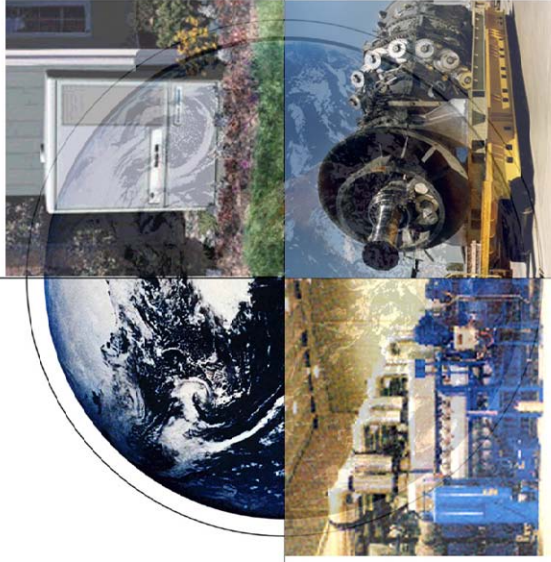


# Development of a Fiber Coupled, End Pumped, Nd:YAG Laser Spark Plug



**Steven D. Woodruff  
Dustin L. McIntyre**

**National Energy Technology Laboratory**

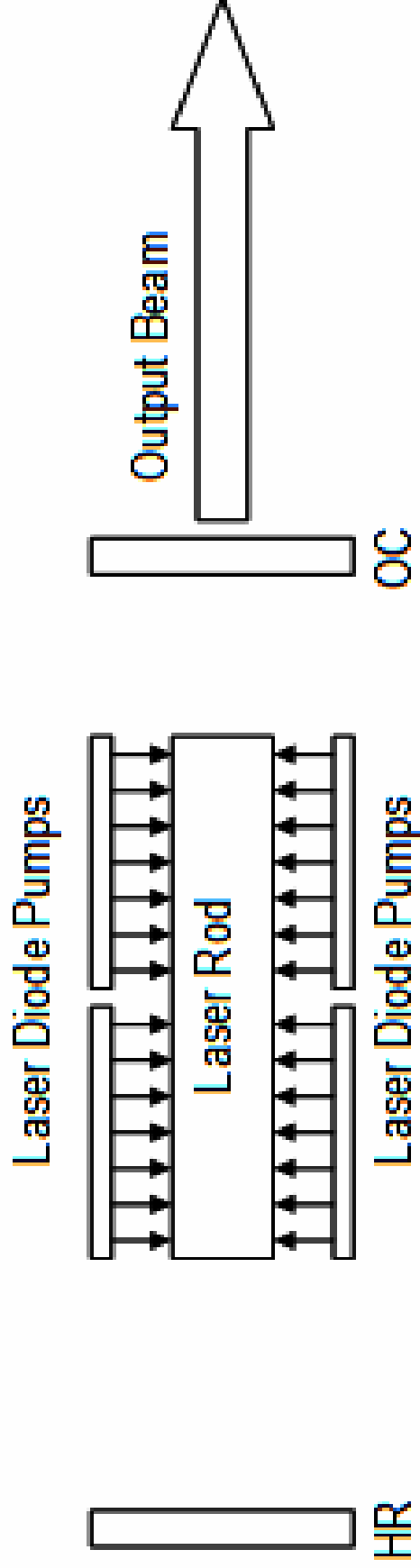
**4th Annual Advanced Stationary  
Reciprocating Engines Conference**

**September 18, 2007**

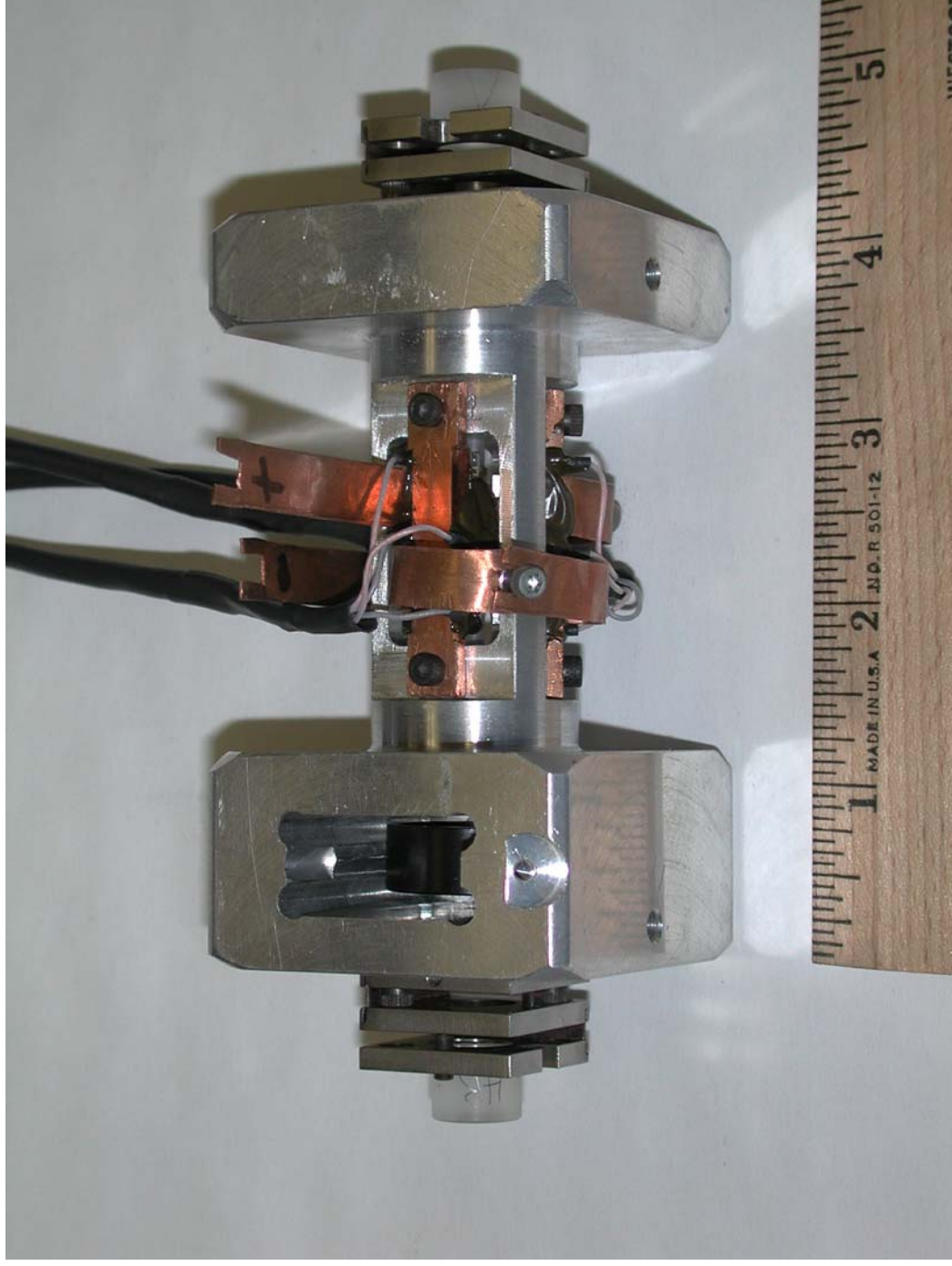


# Side Pumped Nd:YAG Laser

## The Beginning

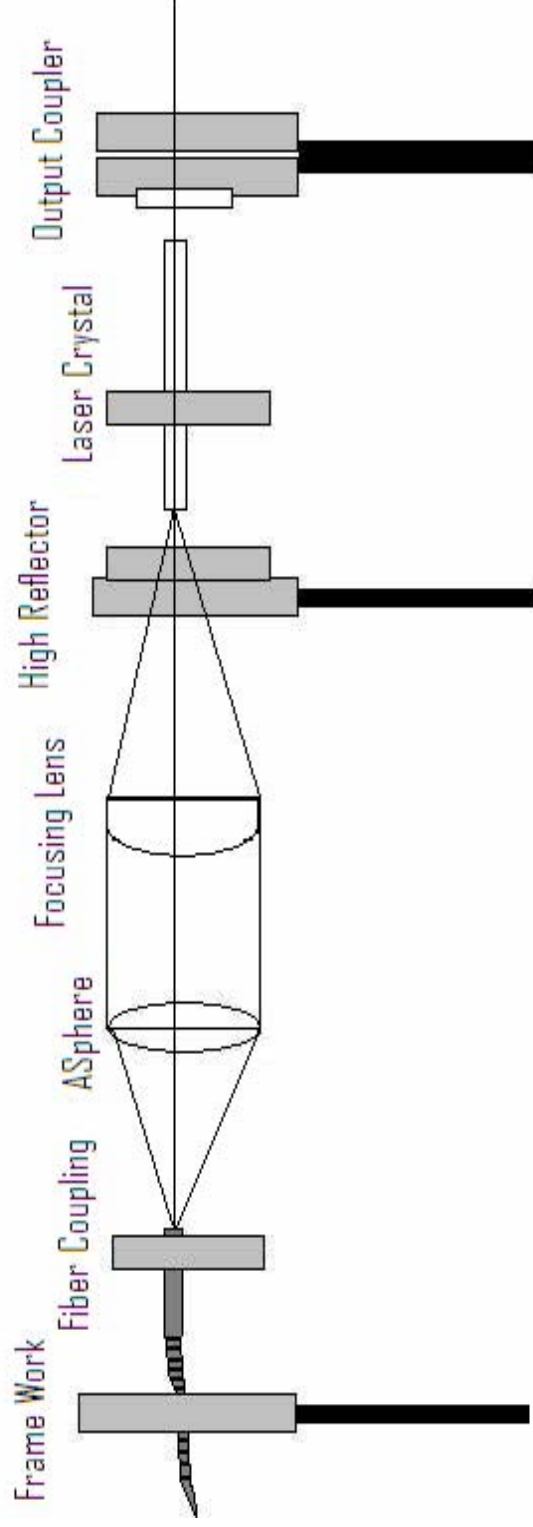


# Side pumped laser spark plug

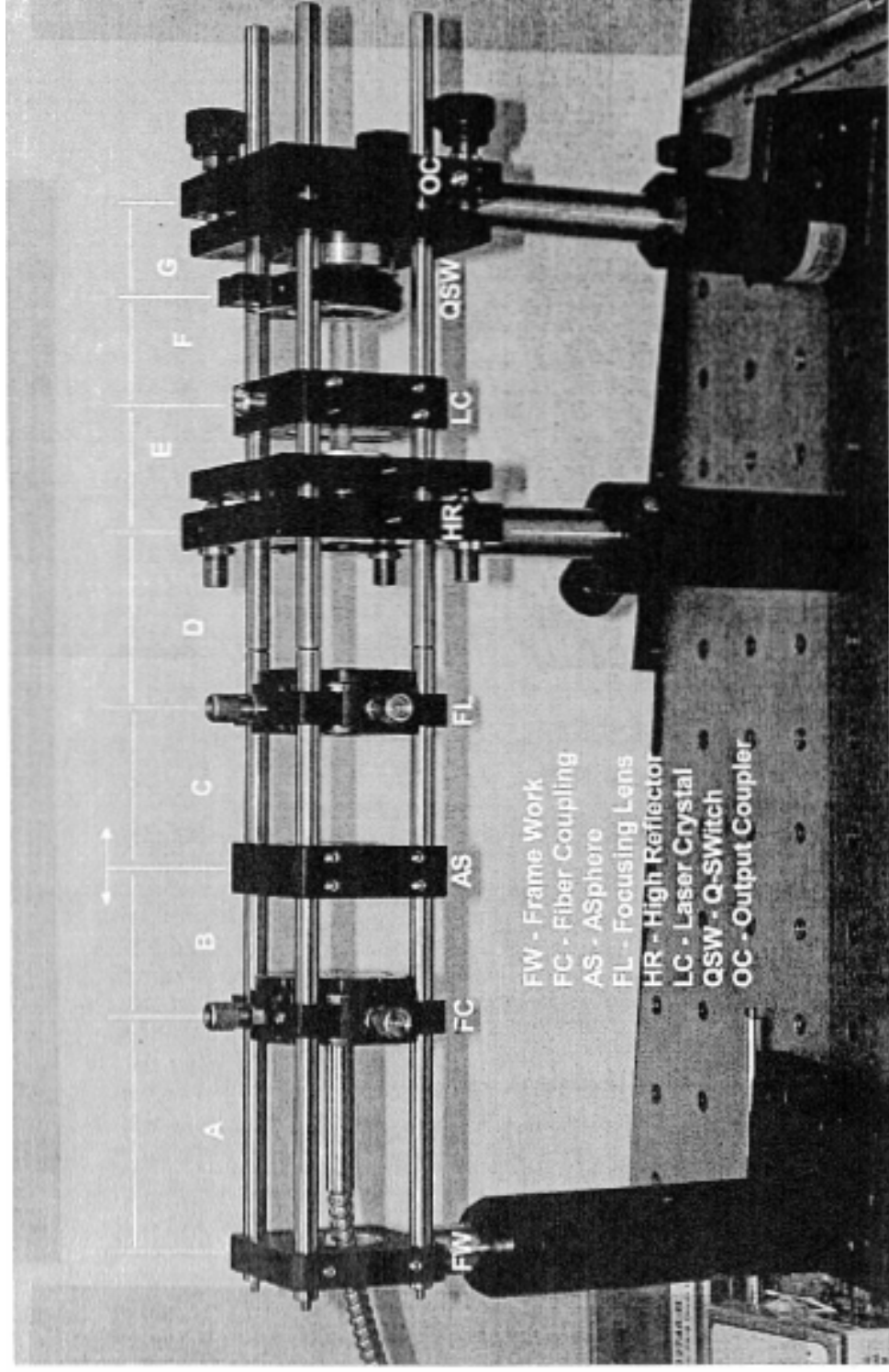


# End Pumped Nd:YAG Laser

## The Next Step



# End pumped, Nd:YAG laser



# End Pumped Laser Spark Plug

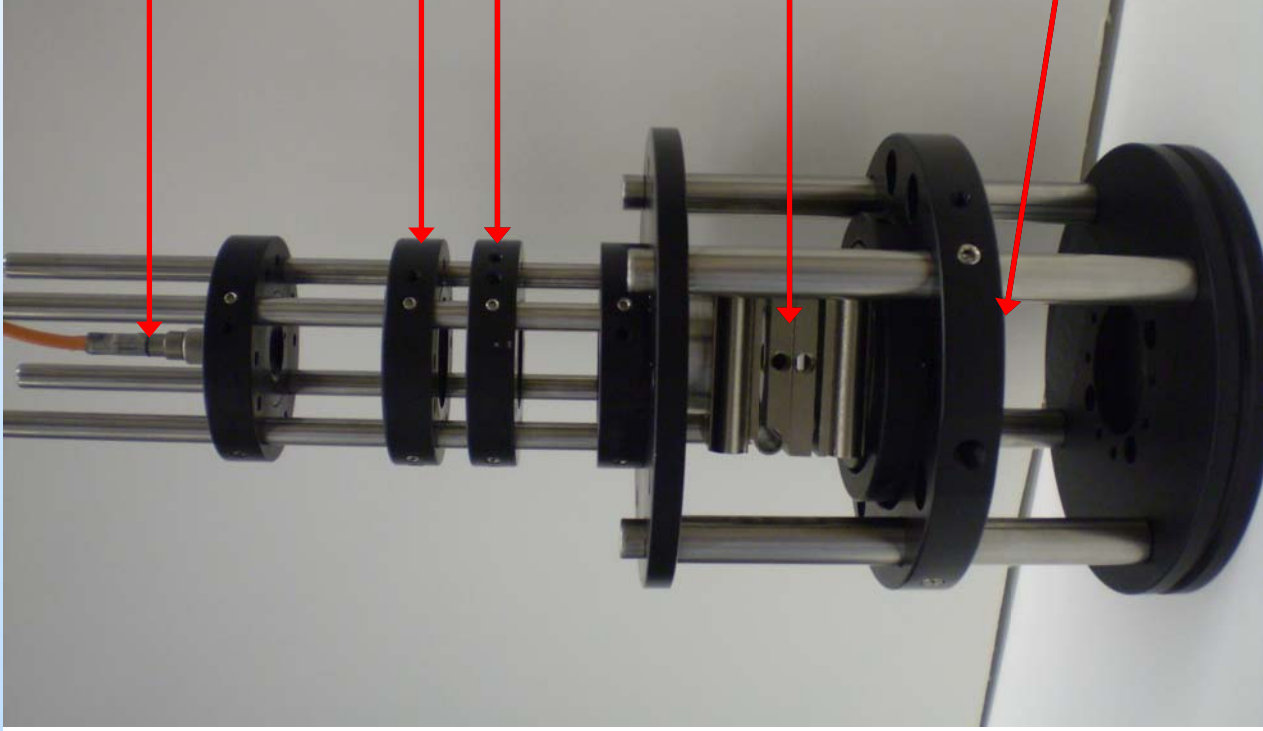
Pump Optical Fiber

Collimating Lens

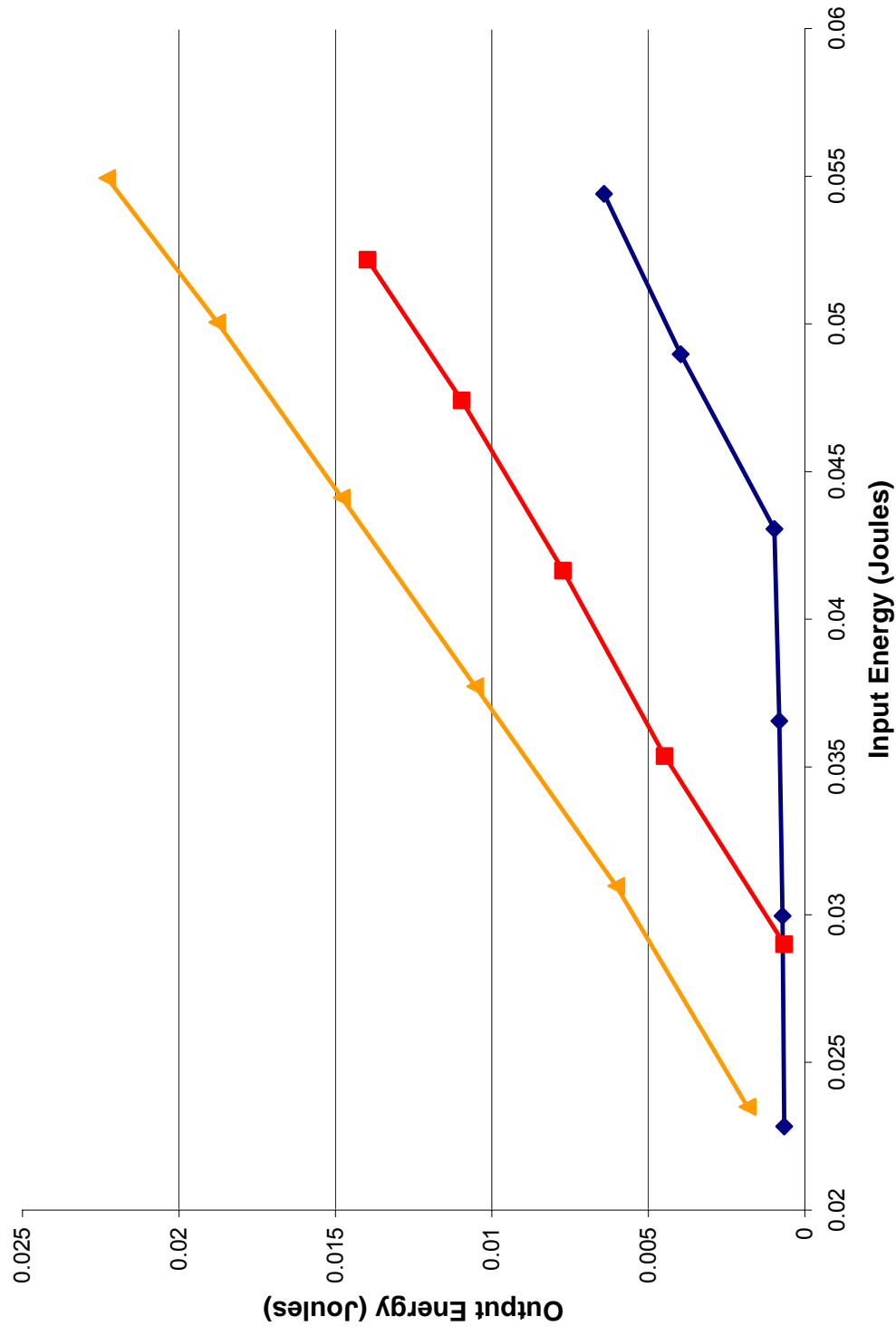
Focusing Lens

Q-switched Nd:YAG Laser

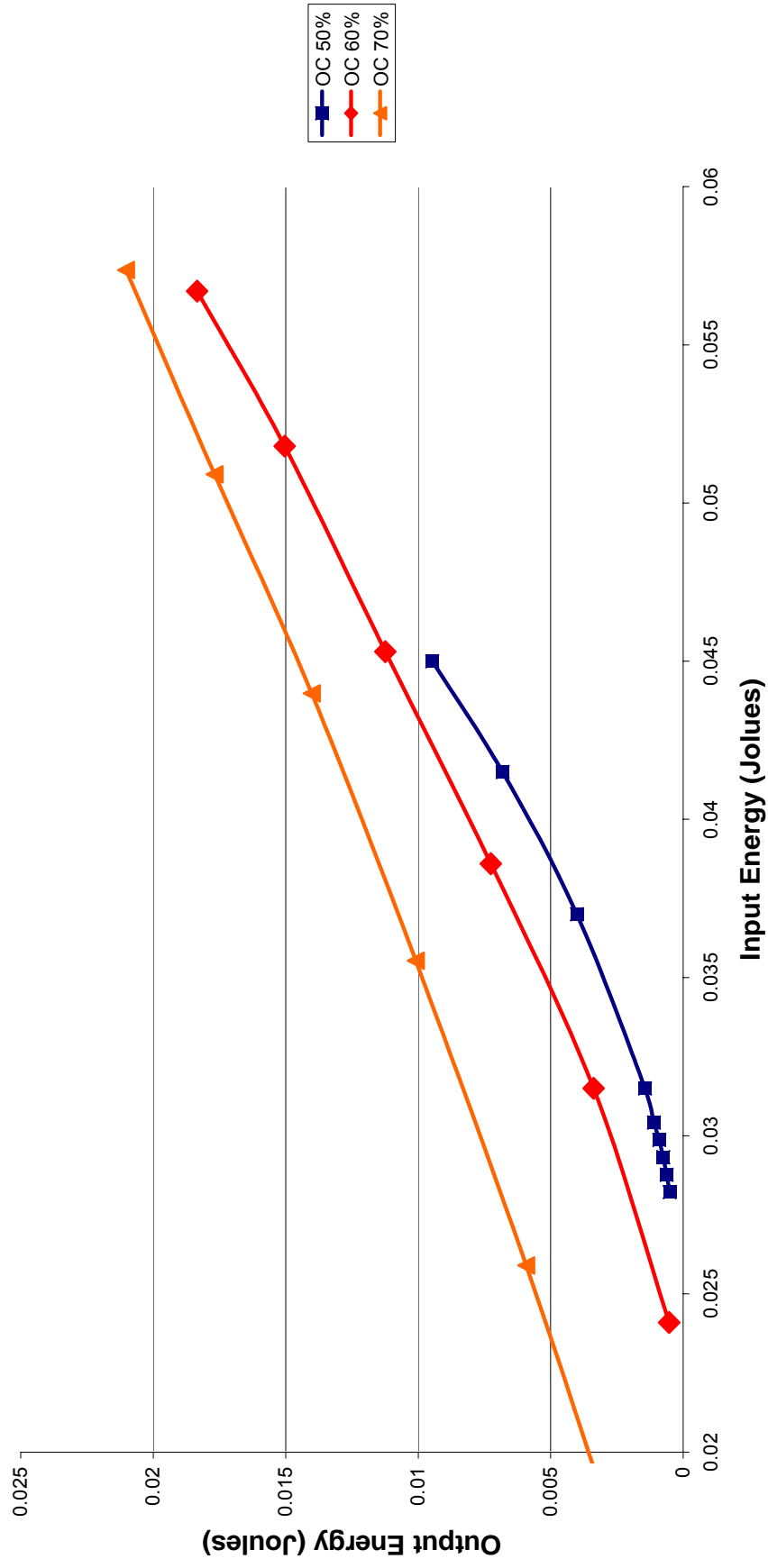
Beam Steering Optics



## Input Energy vs Output Energy (Nd:1.1%)

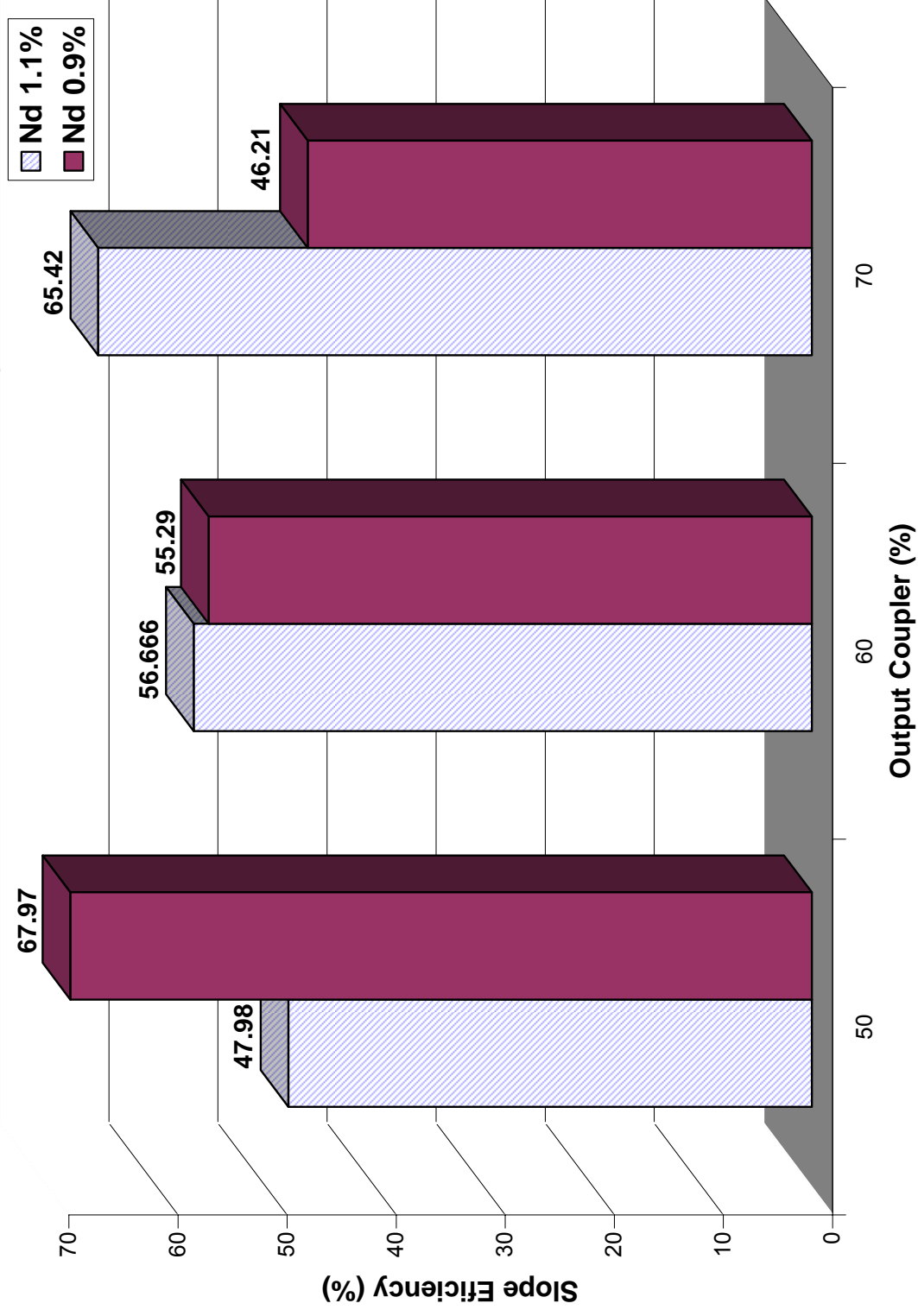


## Input Energy vs Output Energy (Nd:0.9%)

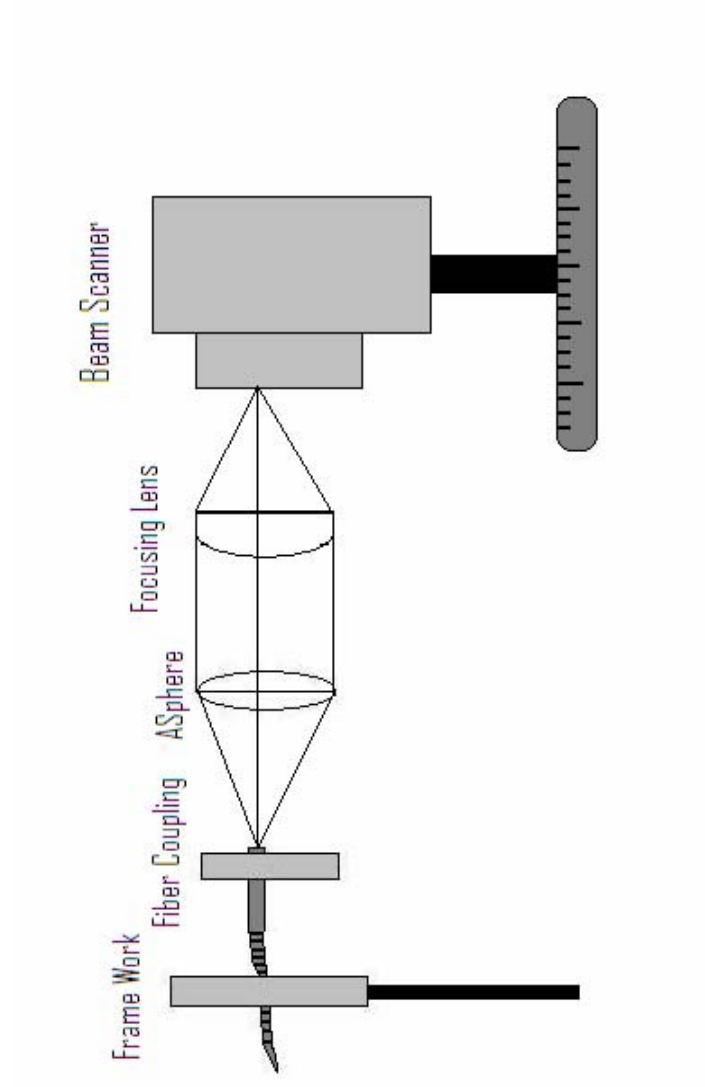




## End Pumped Laser CW Output Analysis

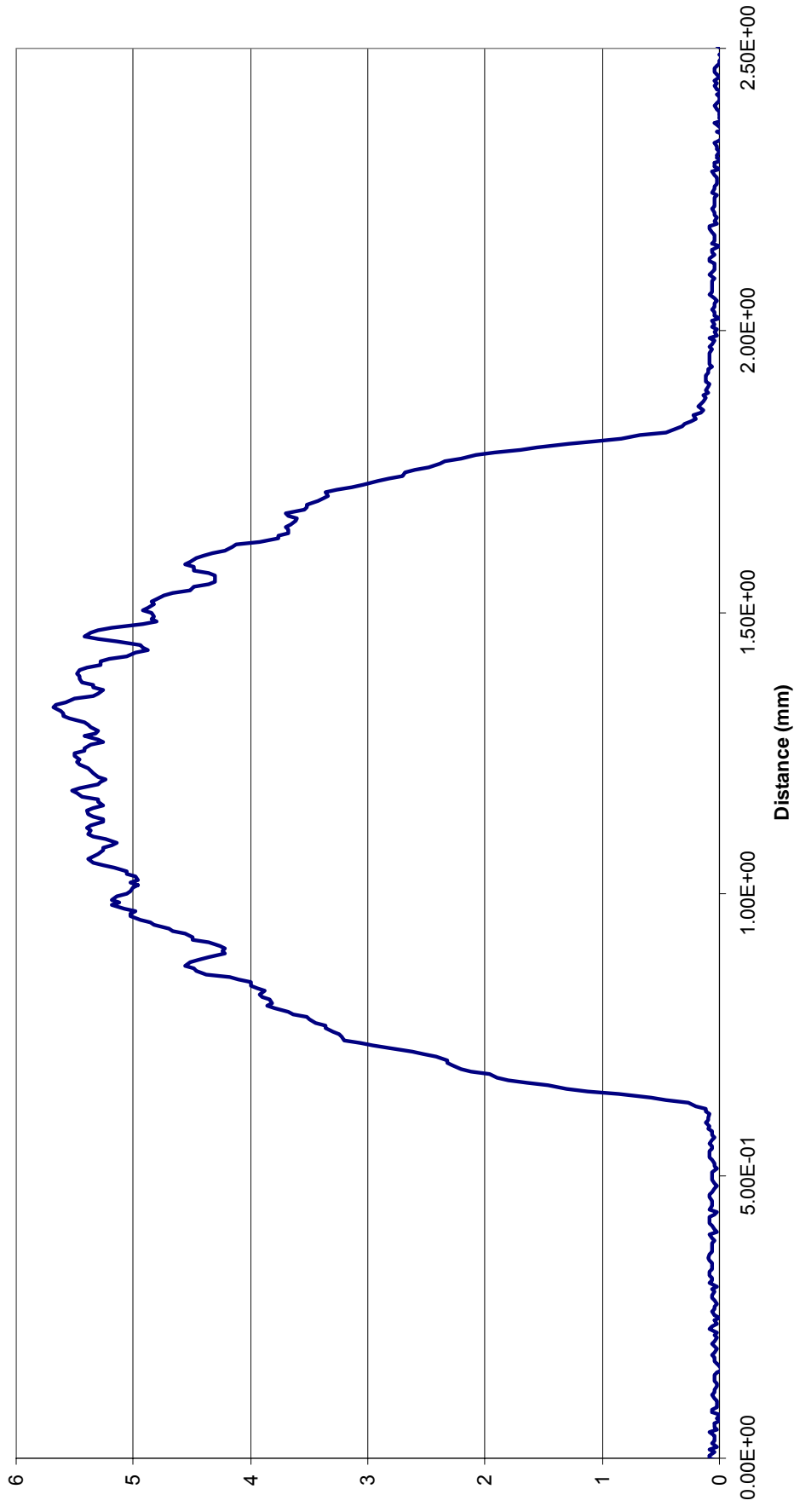


# Pump beam scanning configuration

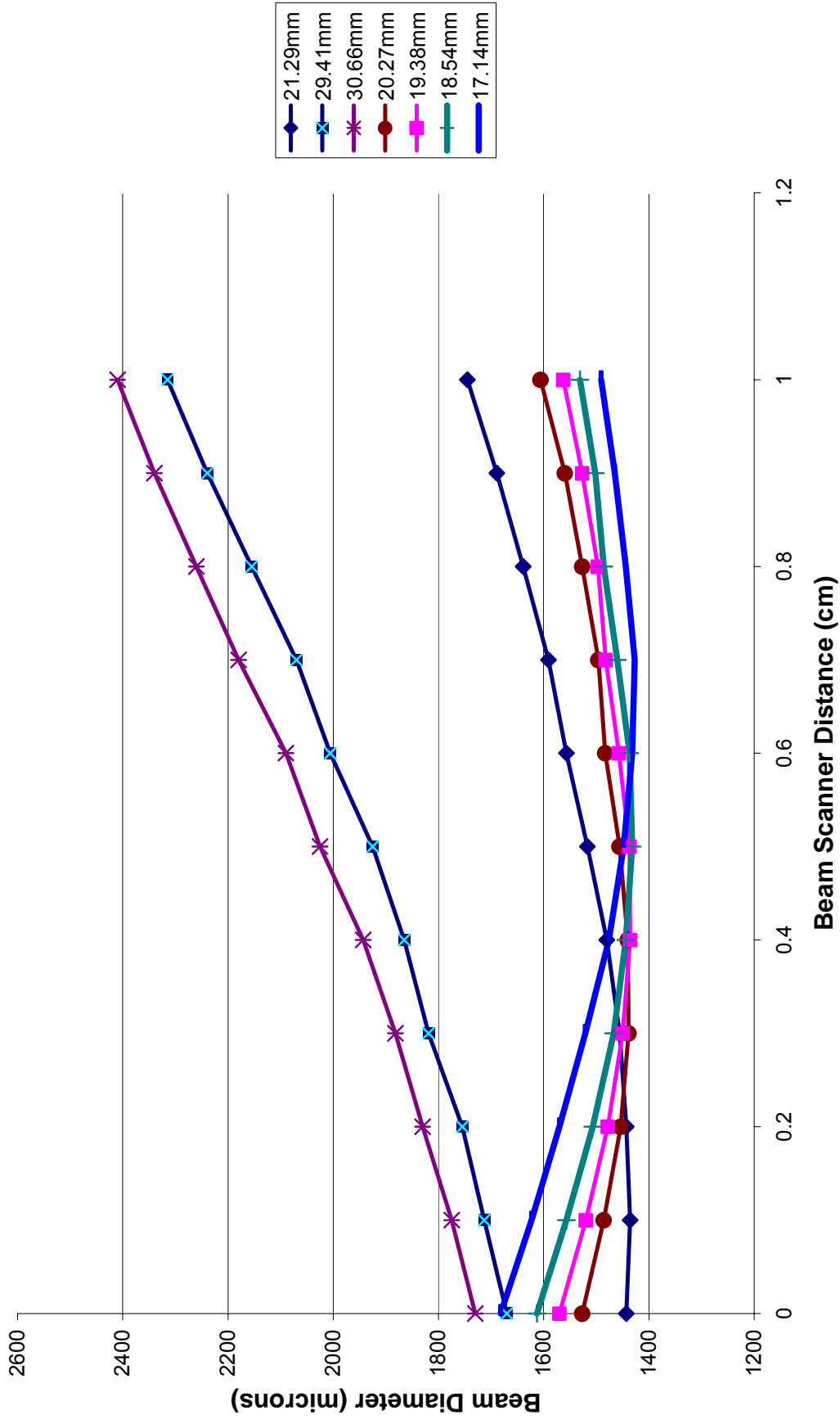


# Beam Shape

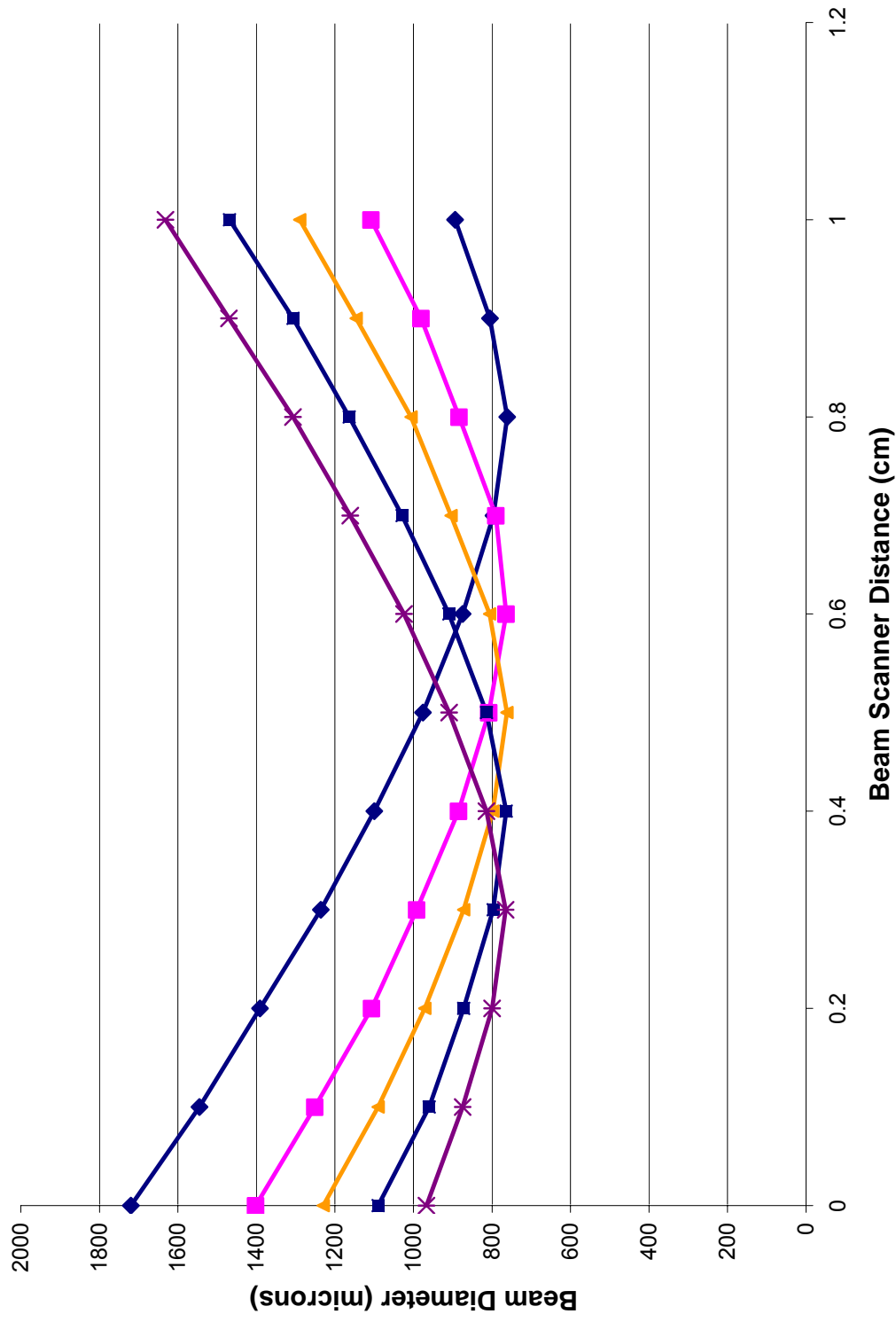
## 40 mm collimating lens, 75 mm focusing lens



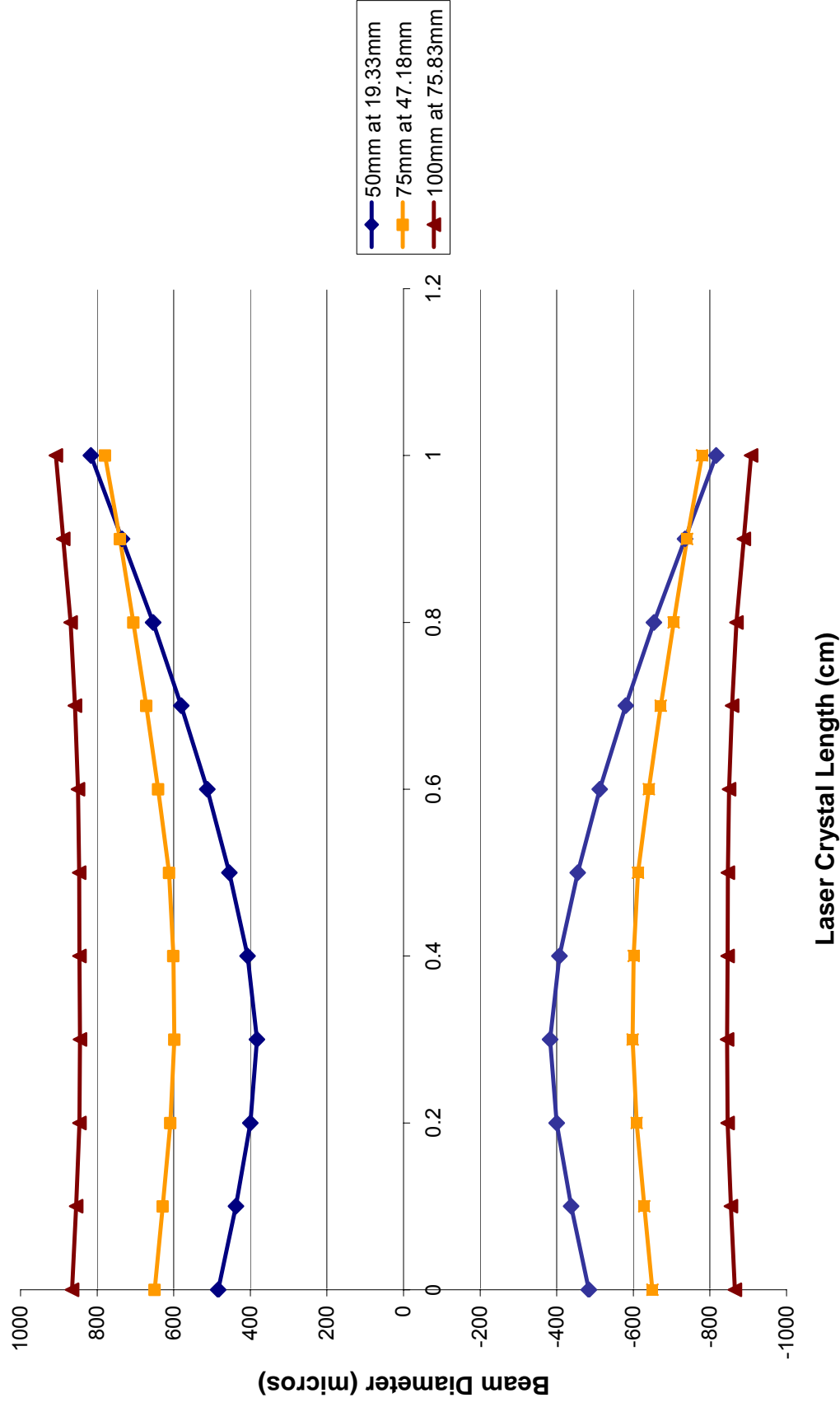
## Fixed Asphere - Beam Diameter w/ 50mm



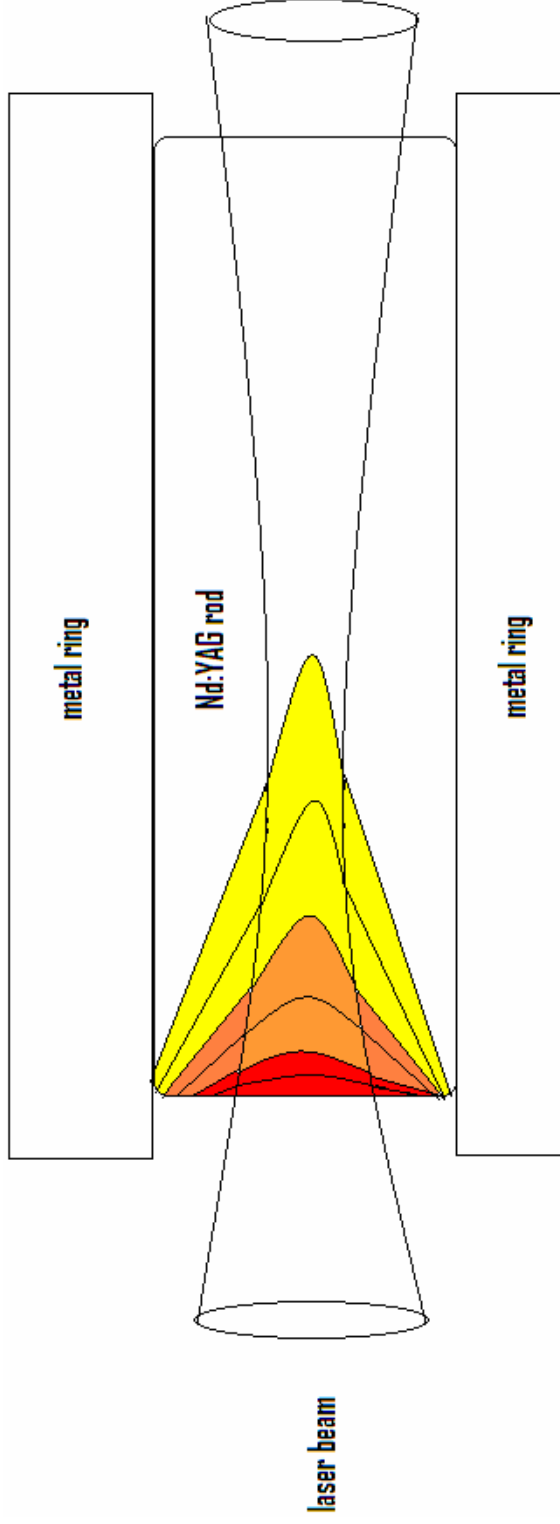
## Fixed FL 40mm - Beam Diameter w/ 50mm



## Optical Focus Position Inside Laser Crystal



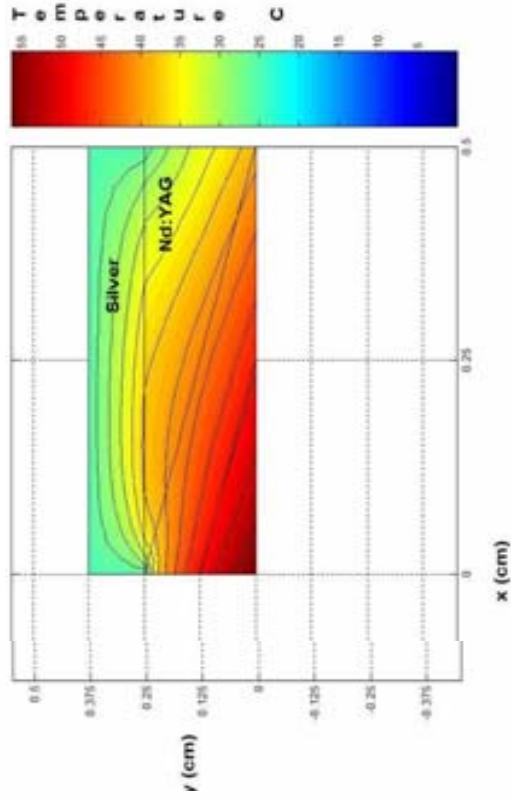
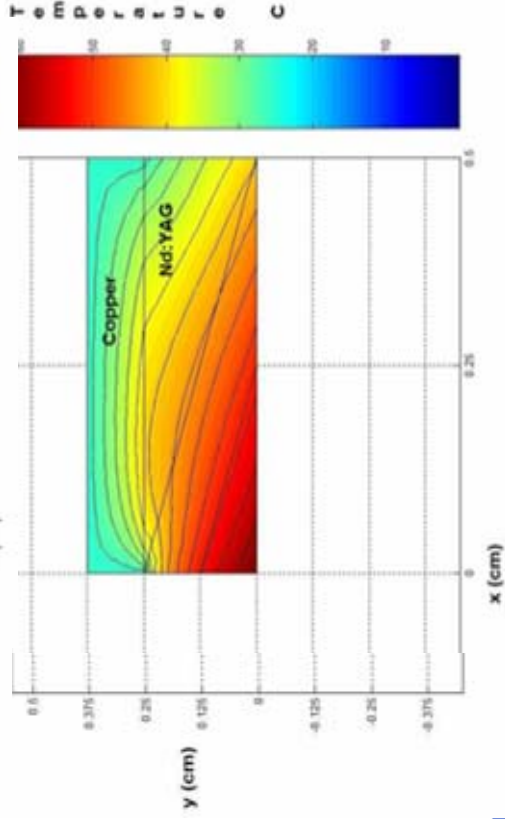
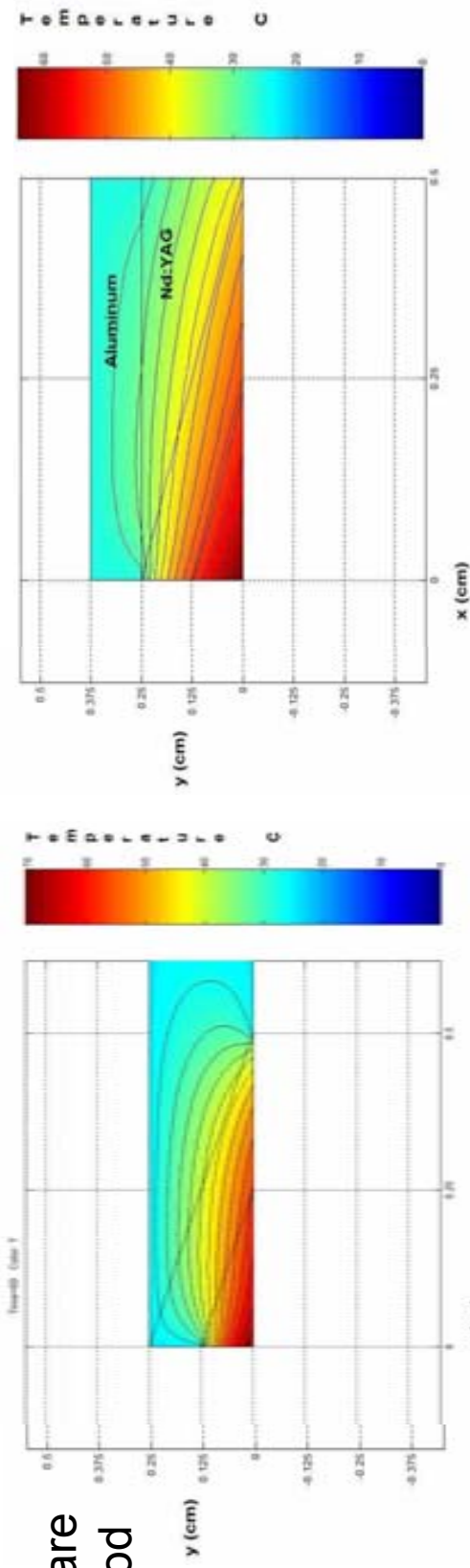
# Thermal management parameters



Material	$\rho$ – density $g \cdot cm^{-3}$	K – thermal conductivity $W \cdot cm^{-1} \cdot K^{-1}$	C specific heat $J \cdot g^{-1} \cdot K^{-1}$
Nd:YAG	4.56	0.14	0.59
Aluminum	2.70	2.37	0.89
Copper	8.96	4.01	0.38
Silver	10.5	4.29	0.23

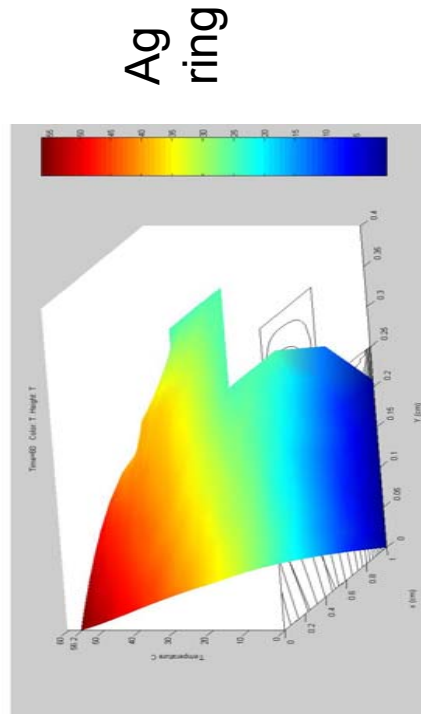
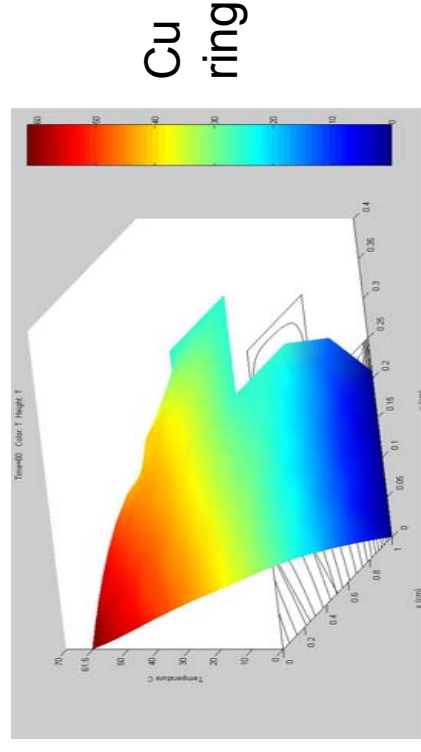
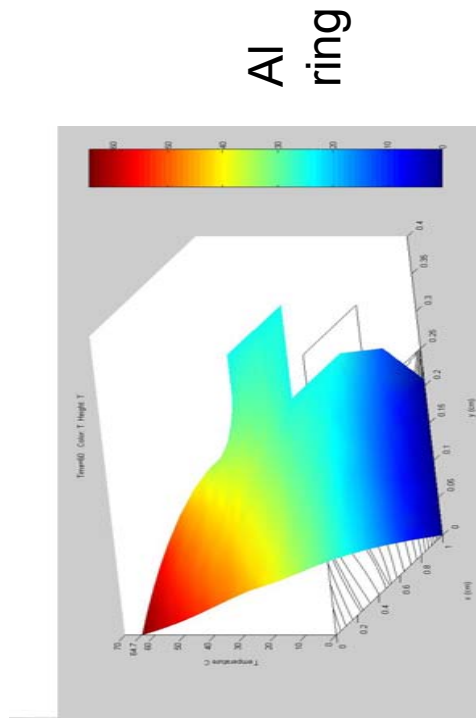
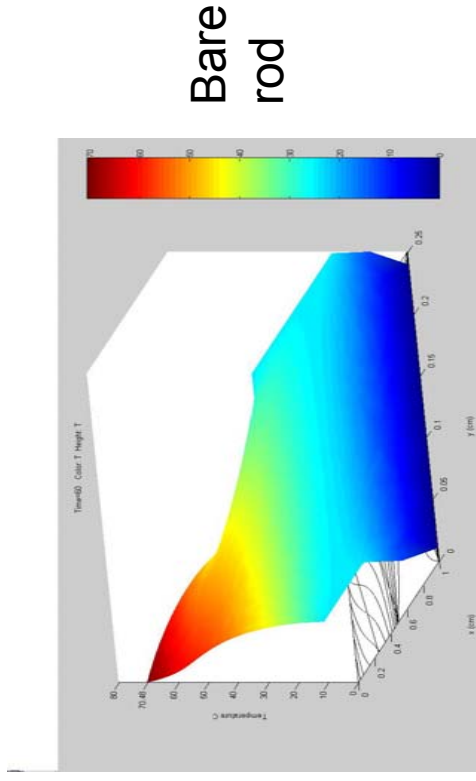
# 2-D view of temperature distribution

Bare  
Rod

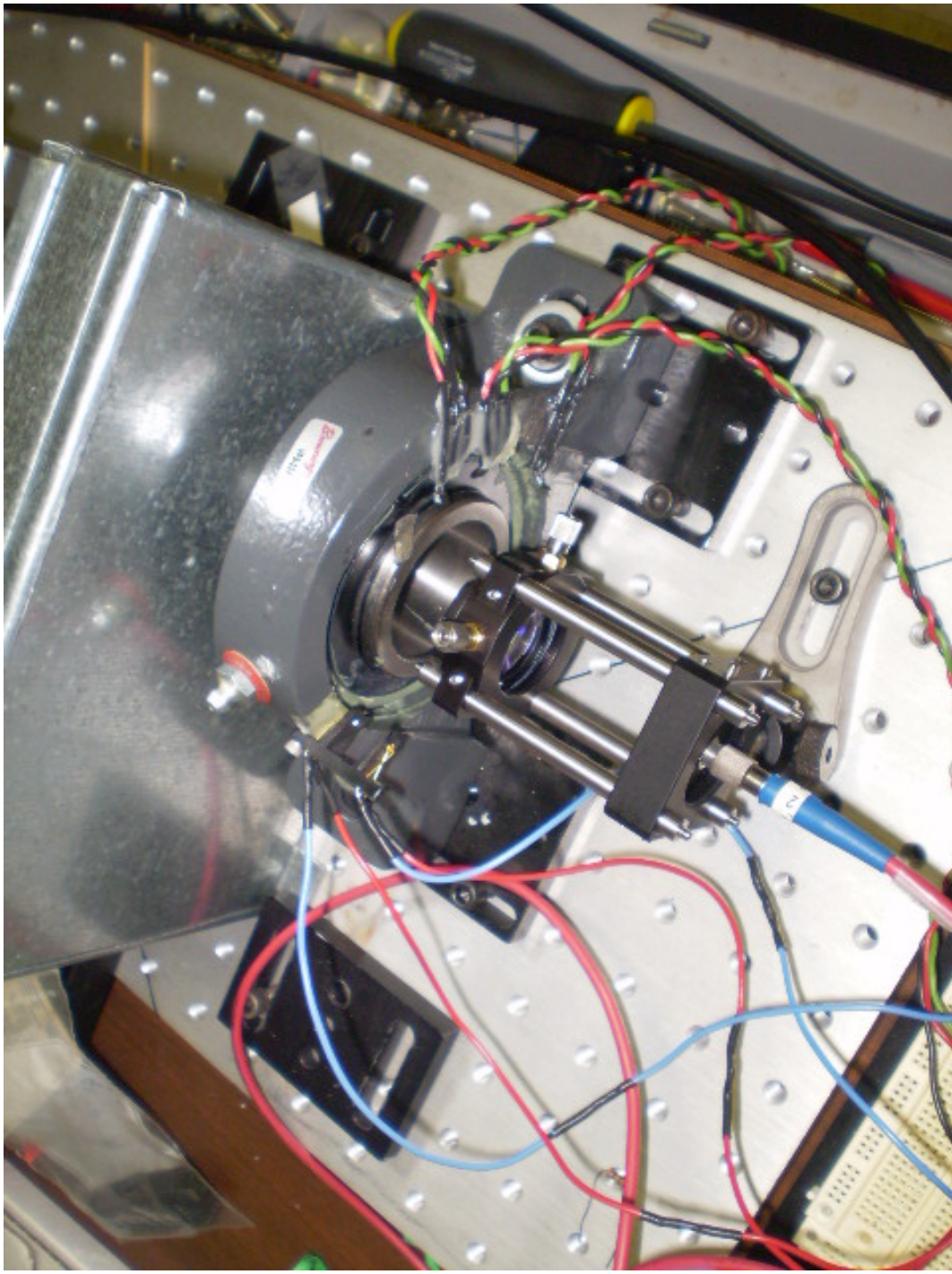




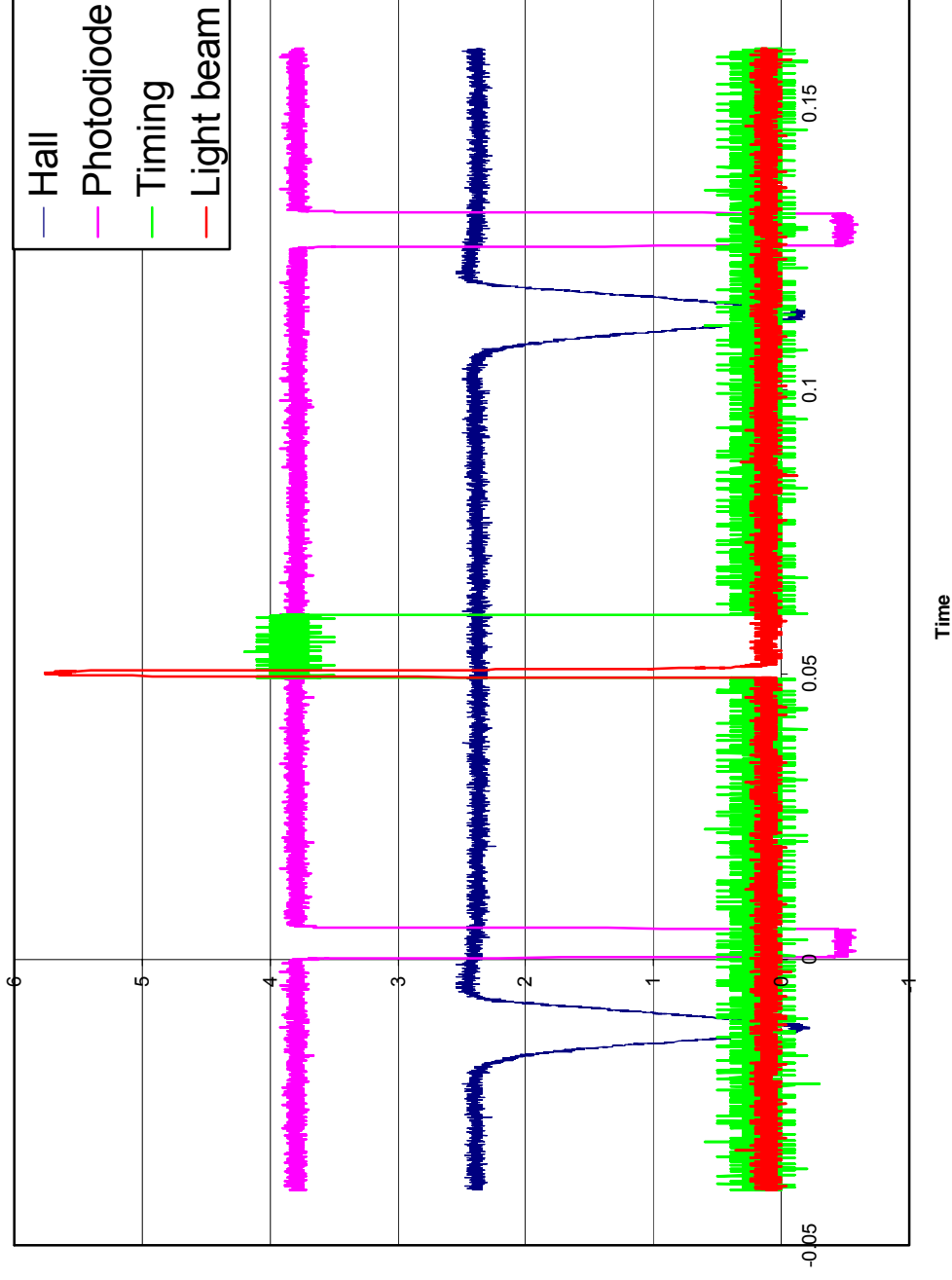
# 3-D view of the temperature distribution



# Optical Distributor



# Distributor Signals



# Current Status

- Pulse energies of >8 millijoule
- Pulse width of 5-6 nanosecond
- $M^2$  to be determined
- Sapphire and fused silica lens assemblies under construction
- Costs are dropping...

# To Do List

- **Test laser components**
  - Test higher concentrations of Cr:YAG
  - Test lower reflectivity output couplers
  - Cool the YAG rod
- **Test 200 watt, 400 micrometer fiber laser**
- **Test plug lens assemblies**
- **Engine test**

# Laser Sparkplug Costs

- **Single Unit, OTS costs**
  - Laser pump source - ~\$12k
  - Pump power supply - ~\$7k
  - Optical fiber - <\$30/m
  - Distributor - ~\$300 + a motor driver
  - Laser plugs ~\$800 + mounts
- **Source + Distributor <\$20k + plug costs**
- **Should drop with mass production**

# Thanks to MLEF Students

- **Ricardo Velez – Univ. of Mass.**
- **Adrian Comacho-Berrios – Univ. of Mayaguez**
- **Candace Cobb – Norfolk Univ.**