Product Requirements Document: DUV SP1

"Prototype Spectrophotometers in one Semester"

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Document Number 001

Revision Level	Date
F	12/9/2015

OPT 310 – Senior Design
University of Rochester
The Institute of Optics

REVISION TABLE			
Rev.	**Description**	**Date**	**Authorization**
A	Initial Release	25-Oct-15	ZJE
B	Updated specifications per Document 002	8-Nov-15	ZJE
C	Updated specifications per Document 003	9-Nov-15	ZJE
D	Updated specifications per Document 004 as well as additional research and calculations performed by the team.	28-Nov-15	WJM
E		6-Dec-15	WJM
F	Added block diagram and energetiq eq-x99 specs.	9-Dec-15	ZJE

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Vision:

- Create a device that can accurately measure broadband spectral reflectivity of an optic for the purpose of evaluating coating deposition uniformity

Problem:

- Coating deposition is non-uniform by nature on surfaces with a radius of curvature
- In coating manufacture, deposition uniformity can be corrected, but it is dependent on being able to accurately measure spectral reflectivity
- There are limited options for measuring spectral reflectivity
    - Tabletop Spectrophotometers: only measures test samples
        - Small flat test optics only
    - Fiber Spectrophotometer: contact measurement only
        - Results depend highly upon user accuracy
        - No reference beam: can't compensate for source irregularity
- Lithography systems demand high coating performance
    - Many lens surfaces in system require low reflectivity to maintain throughput
    - High radii of curvature and large element diameters
    - Great need for non-contact method in order to maintain cleanliness

Environment:

- Class 10,000 clean room
    - Specifically the Optimax Coating Department
- Temperature Range
    - 15-25^{o}C (Relatively stable due to controlled environment)
- Humidity:
    - Non-condensing

Major Requirements:

- Non-contact: preferred in order to be useful for all applications
- Between Optical and Mechanical design, the rays need to hit the surface of the optic at ±8°
- Polarization is not a concern and does not need to be accounted for
- Measurement of reflectance of normally incident light
- Wavelength Range: 200-500nm
- Clear Aperture: up to 300mm
- Scan Time: < 5mins
- Spectral Resolution: .5 – 1 nm
- Spectral Photometric Accuracy: 1% accuracy of 0-4% reflectance
- Sample Points across scan: > 5 points across clear aperture
- Warm up time: < 1 hour
- Budget: Addressed by the deliverables (cost to benefits report)

Deliverables:

- System design: include parts list and cost estimates
- Report: include anticipated performance with relation to defined specifications
- Report: include cost-performance trade-offs

- First prototype build: Not required by customer, but may be necessary for the purpose of the cost-performance trade-off report

Photon Budget:

- TBD pending components chosen. Please see Appendix for further description on the photon budget calculations.

Timeline:

Fall 2015	
Task	**Due Date**
Complete final PRD.	12/11/15
Complete 1st order design	12/11/15
Develop and submit a BOM for the customer	12/11/15
Have final meeting with customer and establish purchase dates	12/11/15
Spring 2016	
Task	**Tentative Due Date**
Assemble parts list and develop final test procedures	1/20/15
Finish any final designs	1/20/15
Build 1st test bench prototype	3/01/15
Assess performance and make any possible revisions	4/01/15

Regulatory Concerns:

- UV radiation poses a major safety risk to exposed individuals. The possibility of skin and major eye damage creates a need for adequate safety protocols when working with UV sources.
- OSHA does not lay out specific standards for limiting the UV exposure of employees, and system operators, stating on the “non-ionizing” radiation online article only:
    - “Ultraviolet radiation (UV) has a high photon energy range and is particularly hazardous because there are usually no immediate symptoms of excessive exposure. Sources of UV radiation include the sun, black lights, welding arcs, and UV lasers.”
- Universities have in place differing levels of UV protective procedures
    - The University of Rochester’s current policy on UV radiation, laid out in the URMC “Ultraviolet Light Safety Guidelines” is to simply limit all forms of unnecessary UV radiation. The university does not lay out specific instructions based on the severity of UV radiation, or how individuals should handle UV sources.

    - Columbia University states in their “Working safely with Ultraviolet Radiation” form, that their method for ensuring the safe use of UV radiation is through a combination of administrative, and engineering approaches. They require lock out procedures to be taken when maintenance is being conducted on UV sources, and that all UV sources have protective enclosures to limit undesired exposure.

- Irrespective of how institutions determine their safety standards, it should be ensured that any applicable system designed in this project would be determined as safe under even the strictest guidelines. Protocols should be designed such that the system can be locked out when maintenance is in progress, and the design should ensure that during daily use negligible levels of radiation are allowed to escape the unit. For example: a sub system of the spectrophotometer should be in place which guarantees that replacing the unit under test (UUT) does not cause a drastic increase in UV exposure.
    - It is desired that proper use of the system does not entail the use of UV protective glasses or special UV protective clothing.
- Ozone is produced by sub 250nm light, and can be a safety hazard. OSHA outlines that the largest acceptable exposure of ozone in an 8-hour day is 1 part per million (0.0001%).
    - Methods exist to limit the ozone produced in these systems such as nitrogen purging the system, and ventilation systems to take the ozone from the lab.
    - It should be noted that ozone absorbs DUV light, and is thus detrimental to the use of the system, eliminating it is a safety requirement, as well as an operational requirement.

Required Standards Documents:

Document	Relevance to Project
ASTME958-13	Outlines procedures for determining the spectral bandwidth of a spectrophotometer which uses either a polychromator or monochromator style spectrometer.
ASTME1866-97(2013)	Outlines the procedures to develop spectrophotometer performance tests. It does not outline the current standard procedures, however outlines methods to properly develop custom standards if standards do not exist (such as when working in the DUV).

What We Are Not Responsible For:

- Mechanical requirements of the system will be managed and designed by the mechanical engineering (ME) senior design team assigned to the project.
- The optical engineering (OE) senior design team will not be responsible for keeping the optic normal to the optical axis of the spectrophotometer.
    - If an off-axis design were to be developed, the OE team would not be responsible for maintaining a specified optical axis angle of incidence with respect to the surface of the UUT.
- The OE team will not be responsible for aligning the system to multiple points of measurement along the UUT.
    - The ME team will be responsible for moving the UUT in order to measure multiple points from the center to the edge of the clear aperture of the UUT.

System Block Diagram

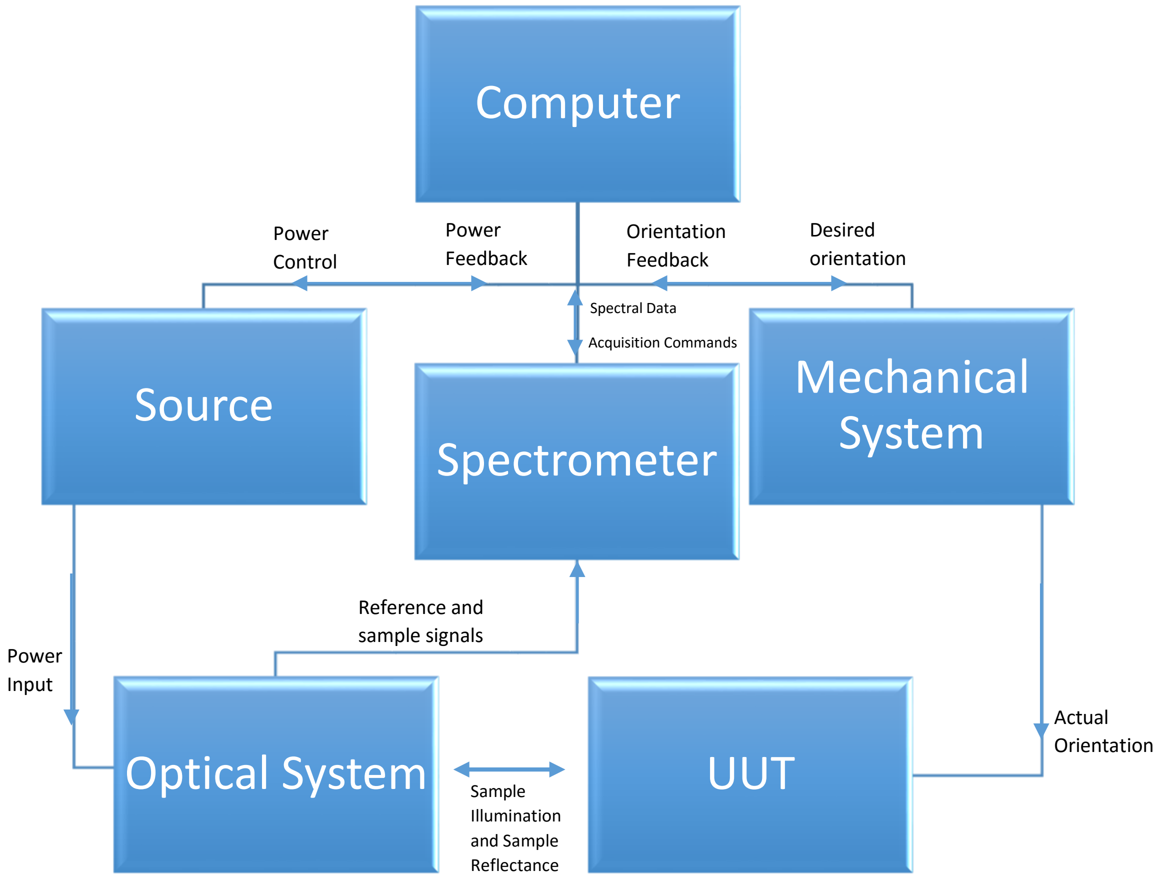
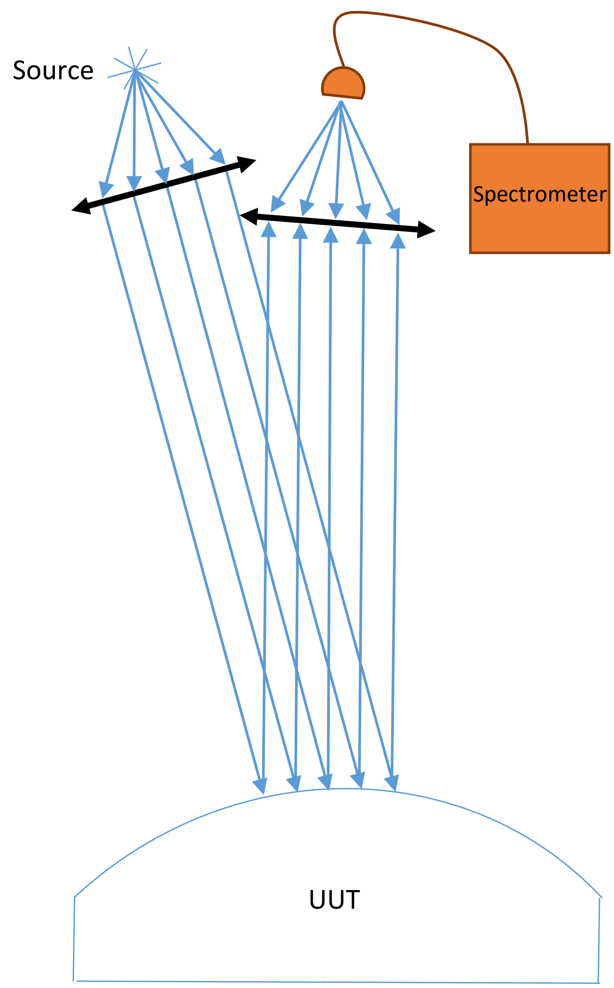


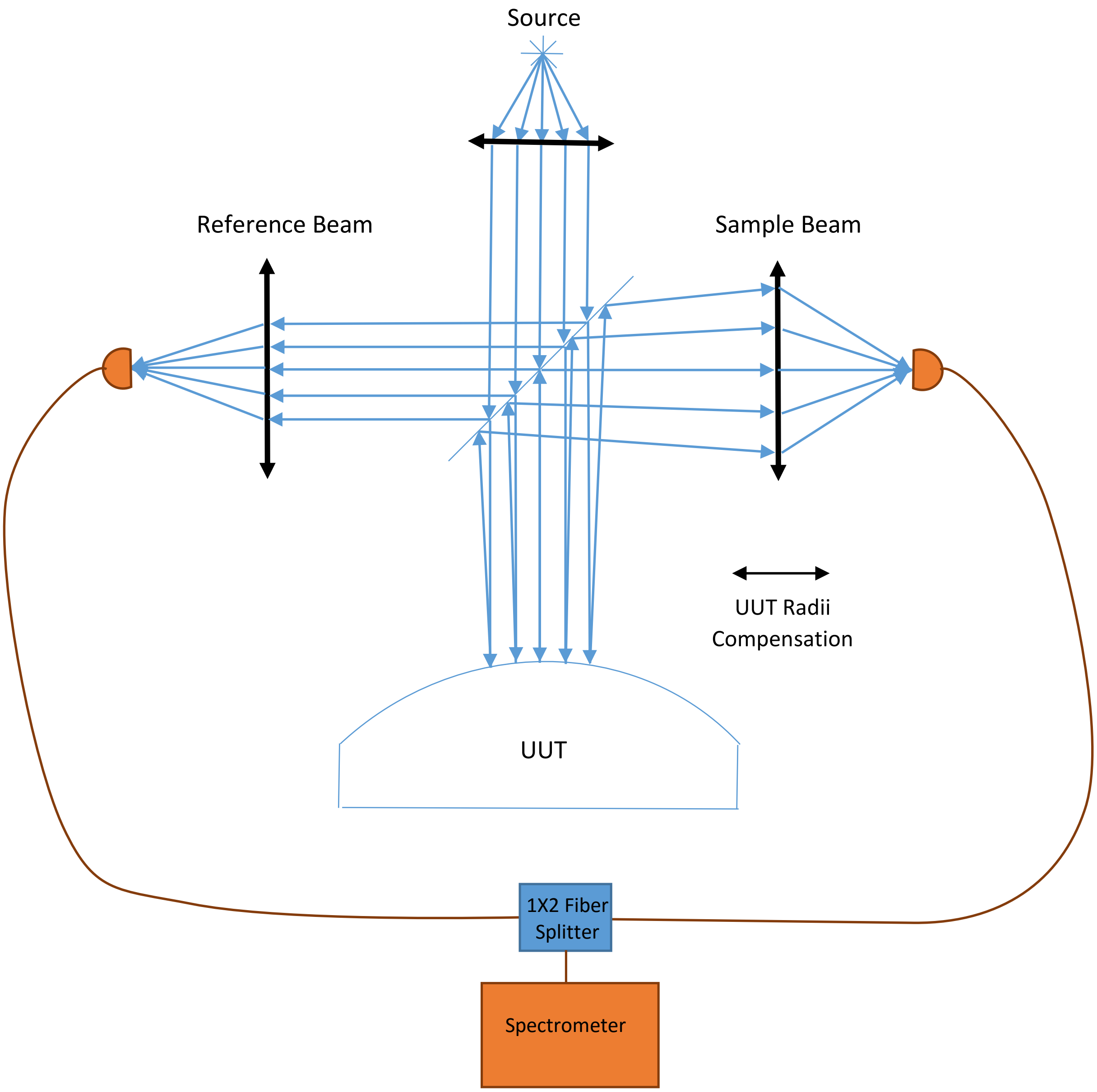
Figure 1: Block diagram of system. The arrows designate how the components and subsystems interact with each other. For example, the computer sends a signal to the mechanical system which contains the desired UUT orientation, and the mechanical system returns a feedback signal which measures the actual UUT orientation. The "optical system" is one of the systems which are laid out in Appendix A.

Appendix A: First Order Designs

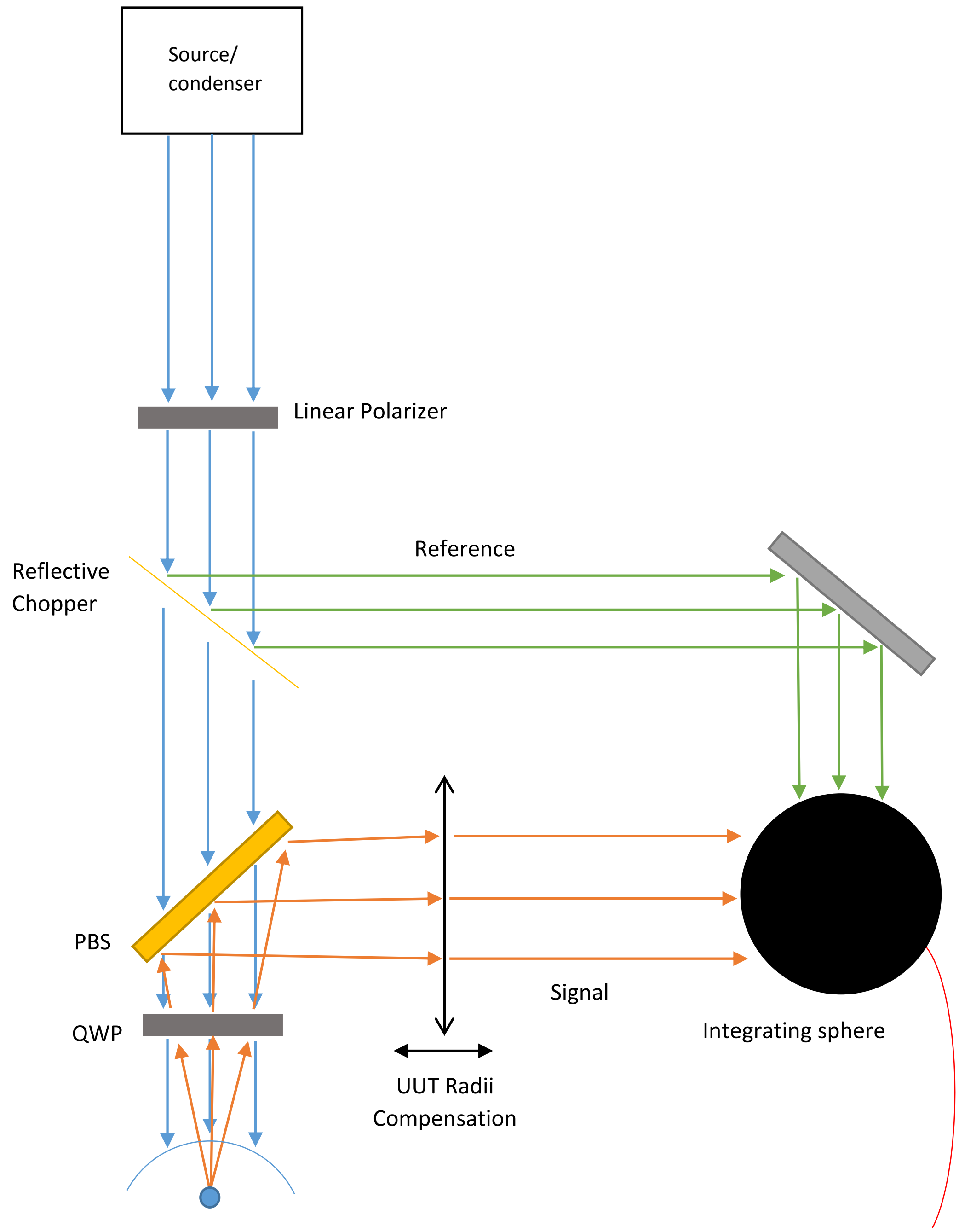
First Order Designs:



Pros	Cons
-Cost Effective	-Highly dependent on UUT radius
-Fewer Variables	-Low throughput,
-Fast measurement	-Off-axis design increases uncertainty
	-No reference beam
	-increased angle of incidence

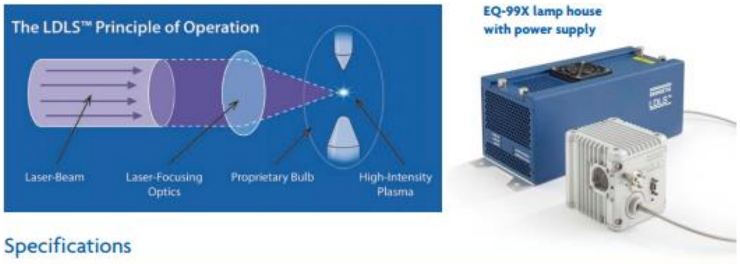


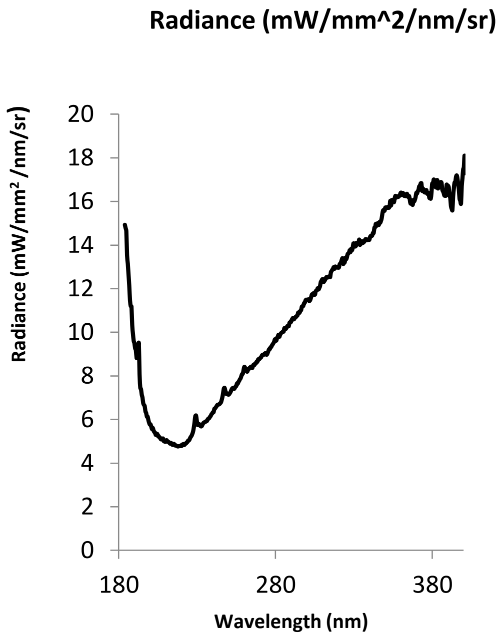
Pros	Cons
-Reference Beam	-More elements to induce error and higher cost
-On Axis Design	-Slightly less cost effective
-Fast measurement	-Throughput limited by fiber NA
-Compensation for UUT radii	
-Greater Throughput	



Pros	Cons
-Reference Beam -Compensation for UUT Radii -Integrating sphere minimizes errors -On Axis Measurement -Fast measurement	-Greater Complexity -Throughput limited by fiber NA -Use of a Broadband QWP and DUV PBS is not ideal

Appendix B: Energetiq EQ-X99 Product Specifications





Specifications

Overview	• Spectral output from 170nm to 2100nm • Large collectable view angle – Numerical Aperture (NA): up to 0.47 • Typical bulb life > 9,000 hrs. • Flexible optical interface for free-space optics (SM1 thread) • Various precision reflective coupling optics are available from Energetiq - call for details	
Physical Specifications	**System Dimensions (H x W x D)**	**Weight**
• Lamp House	82.3 x 85.7 x 76.2 mm (3.2 x 3.4 x 3.0 in)	0.7 kg (1.5 lbs)
• Power Supply	107 x 111 x 254 mm (4.2 x 4.4 x 10 in) (excl feet)	1.4kg (3 lbs)
Utility Requirements		
• Electrical	100-240v, 50/60Hz, 2.5A	
• Cooling	Ambient air, no auxiliary cooling necessary	
• Nitrogen	Recommended purging for longest life & for DUV operation, Grade 6	
• Compliance	CE Mark, Class 1 Laser Product	

Patent Numbers: US 7,435,982; US 7,786,455; GB 2,450,045; Other patents applied for.

Options for free space output with off axis parabolic collimating:

	2" EFL OAP	4" EFL OAP	6" EFL OAP	8" EFL OAP
Effective Focal Length (EFL)	2.0" (50.8mm)	4.0" (101.6mm)	6.0" (152.4mm)	8.0" (203.2mm)
Diameter	1.5"	1.5"	1.5"	1.5"
Magnification *	1x	2x	3x	4x
Numerical Aperture	0.375	0.188	0.125	0.094
f/#	1.33	2.67	4.00	5.33

• Magnification is based on an OAP pair with 2" EFL OAP as the collecting mirror and the second OAP (listed above) as the focusing mirror.

Pertinent Characteristics:

Warm-up time: 30minutes recommended

Lamp Housing Purging: Use grade 6 or better dry nitrogen gas

Output NA: 0.47

Bulb Lifetime: >9,000 hours

Power Reduction per 1000 hours: 1-2%

Plasma position stability: ± <0.5um

Computer Controlled Power supply available