University of Nevada, Reno

Nevada Center for Applied Research

NTF/NSTec Laser Plasma Diagnostics Development for the Dense Plasma Focus

Quarterly Progress Report

Reporting Period: July 1st to September 30th, 2015

October 2015

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Project Purpose

A state-of-the-art core laser diagnostics package (shadowgraphy, interferometry and Faraday rotation) will be developed for installation on NSTec's N. Las Vegas Dense Plasma Focus (DPF). The DPF is a key diagnostic probe of Sub-Critical Experiments (SCE) at the NNSS. SCE experiments form the backbone of technical efforts at the NNSS and employ a large number of highly-skilled workers in the state of Nevada. The laser diagnostics system will be designed, tested and installed by Dr. Vladimir Ivanov, a postdoctoral research scholar and UNR students. The new diagnostic system will be based on similar diagnostics already developed and in operation at the Nevada Terawatt Facility (NTF).

In the past, NSTec DPF d-d neutron yields have plateaued near 10^12 neutrons per shot and shot-to-shot repeatability did not always meet stringent SCE requirements. Moreover, it has been difficult to reduce the temporal duration of DPF neutron pulses below ~80 ns full-width-at-half-maximum (FWHM), an improvement which would improve many SCE measurements. The laser diagnostics system will help NSTec scientists and engineers to more fully understand the evolution of the DPF plasma and will provide data that will help improve numerical simulations of machine behavior. The purpose of this project is multifold. First, data from the laser diagnostics will help to create more accurate models of DPF performance. These in turn can help the NSTec technical staff to find operating conditions that optimize neutron yield and stabilize machine behavior. Secondly, this effort will help to train the next generation of scientists and engineers with highly technical skill sets needed to accomplish the mission of the NNSS. It will also provide opportunities for UNR students to find competitive employment in Nevada.

Section I: Proposal Progress

Project activities for the July 1st- September 30th, 2015 reporting period are summarized below. A majority of effort focused on formative administrative tasks, preliminary technical design, equipment selection and acquisition and initiating hires for key project technical personnel.

Formative administrative tasks included setting up an ongoing task order from NSTec to NTF for this project. This task orders allowed NSTec to send promised matching funds and allowed us to initiate the project. After we received final approval from GOED on August 8th, 2015 we started working with UNR OSPA in order to set up accounts and hire personnel. These accounts were put into place by mid-September. Other administrative efforts including starting to define the safety protocols that will be needed to operate a Class IV laser at the DPF.

Dr. Covington and Ivanov travelled to NSTec in late May to see the DPF and more clearly understand the physical layout of the laboratory and how we might be able to most effectively interface with the apparatus and existing infrastructure. Upon returning, Dr. Ivanov started the optical design of the system and the selection the laser that would most effectively meet the unique needs of the DPF.

It was decided that the safest and most cost effective way to ensure that a laser would be delivered and installed early next February was to allow NSTec to purchase a dedicated system that would be delivered in Las Vegas. This would allow NSTec personnel to start the process of installing power and water for the laser and ensuring that it met rigorous NSTec/DOE safety requirements.

During the reporting quarter, significant progress has been made toward meeting proposed metrics. Major accomplishments for the current reporting period include:

1. Major Accomplishment 1

The overall design of the laser diagnostics system to be used at NSTec's N. Las Vegas DPF has been completed by Dr. Ivanov (see attachment #1).

2. Major Accomplishment 2

Drs. Ivanov and Covington have started purchasing the various optical components, holders and cameras (see attachment #2). It is anticipated that all of these will be delivered to UNR for assembly and testing by December 2015. Certain sub-components are already being tested and validated on existing NTF systems as they arrive.

3. Major Accomplishment 3

The pulsed laser was specified (see attachment #3) by Dr. Ivanov and ordered by Dr. Aaron Luttman (NSTec). The laser is due for delivery and installation in Las Vegas by Ekspla personnel in late February.

4. Additional Accomplishments

a. A Postdoctoral research fellow (Dr. Austin Anderson) has been selected to work on the project ½ time. Dr. Anderson has extensive background in pulsed power systems and plasma diagnostics. It is anticipated that he will start in his new position in mid-October after his paperwork has been processed.

b. A Physics Department Graduate Student (Alex Angermeier) and a Mechanical Engineering undergraduate student (Adam Larson) have been selected to work on the project starting in the Spring Semester, 2016.

c. Erik McKee- UNR Physics Graduate Student was sent to NSTec Las Vegas for one week in August to calibrate all NTF neutron detectors against those at the DPF in order to facilitate benchmarking plasma diagnostic systems between facilities. NSTec has also allowed Erik to borrow a calibrated set of PMTs for his ongoing experiments at UNR.

d. Drs. Luttman and Covington have also set up an open-ended task order to streamline the transfer of resources between NSTec and UNR.

5. Commercialization & Partnering

This project has involved a close partnership with NSTec from inception.

6. Intellectual Property

N/A

7. Programmatic & Project Changes

A Postdoctoral Research Fellow (Post Doc) has been hired in place of a Graduate Research Assistants (GRA) to help with NSTec projects. This will replace one GRA and overload for a faculty member in the original budget. This was necessary given that the Physics Department and NTF have recently landed five separate competitive research grants and there were not enough uncommitted GRAs to cover all projects. In addition, Dr. Roberto Mancini, who will be helping with plasma modeling efforts, is already oversubscribed and no longer has any overload available. In this case, a dedicated post doc who has both modeling and experimental experience would be extremely beneficial to help get these projects moving in the short 2-year window we have to deliver on these systems.

8. Looking Forward

This project has been broken down into three distinct phases.

Phase I (July-December 2015) involves the design of the system, acquisition of equipment and testing of system sub-components. This phase is well underway and should be completed by the end of December, once all equipment items are on hand.

Phase II (January-June 2016) will concentrate on final assembly and testing of the diagnostic system, transport of the system to Las Vegas, interface with the laser, installation of the system on DPF, and if scheduling permits, testing of the system on DPF experiments.

Phase III (July 2016-June 2017) will focus on the implementation of the laser diagnostics system on a wide variety of experiments, training of NSTec personnel on the use of the diagnostics and affiliated analysis software, and interpretation of the data to help provide NSTec modelers with high quality plasma data needed to understand and improve machine performance.

Section II: Performance

Table 2. Progress toward Metrics

[No narrative just insert Scorecard here.]

Project Scorecard Narrative

[Add supporting narrative here]

Section III: Budget

[Optional budget narrative related to project expenditures. This does not replace the need to report to the GOED Business Office.]

NTF/NSTec Laser Plasma Diagnostics GOED KF Expenditures July 1st – September 30th, 2015			
	Estimate (Year 1)	**Expenditures** Inception to Date July 1st – Sept 30, 2015	**Expenditures** Current Period July 1st –Sept 30th, 2015
Total Salary & Benefits	$ 62,971	$ 0,000	$ 0,000
Equipment	$ 20,000	$ 0,000	$ 0,000
Travel	$ 9,009	$ 551	$ 551
Other Direct Costs	$ 8,020	$ 2,196	$ 2,196
Graduate Tuition	$ 0,000	$ 0,000	$ 0,000
Total	**$ 100,000**	**$ 2,747**	**$ 2,747**

NTF/NSTec Laser Plasma Diagnostics NSTec Expenditures July 1st – September 30th, 2015			
	Estimate (Year 1)	**Expenditures** Inception to Date July 1st – Sept 30, 2015	**Expenditures** Current Period July 1-Sept 30, 2015
Total Salary & Benefits	$ 15,000	$ 13,888	$ 13,888
Equipment	$ 120,000	$ 116,468	$ 116,468
Travel	$ 5,000	$ 2,580	$ 2,580
Other Direct Costs	$ 10,000	$ 3,426	$ 3,426
Graduate Tuition	$ 0,000	$ 0,000	$ 0,000
F&A	$ 10,000	$ 8,655	$ 8,655
Total	**$ 150,000**	**$ 136,362**	**$ 136,362**

Project Income in each category is as follows:

Grants/Contracts:

This project brought in grant/contract income from NSTec for preliminary system design, etc. In addition, the dedicated laser system that will be used to probe the DPF was ordered.

Gifts: N/A.

Cont Ed/ Outreach: N/A

Other contributions:

NSTec has provided our team with four matched photomultiplier tubes for use with scintillation neutron detectors we have on hand at NTF. In addition, they provided one of our graduate students one week of dedicated access to the DPF to make sure all of neutron detectors (activation detectors, etc.) were calibrated. Typically, use of the DPF facility costs upwards of $50k/week for NNSA projects. I have not added this into the totals below since it did not involve a transfer of funds.

NTF/NSTec Laser Plasma Diagnostics Income

July 1st – September 30th, 2015

	Estimate (Year 1)	Income Inception to Date April 1, 2014 – Month 31, 2015	**Income** Current Period Month 1-Month 31, 2015
Grants / Contracts*	$ 150,000	$ 136,362	$ 136,362
Gifts	$ -	$ -	$ -
Cont. ED/ Outreach	$ -	$ -	$ -
Other Contributions*	$	$	$
Knowledge Fund	$ 100,000	$ 2,747	$ 2,747
Total	**$ 250,000**	**$ 139,109**	**$ 139,109**

Section IV: Weekly/Monthly Logs of [Project] Activities for Reporting Quarter

Section V: Appendices

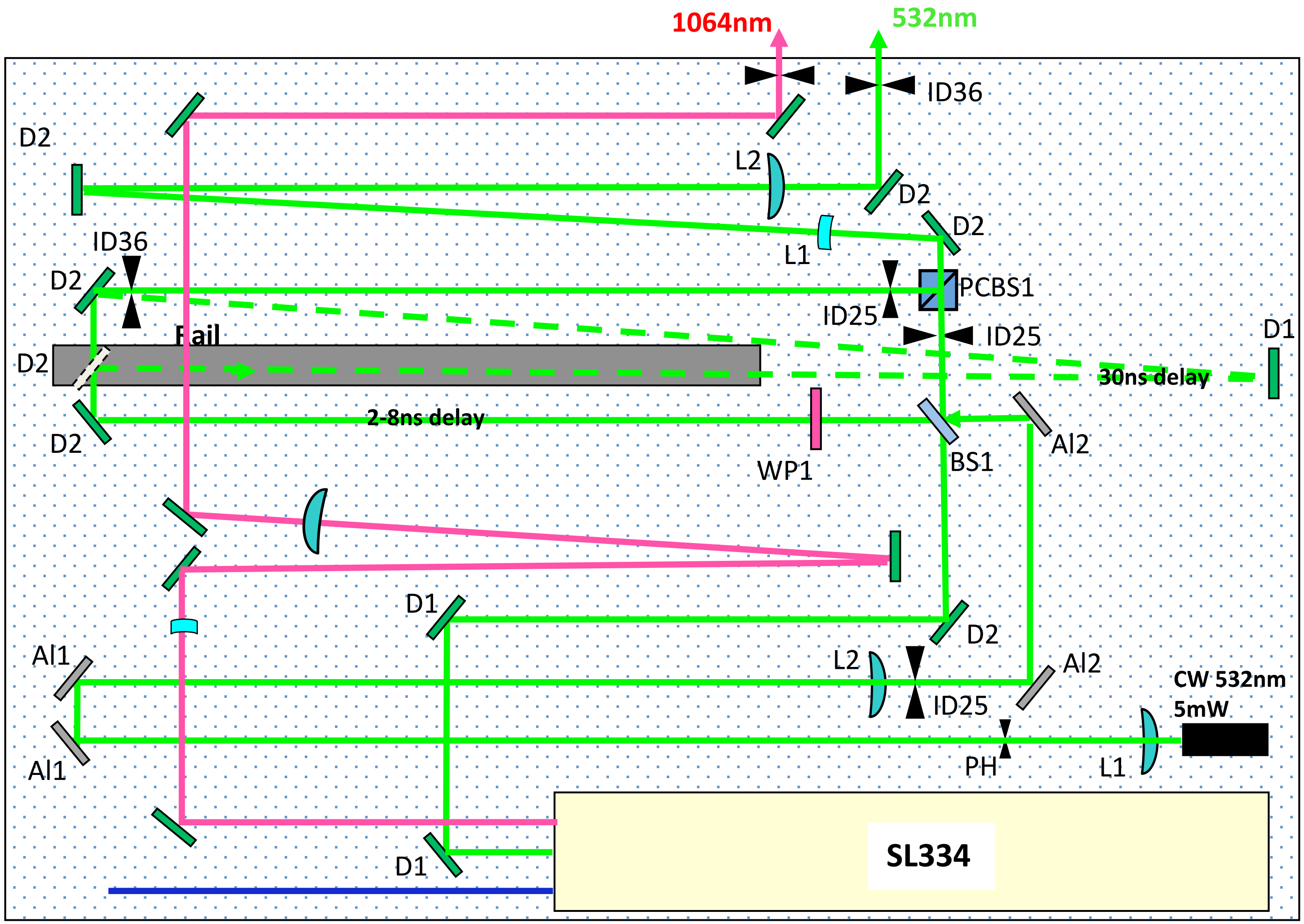
Appendix 1 – Sales Pipeline

[Only include opportunities that are new or have progressed in the sales pipeline. List multiple opportunities with the same company separately. Include the TOTAL previous and current number (#) of opportunities in each stage of the sales pipeline. Company names may be anonymized with unique identifiers only if required by confidentiality agreements. Attach spreadsheet if needed]

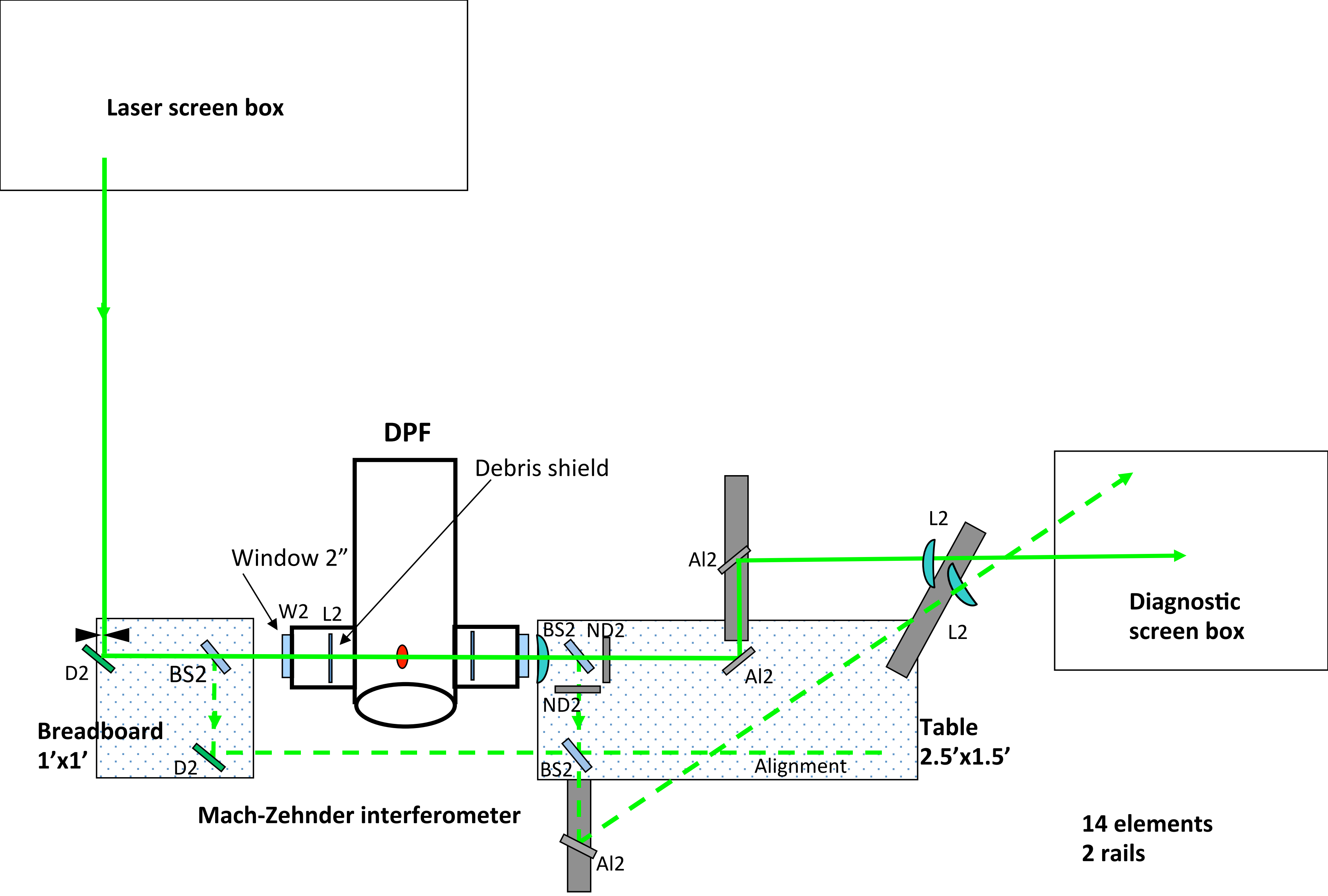
Company Name	Company Type	Opportunity Type	Notes (Progression and Next Step)
Leads - Awareness (346 - 432)			
Bayer	Life Science	Collaboration	Follow-up discussion at a conference
Prospects - Interest (56 - 79)			
MGM Resorts	Hotels and Gaming	Option	Expressed interest in licensing a game - Setup Demo
Qualified - Desire (19 - 26)			
Sams Software	Startup	License	Experienced entrepreneur wants to use IP for a startup - conduct background check
Negotiation - Action (7 - 5)			
Outotec	Water Solution Provider	Membership	Membership proposal submitted, awaiting response - follow-up next week
Won or Lost (2 - 4)			
VA Hospital	Hospital	Product Sales	2 year supply of widgets - make more widgets

Appendix 2 – Scorecard Supporting Documentation

Laser screen box with an optical table ~6' x 4'

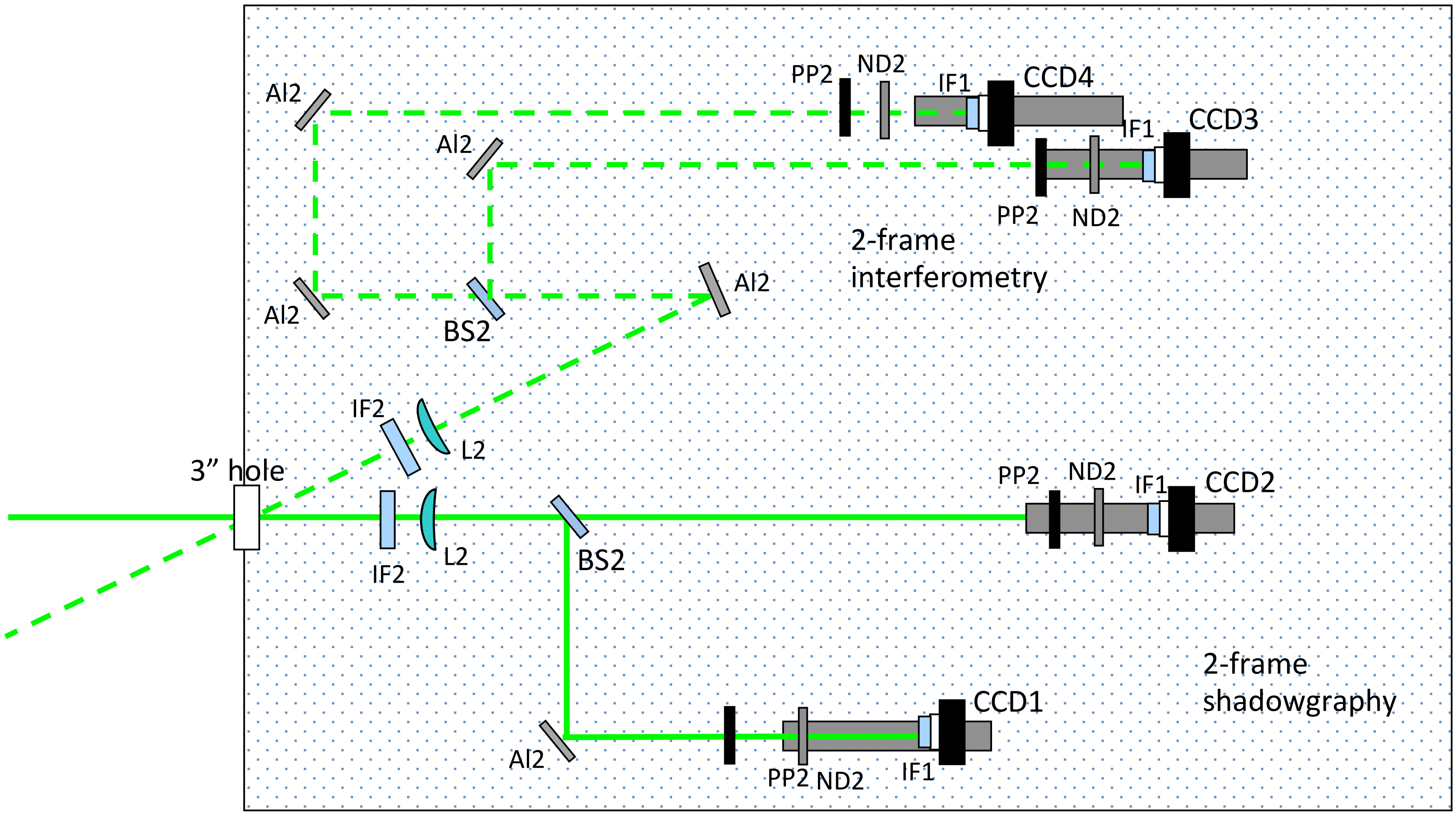


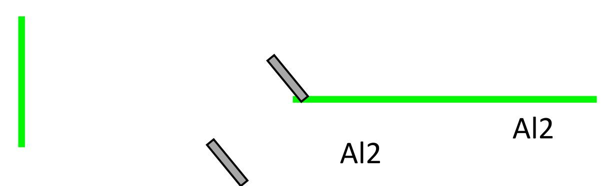
28 elements (no IR)
1 rail



Laser screen box
DPF
Debris shield
Window 2”
W2
L2
BS2
ND2
Al2
L2
L2
Diagnostic screen box
D2
BS2
Breadboard 1’x1’
D2
ND2
Al2
BS2
Alignment
Table 2.5’x1.5’
Mach-Zehnder interferometer
Al2
14 elements
2 rails

Diagnostic screen box with an optical table 6’ x 4’





25 element
4 rails

	Vendor	$		#
CW laser, 532nm, 5mW	aixiz	49		AIX-532-5L
Mirror Al 1"	thorlabs	50	uv	PF10-03-F01
Mirror Al 2"	thorlabs	94.8	uv	PF20-03-F01
Dielectric mirror, 532nm, 1" 45°	optosigma	112	8J	TFM-25.4C05-532
Dielectric mirror, 532nm, 1" 45°	optosigma	216	26J	TFMHP-25.4C05-532
Dielectric mirror, 532nm, 1" 0°	cvi	135	6.8J/10ns	Y2-1025-0
Dielectric mirror, 532nm, 2" 0°	cvi	225		Y2-2037-0
Dielectric mirror, 532nm, 2" 45°	cvi	225		Y2-2037-45
Cube polarizer, 532nm, 1"	thorlabs	500	10J/10ns	PBS25-532-HP
Cube polarizer, 532nm, 1"	thorlabs	232	4J/10ns	PBS25-532
Half-wave plate, 532nm, 1"	cvi	332	1"	QWPM-532-10-2
Interference filter 532nm/3nm, 1"	cvi	123	1" 3nm	F03-532.0-4-1.00
Plate beamsplitter, 532nm, 50% , 2"	cvi	312	10J	BS1-532-50-2025-45UNP
Plastic polarizer, 2"	thorlabs	150		LPVISE200-A
Plastic polarizer, 2x2"	thorlabs	8		LPVISE2X2
Neutral filter, 2"x2", OD=3, 0.1%	optosigma	62		AND-50S-001
Neutral filter, 2"x2", OD=2, 1%	optosigma	62		AND-50S-01
Neutral filter, 2"x2", OD=1, 10%	optosigma	62		AND-50S-10
Neutral filter, 2"x2", 12.5%	optosigma	62		AND-50S-12.5
Neutral filter, 2"x2", 20%	optosigma	62		AND-50S-20
Neutral filter, 2"x2", 30%	optosigma	62		AND-50S-30
Neutral filter, 2"x2", 50%	optosigma	62		AND-50S-50
Neutral filter, 2"x2", 70%	optosigma	62		AND-50S-70
BK7 lens 1", F=10cm	optosigma	26		SLB-25-100P
BK7 lens 1", F=-50cm	thorlabs	19.4		LA1908
BK7 lens 2", F=30cm 2-convex	optosigma	47		SLB-50.8B-300P
BK7 lens 2", F=40cm	thorlabs	29.9		LA1725
BK7 lens 2", F=50cm	thorlabs	29.9		LA1380
BK7 lens 2", F=60cm	optosigma	43		SLB-50.8-600P
BK7 lens 2", F=70cm	optosigma	43		SLB-50.8-700P
BK7 lens 2", F=80cm	optosigma	43		SLB-50.8-800P
BK7 lens 2", F=100cm	thorlabs	42		LA1779
Window 2", 12mm BK7	optosigma	120		WG12012

Sh	+ Interf	Total	
2	1	3	147
2	0	2	100
7	7	14	1327.2
2	0	2	224
		2	432
1	0	1	135
1	0	1	225
8	1	9	2025
		1	500
1	0	1	232
1	0	1	332
2	2	4	492
2	4	6	1872
2	2	4	600
2	0	2	16
1	0	1	62
2	1	3	186
3	2	5	310
2	1	3	186
2	2	4	248
2	1	3	186
2	2	4	248
2	2	4	248
1	0	1	26
1	0	1	19.4
2	0	2	94
2	2	4	119.6
2	2	4	119.6
2	2	4	172
2	2	4	172
2	2	4	172
		1	42
2	0	2	240
			11509.8

201 South Wallace, Suite B-2C | Bozeman, Montana 59715
tel 866.658.5404 | fax 866.658.7357 | www.altosphotonics.com

Quote #:Q150408-SG1c **Quoted by Stan Guthrie** **August 3, 2015**

Aaron Luttman
National Security Technologies
2621 Losee Road
North Las Vegas, NV 89030

702-295-0303
luttmaab@nv.doe.gov

	PRICE (USD)
SL334-5 SBS Compressed Q-Switched Laser ○ 500 mJ/pulse at 1064 nm ○ 170 +/-20 ps pulse duration ○ First, second, and fourth harmonics (1064 nm, 532 nm, 266 nm) ○ 2-stage amplifier ○ 5 Hz repetition rate ○ SLM Q-switched oscillator gives robust operation Control by keypad or PC; LabView drivers are included • Note: Cooling water is required, 8 liters/min, <20 C	$ 96,730
Electronics Customization • External pockels cell triggering • Decresed delay (external trigger to optical pulse) Note: delay below 1.5 ms eliminates ability to pre-fire flashlamps, i.e., the laser will run at full power with limited reduction ability	included
Shipping & Handling	$ 1,400
Installation & Training	$ 4,450

Please see www.EKSPLA.com for detailed specifications

TERMS AND CONDITIONS

- **Price:** US Dollars; DDP Destination
- **Payment:** 30 days net
- **Delivery:** 3-4 months ARO
- **Quotation valid:** 60 days
- **Warranty:** 1 year general warranty

201 South Wallace, Suite B-2C | Bozeman, Montana 59715
tel 866.658.5404 | fax 866.658.7357 | www.altosphotonics.com

CLASS IV LASER SYSTEM:

User is responsible for compliance with all local codes and regulations.

Product Warranty: Seller warrants to Buyer that the Products shall be substantially free from defects in materials and workmanship under normal use and service for one year from the date of shipment from the factory (except for optical components which are warranted for 90 days from the date of shipment.)

Buyer's exclusive remedy and Seller's sole liability for any breach of the foregoing warranty shall be for Seller, at Buyer's request within the warranty period by written notice specifying the defect, and at Seller's sole option, to repair or replace the defective Product or refund any amounts paid for the defective Product.

For on-site warranty service, labor and daily expenses are paid by Altos. Within the first 90 days, airfare is paid by Altos when scheduled with reasonable advance notice. If immediate service is needed, or after 90 days, buyer agrees to pay for airfare.

These remedies are available only if Seller's examination discloses to Seller's satisfaction that such defects actually exist and were not caused by Buyer's misuse, abuse, unauthorized modifications or disassembly, neglect, attempts to repair, or by accident, fire, third party materials or other hazard. Repair or replacement of a part does not extend the warranty period beyond the initial warranty period, which commences with the date of shipment.

Seller makes no representation or warranty that the Products supplied hereunder comply with any local laws or ordinances, and Buyer has the responsibility for compliance with local laws and ordinances, including obtaining all permits, licenses, authorizations or certificates required by any regulatory body for installation or use of the Products.

Service Warranty: Services shall be performed consistent with generally prevailing professional and industry standards. Buyer's exclusive remedy and Seller's sole liability for any breach of the foregoing warranty shall be the re-performance of the applicable Services, failing which Seller shall refund the portion of fees paid which relate to the specific non-conforming Services.

No Other Warranties: To the maximum extent permitted by applicable law, the Seller and its suppliers disclaim all other warranties, either expressed or implied, including but not limited to implied warranties of merchantability and fitness for a particular purpose, with regard to the software and any related or accompanying written materials. No liability for damages, to the maximum extent permitted.

Laser Safety: Laser safety training is not provided by Altos Photonics. It is imperative that the customer obtain laser safety training from a qualified Laser Safety Officer, and ensure that lasers are operated in a safe manner and in compliance with applicable regulations. We offer training on use and maintenance of the systems we sell. However, this training does not substitute for laser safety training.

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EKSPLA

PRODUCT TECHNICAL DESCRIPTION

E/O Q-SWITCHED SBS-COMPRESSED Nd:YAG LASER MODEL SL334-5

Highlights

- **Flashlamp pumped Single Longitudinal Mode (SLM) master oscillator with negative feedback control.**
- **Highly efficient backward SBS pulse compression.**
- **Thermally induced birefringence compensation for high pulse repetition rates.**
- **High efficiency pump chambers for maximum pulse energy.**
- **Microprocessor control allows convenient diagnostics and monitoring of the system.**

Specifications [1)]

Max pulse energy:	500 mJ @ 1064 nm;
Pulse duration:	170 +/-20 ps;
Other pulse durations from 150 ps to 1500 ps available on-request.	
Pulse duration stability:	10 % @ 1064 nm (St.Dev).
Pulse energy stability:	4 % @ 1064 nm (StDev);
Repetition rate:	**5 Hz.**
Typical beam diameter:	12 mm. [2)]
Line width:	< 1 cm^{-1} @ 1064 nm.
Polarization ratio:	< 1:100 @ 1064 nm.
Contrast ratio:	10^5:1.
Beam divergence:	< 0.5 mrad. [3)]
Optical pulse jitter in respect to external triggering pulse:	< 0.5 ns (StDev) specified; <250 ps typical

Service requirements

Electrical power:	208 VAC, Three- phase, 50/60 Hz.
Power consumption:	≤ 4 kVA.
Water supply:	< 8 l/min, max temperature 20°C.
Operating ambient temperature:	15 – 30 ^{0}C.
Relative humidity:	20 – 80 % (non-condensing).

1. All specifications are subject to change without notice. The parameters marked typical are not specifications. They are indications of typical performance and will vary with each unit we manufacture. Unless stated otherwise all specifications are measured at 1.064 µm.
2. Beam diameter is measured @ 1.064 µm at laser output at the $1/e^2$ point.
3. Full angle measured at the $1/e^2$ point@ 1.064 µm

Features

a) Laser head

- Precisely machined monolithic aged aluminium alloy optical bench.
- Single Longitudinal Mode (SLM) master oscillator with negative feedback control.
- E/O Q-switching.
- One preamplifier and power amplifier configuration.
- Highly efficient backward SBS pulse compression.
- Thermo stabilised Pockel's cell.
- Size (W × H × L): 446 × 270 × 1020 mm.
- Output beam height: 175-185 mm.

b) Power supply cabinet

- Two power supply units for oscillator, pre- and power amplifiers.
- Simmer power supply reducing EMI noise and improving flash lamp lifetime.
- Microcontroller board enabling:
  - timing control for oscillator and amplifier flash lamps flashes;
  - laser operation control in internal, external and single shot mode;
  - safety interlock status monitoring.
- RS232 socket for PC control via supplied LabVIEW drivers.
- Close loop primary water-cooling system for laser chamber cooling.
- Water-to-water heat exchanger.
- Size (W × H × L): 550 × 860 × 590 mm.

c) Remote Control Pad

- 2.5 meter long connection cable.
- Backlit graphical display visible in the dark.
- Functions:
  - Amplification level control;
  - Laser operation control (starting and stopping);
  - Internal or external triggering mode setting;
  - Pulse burst mode setting (in range from 1 to 99 pulses in the burst);
  - Frequency divider mode setting (reduces pulse rep. rate by 2 to 10 times);
  - Single shot mode;