Stabilized Adaptive Optics Imaging for Laser Microsurgery

NIH NIBIB
Image Guided Interventions Workshop

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Support by EB003111

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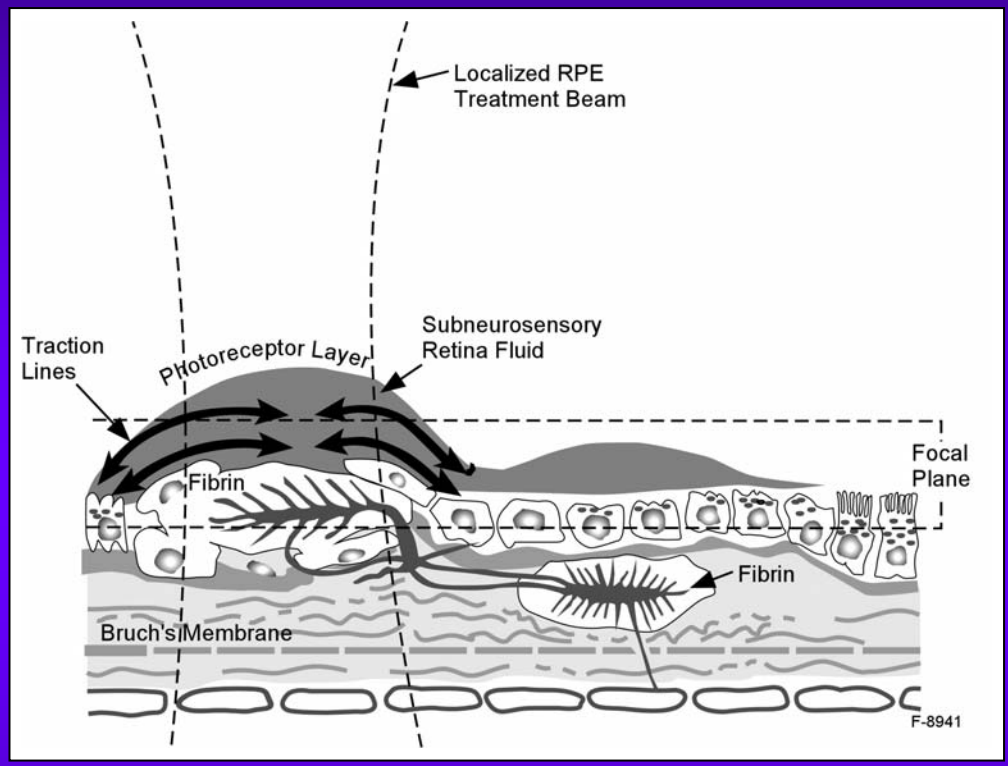
PHYSICAL SCIENCES INC.

Program Objectives

- **Overall Program Goal**
  - **Design, construct, and test a prototype clinical imaging and irradiation system, based upon adaptive optics, retinal tracking, and ultrashort laser pulse-induced retinal damage mechanisms.**
- **Specific Program Objectives**
  - **Design and construct an adaptive optics scanning laser ophthalmoscope (AOSLO).**
  - **Integrate a retinal tracker into the AOSLO (TAOSLO).**
  - **Characterize the TAOSLO imaging and tracking performance in human subject tests at PSI.**
  - **Deliver and setup the TAOSLO for ultrashort pulse delivery at the Optical Radiation Branch (AFRL/HEDO, Brooks AFB TX) and test in an animal model.**

Motivation and Clinical Significance

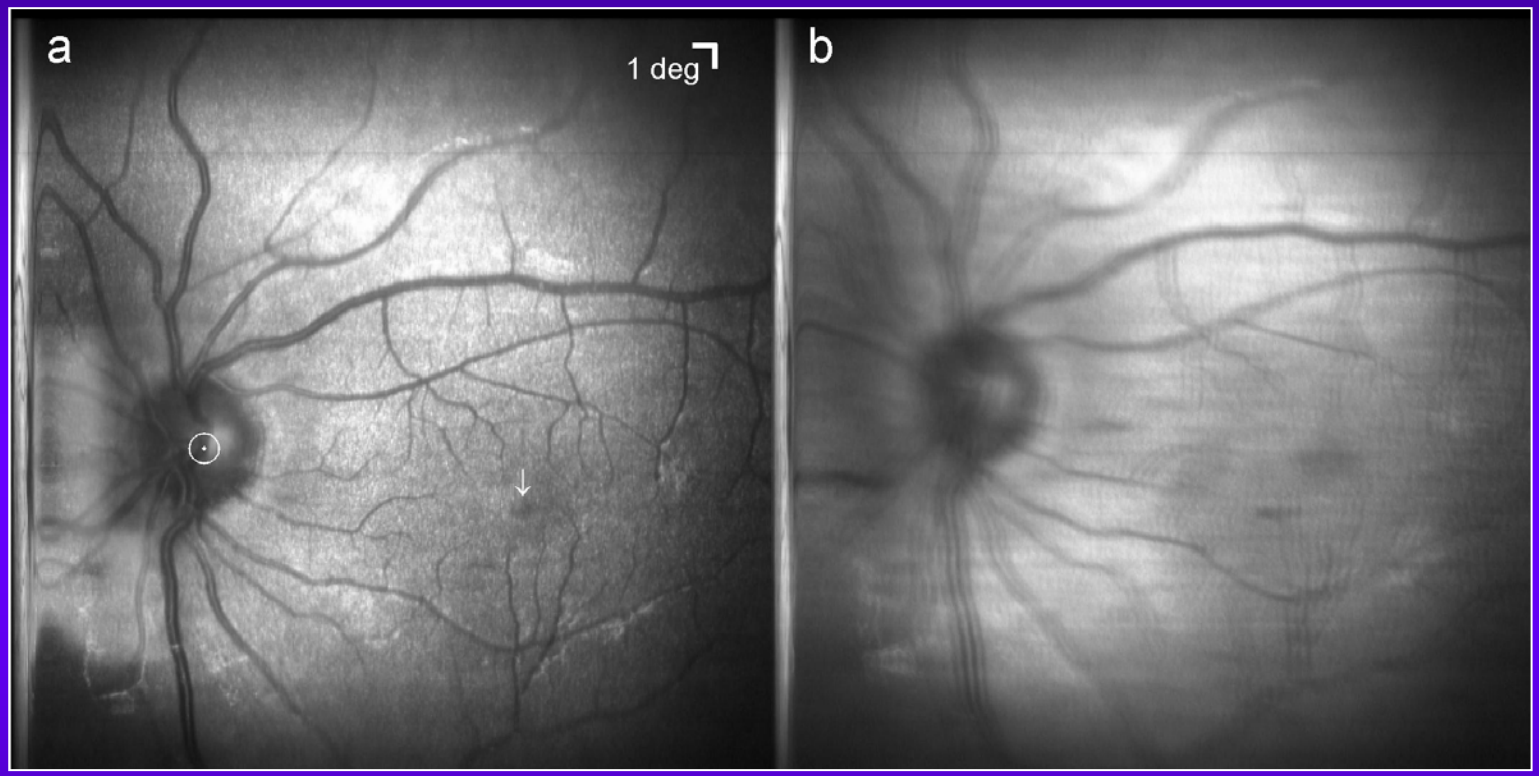
- Advances in diagnostic laser technologies have far outpaced advances in laser therapies (except for PDT)
- Retinal diseases
  - Age-related macular degeneration (AMD)
  - Diabetic retinopathy (DR)
  - Retinitus pigmentosa (RP)
  - Intraocular melanoma (IM)
- Potential therapies with the proposed system - Early detection and treatment for:
  - Selective destruction of RPE with ultrashort pulses (fs-ns)
  - Destruction of feeder vessels in choroidal neovascularization (CNV) related to DR
  - Other potential targets: drusen, small tumors, microaneurysms



AMD retinal pathology

Core Technology

Retinal Tracking

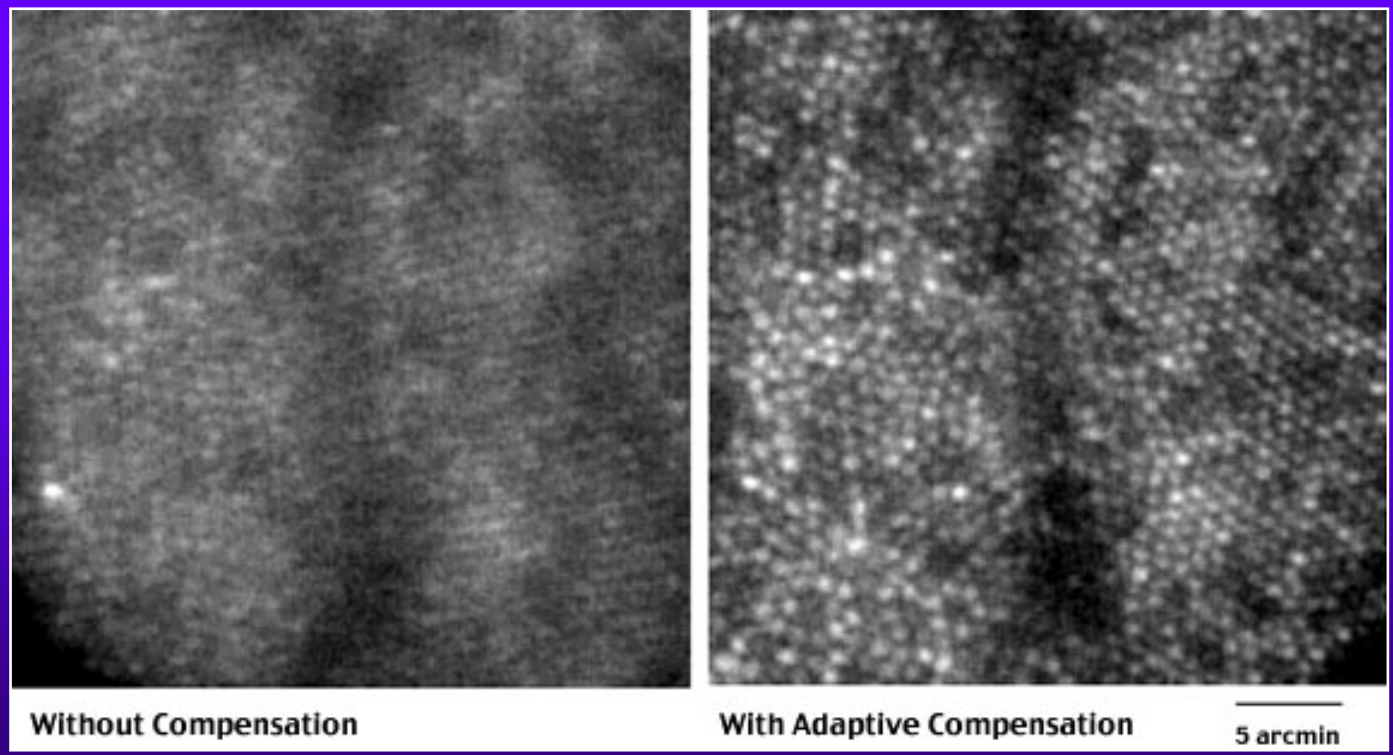


- **PSI's retinal tracking technology**
  - **US Patents 5,767,941 and 5,943,115**
  - **Enables visualization, photonic analysis, and phototherapy of retinal structures with superior sensitivity and resolution**
  - **Absolutely required for precision laser retinal surgery**

Core Technology

Adaptive Optics

- **Correction of ocular aberrations by wavefront compensation & correction allows increased transverse resolution for several imaging technologies (e.g. SLO and OCT)**
- **For precision laser retinal surgery, AO is necessary to achieve a diffraction-limited spot at the retina**



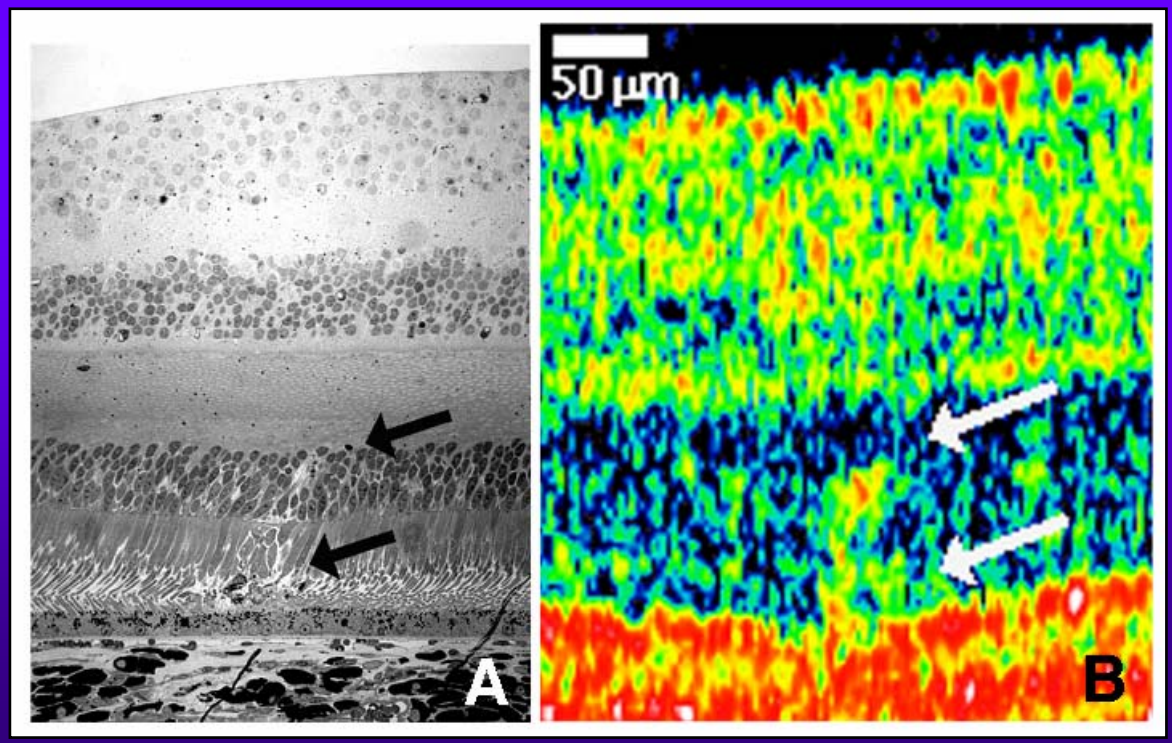
Cone mosaic imaged with and without wavefront compensation

Used with permission from Austin Roorda: http://www.opt.uh.edu/research/aroorda

Core Technology

Ultrashort Pulse Laser Damage

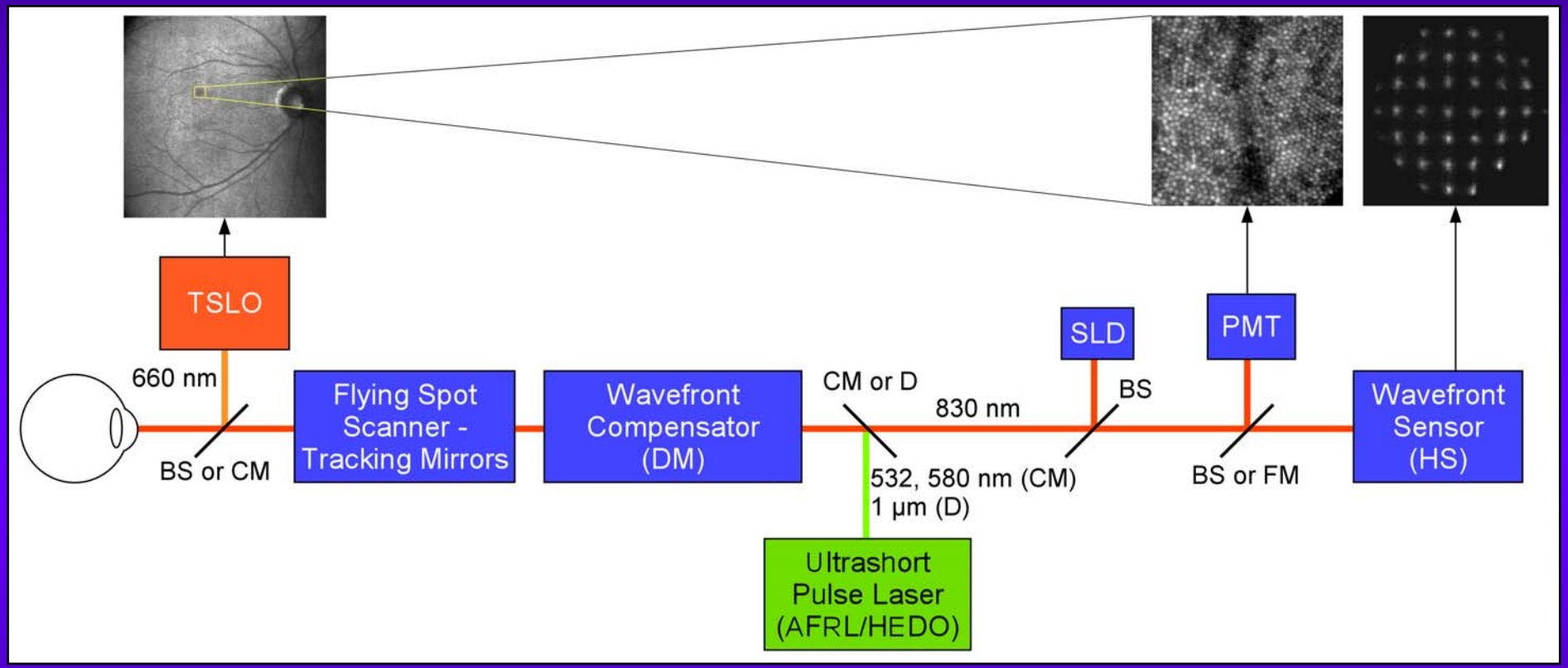
- **Non-linear mechanisms (primarily optical breakdown) mediate retinal damage from ultrashort pulses (< 10 ns).**
- **Ultrashort pulse damage is therefore characterized by**
  - **Low energy thresholds**
  - **Highly localized damage with little collateral damage**
- **Recent engineering advances are moving ultrashort pulse lasers closer to routine use in clinical systems (OCT, refractive surgery, etc.)**



Histology and OCT image of RPE disruption from 3 ps pulses.

Roach et al. JBO, in press.

System Overview



- **Dichroic beamsplitter (D)**
  - **400-860 nm R > 95%**
  - **870-1100 nm T > 85%**
- **Cold mirror (CM)**
  - **400-700 nm R > 95 %**
  - **780-1250 nm T > 85%**

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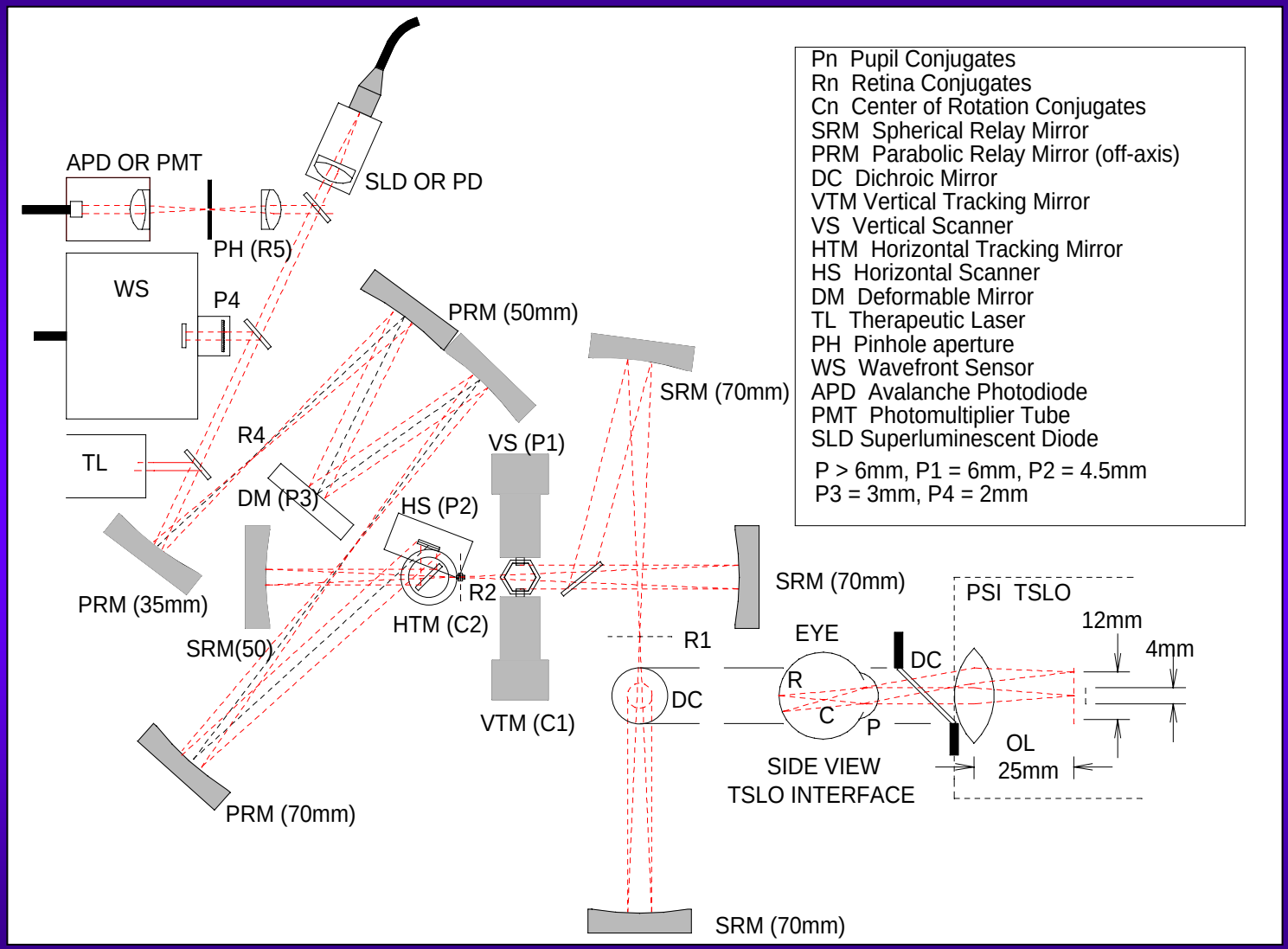
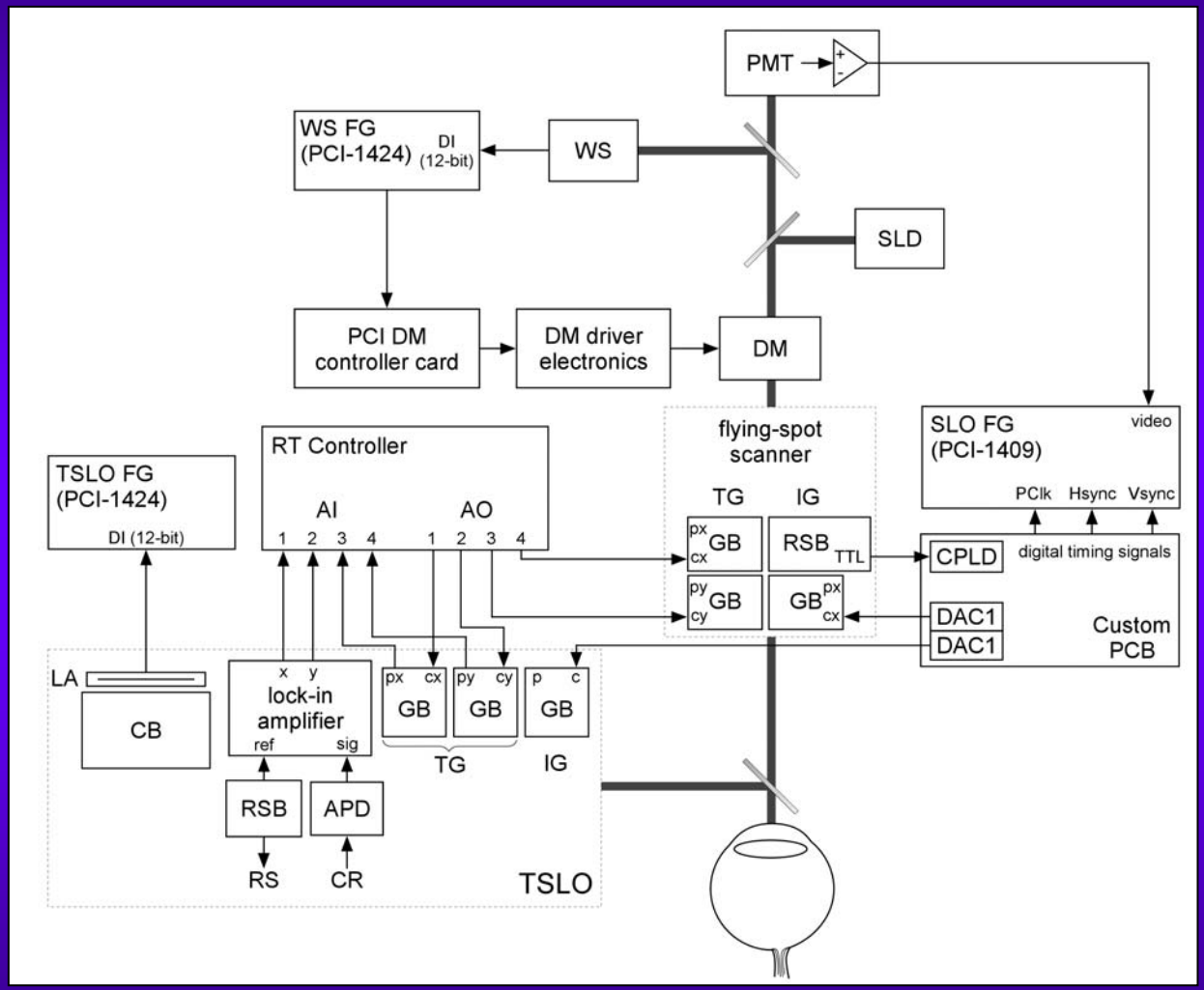
TAOSLO Optical Schematic



TAOSLO Instrumentation



- **Custom PCB**
  - **LUT to linearize SLO image resonant scanner**
  - **Synchronize and drive vertical scanner**
- **3 framegrabbers (FG)**
  - **TSLO**
  - **Flying-spot SLO**
  - **WS**
- **RT controller**
  - **Retinal tracking bandwidth > 1 kHz**
  - **AO closed-loop bandwidth > 10 Hz**

Research Plan and Acknowledgments

- **Research Plan**
  - **Optical and instrumentation design complete**
  - **System construction complete by Fall**
  - **Human and animal subject testing in 2005**
- **Acknowledgments**
  - **Physical Sciences Inc.**
    - **R. Daniel Ferguson**
    - **Nick Iftimia**
  - **Brooks AFB**
    - **Benjamin A. Rockwell**
    - **Clarence Cain**
    - **David Stolarski**
  - **Consulting support**
    - **Austin Roorda, University of Houston School of Optometry**
    - **H. Grady Rylander III, University of Texas at Austin and Eye Institute of Austin**