# Adaptive Optics for Vision Science: Principles, Practices, Design and Applications

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# Introduction

## 1. Introduction (David Williams)

University of Rochester

### *1.1 Goals of the AO Manual (This could also be a separate preface written by the editors)*

*** practical guide for investigators who wish to build an AO system**

*** summary of vision science results obtained to date with AO**

### *1.2 Brief History of Imaging*

#### 1.2.1 The evolution of astronomical AO

The first microscopes and telescopes, Horace Babcock , military applications during Star Wars, ending with examples of the best AO images obtained to date. Requirements for astronomical AO

#### 1.2.2 The evolution of vision science AO

Vision correction before adaptive optics:
first spectacles, first correction of astigmatism, first contact lenses, Scheiner and the first wavefront sensor.
Retinal imaging before adaptive optics:
the invention of the ophthalmoscope, SLO, OCT
First AO systems: Dreher et al.; Liang, Williams, and Miller.
Comparison of Vision AO and Astronomical AO: light budget, temporal resolution
Vision correction with AO:
customized contact lenses, IOLs, and refractive surgery, LLNL AO Phoropter
Retinal Imaging with Adaptive Optics
Highlighted results from Rochester, Houston, Indiana, UCD etc.

### *1.3 Future Potential of AO in Vision Science*

#### 1.3.1 Post-processing and AO

#### 1.3.2 AO and other imaging technologies (e.g. OCT)

#### 1.3.3 Vision Correction

#### 1.3.4 Retinal Imaging

#### 1.3.5 Retinal Surgery

# II. Wavefront Measurement and Correction

## 2. Aberration Structure of the Human Eye (Pablo Artal)

(Murcia Optics Lab; LOUM)

### 2.1 Aberration structure of the human eye

#### 2.1.1 Monochromatic aberrations in normal eyes

#### 2.1.2 Chromatic aberrations

#### 2.1.3 Location of aberrations

#### 2.1.4 Dynamics (temporal properties) of aberrations

#### 2.1.5 Statistics of aberrations in normal populations (A Fried parameter?)

#### 2.1.6 Off-axis aberrations

#### 2.1.7 Effects of polarization and scattering

# 3. Wavefront Sensing and Diagnostic Uses (Geunyoung Yoon)

University of Rochester

## *3.1 Introduction*

### 3.1.1 Why is wavefront sensing technique important for vision science?

### 3.1.2 Importance of measuring higher order aberrations of the eye

**Characterization of optical quality of the eye**
**Prediction of retinal image quality formed by the eye's optics**
**Brief summary of potential applications of wavefront sensing technique**

### 3.1.3 Chapter overview

## *3.2 Wavefront sensors for the eye*

### 3.2.1 History of ophthalmic wavefront sensing techniques

### 3.2.2 Different types of wavefront sensors and principle of each wavefront sensor

**Subjective vs objective method (SRR vs S-H, LRT and Tcherning)**
**Measuring light going into vs coming out of the eye (SRR, LRT and Tcherning vs S-H)**

## *3.3 Optimizing Shack-Hartmann wavefront sensor*

### 3.3.1 Design parameters

**Wavelength, light source, laser beacon generation, pupil camera, laser safety…**

### 3.3.2 OSA standard (coordinates system, sign convention, order of Zernike polynomials)

### 3.3.3 Number of sampling points (lenslets) vs wavefront reconstruction performance

### 3.3.4 Tradeoff between dynamic range and measurement sensitivity

**Focal length of a lenslet array and lenslet spacing**

### 3.3.5 Precompensation

**Trial lenses, trombone system, bite bar (Badal optometer)**

### 3.3.6 Increasing dynamic range without losing measurement sensitivity

**Translational plate with subapertures**
**Computer algorithms (variable centroiding box position)**

### 3.3.7 Requirement of dynamic range of S-H wavefront sensor based on a large population of the eye's aberrations

### *3.4 Calibration of the wavefront sensor*

**3.4.1 reconstruction algorithm - use of simulated spot array pattern**

**3.4.2 measurement performance - use of phase plate or deformable mirror**

### *3.5 Applications of wavefront sensing technique to vision science*

**3.5.1 Laser refractive surgery (conventional and customized ablation)**

**3.5.2 Vision correction using customized optics (contact lenses and intraocular lenses)**

**3.5.3 Autorefraction (image metric to predict subjective vision perception)**

**3.5.4 Objective vision monitoring**

**3.5.5 Adaptive optics (vision testing, high resolution retinal imaging)**

### *3.6 Summary*

# 4. Wavefront Corrector Requirements (Nathan Doble and Don Miller)

University of Rochester / Indiana University

## *4.1 Introduction*

### 4.1.1 Describe the DMs used in current systems.

4.1.1.2 Xinetics type – Williams, Miller, Roorda – (PZT and PMN)
4.1.1.3 Membrane – Artal, Zhu(Bartsch)
4.1.1.4 MEMS – LLNL Phoropter, Doble
4.1.1.5 LC-SLM – Davis System.

## *4.2 Statistics of the two populations*

### 4.2.1 State of refraction:

4.2.1.1 All aberrations present
4.2.1.2 Zeroed Defocus
4.2.1.3 Same as for 4.2.1.2 but with astigmatism zeroed in addition

### 4.2.2 For various pupil sizes (7.5 - 2 mm) calculate:

4.2.2.1 PV Error
4.2.2.2 MTF
4.2.2.3 Power Spectra

### 4.2.3 Required DM stroke given by 95% of the PV error for the various refraction cases and pupil sizes.

### 4.2.4 Plot of the variance with mode order and / or Zernike mode.

## *4.3 Simulation of various Mirror Types*

Determine parameters for all mirrors to achieve 80% Strehl.

### 4.3.1 Continuous Faceplate DMs

4.3.1.1 Describe mode of operation.
4.3.1.2 Modeled as a simple Gaussian
4.3.1.3 Simulations for 7.5mm pupil
4.3.1.4 Parameters to vary:
Number of actuators.
Coupling coefficient.
Wavelength.
4.3.1.5 All the above with unlimited stroke.

### 4.3.2 Piston Only DMs

4.3.2.1 Describe mode of operation.
4.3.2.2 Simulations for 7.5mm pupil with either cases
4.3.2.3 No phase wrapping i.e. unlimited stroke.
Number of actuators.

Packing geometry
Wavelength.
Need to repeat the above but with gaps.

4.3.2.4 Effect of phase wrapping
Two cases:
Phase wrapping occurs at the segment locations.
Arbitrary phase wrap.

### 4.3.3 Segmented Piston / tip / tilt DMs

4.3.3.1 Describe mode of operation.

4.3.3.2 Three influence functions per segment, do the SVD fit on a segment by segment basis.

4.3.3.3 Simulations for 7.5mm pupil.

4.3.3.4 No phase wrapping unlimited stroke and tip/tilt.
Number of actuators - square
Same as above except with hexagonal packing.
Wavelength.
Gaps for both square and hexagonal packing.

4.3.3.5 Effect of phase wrapping
Phase wrapping occurs at the segment locations.
Arbitary phase wrap. Wrap the wavefront and then determine the required number of segments. Everything else as listed in part 1).

### 4.3.4 Membrane DMs

4.3.4.1 Describe mode of operation. Bimorphs as well.

4.3.4.2 Simulations for 7.5mm pupil with either cases.

4.3.4.3 Parameters to vary:
Number of actuators.
Actuator size.
Membrane stress
Wavelength.

# 5. Control Algorithms (Li Chen)

University of Rochester

## *5.1 Configuration of lenslets and actuators*

## *5.2 Influence function measurement*

## *5.3 Control command of wavefront corrector*

### 5.3.1 Wavefront control

### 5.3.2 Direct slope control

### 5.3.3 Special control for different wavefront correctors

## *5.4 Transfer function modelization of adaptive optics system*

### 5.4.1 Transfer function of adaptive optics components

### 5.4.2 Overall system transfer function

### 5.4.3 Adaptive optics system bandwidth  analysis

## *5.5 Temporal modelization with Transfer function*

### 5.5.1 Feedback control

### 5.5.2 Proportional integral control

### 5.5.3 Smith compensate control

## *5.6 Temporal controller optimization*

### 5.6.1 Open-loop control

### 5.6.2 Closed-loop control

### 5.6.2 Time delay effect on the adaptive optics system

### 5.6.3 Real time considerations

## *5.7 Summary*

# 6. Software/User Interface/Operational Requirements (Ben Singer)

University of Rochester

## *6.1 Introduction*

## *6.2 Hardware setup*

### 6.2.1 Imaging

#### 6.2.1.1 Hartmann-Shack Spots
#### 6.2.1.2 Pupil Monitoring
#### 6.2.1.3 Retinal Imaging

### 6.2.2 Triggered devices: Shutters, lasers, LEDs

### 6.2.3 Serial devices: Defocusing slide, custom devices

### 6.2.4 AO Mirror control

## *6.3 Image processing setup*

### 6.3.1 Setting regions of interest: search boxes

### 6.3.2 Preparing the image

#### 6.3.2.1 Thresholding
#### 6.3.2.2 Averaging
#### 6.3.2.3 Background subtraction
#### 6.3.2.4 Flat-fielding

### 6.3.3 Centroiding

### 6.3.4 Bad data

## *6.4 Wavefront reconstruction and visualization*

### 6.4.1 Zernike mode recovery and RMS

#### 6.4.1.1 Display of modes and RMS: traces, histograms
#### 6.4.1.2 Setting modes of interest

### 6.4.2 Wavefront visualization

#### 6.4.2.1 Continuous grayscale image
#### 6.4.2.2 Wrapped grayscale image
#### 6.4.2.3 Three-D plots

## *6.5 Adaptive optics*

### 6.5.1 Visualizing and protecting write-only mirrors

### 6.5.2 Testing, diagnosing, calibrating

### 6.5.3 Individual actuator control

### 6.5.4 Update timing

### 6.5.5 Bad actuators

## *6.6 Lessons learned, future goals*

### 6.6.1 Case studies from existing systems at CVS and B&L

#### 6.6.1.1 One-shot wavefront sensing vs realtime AO
#### 6.6.1.2 Using AO systems in experiments: Step Defocus

### 6.6.2 Engineering trade-offs

#### 6.6.2.1 Transparency vs Simplicity
#### 6.6.2.2 Extensibility vs Stability

### 6.6.3 How to please everyone

#### 6.6.3.1 Subject
#### 6.6.3.2 Operator
#### 6.6.3.3 Experimenter
#### 6.6.3.4 Programmer

### 6.6.4 Software tools

## *6.7 Summary*

# 7. AO Assembly, Integration and Troubleshooting (Brian Bauman)

**Lawrence Livermore**

## *7.1 Introduction and Philosophy*

## *7.2 Optical alignment*

### 7.2.1 General remarks

### 7.2.2 Understanding the penalties for misalignments

### 7.2.3 Having the right knobs: optomechanics

### 7.2.4 Common alignment practices

#### 7.2.4.1 Tools
#### 7.2.4.2 Off-line alignment of sub-systems
#### 7.2.4.3 Aligning optical components
#### 7.2.4.4 Sample procedures (taken from the AO phoropter project)

## *7.3 Wavefront sensor checkout*

### 7.3.1 Wavefront sensor camera checkout

### 7.3.2 Wavefront sensor checkout

#### 7.3.2.1 Proving that centroid measurements are repeatable.
#### 7.3.2.2 Proving that the centroid measurements do not depend on where centroids are with respect to pixels
#### 7.3.2.3 Measuring plate scale.
#### 7.3.2.4 Proving that a known change in the wavefront produces the correct change in centroids.

## *7.4 Wavefront Reconstruction*

### 7.4.1 Testing the reconstruction code: Prove that a known change in the wavefront produces the correct change in reconstructed wavefront.

## *7.5 Aligning the “probe” beam into the eye*

## *7.6 Visual stimulus alignment*

## *7.7 Flood-illumination alignment*

## *7.8 DM-to-WFS Registration*

### 7.8.1 Tolerances & penalties for misregistration

### 7.8.2 Proving that the wavefront sensor-to-SLM registration is acceptable.

## *7.9 Generating control matrices*

### 7.9.1 System ("push") matrix

### 7.9.2 Obtaining the control matrix

### 7.9.3 Checking the control matrix

### 7.9.4 Null spaces

## *7.10 Closing the loop*

### 7.10.1 Checking the gain parameter

### 7.10.2 Checking the integration parameter

## *7.11 Calibration*

### 7.11.1 Obtaining calibrated reference centroids.

### 7.11.2 Proving that reference centroids are good

### 7.11.3 Image-sharpening to improve Strehl performance.

## *7.12 Science procedures*

## *7.13 Trouble-shooting algorithms*

# 8. System Performance: Testing, Procedures, Calibration and Diagnostics (Bruce Macintosh, Marcos Van Dam)

Lawrence Livermore / Keck Telescope

## *8.1 Spatial and Temporal characteristics of correction*

## *8.2 Power Spectra calculations*

## *8.3 Disturbance rejection curves*

## *8.4 Strehl ratio/PSF measurements/calculations*

## *8.5 Performance vs. different parameters (beacon brightness, field angle, …)?*

## *8.6 Summary Table and Figures of above criteria*

### 8.6.1 Results from Xinetics, BMC, IrisAO

# IV. Retinal Imaging Applications

## 9. Fundamental Properties of the Retina (Ann Elsner)

Schepens Eye Research Institute

### *9.1 Shape of the retina, geometric optics*

#### 9.1.1 Normal fovea, young vs. old

**9.1.1.1. foveal pit**
**9.1.1.2. foveal crest**

#### 9.1.2 Normal optic nerve head

#### 9.1.3 Periphery and ora serrata

### *9.2 Two blood supplies, young vs. old*

#### 9.2.1 Retinal vessels and arcades

#### 9.2.2 0 – 4 layers retinal capillaries, foveal avascular zone

#### 9.2.3 Choriocapillaris, choroidal vessels, watershed zone

### *9.3 Layers vs. features, young vs. old, ethnic differences*

#### 9.3.1 Schlera

#### 9.3.2 Choroidal vessels, choroidal melanin

#### 9.3.3 Bruch's membrane

#### 9.3.4 RPE, tight junctions, RPE melanin

#### 9.3.5 Photoreceptors, outer limiting membrane

**9.3.5.1 Outer segment**
**9.3.5.2 Inner segment**
**9.3.5.3 Stiles-Crawford effect**
**9.3.5.4 Macular pigment**

#### 9.3.6 Neural retina

#### 9.3.7 Glia, inner limiting membrane, matrix

#### 9.3.8 Inner limiting membrane

#### 9.3.9 Vitreo-retinal interface, vitreous floaters

## *9.4 Spectra, layers and features*

### 9.4.1 Main absorbers in the retina

### 9.4.2 Absorbers vs. layers

### 9.4.3 Features in different wavelengths

### 9.4.4 Changes with aging

## *9.5 Light scattering, layers and features*

### 9.5.1 Directly backscattered light

### 9.5.2 Multiply scattered light

### 9.5.3 Geometric changes in specular light return

### 9.5.4 Layers for specular and multiply scattered light

### 9.5.5 Imaging techniques to benefit from light scattering properties

## *9.6 Polarization*

### 9.6.1 Polarization properties of the photoreceptors

### 9.6.2 Polarization properties of the nerve fiber bundles, microtubules

### 9.6.3 Anterior segment and other polarization artifacts

### 9.6.4 Techniques to measure polarization properties

## *9.7 Imaging techniques to produce contrast from specular or multiply scattered light*

### 9.7.1 Confocal imaging

### 9.7.2 Polarization to narrow the point spread function

### 9.7.3 Polarization as a means to separate directly backscattered light from multiply scattered light, demonstration using the scattered light

### 9.7.4 Coherence techniques as a means to separate directly backscattered light from multiply scattered light, with a goal of using the scattered light

# 10. Strategies for High Resolution Retinal Imaging (Austin Roorda, Remy Tumbar, Julian Christou)

University of Houston / University of Rochester / University of California, Santa Cruz

## *10.1 Conventional Imaging (Roorda)*

### 10.1.1 Basic principles

This will be a simple optical imaging system

### 10.1.2 Basic system design

Show a typical AO flood-illuminated imaging system for the eye

### 10.1.3 Choice of optical components

Discuss the type of optical you would use (eg off axis parabolas)

### 10.1.4 Choice of light source

How much energy, what bandwidth, flash duration, show typical examples

### 10.1.5 Controlling the field size

Where to place a field stop and why

### 10.1.6 Choice of camera

What grade of camera is required? Show properties of typical cameras that are currently used

### 10.1.7 Implementation of wavefront sensing

Where do you place the wavefront sensor. Using different wavelengths for wfs.

## *10.2 Scanning Laser Imaging (Roorda)*

### 10.2.1 Basic principles

This will show how a simple scanning imaging system operates

### 10.2.2 Basic system design

This shows the layout of a simple AOSLO

### 10.2.3 Choice of optical components

What type of optical components shoud you use and why (eg mirrors vs lenses). Where do you want to place the components (eg raster scanning, DM etc) and why.

### 10.2.4 Choice of light source

How to implement different wavelengths. How to control retinal light exposure

### 10.2.5 Controlling the field size

Optical methods to increase field size
Mechanical (scanning mirror) methods to increase field size

#### **10.2.6 Controlling light delivery**

Acousto-optical control of the light source for various applications

#### **10.2.7 Choice of detector**

PMT vs APD what are the design considerations

#### **10.2.8 Choice of frame grabbing and image acquisition hardware**

What are the requirements for a frame grabber. What problems can you expect.

#### **10.2.9 Implementation of wavefront sensing**

Strategies for wavefront sensing in an AOSLO

#### **10.2.10 Other: pupil tracking, retinal tracking, image warping**

### *10.3 OCT systems (Tumbar)*

#### 10.3.1 Flood illuminated vs. Scanning

### *10.4 Future ideas (Tumbar)*

#### 10.4.1 DIC (Differential Interference Contrast)

#### 10.4.2 Phase Contrast

#### 10.4.3 Polarization Techniques

#### 10.4.4 Two-photon

#### 10.4.5 Fluorescence/Auto-fluorescence

### *10.5 Survey of post-processing/image enhancement strategies (Christou)*

# 11. Design Examples

## *11.1 Design of Houston Adaptive Optics Scanning Laser Ophthalmoscope (AOSLO) (Krishna Venkateswaran)*

### 11.1.1 Basic optical design

Effect of double pass system on psf, imaging in conjugate planes

### 11.1.2 Light delivery optics

Fiber optic source and other optics

### 11.1.3 Raster scanning

Scanning speeds etc.,

### 11.1.4 Physics of confocal imaging

### 11.1.5 Adaptive optics in SLO

Wavefront sensing, Zernike polynomials, Deformable mirror, correction time scales

### 11.1.6 Detailed optical layout of the AOSLO

Lens, mirrors, beam splitters with specs

### 11.1.7 Image acquisition

Back end electronics, frame grabber details

### 11.1.8 Software interface for the AOSLO

Wavefront sensing, Image acquisition

### 11.1.9 Theoretical model of AOSLO:

Limits on axial and lateral resolution

### 11.1.10 Image registration

### 11.1.11 Results

### 11.1.12 Discussions on improving performance of AOSLO

Light loss in optics, Deformable mirror, Wavefront sensing,

### 11.1.13 Next generation AOSLO type systems

## *11.2 Indiana University AO Coherence Gated System (Don Miller)*

### 11.2.1 Resolution advantages of an AO-OCT retina camera

### 11.2.2 AO-OCT basic system design concepts

**11.2.2.1 Application-specific constraints**

- **Sensitivity to weak tissue reflections**
- **Tolerance to eye motion artifacts**
- **Yoking focal plane to the coherence gate**

**11.2.2.2 Integration of AO and OCT sub-systems**

- **Generic OCT system**
- **Specific OCT architectures**
- **Preferred AO-OCT embodiments**

### 11.2.3 Description of the Indiana AO-OCT retina camera

**Optical layout of the Indiana AO-OCT retina camera**

**11.2.3.1 Adaptive Optics for correction of ocular aberrations**

**A. System description**

**B. Results**

**11.2.3.2 1D OCT axial scanning for retina tracking**

**A. System description**

**B. Results**

**11.2.3.3 High speed 2D incoherent flood illumination for focusing and aligning**

**A. System description**

**B. Results**

**11.2.3.4 CCD-based 2D OCT for *en face* optical sectioning the retina**

**A. System description**

**B. Results**

### 11.2.4 Future developments

**11.2.4.1 Smart photodiode array**

**11.2.4.2 *En face* and tomographic scanning**

**11.2.4.3 Reduction of image speckle**

**11.2.4.4 Detector sensitivity**

**11.2.4.5 Faster image acquisition**

## *11.3 Rochester Second Generation AO System (Heidi Hofer)*

# V. Vision Correction Applications

## 12. Customized Vision Correction Devices (Ian Cox)

**Bausch & Lomb**

### *12.1 Contact Lenses*

#### 12.1.1 Rigid or Soft Lenses?

#### 12.1.2 Design Considerations – More Than Just Optics

#### 12.1.3 Measurement – The Eye, the Lens or the System?

#### 12.1.4 Manufacturing Issues – Can The Correct Surfaces Be Made?

#### 12.1.5 Who Will Benefit?

#### 12.1.6 Summary

### *12.2 Intraocular Lenses*

#### 12.2.1 Which Aberrations - The Cornea, The Lens or The Eye?

#### 12.2.2 Surgical Procedures – Induced Aberrations

#### 12.2.3 Design & Manufacturing Considerations

#### 12.2.4 Future Developments & Summary

# 13. Customized Refractive Surgery (Scott MacRae)

**University of Rochester / StrongVision**

# 14. Visual Psychophysics (UC Davis Team, headed by Jack Werner)

**UC Davis**

## *14.1 Characterizing visual performance*

### 14.1.1 Acuity

### 14.1.2 Contrast sensitivity functions (CSFs)

### 14.1.3 Photopic/scotopic performance (include various ways to define luminance)

## *14.2 What is psychophysics?*

### 14.2.1 Studying the limits of vision

### 14.2.2 Differences between detection, discrimination and identification

## *14.3 Psychophysical methods*

### 14.3.1 Psychometric function

### 14.3.2 signal detection theory

### 14.3.3 measuring threshold

### 14.3.4 Criterion-free methods

### 14.3.5 Method of constant stimuli, method of adjustment, adaptive methods (e.g. Quest).

## *14.4 The visual stimulus*

### 14.4.1 Issues in selecting a display system

**Temporal resolution**
**Spatial resolution**
**Intensity (maximum, bit depth)**
**Homogeneity**
**Spectral characteristics**

### 14.4.2 Hardware options

**Custom optical systems (LEDs, Maxwellian view)**
**Displays**
- **CRTs**
- **DLPs**
- **LCDs**
- **Plasma**
- **Projectors**

**Display generation**
- **custom cards**
- **VSG**
- **Bits++**
- **10-bit cards**
- **Pelli attenuator**
- **Dithering/bit stealing**

### 14.4.3 Software

**Off the shelf software is not usually flexible enough. We recommend doing it yourself. This can be done using entirely custom software (e.g. C++) or by using software libraries such as VSG (PC) or PsychToolbox (Mac/PC).**

### 14.4.4 Calibration

**Gamma correction**
**Spatial homogeneity**
**Temporal and spatial resolution**

## *14.5 Summary*

# 15. Wavefront to Phoropter Refraction (Larry Thibos)

Indiana University

## *15.1 Basic terminology*

### 15.1.1 Refractive error

### 15.1.2 Refractive correction

### 15.1.3 Lens prescriptions

## *15.2 The goal of subjective refraction*

### 15.2.1 Definition of far point

### 15.2.2 Elimination of astigmatism

### 15.2.3 Using depth-of-focus to expand the range of clear vision

### 15.2.4 Placement of far-point at hyperfocal distance

## *15.3 Methods for estimating the monochromatic far-point from an aberration map*

### 15.3.1 Estimating center of curvature of an aberrated wavefront

15.3.1.1 Least-squares fitting
15.3.1.2 Paraxial curvature matching

### 15.3.2 Estimating object distance that optimizes focus

15.3.2.1 Metrics based on point objects
15.3.2.2 Metrics based on grating objects

## *15.4 Ocular chromatic aberration and the polychromatic far-point*

### 15.4.1 Polychromatic center of curvature metrics

### 15.4.2 Polychromatic point image metrics

### 15.4.3 Polychromatic grating image metrics

## *15.5 Experimental evaluation of proposed methods*

### 15.5.1 Conditions for subjective refraction

### 15.5.2. Monochromatic predictions

### 15.5.3 Polychromatic predictions

## 16. Design Examples

*Detailed Layouts, Numbers, Noise Analysis, Limitations for Visual Psychophysics:*

*16.1 LLNL/UR/B&L AO Phoroptor (Scot Olivier)*

*16.2 UC Davis AO Phoropter (Scot Olivier)*

*16.3 Rochester 2nd Generation AO System (Heidi Hofer)*

# V. Appendix/Glossary of Terms (Hope Queener, Joseph Carroll)

- **Laser safety calculations**
- **Other ideas?**
- **Glossary to define frequently used terms**