AN033

Adaptive Optics Course Outline

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Introduction

We have sold adaptive optics (AO) kits to many universities. Our AO hardware and software is perfect for students learning about AO because it is easy to get something simple working immediately and is also flexible enough for students to write any part of the AO control system themselves using our provided Matlab class interface. In this application note we provide an example outline for teaching a graduate course in adaptive optics either using AOS hardware or a modeling-only based approach.

Outline for a Course in

Adaptive Optics with a Laboratory

Requirements: Electromagnetics Physics, Calculus, Introductory Computer Programming
Recommended Prerequisite Course(s): Fourier Optics, Introductory Optics
Recommended Reference Texts: J. Goodman's Fourier Optics, A. E. Siegman's Lasers, J. Schmitt's Optical Modeling, Application Notes at www.aos-llc.com
Recommended Textbook: R. Tyson's Introduction to Adaptive Optics

Week	Lecture	Laboratory
1	Introduction to Adaptive Optics Applications of Adaptive Optics	Introduction to Matlab
2	Review of Maxwell's Equations Derivation of the Wave Equation	Introduction to Matlab Script & Function Programming
3	Review/Introduction to Fourier Optics	Write a script to perform 1D Fourier Transforms in Matlab
4	Fresnel & Fraunhofer Diffraction Gaussian Beam Propagation ABCD Propagation	Setup a large collimated beam using a shear plate. Measure Gaussian Beam Propagation in the laboratory with a beam profiler or a camera. *Alternative Laboratory:* Write a Matlab script to model the propagation of a Gaussian beam through a

		series of lenses using ABCD matrix theory.
5	Numerical Methods for Modeling Optical Propagation Fourier Mesh Requirements	Write a function to propagate an arbitrary 2D optical field.
6	Siedel Polynomials & Zernike Polynomials Effect of Aberrations on a top-hat beam propagating to focus.	Tilt a lens and measure the induced aberration on the focus of a beam. Place a beam splitter in the converging beam. Tilt the beam and show the induced aberration. Model the propagation of a beam with an aberration in Matlab. Compare the lab results with your model *Alternative Lab:* Write a function for the real Zernike polynomials. Show the effect of each of the first 15 polynomials on the far-field of a circular top-hat beam.
7	Wavefront Sensors – Interferometers, Hartmann Sensors, and Curvature Sensors	Setup a collimated beam into a Hartmann wavefront sensor. Calibrate the wavefront sensor on the beam. Measure a lens placed into the beam. Observe the effect of moving the lens away from the wavefront sensor. Observe the effect of tilting the lens. Setup a simple 2-lens telescope and observe the effect of moving the lenses. *Alternative/Additional Lab:* Build an interferometer using a HeNe laser, a beam splitter or sampler, and 2 mirrors (one of which could be deformable). *Alternative Lab:* Model the effect of a Zernike aberration on a variety of wavefront sensors (interferometer, Hartmann sensor, curvature sensor)
8	Deformable Mirrors – Plate-type, Membrane, Bimorph, & MEMS Comparison of the influence functions Comparison of the advantages and disadvantages for common AO applications.	Reflect a collimated beam from the membrane deformable mirror. Observe the effect of electrically adjusting the actuators on the beam propagated a distance from the DM. Observe the effect of the actuators near the focus of a beam. *Alternative Lab:* Perform the experiment above numerically

		using a simulated DM. *Alternative Lab 2:* Choose an application of adaptive optics (ophthalmology, directed energy, imaging, astronomy) and make an argument for which DM would be best for this application now and in the future.
9	Kolmogorov Turbulence Statistics of Kolmogorov Turbulence Phase Structure Functions Create a Matlab function to generate Kolmogorov turbulence using the propbability density function. Greenwood frequency Statistics of compensation of Kolmogorov turbulence using a DM	Measure turbulence in the lab by propagating a collimated beam over a large a distance as is practical and observe the effect of the air motion. Place an arm under the beam and observe the air motion due to the heat coming off of the arm. Place a warm/hot object (coffee cup with warm water, hair dryer, hotplate, etc.) underneath the beam and measure the induced aberration again. Use Matlab to analyze the data and calculate the phase structure function for each case *Alternative Lab:* Use Matlab to model generation and compensation of Kolmogorov turbulence with a DM with Gaussian influence functions.
10	Metric Adaptive Optics Common Metrics: Sharpness, Second Moment, RMS Slopes, Beam Shape, etc. Common Techniques: Stochastic Parallel Gradient Descent (SPGD), Guided Evolutionary Simulated Annealing (GESA), Axial Searching, Stochastic Axial Searching	Use camera or photodiode feedback to close a metric AO loop to minimize spot size (second moment). *Alternative Laboratory:* Take a provided aberrated optical field and use metric AO techniques to compensate the beam with either a set of Zernike polynomials or with DM influence functions.
11	Matrix-Based AO Simple tilt control SVD Inverse with Mode Removal Slope Discrepancy	Add a wavefront sensor to the experiment from the prior week. Perform active flattening of a membrane DM. Compare the results with the metric AO result. *Alternative Laboratory:* Take the same field from the prior week and compensate it using a modeled wavefront sensor feedback.
12	Advanced Concepts / State of the Art	Advanced Concepts / State of the Art
13	Review for the Final Exam or More Advanced Concepts	Final Exam or Research Paper or Final Oral Presentation (15 minutes each)