Optical Diagnostics

BROOKHAVEN NATIONAL LABORATORY
Instrumentation Division Ultrafast Laser Laboratory

- tight environment
- high radiation area
- non-serviceable area
- passive components
- optics only, no active electronics
- transmit image through flexible fiber bundle

Optical Diagnostics

glass imaging fibers

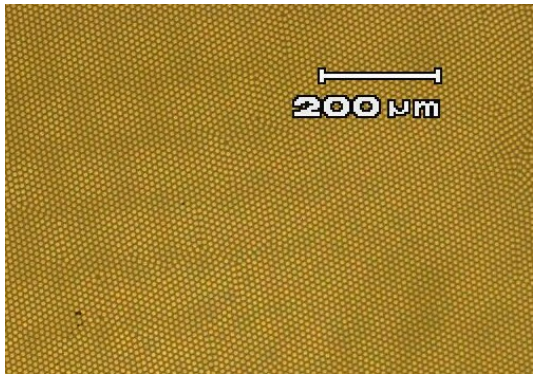
BROOKHAVEN NATIONAL LABORATORY

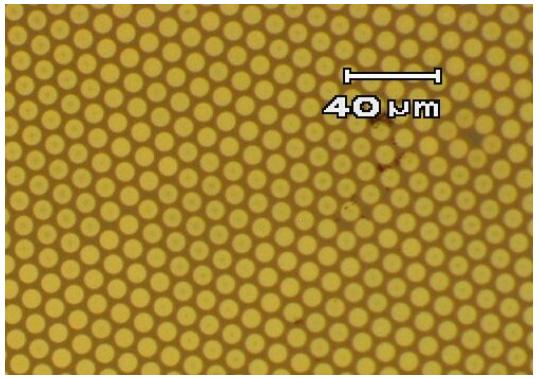
Instrumentation Division Ultrafast Laser Laboratory

SMD camera

CCD size:	13.4 x 13.4 mm
Pixels:	960x960
Single frame:	240x240 pixels
	57,600 picture elements
Reduced pixel size:	56 x 56 um

glass imaging fiber bundle
Core size: 12 µm, diameter: 1/8”





Total fiber counts ~50,000 in 3.17 mm diameter
Imaging ~243 x 243 fibers on 960 x 960 CCD array

~1 imaging fiber on ~4x4 pixels on full frame

~1 imaging fiber on ~1 pixel on a single frame

Optical Diagnostics

retroreflected illumination

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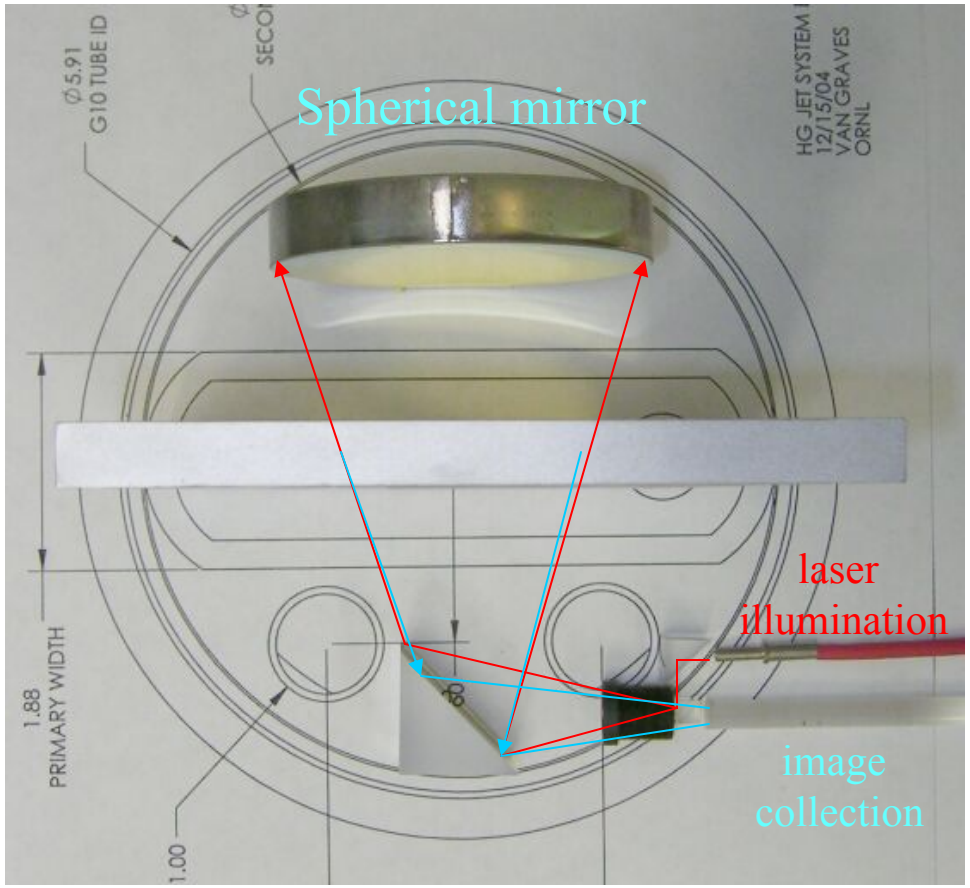

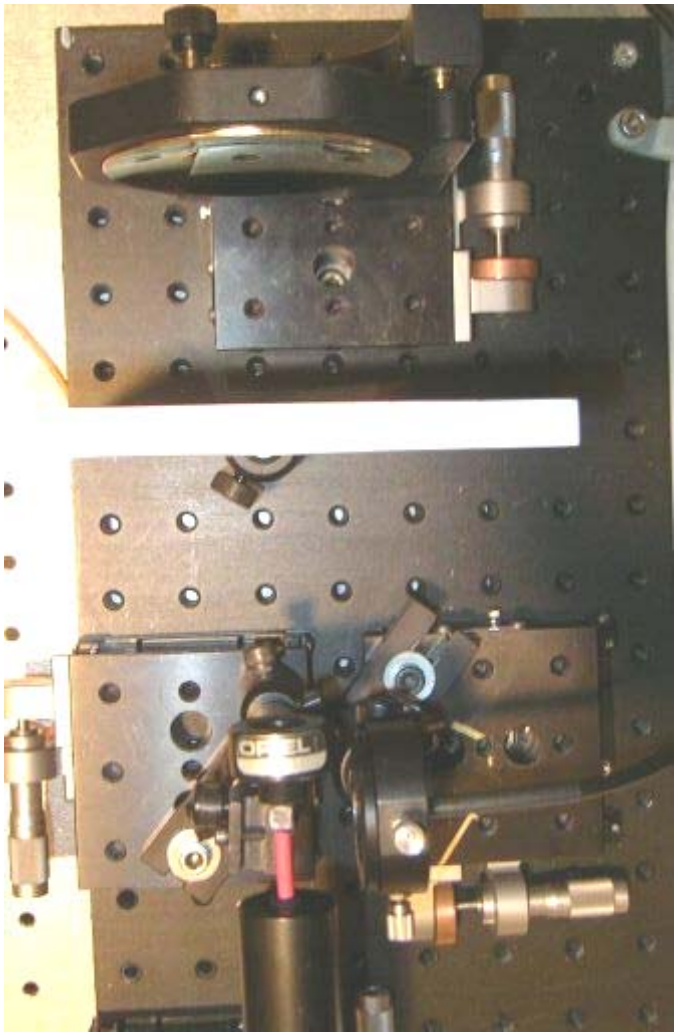

Works OK in this tight environment

Optical Diagnostics

Exp test setup

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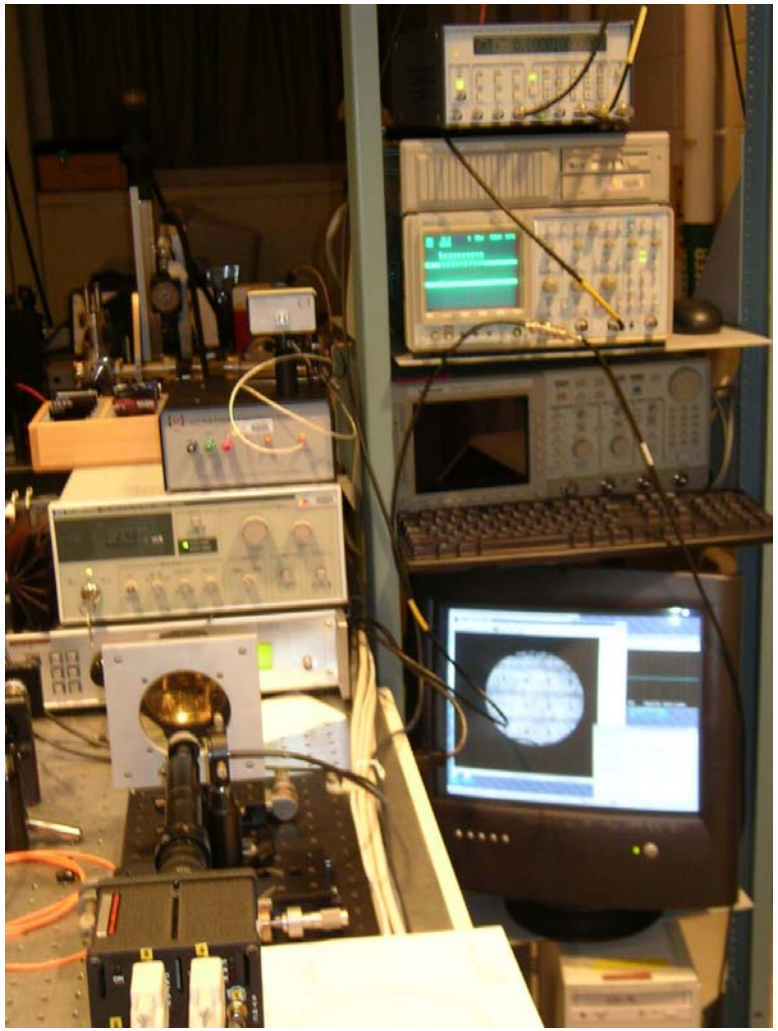

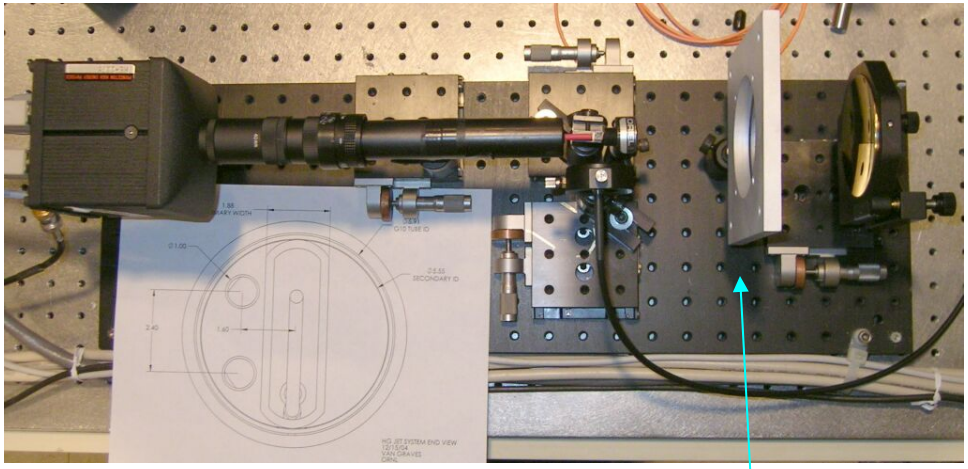

Optical Components

- 50/50 beam splitter: Edmund, 0.5 cm cube
- spherical mirror: Edmund, f=3-in, D=3in< Au coated
- small prism mirror: Edmund, 1x1x1.4 cm, Au coated
- large prism mirror: Edmund, 2.5x2.5x3.54 cm. Au coated
- imaging fiber Edmund: ⅛-in diameter, 12-µm core, 0.55 NA
- illumination fiber: ThorLabs, 0.22 NA, SMA-905 840 -µm core
- imaging lens: Sunex, f=0.38-cm, f/# 2.6, diagonal FOV 54°, φ1.4-cm x 2.0 cm

Optical Diagnostics

Field of view – NIR laser illumination & imaging

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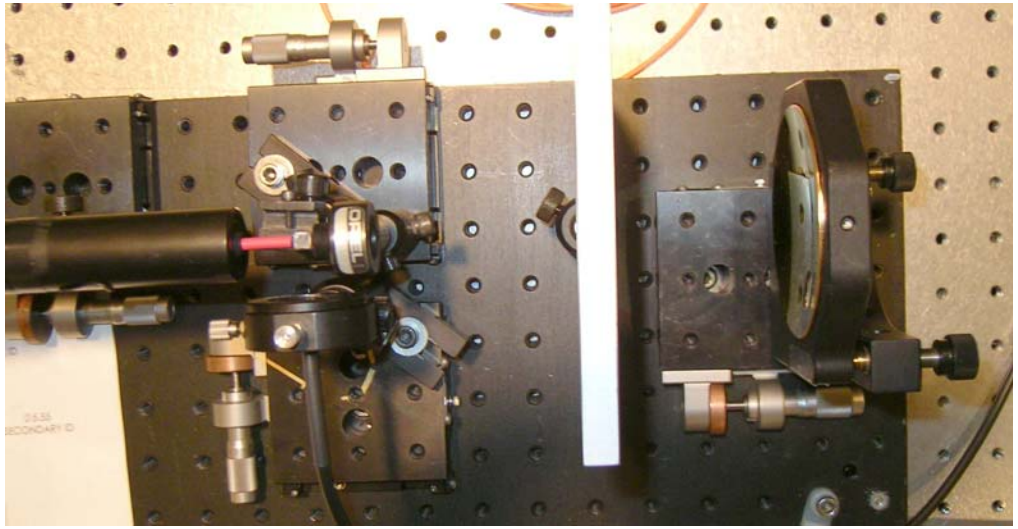

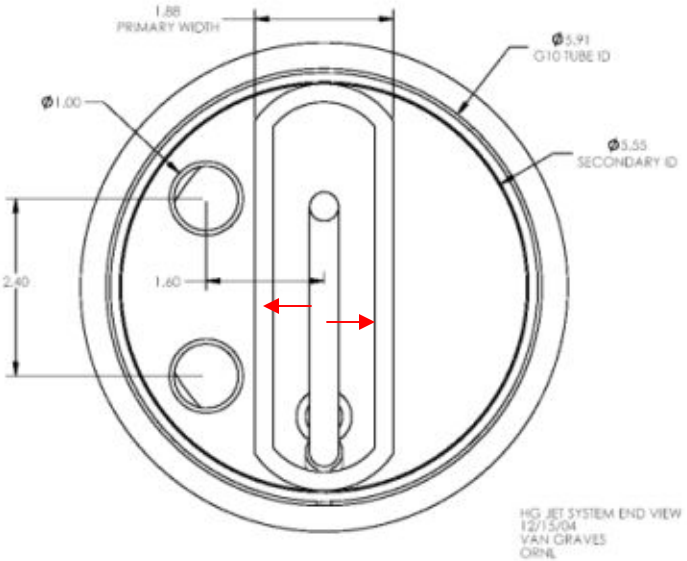

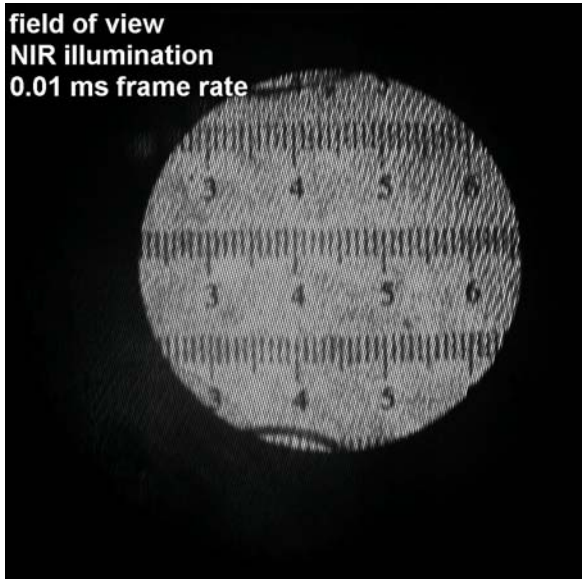

Optical Diagnostics

optical design in secondary containment

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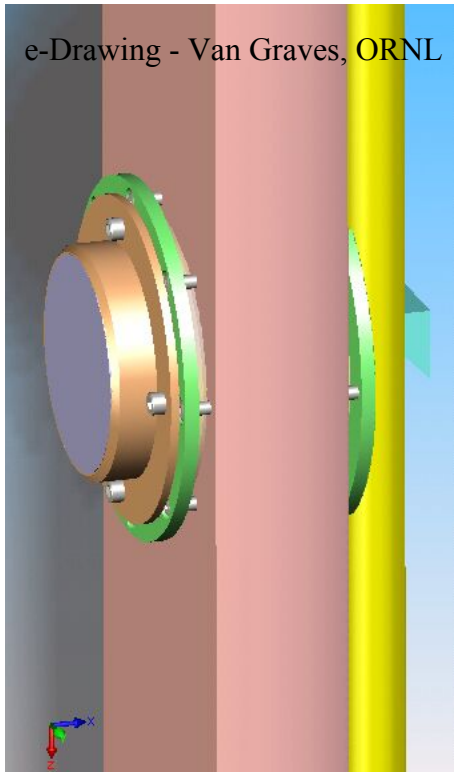

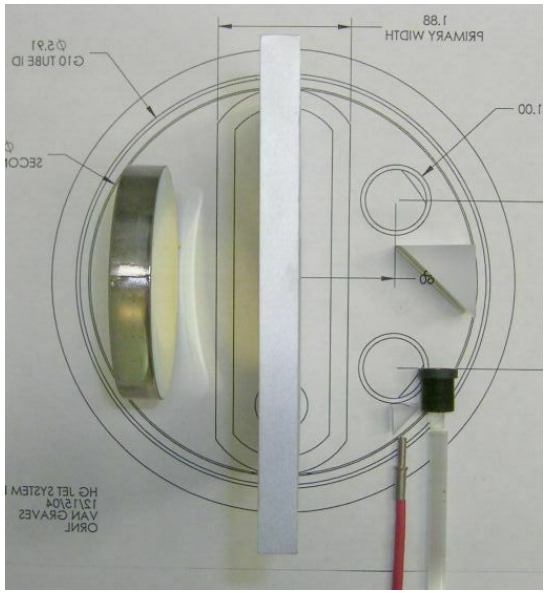

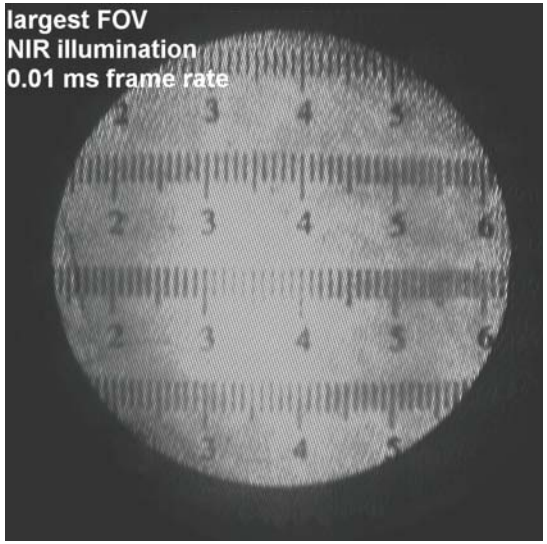

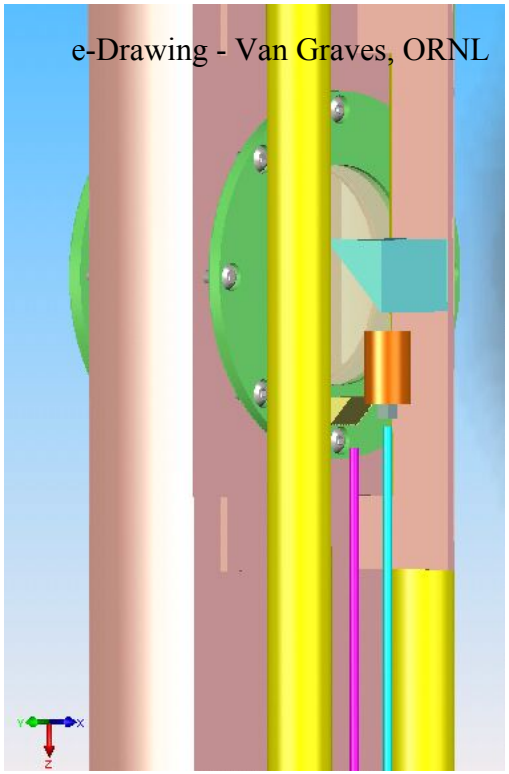

One set of optics per viewport

Conceptual design completed

Optical Diagnostics

An optical chopper in motion @ 4 kHz

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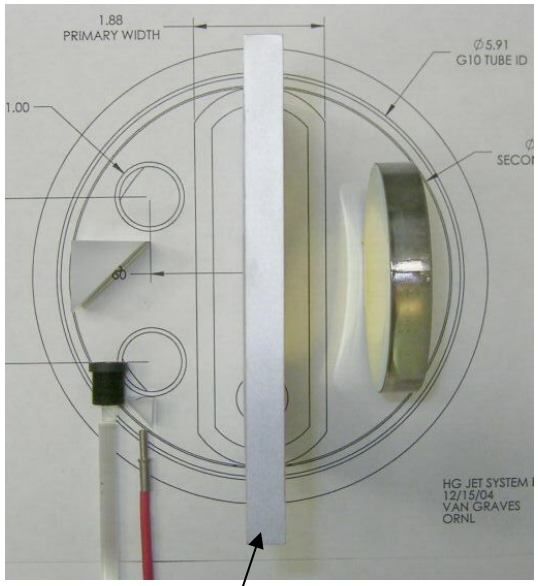
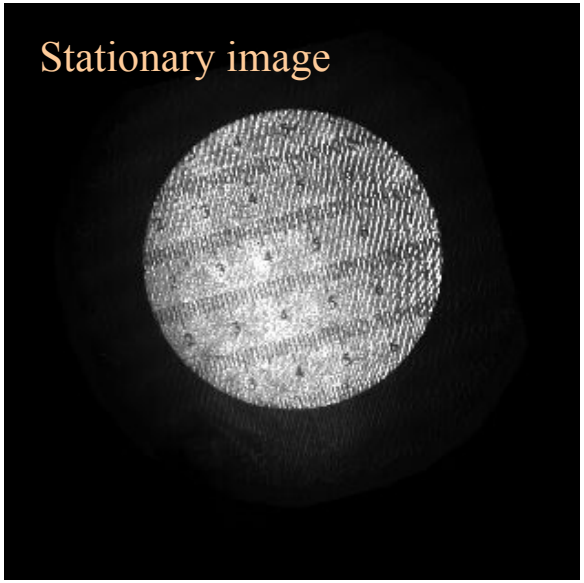
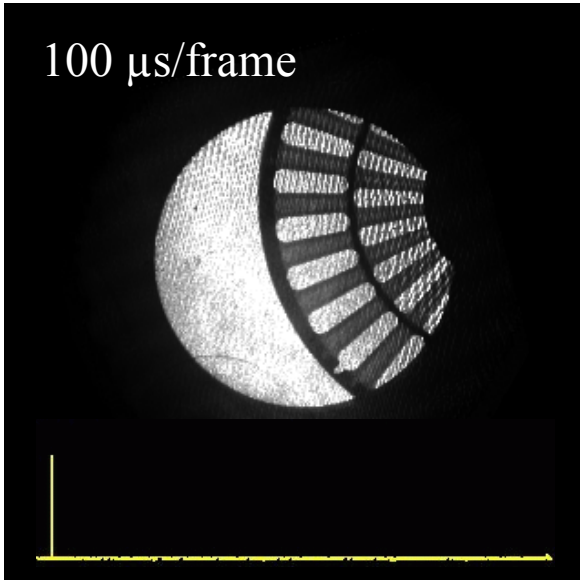
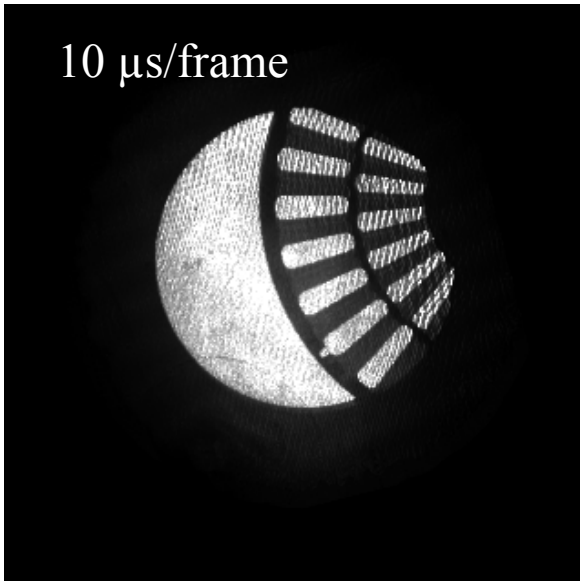
Instrumentation Division Ultrafast Laser Laboratory

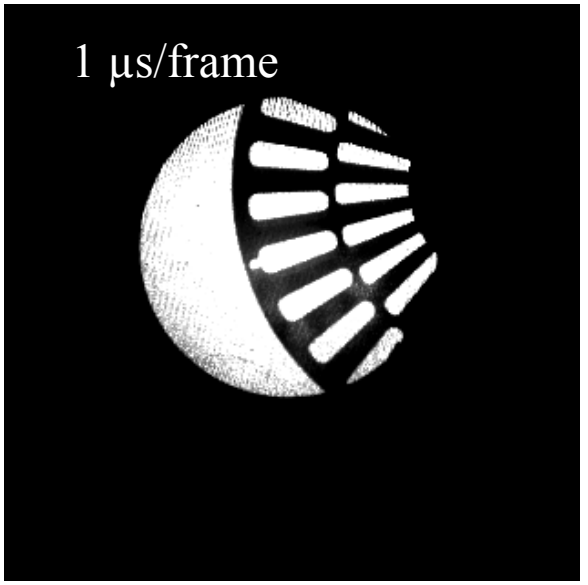


Velocity @ ~40 m/s





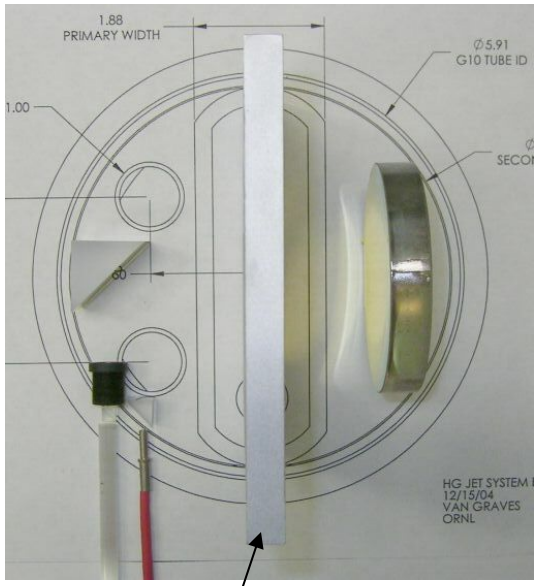




Optical Diagnostics

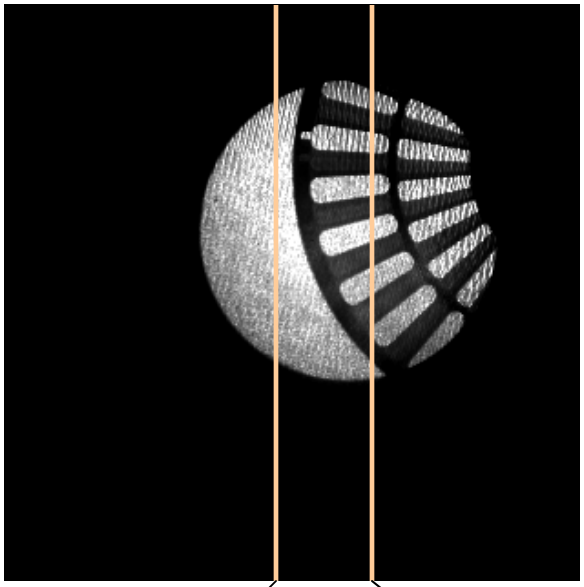
An optical chopper in motion @ 4 kHz cont'

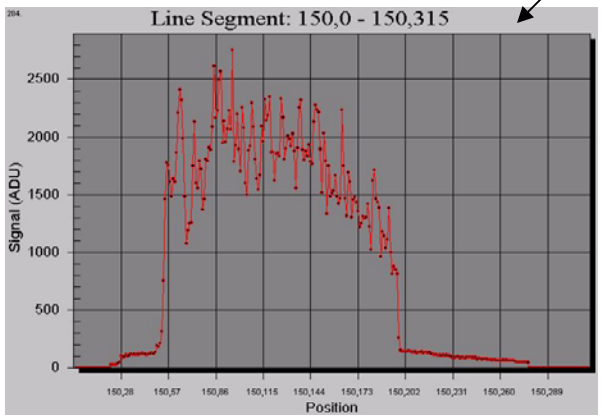
BROOKHAVEN NATIONAL LABORATORY
Instrumentation Division Ultrafast Laser Laboratory

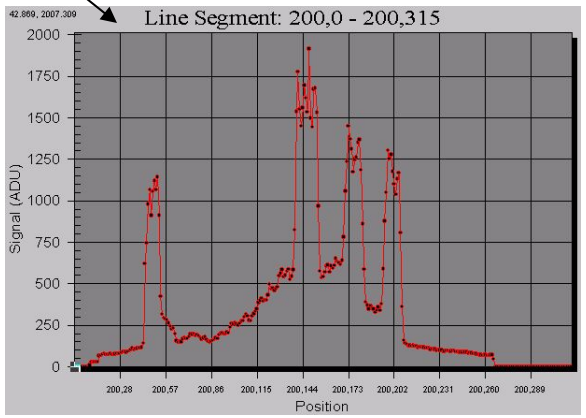


Velocity @ ~40 m/s

100 μs/frame
with reflective mask

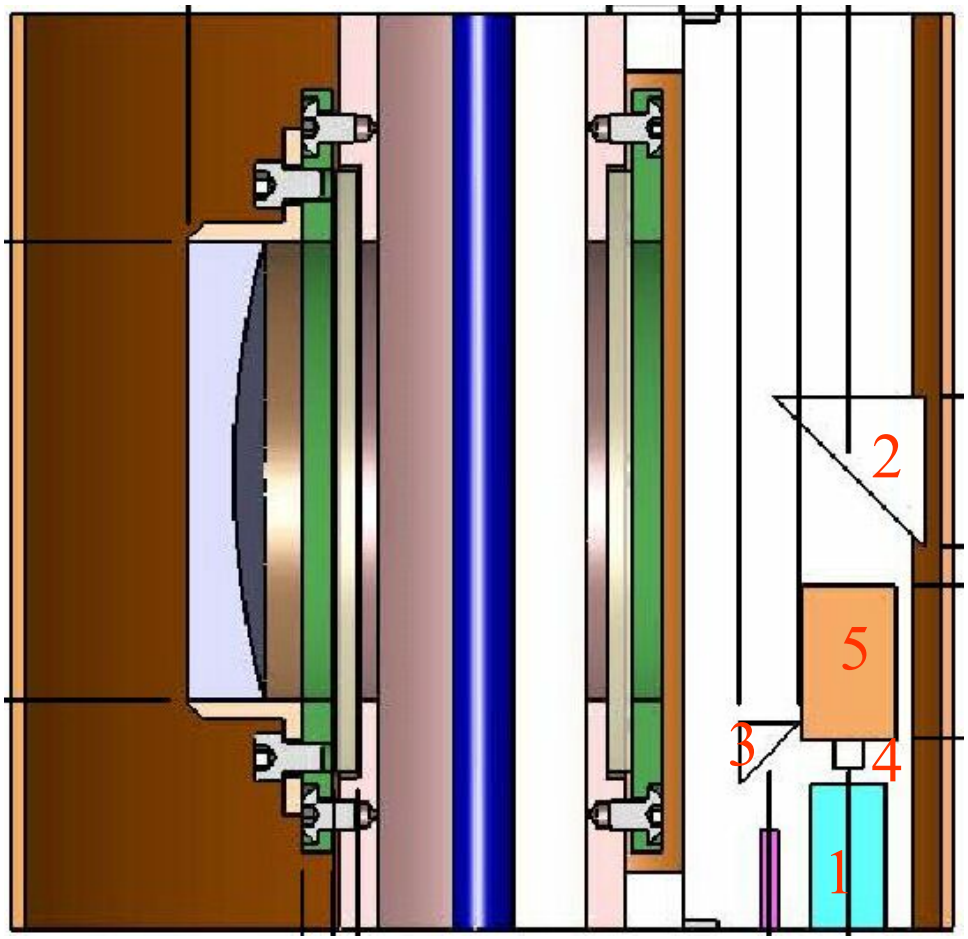






frame #12

Irradiation Studies of Optical Components



CERN, ~ April 15-24, 2005
1.4 GeV proton beam
4 x 10^{15} proton
Irradiation dose: equivalent to
40 pulses of 24 GeV proton beam
28 TP/pulse
total of 1.2 x 10^{15} proton

Received radiation dose:
3231 Gy, ~ 3.2 x 10^5 rad
or
3.2 x 10^6 rem
(assume a quality factor of 10)

Optical components

Irradiation summary – transmittance/reflectance measurements

	A	B	C	D	E
1		13-Jul-2005			
2		Results of optical components irradated at CERN on April 15, 2005			
3		proton beam energy: 1.4 GeV			
4		no. of protons: 4x10^15			
5		transmittance and reflectance measured at the HeNe wavelength			
6					
7	**item #**	**components**	**before**	**after**	**results**
8	2	Large gold mirror reflectance	0.910	0.920	no change
9	3	Small gold mirror reflectance	0.930	0.940	no change
10	4	50/50 beam splitter: transmittance	0.450	0.360	drop 20%
11	4	50/50 beam splitter: reflectance	0.530	0.423	drop 21%
12	5	imaging lens: transmittance	0.880	0.610	drop 31%
13	6	1-mm thick sapphire plate	0.863	0.867	no change
14	7	1-mm thick fused silcia	0.914	0.859	drop 5%
15					
16	1	3-fleet long imaging fiber	0.394	0.000	no measureable light transmitted
17					at the HeNe or 800 nm wavelengths
18					

Activity right after irradiation: 4 mSv/h on contact
30 μSv/h at 50 cm away

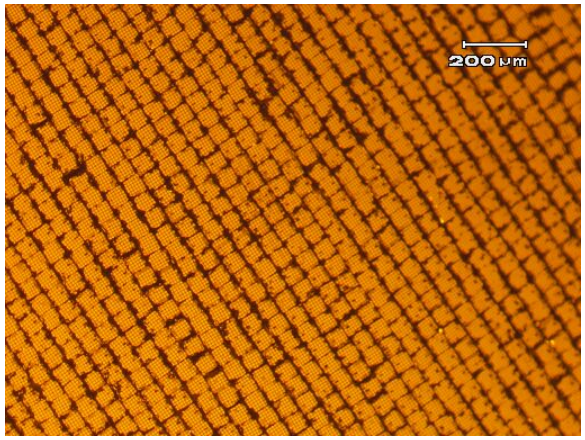
Activity ~ 1 month later (5/23/05): 0.5 mSv/hr on contact (50 μrem/h)

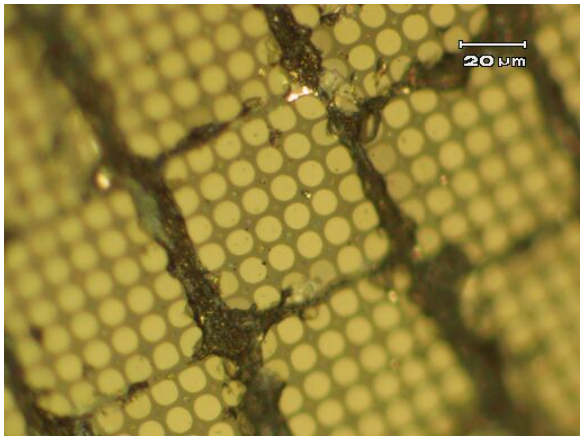
Activity arrived at BNL ~ background level

3-feet long of Schott imaging fiber before and after irradiation

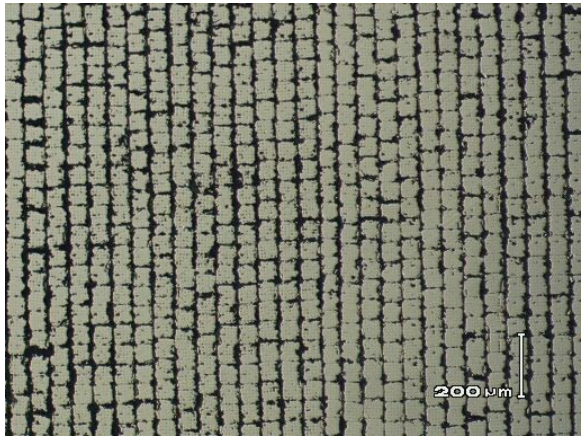
50 x 500 x

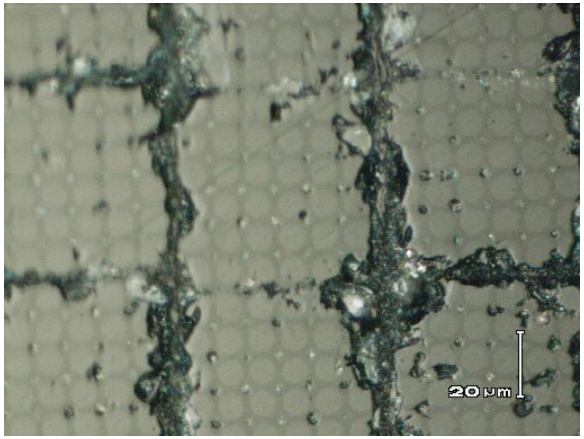
before





after





$I = I_o\, e^{-\alpha t}$

From fused silica results: $\alpha = 0.62$, for $t = 0.1$ cm

Projected transmission for t=3-ft of the imaging fiber:

$e^{-(0.62)(91\ \text{cm})} = 3 \times 10^{-25}$!!! for ~40 proton pulses

If α is linearly prop. to # of proton pulses, transmission for 1 proton pulse = 0.244 for 1-meter

$= 4 \times 10^{-4}$ for 5-meter

Fujikura imaging fibers

Table 3

ULTRATHIN IMAGEFIBER SPECIFICATIONS

(FIGH series N-Type 50k-100k)

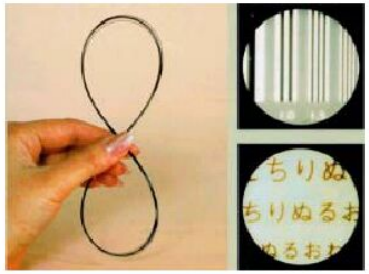
Item	FIGH-50-1100N	FIGH-70-1300N	FIGH-100-1500N
Number of picture elements (nominal)	50,000 (Nominal)	70,000 (Nominal)	100,000 (Nominal)
Imagecircle diameter (μm)	1,025 +80/-80	1,200 +100/-100	1,400 +120/-120
Fiber diameter (μm)	1,100 +80/-80	1,300 +100/-100	1,500 +120/-120
Coating diameter (μm)	1,200 +100/-100	1,450 +100/-100	1,700 +150/-150
Minimum bending radius (mm)	110*1(80*2)	150*1(100*2)	200*1(130*2)
Coating material	Silicone resin		
Lattice defect (%)	< 0.1		
Uncirculality (%)	< 5		

*1:Minimum bending radius in storage

*2:Recommended bending radius in use (For your reference only, possibly to be happened breakage by static fatigue.)

Fujikura Ltd.

Sumitomo imaging fibers



TP03105B

SEI

Product Lineup

	IGN-02/03	IGN-028/06	IGN-035/06	IGN-037/10	IGN-05/10	IGN-08/30	IGN-15/30	IGN-20/50
Number of picture elements	3,000	6,000	6,000	10,000	10,000	30,000	30,000	50,000
Jacketing diameter (um)	200	280	350	370	500	800	1,500	2,000
Picture elements area diameter (um)	180	252	315	333	450	720	1,350	1,800
Coating diameter (Primary) (um)	250	340	420	450	590	960	1,900	2,400
Coating diameter (Secondary) (um)	---	---	---	---	---	---	2,500	3,000
Circularity	>= 0.93							
Core material	GeO2 Containing Silica							
Cladding material	F Containing Silica						Pure Silica	
Coating material	Silicone						Silicone + PFA	
Numerical aperture	0.35						0.30	
Lattice defect (%)	<= 0.1							
Allowable bending radius (mm)	10	15	15	20	25	40	75	100
Allowable max temp. (C)	150							

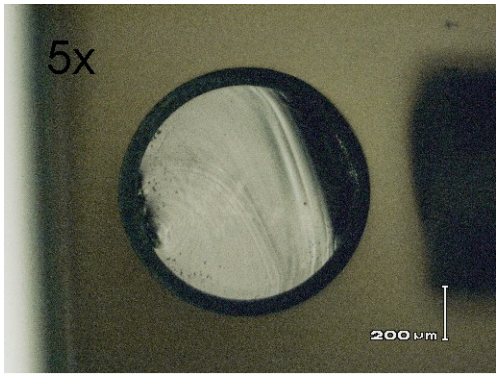
SUMITOMO ELECTRIC

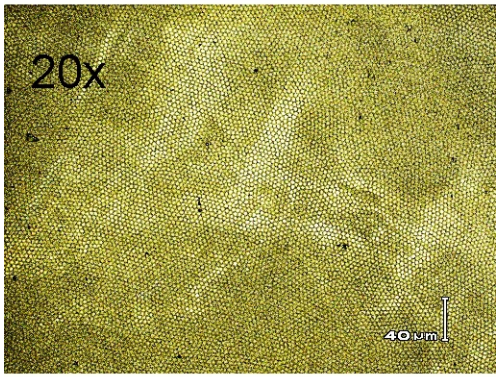
All have small imaging area
<2 mm diameter
Rad-hard?

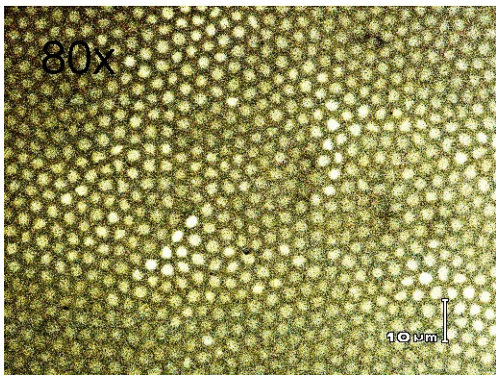
>20 meter available

5 meter limit

IGN-08/20 - sample







Optical Diagnostics

Other issues

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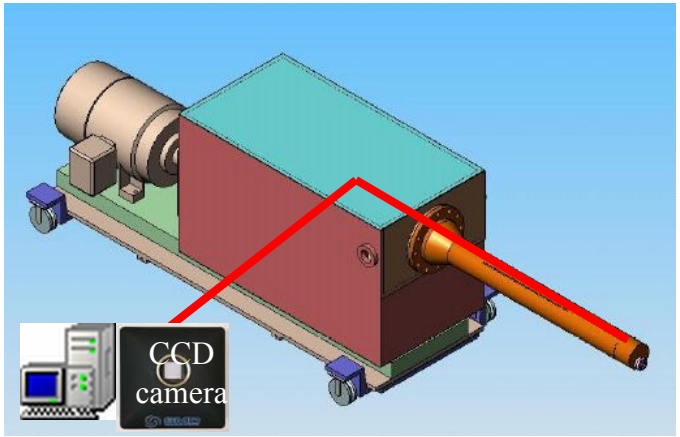
Instrumentation Division Ultrafast Laser Laboratory

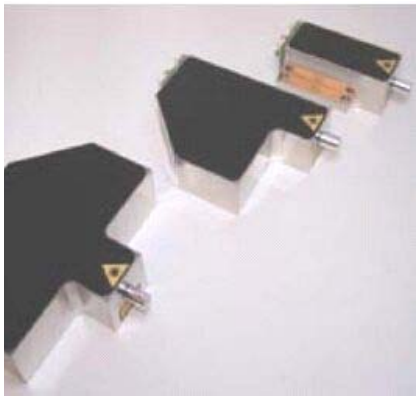
1. Laser power increase to ~40 W/pulse (instead of 10 Watt/pulse)
2. Depth of focus → apparent image size variation
3. 3-in diameter spherical retroreflecing mirrors – on hand
4. Anti-reflection coated (@ 800 nm) viewports: lexan, sapphire, or fused silica
5. Number of viewports ? 4
6. Location of the viewports ? 6-inches aparts
7. How many fast CCD camera ? 1 fast (1 μs), ~2 slower (250 μs), 1 video?
8. Switch from one viewport to the next with one (fast) laser/camera system ?
9. ~20-m long flexible rad-hard imaging fiber bundles
10. Radiation resistance of imaging fiber bundle and optics ? continue testing
11. …



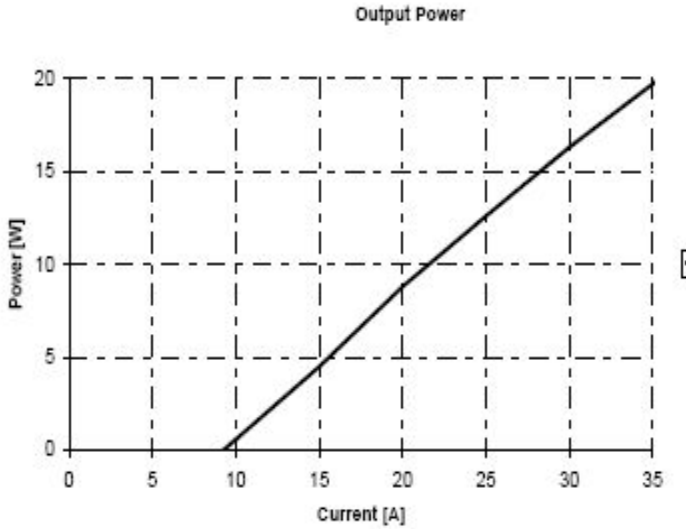
BrightSolutions
SOLUZIONI LASER INNOVATIVE

BDL20-808-F6

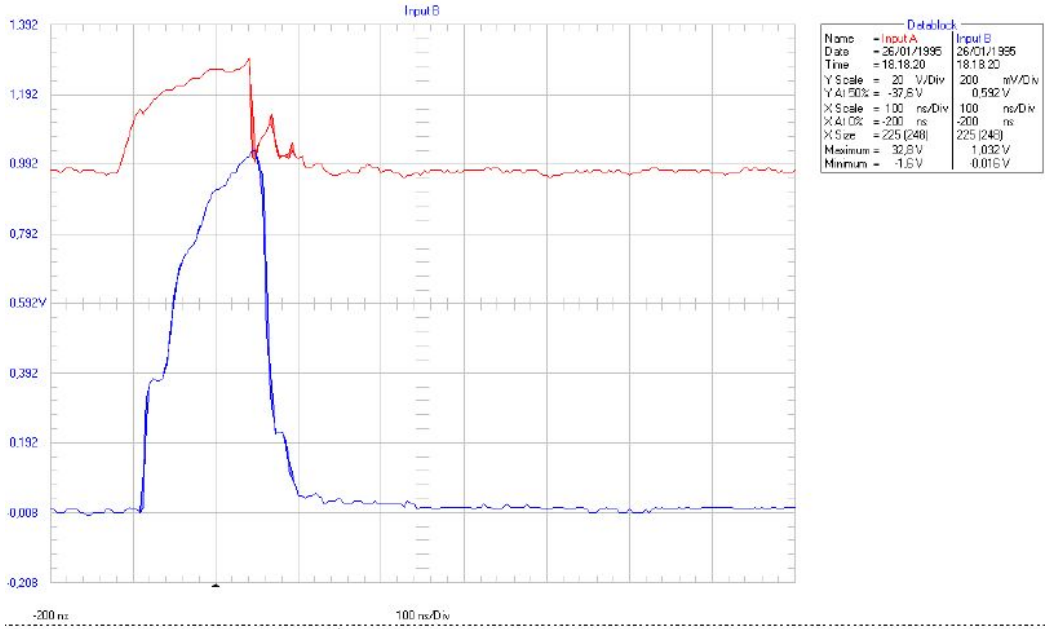
s/n: 05091745



RPMC Lasers, Inc.
203 Joseph Street
O'Fallon, MIssouri 63366 USA
(636) 272-7227
(636) 272-3909 (Fax)
www.rpmclasers.com



Parameter	Value	Unit
Temperature	25	°C
Rated power	20	W
Current at rated power	35.38	A
Maximum current	41.63	A
Threshold current	9.2	A
Center wavelegth	808.6	nm
Linewidth FWHM	2.64	nm

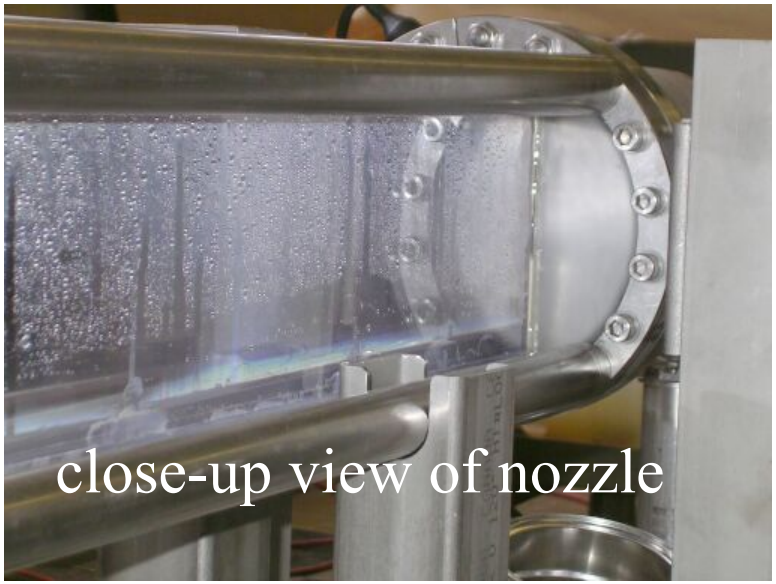


Input A: Current 20 A/div
Input B: Optical Power 4 W/div

Video camera capture of waterjet, August 19, 2005 @ Princeton

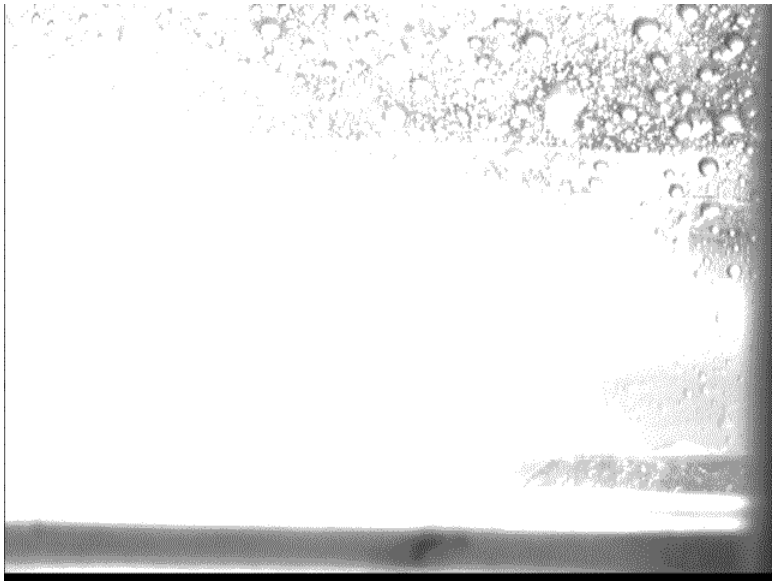
Camera: 30 frame/sec conventional video camera

nozzle: diameter ~? mm, length ?-inch



640x480 pixels, 30 frame/sec, 20 frames

front view



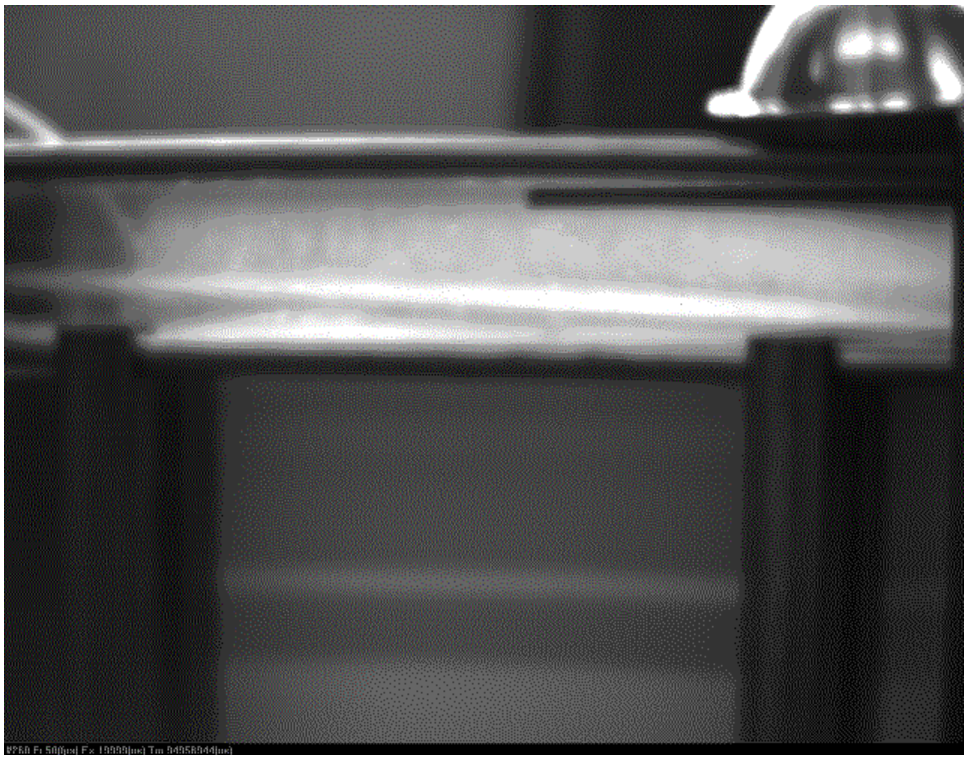
angle view

Fast camera capture of waterjet
September 16, 2005 @ Princeton

Camera: FastVision 13 capability
1280x1024 pixels, 500 frames/sec, 0.5 sec video
or …

nozzle: diameter ~8 mm, length 6-inch

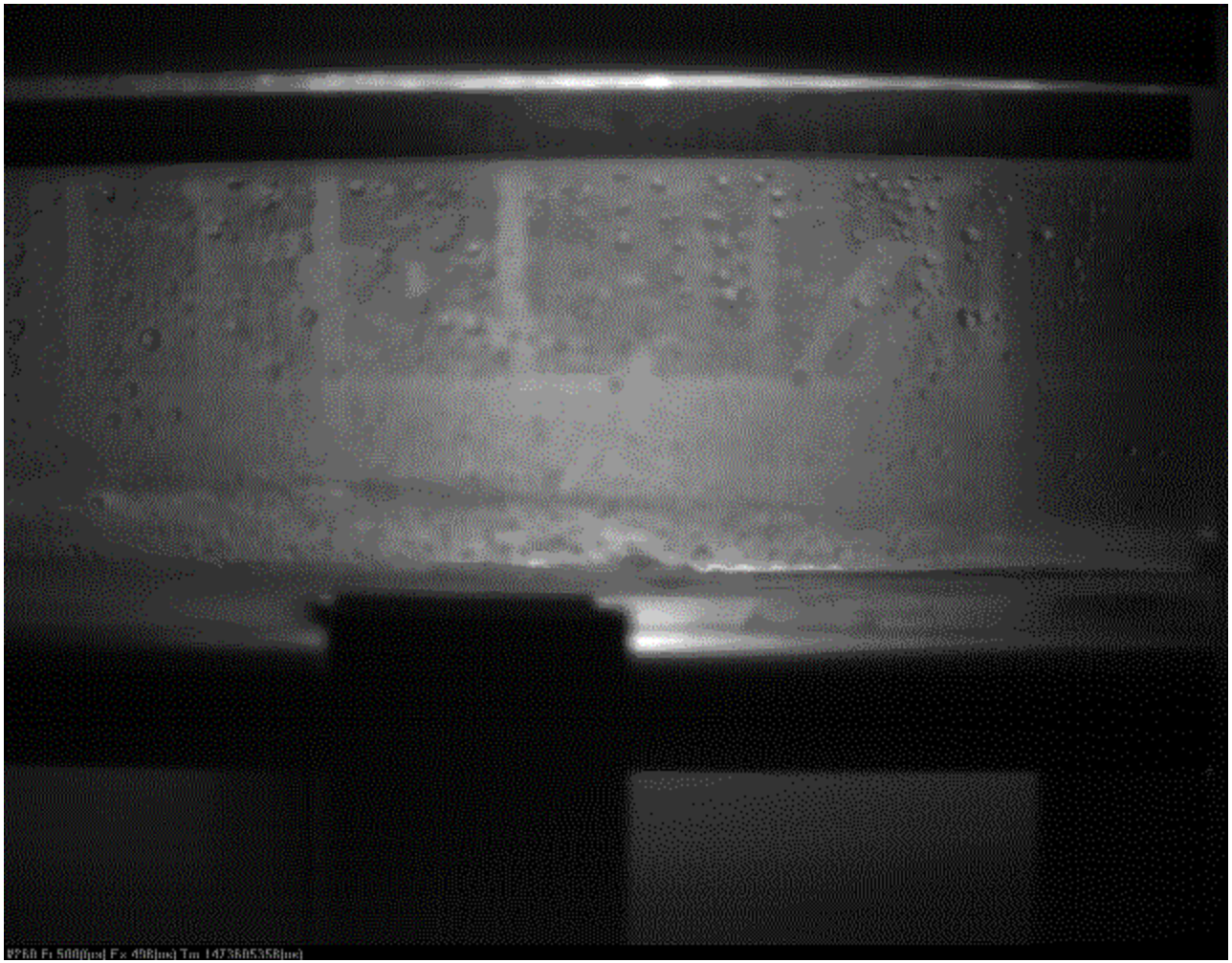
waterjet in action: movie



1280x1000 pixels
50 frame/sec
20 frames of video

close-up view of waterjet

1st run @ 8:25 am



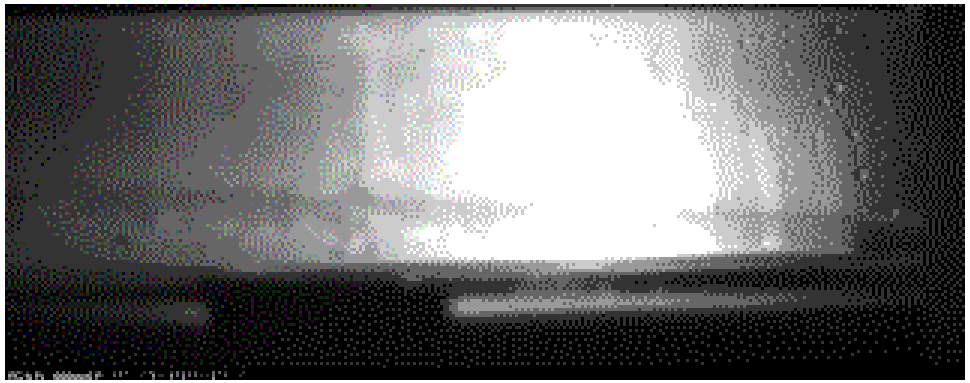
22 cm

Frame rate: 500 frame/sec (2 ms per frame)
1280x1000 pixels, exposure time 0.5 ms
20 frames of video

waterjet velocity ~12-17 meter/sec

waterjet at varies pump speeds

6^{th},7^{th}, & 8^{th} runs @ 9:14 to 9:24 am

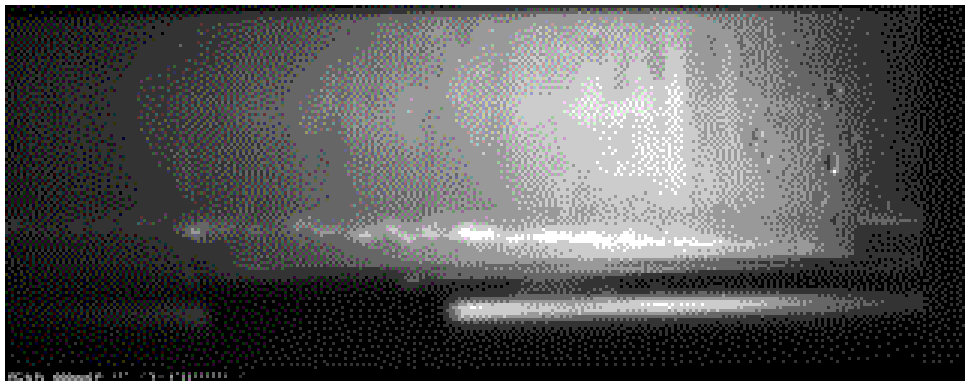


Frame rate: 1000 frame/sec (1 ms per frame)
1280x500 pixels, exposure time 0.25 ms
20 frames of video

full speed

75% speed

50% speed



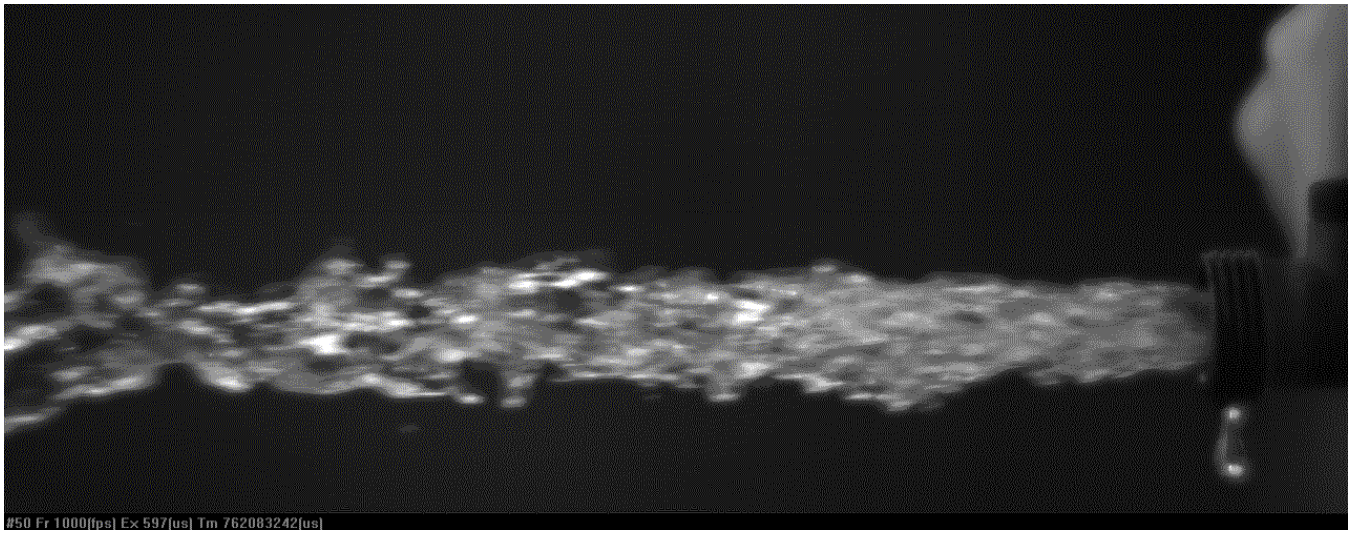
22 cm

waterjet velocity
~10, 12, & 7 meter/sec, respectively

Fast camera capture of garden hose spray

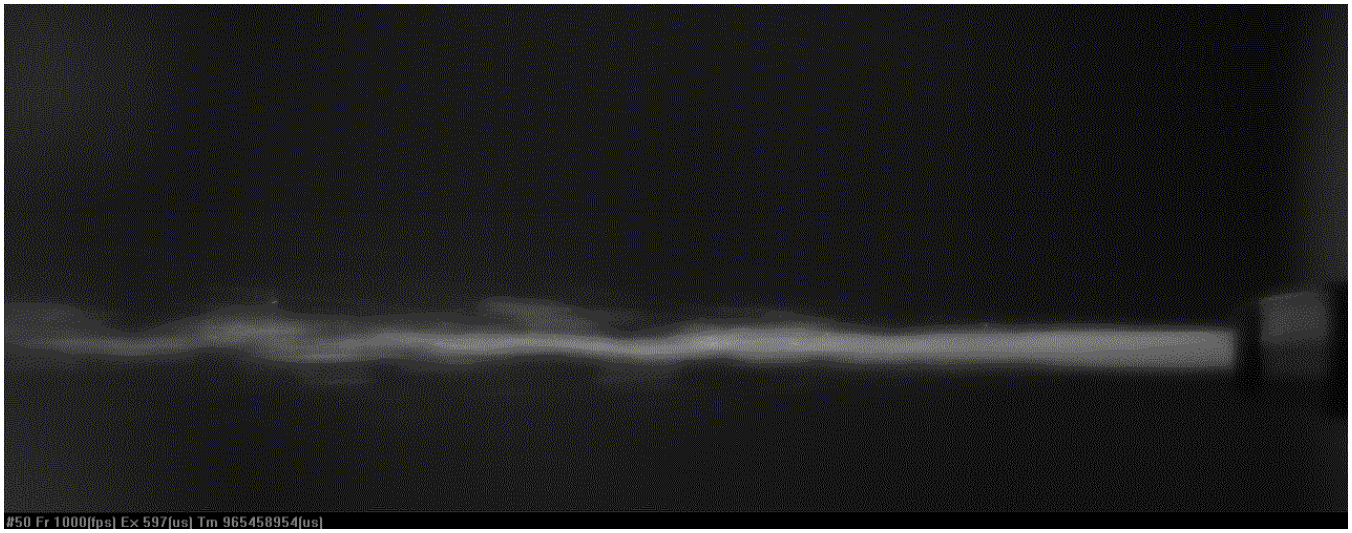
September 9, 2005

Camera: FastVision, 1280x500 pixels



1280x500 pixels
1000 frame/sec
20 frames of video

Velocity ~ 6.7 meter/s



1280x500 pixels
1000 frame/sec
20 frames of video

Velocity ~ 20 meter/s

22 cm