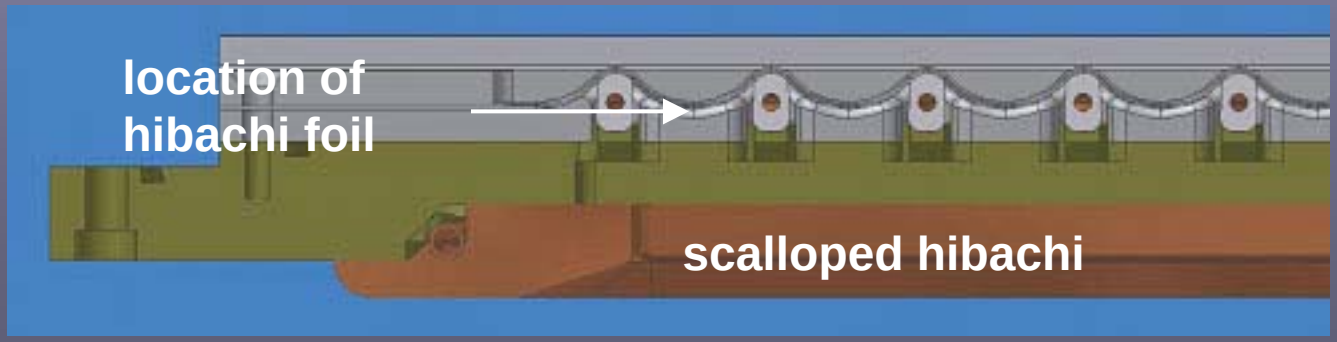


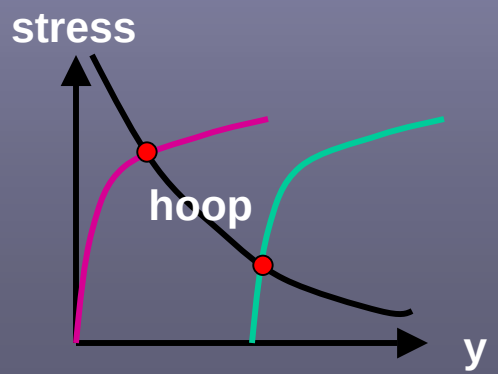
		stress/yield (long term fatigue) at room temp					
		304 SS		Inconel 600		Monel 400	
θ (deg)	Applied Stress (psi)	Allowed Stress (psi)	Ratio	Allowed Stress (psi)	Ratio	Allowed Stress (psi)	Ratio
5	153585	29700	5.17	45000	3.41	34800	4.41
10	77086	29700	2.60	45000	1.71	34800	2.22
30	26772	29700	0.90	45000	0.59	34800	0.77
40	20825	29700	0.70	45000	0.46	34800	0.60
50	17466	29700	0.59	45000	0.39	34800	0.50

As rolled (yield)
304 SS: 49,100 psi
Inconel 600: 60,100 psi (ATI Allegheny Ludlum)

for annealed materials



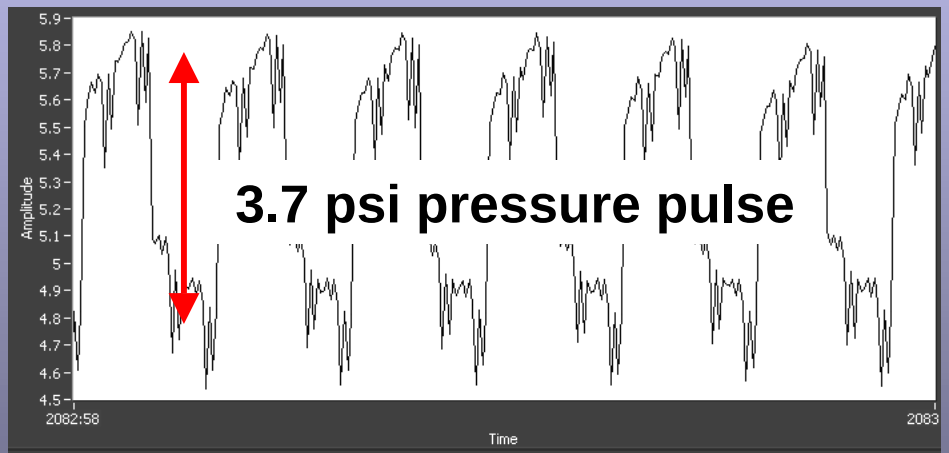


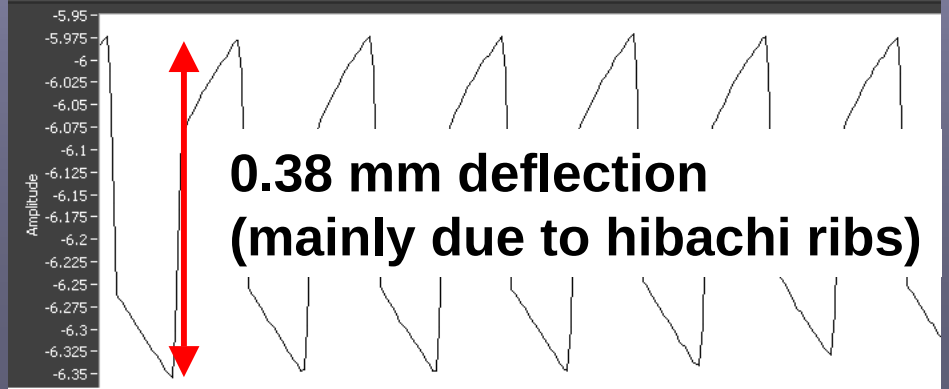


Scolloped Hibachi Design has been Tested Successfully

Foil/Scalloped Hibachi tester applies pressure pulse at 1 to 5 Hz, combined with a laser displacement sensor.

1 mil 5052 Al foil has been tested for > 4,000 continuous pulses at 28 psi base pressure + 3.7 psi pulse without failure.

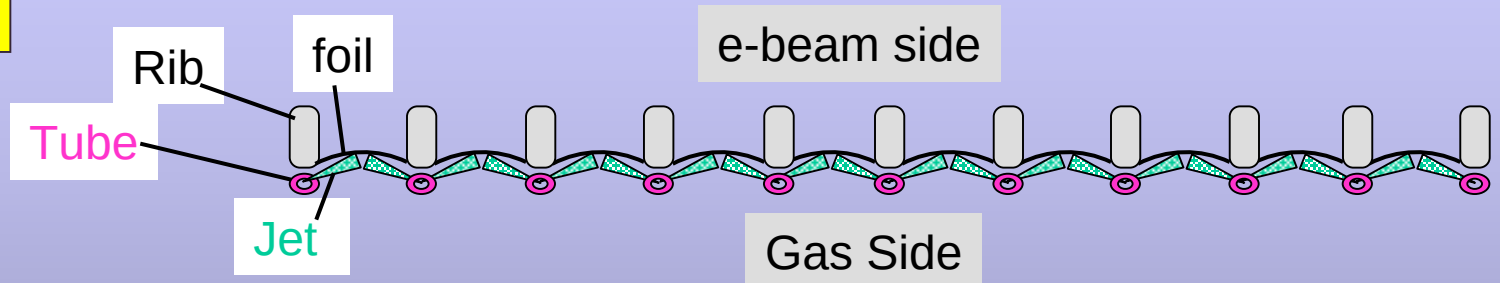




"Jet" Foil Cooling Technique Developed by Georgia Tech

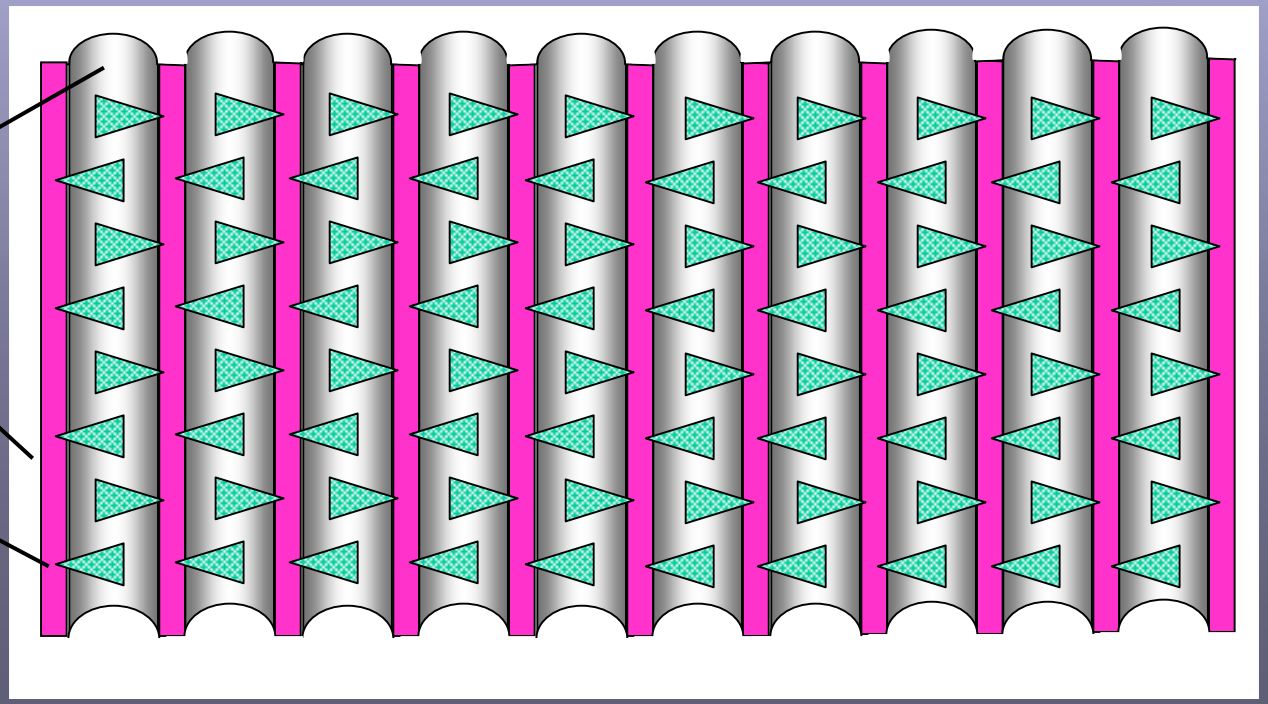
Full size experiments will be performed in April 2008

TOP VIEW

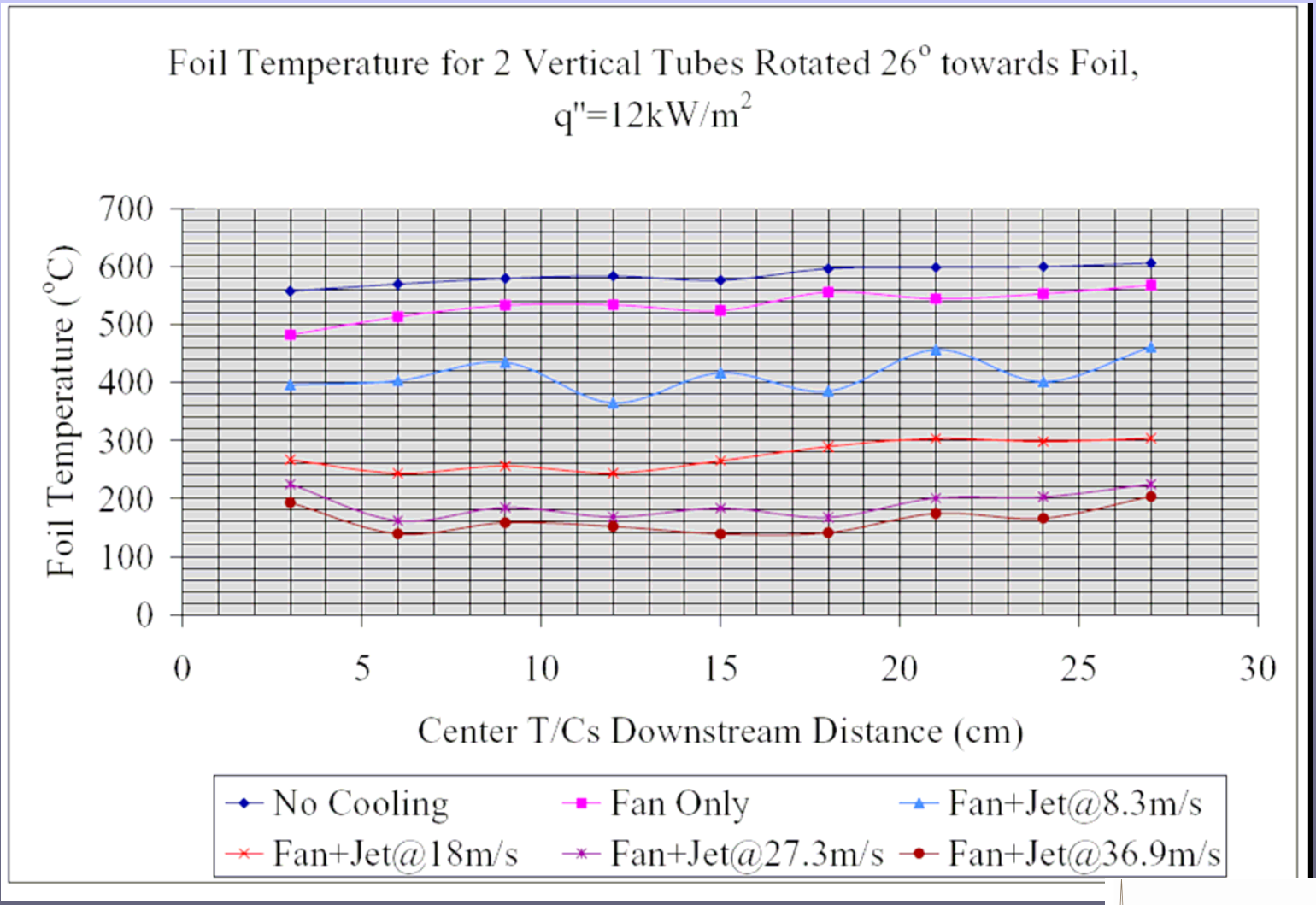


VIEW FROM GAS INTO THE DIODE

Main Gas Flow



Jet Foil Cooling Technique Successfully Demonstrated on Bench at GA Tech



Georgia Institute of Technology

Summary

Primary KrF laser components are under continuous development and improvement

- **pulsed power,**
- **cathodes,**
- **hibachi,**
- **foils, and**
- **cooling technologies,**

while full scale laser operations are undertaken.

A summary of previous developments and recent results on the Electra Laser System is presented at the NRL (John Giuliani) poster