Optics Education and Outreach in Southern California

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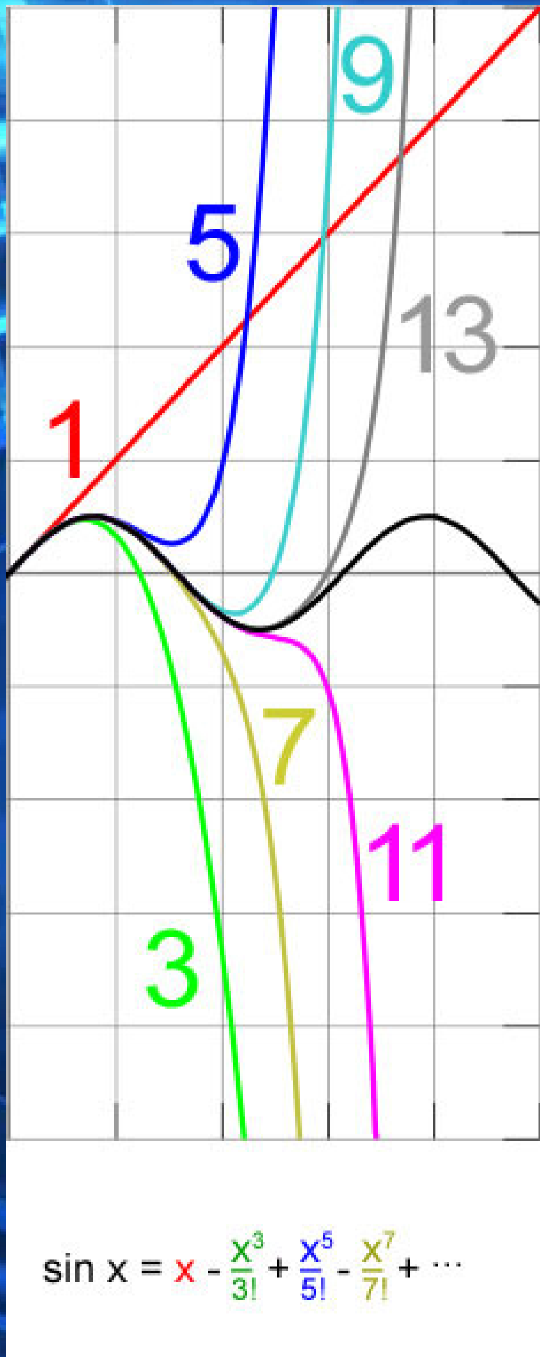
Optical Society of Southern California
June 11, 2008

Presentation Outline

- Technician Training Programs
- Professional Optics Education
  - Optical Instrument Design Program
- K-12 & Community Outreach Programs



Basic Math is a Stumbling Block for Most

- ❑ Geometry
  - ❑ Conic Sections
- ❑ Algebra Fundamentals
  - ❑ Quadratic Equation
  - ❑ Taylor Series
- ❑ Elementary Trig
  - ❑ Sine Curve

  -- shown on left is Taylor Series expansion of sine curve --

Can't Teach Geometrical Optics without Geometry

Skill Set for Optics Technician

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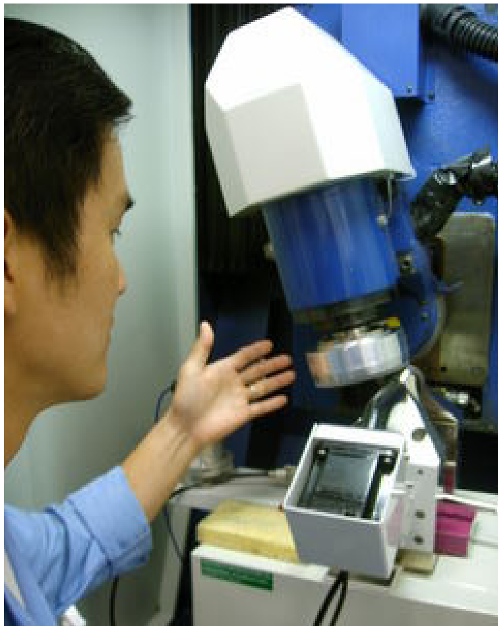

- Basic computational knowledge of
  - -- Geometric and physical optics
  - -- Geometry, algebra, and trig
  - -- Optical shop instruments
  - -- Measurement procedures and metric system
- Proficiency in using
  - -- Blueprints and tolerances for optics manufacturing
  - -- Computers
  - -- Common optical equipment and machinery
  - -- Computer Numerical Controlled (CNC) equipment
  - -- Optical interferometry
- Knowledge of
  - -- Cleaning and handling of optics
  - -- Clean room procedures and work area maintenance
  - -- Inspection procedures and quality control
- Ability to troubleshoot problems and maintain equipment for optimal use and productivity

Optics + Photonics Courses at Irvine CACT

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www.irvinecact.com

- ❑ 3 Curricula of 3 Courses Each
  - Core Photonics
  - Fabrication & Metrology
  - Optical Instrument Design (>>> UCI Ext.)
- ❑ Pilot Course: Holography -- Science & Art
- ❑ Workshops
  - Laser Safety
  - Optics Cleaning, Handling and Inspection

❖ **Key Point - Qualified Instructors Essential**

Hands-on Teaching Model

Fundamentals of Optics course taught using PASCO *Introductory Optics System* kit

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Core Photonics Curriculum

- Fundamentals of Optics
- Introduction to Lasers
- Introduction to Fiber Optics

Fundamentals of Optics

(CACT 21 Donn Silberman (next class starts in Sept.))

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Textbook: Jenkins & White, Fundamentals of Optics, 4^{th} ed. (McGraw-Hill, 2001)

- Light Rays, Law of Reflection, Snell's Law, Index of Refraction, Scattering
- Paraxial Rays, Prisms, Dispersion
- Transmission and Reflection of Plane Surfaces (Fresnel Equations): Total Internal Reflection (Critical Angle), Brewster Angle
- Spherical Mirrors, Lenses: Lensmaker's Equation, real & virtual Images
- Aberrations (spherical, astigmatism, coma, field curvature, distortion, chromatic, polarization), Achromatic lenses
- Optics of Eye, Optical Instrument Speed, Microscopes
- Dioptric and Catoptric Telescopes, Adaptive Optics
- Light Waves: phase and group velocity, Michelson Speed of Light Interference: double slit, Michelson Interferometer, fringe visibility
- Diffraction: single slit, straight edge, Circular aperture, near & far fields
- Optical Gratings and Resonators, Thin Film Optics
- Polarization, Interference of polarized light, polarizers
- Crystal Optics: double refraction, uniaxial and biaxial crystals
- Optical Rotatory Power, Faraday Effect

Introduction to Lasers

(CACT 20) Jim Hauck (next class starts in July)

Textbook: Jeff Hecht, Understanding Lasers: An Entry Level Guide (Wiley, Third Edition, 2008) in IEEE Press Series Understanding Science & Technology

- Spontaneous and induced atomic transitions, absorption and amplification, atomic pumping
- Optical resonators, modes, and Gaussian beams
- Mode-locked and Q-switched lasers,
- Review of specific lasers: Nd:YAG and other solid-state lasers; He-Ne, argon-ion, carbon dioxide lasers; semiconductor diode lasers
- Laser applications.

Introduction to Fiber Optics

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(CACT 22) Paul Young (next class starts in Jan 09)

Textbook: *Understanding* Fiber *Optics*, 4th edition, Jeff Hecht (Prentice Hall, 2002)

- **Fundamentals of Fiber-Optic Components**: power, power meters
- **Types and Properties of Optical Fibers**
- **Fiber Materials & Manufacture**
- **Light Sources**: lasers and light emitting diodes (LED), characteristics of laser pulses
- **Optical Transmitters**: introduction to modulators
- **Optical Receivers, Repeaters, Amplifiers**: digital-signal link
- **Connectors, splices and other passive components**
- **Analog-signal Fiber Optic Link**: FO link measurements
- **O/E Switches, Modulators and WDM devices**
- **Wavelength-Division Multiplexing Optics**
- **Fiber Optic Measurements & Trouble Shooting**
- **Fiber Optic System Networking: Standards and Systems**
- **Local, Regional & Global Networks**
- **Fiber Optic Sensors & Imaging-Illuminating**

Fabrication & Metrology Curriculum

- Optics Fabrication I
- Optics Fabrication II
- Optical Interferometry & Metrology
- Workshop on Optics Cleaning, Handling and Inspection



Optics Fabrication I and II

(CACT 101 &102) Gene Dempsey

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(next class starts in Sept.)

Textbook: Fabrication Methods for Precision Optics, Hank H. Karow (Wiley, 1993)

Skills in fabrication techniques with hands-on emphasis on the practices used in producing precision optical components. Successfully fabricate an optical component from raw form to a finished state.

Learn basic optics terms, raw materials, tooling, blocking, generating, shaping, beveling, grinding, polishing, edging, centering and final inspection.

CACT 101: Entry-level course involves plano shaping, grinding and polishing, resulting in a hand-polished 3.8-cm glass cube.

CACT 102: Second semester produces a matching set of master test plates to be standard for measuring optical wavefront radii.

Course is held in CACT optics fabrication workshop

Equipment donated by Newport Corp., Schott Glass, Zygo

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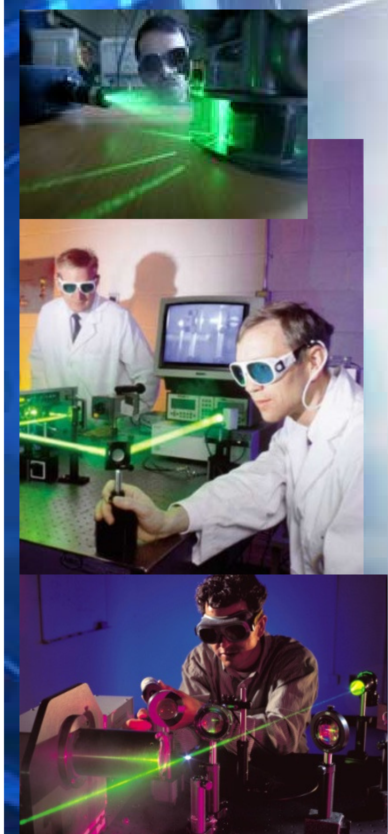
Workshop on Optics Cleaning, Handling and Inspection

Workbook on Optics Cleaning, Handling and Inspection, (short courses offered upon request)

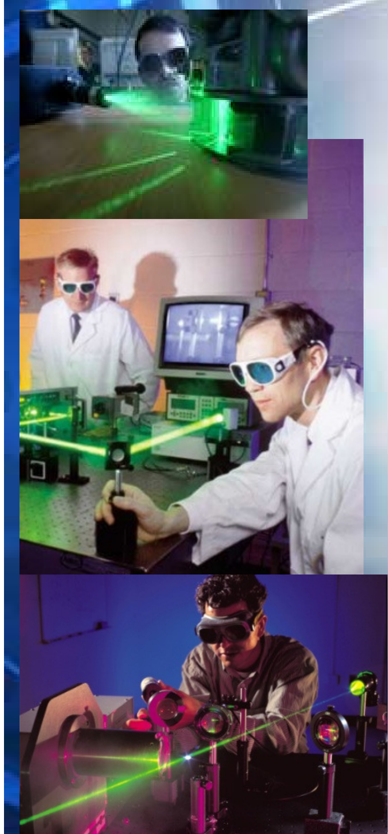


- **Cleaning**
  - **Cleanroom work environment at laminar flow bench with no particles larger than 0.5 μm**
  - **Clean with solvent (acetone or IPA) with lens tissue swab**
- **Handling**
  - **Storage containers for transport**
- **Inspecting Optical Surface Quality**
  - **Inspection Box D-667-11 (Davidson Optronics)**
  - **Scratch & Dig Specification (Mil Spec)**

Hands-on Exercises for Attendees

Military Specification

MIL-O-13830

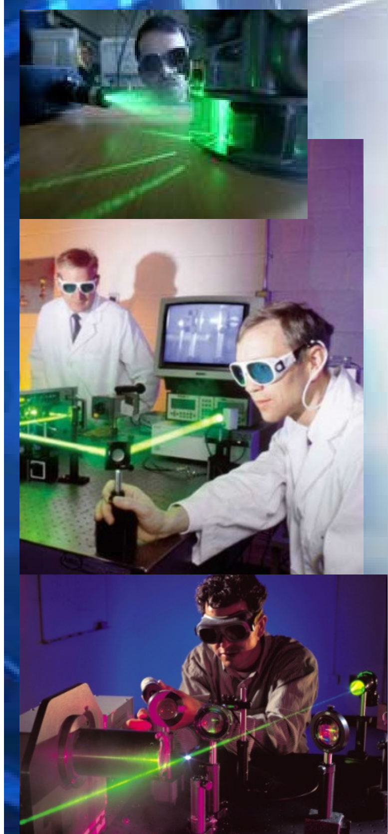


- 1954 -- MIL-O-13830 developed by U.S. Army to define method for specifying and inspecting optical surface quality.
- 1994—Department of Defense decided that it would no longer maintain standards for the military and will defer to voluntary national standards.
- 1996—Optics and Electro-Optics Standard Council (OEOSC) formed to provide mechanism for development of voluntary optical standards.
- 2000—American National Standards Institute (ANSI) accredited OEOSC to act as the national optical standards committee to develop a replacement standard for MIL-O-13830.

Inspection Box

D- 667-11

Scratch & Dig Guide to Surface Quality



- Optical surface quality is specified by two numbers (*e*.g., 60-20). The first number is the maximum “scratch number” and the second number is the maximum “dig number.”
- A scratch is a surface defect (tear) having length well in excess of width.
- A dig is a surface defect (pit or hole) having length approximately equal to width or being roughly circular in appearance.

Optical Interferometry & Metrology (CACT 105)

Donn Silberman & Jeff Padgett

(next class TBD)

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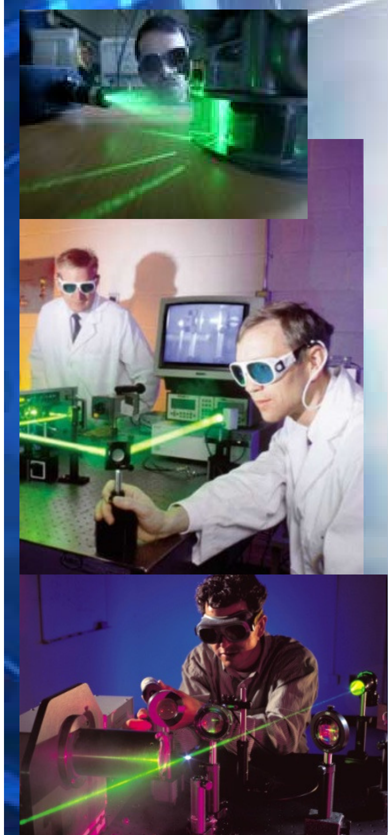

Textbook: Field Guide to Interferometric Optical Testing, Eric P. Goodwin and James C. Wyant (SPIE Press, 2006)

Interferometry Fundamentals: coherence, fringe visibility, beamsplitters

Interferometers: Fizeau, Twyman-Green, Mach-Zehnder, lateral shear

Interferograms: aberration content, Zernike polynomials, moiré

Phase Shifting Interferometry: methods for phase shifting

Surface Microstructure

Flat Surface Testing: mirrors, windows, prisms, corner cubes

Curved Surface Testing: test plate, cat's eye position, lens testing, laser-based Fizeau

Absolute Measurements: flats, spheres

Aspheric Surface Testing: conics

Other Optical Testing: Foucault Knife-Edge, Shack-Hartmann test

Support by Zygo Corp. for Zygo GPI XP/D Interferometer at CACT

Optical Instrument Design Curriculum

Valentina Doushkina - (first taught @ CACT in 2007)

Moving to UC Irvine Extension in Jan. 2009

- ❑ **Lens Design** (using Zemax®)
- ❑ **Optical System Design** (using Zemax®)
- ❑ **Opto-mechanical Design** (using SolidWorks®)

Lens Design

(CACT 120)

Textbook: Introduction to Lens Design: With Practical *Zemax* Examples, Joseph Geary (Willmann-Bell, 2002) www.willbell.com

Reference: Imaging System Performance for Homeland Security Applications, (CORD Optics and Photonics Series, 2007) – MTF measurement

First order optics: stops, pupils, marginal and chief rays

Aberration theory: description, identification and balancing

Lens design with *Zemax®* (How optical design programs model lenses)

Modulation transfer function (MTF): diffraction effects and measurement

Singlet lens design: merit function construction, optimization

Achromat lens design: correcting chromatic aberrations

Multi-element lenses: Cooke triplet, zoom lens, scanning systems

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Optical System Design

(CACT 121)

Using Zemax® optical system design and SolidWorks® 3D CAD software

- **Modeling with coordinate break:** prisms, beamsplitters, fold mirrors, off-axis design, tilting and de-centering, multiple apertures
- **Modeling with multi-configurations:** interferometers, multi-channel systems, zoom lens, scanning systems
- **Optimization of multi-configured systems:** merit function design, optimization with MTF & RMS, boundary constraints
- **Systems analysis:** spot size, optical path difference (OPD) diagrams, thermal analysis and system athermalization, wavefront analysis
- **System tolerancing**: error budget, construction and assembly errors, alignment design and analysis
- **Gaussian beam propagation**

Opto-Mechanical Design

(CACT 122)

Textbook: Opto-Mechanical Systems Design, 2nd edition, Paul R. Yoder Jr. (Dekker, 1993)

Design Process: specifications, constraints, error budget and tolerances, modeling and design reviews

Environment: temperature, thermal expansion, vibration, shock

Materials for Mechanical Components

Mounting Optics: individual and multiple lenses, small mirrors, prisms, windows and filters

Mounting Mirrors: lightweight nonmetallic mirrors, large mirrors for horizontal, vertical and variable axis orientation

Metallic Mirrors: precision diamond turning, plating

Housing Configuration

Instrument Structural Design

Teaching Philosophy & Implementation

- Fuse 'lectures' with hands-on learning
- Optics Fundamentals

  pre-requisite to Optical Design Program courses
  - Three hour class – ½ lecture, ½ lab
- Optical Design Program courses
  - Three hour class – students follow instructor as she goes through the lessons
  - Students work on designs during the class and at home – they turn in their results as homework

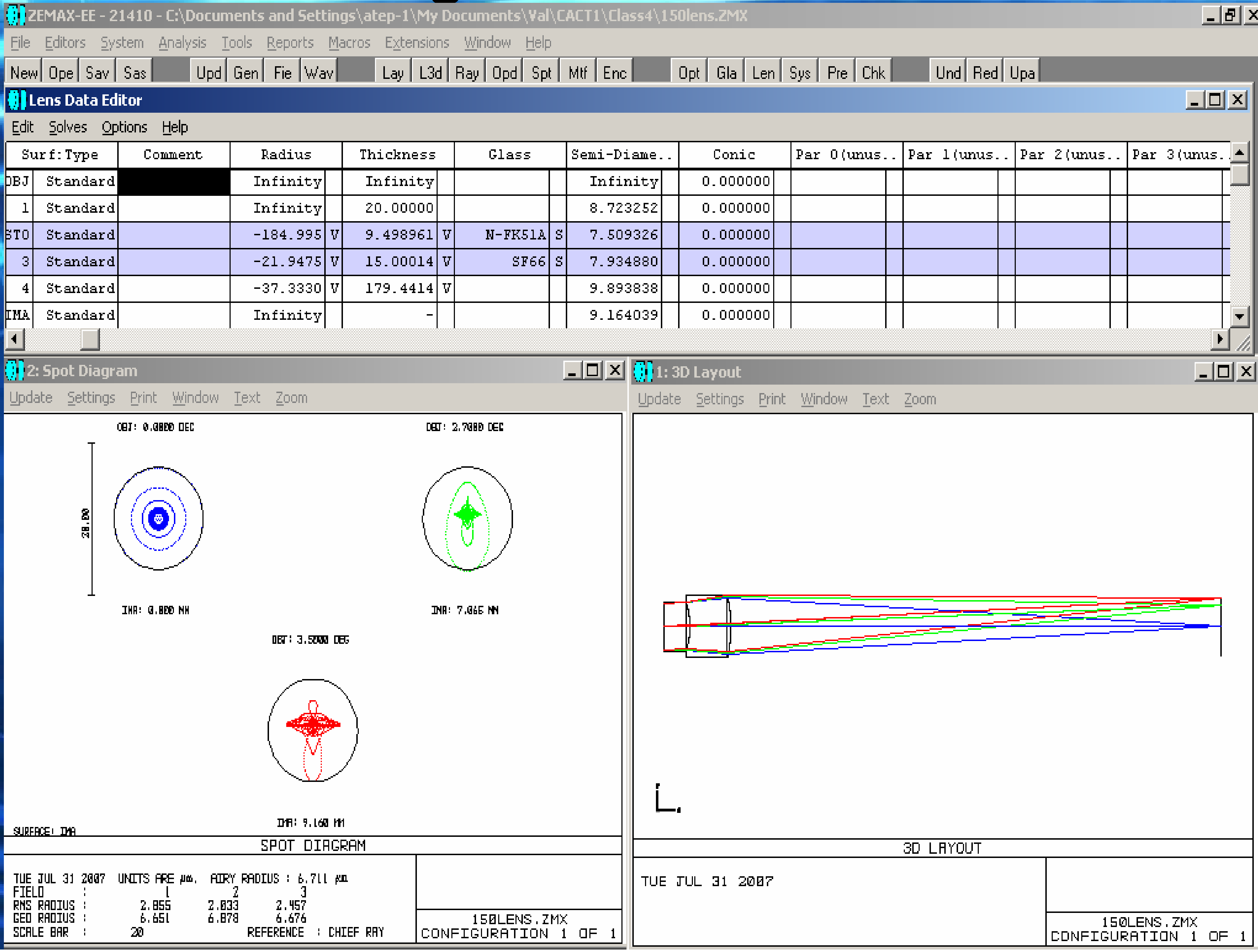
Course 1: Lens Design

- Course Curriculum
- Teaching aberration identification & balancing
- Multi-element design: The Cook Triplet

Lens Design Course Curriculum

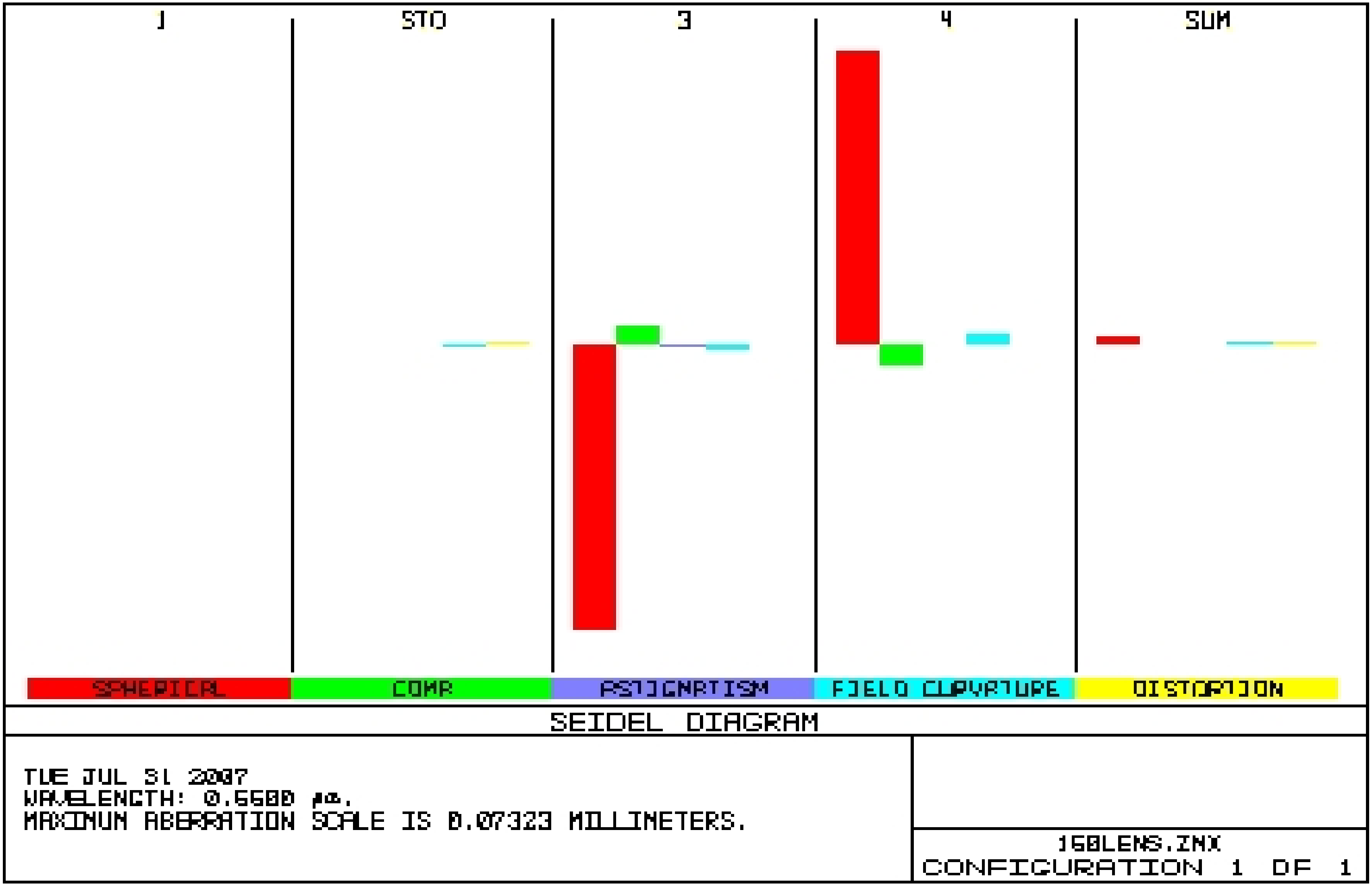
- **First-order optics**
  - Refraction and reflection
  - Glass definition and properties
  - Image formation and ray tracing
  - Stops, pupils, marginal and chief rays
- **Aberration theory**
  - Aberration descriptions
  - Identifying aberrations
  - Aberration balancing
- **Lens design with *ZEMAX***
  - How optical design programs model lenses
  - Surface, field, wavelength, system data
  - Apertures, f-numbers
  - Use of solves and variables
  - Spot diagrams
  - 2D, 3D, wireframe, and solid model layouts
  - MTF plots
  - Diffraction effects
  - Other diagnostic tools
- **Singlet design**
  - Merit function construction
  - Using optimization, setting variables
  - Boundary constraints
- **Achromat design**
  - Magnification, EFL, spacings
  - Correcting chromatic aberrations
  - Glass selection and optimization
- **Multi-element lenses**
  - Cooke triplet
  - Collimation
  - Beam expanders
  - Designing with stock lenses
  - Double Gauss
  - Zoom lens design
  - Scanning systems

Teaching aberration identification

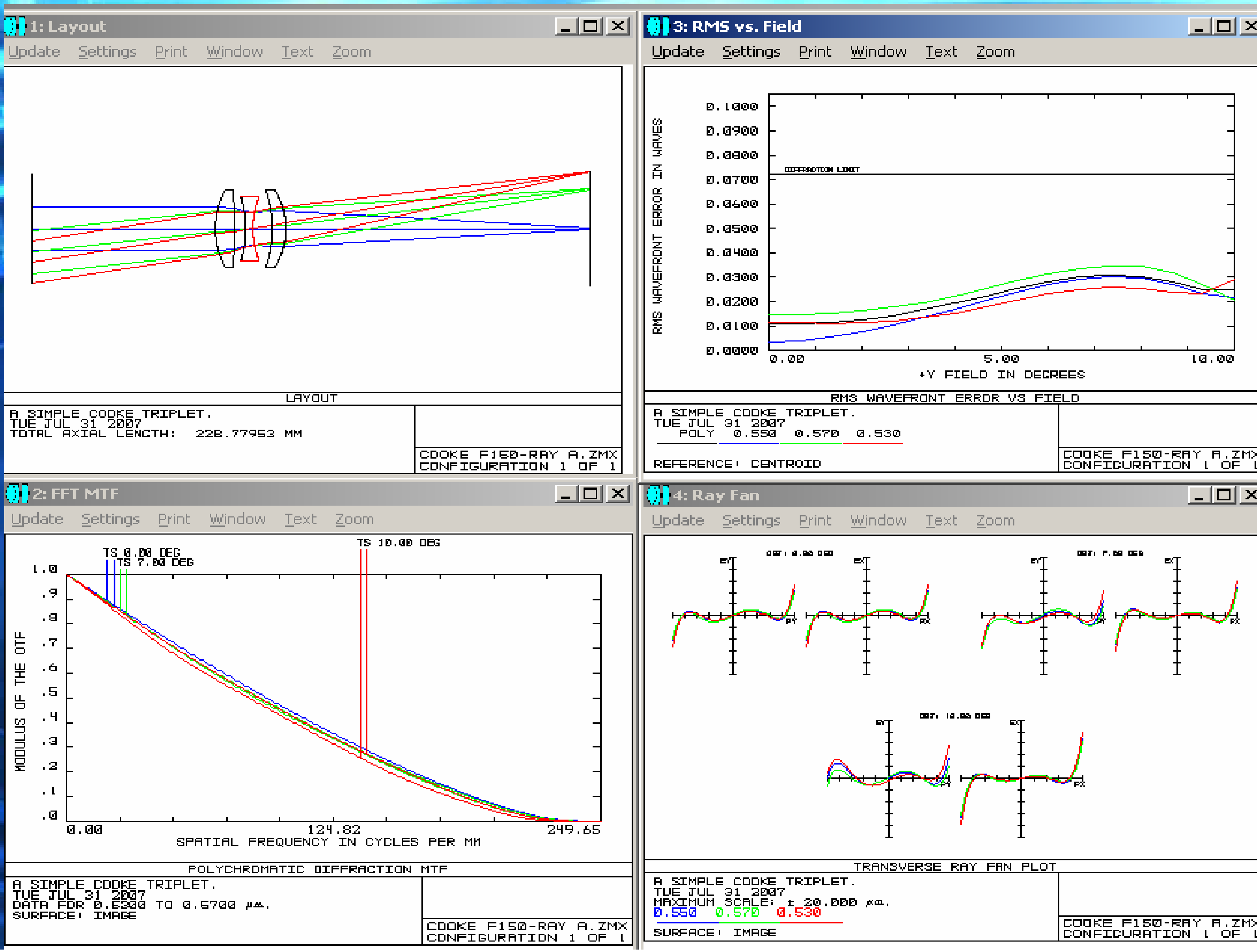


Surf:Type	Comment	Radius		Thickness		Glass		Semi-Diame..	Conic	Par 0(unus..	Par 1(unus..	Par 2(unus..	Par 3(unus..
OBJ Standard		Infinity		Infinity				Infinity	0.000000				
1 Standard		Infinity		20.00000				8.723252	0.000000				
STO Standard		-184.995	V	9.498961	V	N-FK51A	S	7.509326	0.000000				
3 Standard		-21.9475	V	15.00014	V	SF66	S	7.934880	0.000000				
4 Standard		-37.3330	V	179.4414	V			9.893838	0.000000				
IMA Standard		Infinity		-				9.164039	0.000000				

Teaching aberration balancing



Multi-element lens design: The Cooke Triplet



Course 2: Advanced optical systems design and analysis

- Course Curriculum
- Modeling a 2 channel system using coordinate breaks and multi-configurations
- Thermal analysis and system athermalization
- Merit functions
- Tolerancing of the Optical System
- Physical Optics

Adv. Optical Sys. Design & Anal. Curriculum

- **Modeling with coordinate break**
  - Prisms, beamsplitters, fold mirrors;
  - Off axis designs;
  - Tilting and de-centering object, lens, image;
  - Multiple apertures
- **Modeling with multi-configurations**
  - Interferometers,
  - Multi channel systems;
  - Zoom lens;
  - Scanning Systems
  - Gradient index lenses
  - Double pass system
- **Optimization of multi-configured systems**
  - Default and custom merit function design for multi-configured systems
  - Optimization with MTF, RMS, and PTV
  - Boundary constrains and control
  - Hammer optimization
  - Global Search
  - Ray aiming
- **System Analysis**
  - Geometrical and diffraction optics analysis;
  - Spot size, Ray Fan, OPD diagrams, field curvature/distortion, aberrations;
  - PSF, MTF,
  - Gaussian beam;
  - Thermal Analysis and system Athermalization
  - Tool for system analysis
  - Interferograms, wave front analysis
- **System tolerancing**
  - Error budget and tolerances
  - Construction and assembly errors
  - Passive and active compensators
  - Monte Carlo statistical tolerance analysis
  - Test plates fitting
  - Alignment design and analysis
- **Physical Optics**
  - Gaussian beam propagation, analysis and control
  - Beam characterization

Modeling a 2 channel system using coordinate breaks and multi-configurations

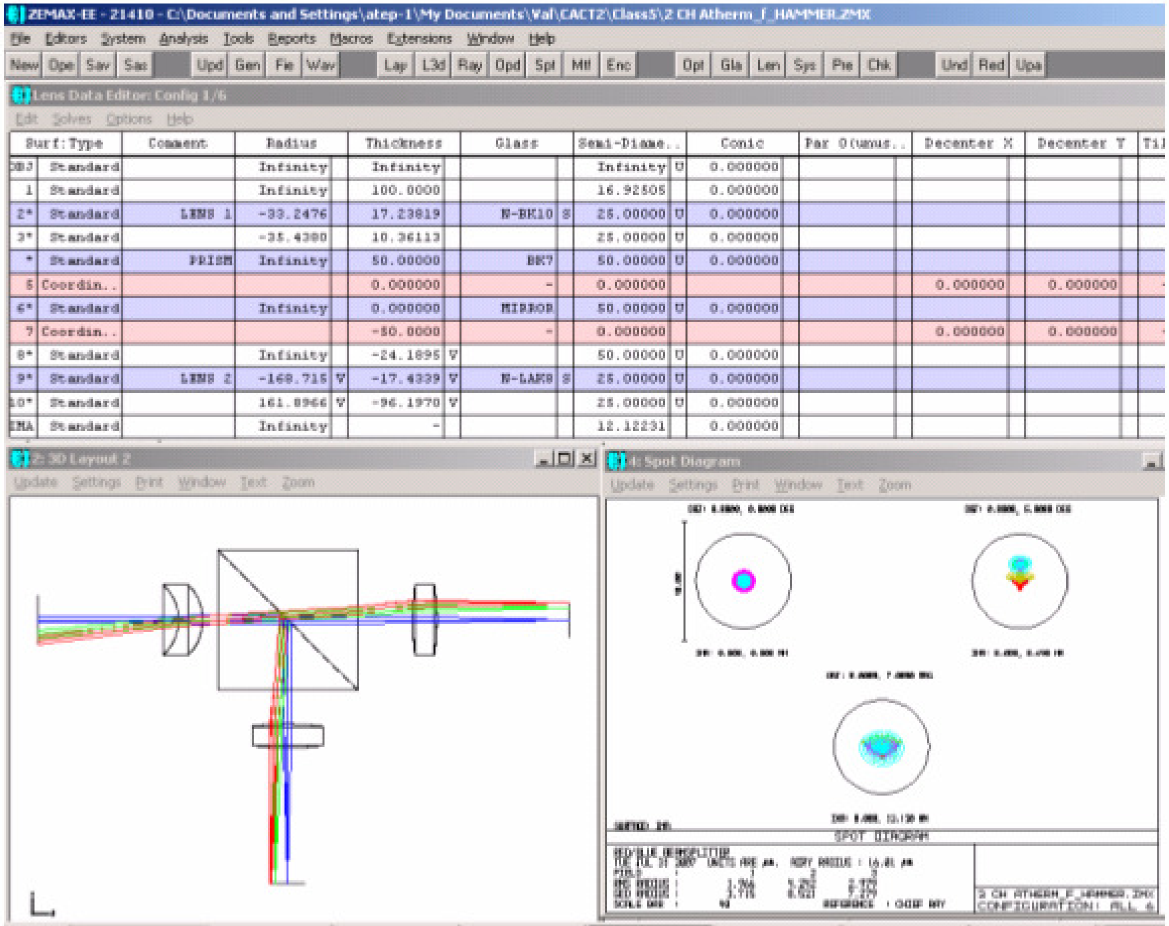


Fig. 4. A 2 channel system using coordinate breaks multi-configurations.

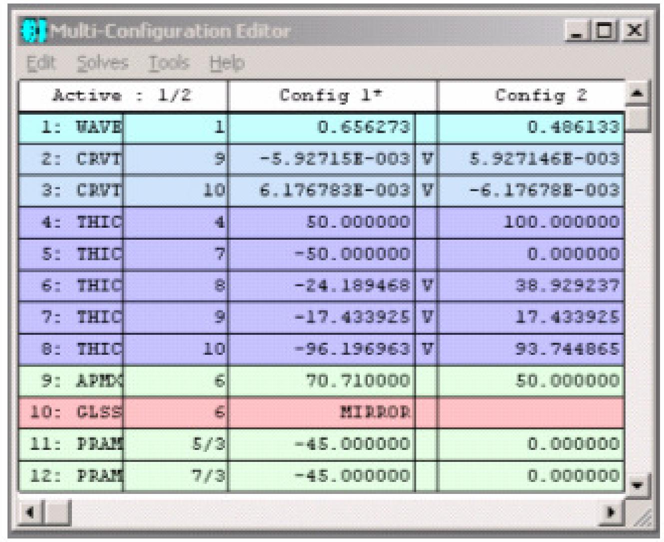


Fig.5. Multi-configurations editor controls the lens data editor.

Thermal analysis and system athermalization

Multi-Configuration Editor

Edit Solves Tools Help

Active : 1/6		Config 1*		Config 2		Config 3		Config 4		Config 5		Config 6	
1: TEMP	0	20.000000		20.000000		0.000000		40.000000		0.000000		40.000000	
2: WAVE	1	0.656273		0.486133		0.656259	T	0.656284	T	0.486123	T	0.486141	T
3: PRES	0	1.000000		1.000000		1.000000		1.000000		1.000000		1.000000	
4: CRVT	2	-0.030077		-0.030077		-0.030081	T	-0.030074	T	-0.030081	T	-0.030074	T
5: CRVT	3	-0.028218		-0.028218		-0.028222	T	-0.028215	T	-0.028222	T	-0.028215	T
6: CRVT	9	-5.92715E-003	V	5.927146E-003	P	-5.92781E-003	T	-5.92648E-003	T	5.927810E-003	T	5.926482E-003	T
7: CRVT	10	6.176783E-003	V	-6.17678E-003	P	6.177475E-003	T	6.176091E-003	T	-6.17747E-003	T	-6.17609E-003	T
8: THIC	1	100.000000		100.000000		100.001994	T	99.998007	T	100.001994	T	99.998007	T
9: THIC	2	17.238189		17.238189		17.236189	T	17.240189	T	17.236189	T	17.240189	T
10: THIC	3	10.361135		10.361135		10.361333	T	10.360931	T	10.361333	T	10.360931	T
11: THIC	4	50.000000		100.000000		49.992900	T	50.007100	T	99.985800	T	100.014200	T
12: THIC	7	-50.000000		0.000000		-50.000000	T	-50.000000	T	0.000000	T	0.000000	T
13: THIC	8	-24.189468	V	38.929237	V	-24.179219	T	-24.199717	T	38.912355	T	38.946119	T
14: THIC	9	-17.433925	V	17.433925	P	-17.431973	T	-17.435878	T	17.431973	T	17.435878	T
15: THIC	10	-96.196963	V	93.744865	V	-96.154338	T	-96.239587	T	93.703344	T	93.786385	T
16: GLSS	2	N-BK10	S	N-BK10	P	N-BK10	P	N-BK10	P	N-BK10	P	N-BK10	P
17: GLSS	4	BK7		BK7		BK7	P	BK7	P	BK7	P	BK7	P
18: GLSS	9	N-LAK8	S	N-LAK8	P	N-LAK8	P	N-LAK8	P	N-LAK8	P	N-LAK8	P
19: SDIA	2	25.000000		25.000000		24.997100	T	25.002900	T	24.997100	T	25.002900	T
20: SDIA	3	25.000000		25.000000		24.997100	T	25.002900	T	24.997100	T	25.002900	T
21: SDIA	4	50.000000		50.000000		49.992900	T	50.007100	T	49.992900	T	50.007100	T
22: SDIA	6	50.000000		50.000000		49.992900	T	50.007100	T	49.992900	T	50.007100	T
23: SDIA	8	50.000000		50.000000		49.977500	T	50.022500	T	49.977500	T	50.022500	T
24: SDIA	9	25.000000		25.000000		24.997200	T	25.002800	T	24.997200	T	25.002800	T
25: SDIA	10	25.000000		25.000000		24.997200	T	25.002800	T	24.997200	T	25.002800	T
26: APMD	6	70.710000		50.000000		70.710000	P	70.710000	P	50.000000	P	50.000000	P
27: GLSS	6	MIRROR				MIRROR		MIRROR					
28: PRAM	5/3	-45.000000		0.000000		-45.000000	P	-45.000000	P	0.000000	P	0.000000	P
29: PRAM	7/3	-45.000000		0.000000		-45.000000	P	-45.000000	P	0.000000	P	0.000000	P

Merit functions

Merit Function Editor: 1.846324E+001

Edit Tools Help

Oper #	Type		Wave					Target	Weight	Value	% Contrib
1 CONF	CONF	1									
2 EFFL	EFFL		1					0.000000	0.000000	99.999687	0.000000
3 REAY	REAY	11	1	0.000000	1.000000	0.000000	0.000000	0.000000	1.000000	12.119834	0.525812
4 REAY	REAY	11	1	0.000000	0.700000	0.000000	0.000000	0.000000	0.000000	8.517329	0.000000
5 RGLA	RGLA	1	11	0.000000	0.000000	0.000000		0.020000	0.100000	0.020000	0.000000
6 BLNK	BLNK	Blue @20									
7 CONF	CONF	2									
8 REAY	REAY	11	1	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	12.119663	0.000000
9 REAY	REAY	11	1	0.000000	0.700000	0.000000	0.000000	0.000000	0.000000	8.523008	0.000000
10 DIFF	DIFF	3	8					0.000000	1.000000	1.708E-004	1.044E-010
11 DIFF	DIFF	4	9					0.000000	1.000000	-5.68E-003	1.154E-007
12 BLNK	BLNK	Red @0									
13 CONF	CONF	3									
14 REAY	REAY	11	1	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	12.118999	0.000000
15 REAY	REAY	11	1	0.000000	0.700000	0.000000	0.000000	0.000000	0.000000	8.516734	0.000000
16 BLNK	BLNK	Red@40									
17 CONF	CONF	4									
18 REAY	REAY	11	1	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	12.120639	0.000000
19 REAY	REAY	11	1	0.000000	0.700000	0.000000	0.000000	0.000000	0.000000	8.517904	0.000000
20 DIFF	DIFF	3	14					0.000000	1.000000	8.351E-004	2.496E-009
21 DIFF	DIFF	3	18					0.000000	1.000000	-8.05E-004	2.321E-009
22 BLNK	BLNK	Blue@0									
23 CONF	CONF	5									
24 REAY	REAY	11	1	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	12.119492	0.000000
25 REAY	REAY	11	1	0.000000	0.700000	0.000000	0.000000	0.000000	0.000000	8.522868	0.000000
26 BLNK	BLNK	Blue @40									
27 CONF	CONF	6									
28 REAY	REAY	11	1	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	12.119789	0.000000
29 REAY	REAY	11	1	0.000000	0.700000	0.000000	0.000000	0.000000	0.000000	8.523116	0.000000
30 DIFF	DIFF	8	24					0.000000	1.000000	1.711E-004	1.049E-010
31 DIFF	DIFF	8	28					0.000000	1.000000	-1.26E-004	5.696E-011
32 DIFF	DIFF	9	25					0.000000	1.000000	1.399E-004	7.002E-011
33 DIFF	DIFF	9	29					0.000000	1.000000	-1.08E-004	4.201E-011
34 BLNK	BLNK										

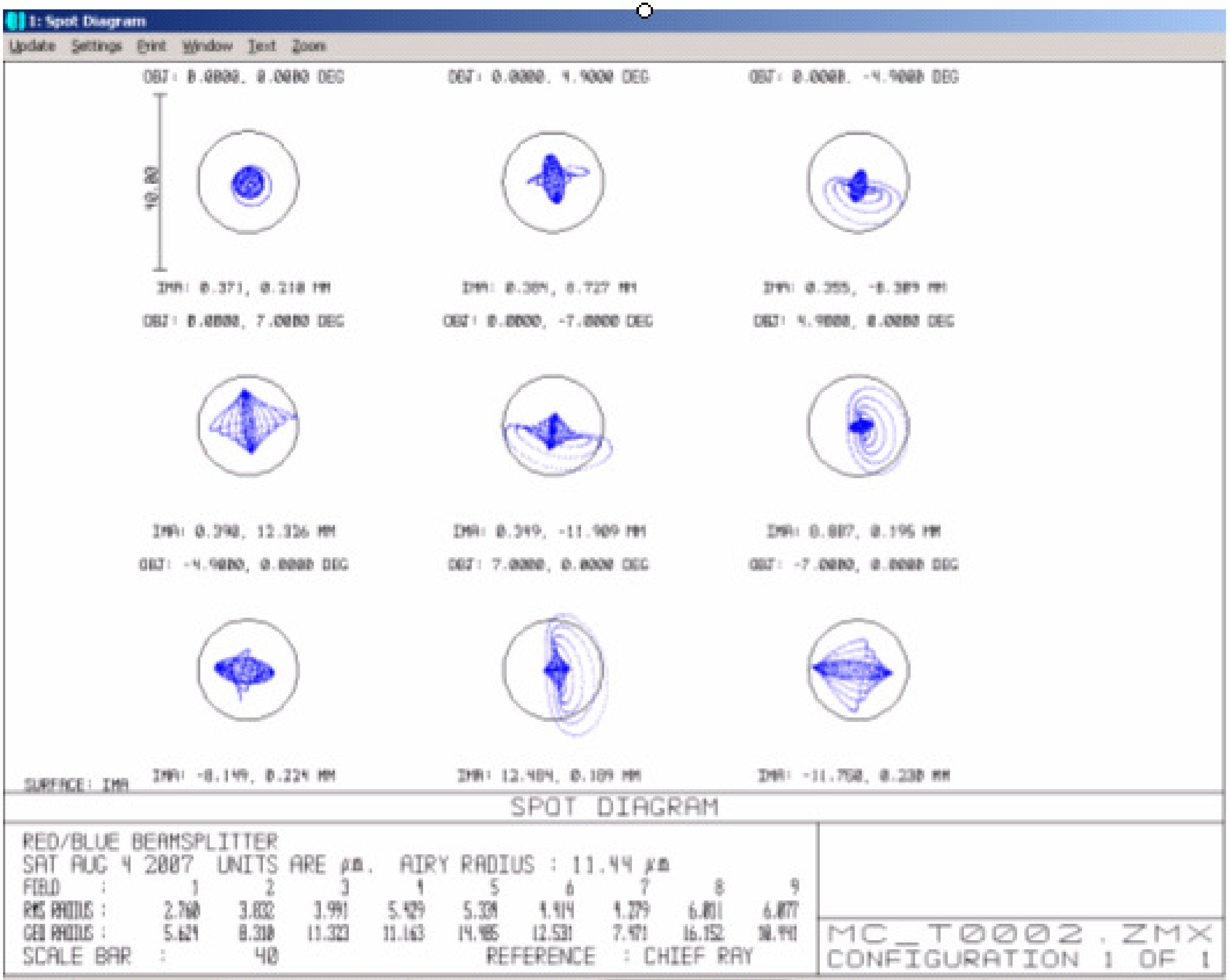
Tolerancing of the Optical System

Tolerance Data Editor

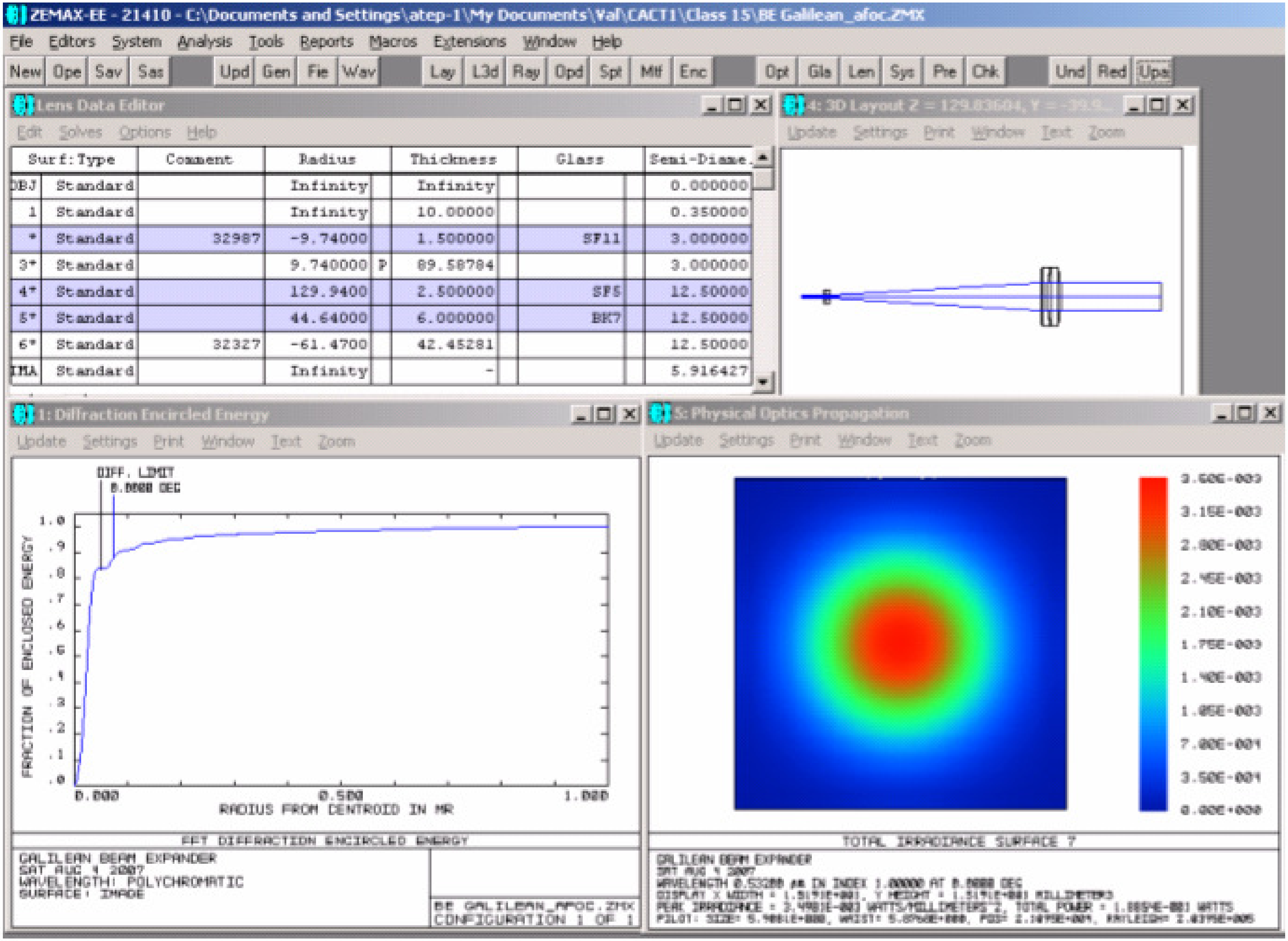
Edit Tools Help

Oper #	Type	Surf	-	-	Nominal	Min	Max	Comment
1 (COMP)	COMP	10	0	-	0.000000	-5.000000	5.000000	Default compensator on back focus.
2 (TWAV)	TWAV	-	-	-	-	0.632800	-	Default test wavelength.
3 (TRAD)	TRAD	2	-	-	-33.246028	-0.100000	0.100000	Default radius tolerances.
4 (TRAD)	TRAD	3	-	-	-35.581261	-0.100000	0.100000	
5 (TRAD)	TRAD	9	-	-	-156.46700	-0.100000	0.100000	
6 (TRAD)	TRAD	10	-	-	196.610510	-0.100000	0.100000	
7 (TTHI)	TTHI	1	3	-	100.000000	-0.050000	0.050000	Default thickness tolerances.
8 (TTHI)	TTHI	2	3	-	17.152327	-0.050000	0.050000	
9 (TTHI)	TTHI	3	8	-	10.031992	-0.050000	0.050000	
10 (TTHI)	TTHI	4	8	-	50.000000	-0.050000	0.050000	
11 (TTHI)	TTHI	5	8	-	0.000000	-0.050000	0.050000	
12 (TTHI)	TTHI	6	8	-	0.000000	-0.050000	0.050000	
13 (TTHI)	TTHI	7	8	-	-50.000000	-0.050000	0.050000	
14 (TTHI)	TTHI	8	10	-	-26.234115	-0.050000	0.050000	
15 (TTHI)	TTHI	9	10	-	-17.986224	-0.050000	0.050000	
16 (TSDX)	TSDX	2	-	-	0.000000	-0.025000	0.025000	Default surface dec/tilt tolerances 2.
17 (TSDY)	TSDY	2	-	-	0.000000	-0.025000	0.025000	
18 (TSTX)	TSTX	2	-	-	0.000000	-0.100000	0.100000	
19 (TSTY)	TSTY	2	-	-	0.000000	-0.100000	0.100000	
20 (TSDX)	TSDX	3	-	-	0.000000	-0.025000	0.025000	Default surface dec/tilt tolerances 3.
21 (TSDY)	TSDY	3	-	-	0.000000	-0.025000	0.025000	
22 (TSTX)	TSTX	3	-	-	0.000000	-0.100000	0.100000	
23 (TSTY)	TSTY	3	-	-	0.000000	-0.100000	0.100000	
24 (TSDX)	TSDX	4	-	-	0.000000	-0.025000	0.025000	Default surface dec/tilt tolerances 4.
25 (TSDY)	TSDY	4	-	-	0.000000	-0.025000	0.025000	
26 (TSTX)	TSTX	4	-	-	0.000000	-0.100000	0.100000	
27 (TSTY)	TSTY	4	-	-	0.000000	-0.100000	0.100000	
28 (TSDX)	TSDX	6	-	-	0.000000	-0.025000	0.025000	Default surface dec/tilt tolerances 6.
29 (TSDY)	TSDY	6	-	-	0.000000	-0.025000	0.025000	
30 (TSTX)	TSTX	6	-	-	0.000000	-0.100000	0.100000	
31 (TSTY)	TSTY	6	-	-	0.000000	-0.100000	0.100000	
32 (TSDX)	TSDX	8	-	-	0.000000	-0.025000	0.025000	Default surface dec/tilt tolerances 8.
33 (TSDY)	TSDY	8	-	-	0.000000	-0.025000	0.025000	
34 (TSTX)	TSTX	8	-	-	0.000000	-0.100000	0.100000	
35 (TSTY)	TSTY	8	-	-	0.000000	-0.100000	0.100000	
36 (TSDX)	TSDX	9	-	-	0.000000	-0.025000	0.025000	Default surface dec/tilt tolerances 9.

Worst case performance spot diagram for 9 field angles



Physical Optics



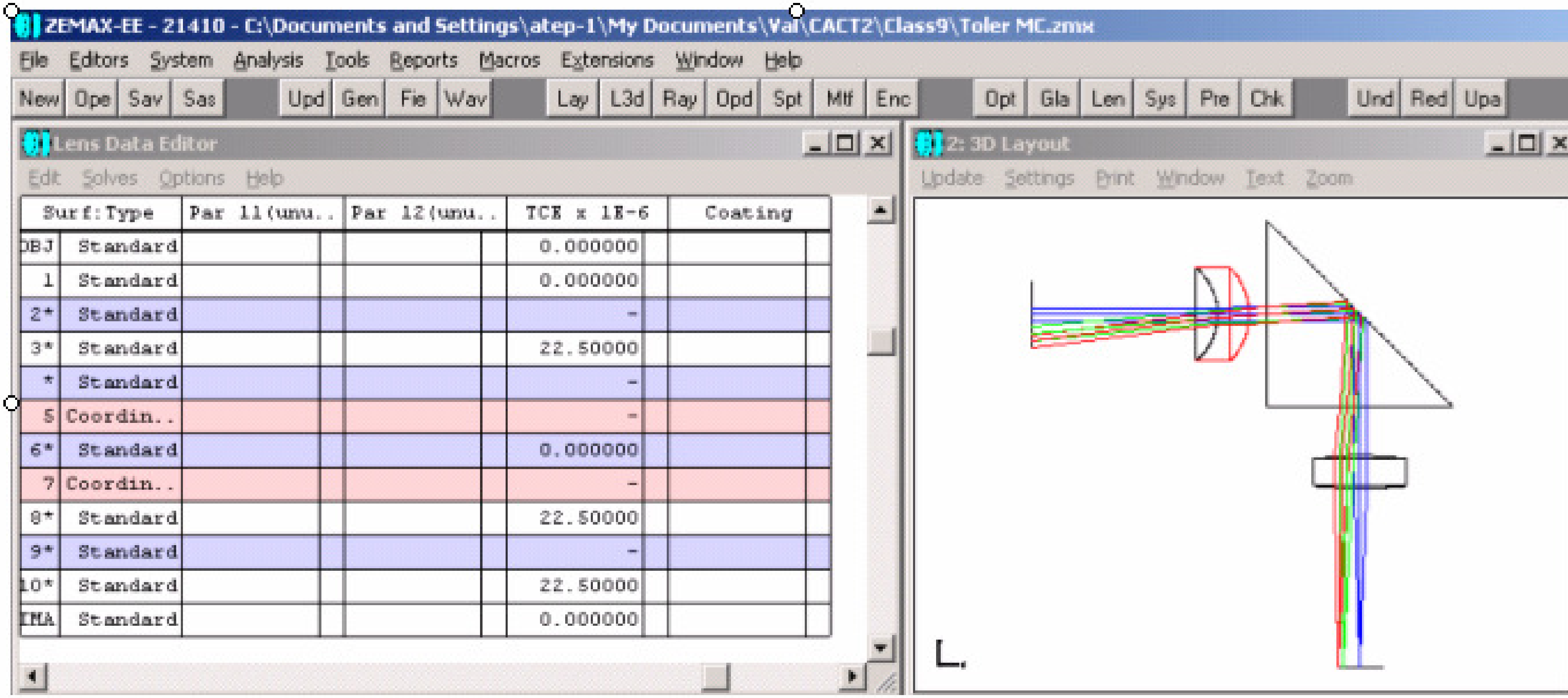
Course 3: Optomechanical Design

- Course Curriculum
- Integration of the optical design into the optomechanical model
- System design and top level assembly

Optomechanical Design Curriculum

- **Introduction to optomechanical design**
  - Performance specifications
  - Preliminary design
  - Error budgets and tolerancing
- **Integration of optical and mechanical designs**
  - Export optical model to 3D SolidWorks
  - Thermal Analysis
  - Material selection for optical and mechanical components
- **Optical components mounting techniques**
  - Mounting:
    - Lenses
    - Prisms
    - Mirrors
    - Filters
    - Windows
  - Multi-components assembly design
  - Glass to metal interfaces
  - Lens assemblies with moving parts
  - Adhesive selection
- **System design and top level assembly**
  - Consideration of centered optics
  - Establishing the optical axis
  - 'Wrapping' mechanics around optical model
  - Stray light considerations
    - Black anodizing
    - Placement of baffles
  - Packaging and enclosure considerations
- **Instrument alignment strategy and procedure**
  - Alignment procedures
  - Selection of alignment jigs
  - Design of alignment jigs
- **System test**
  - Final system test considerations

Integration of the optical design into the optomechanical model



Surf:Type		Par 11(unu..	Par 12(unu..	TCE x 1E-6	Coating
OBJ	Standard			0.000000	
1	Standard			0.000000	
2*	Standard			-	
3*	Standard			22.50000	
*	Standard			-	
5	Coordin..			-	
6*	Standard			0.000000	
7	Coordin..			-	
8*	Standard			22.50000	
9*	Standard			-	
10*	Standard			22.50000	
IMA	Standard			0.000000	

Fig. 11. Example of Lens Data Editor showing thermal coefficient of expansion (TCE).

Integration of the optical design into the optomechanical model

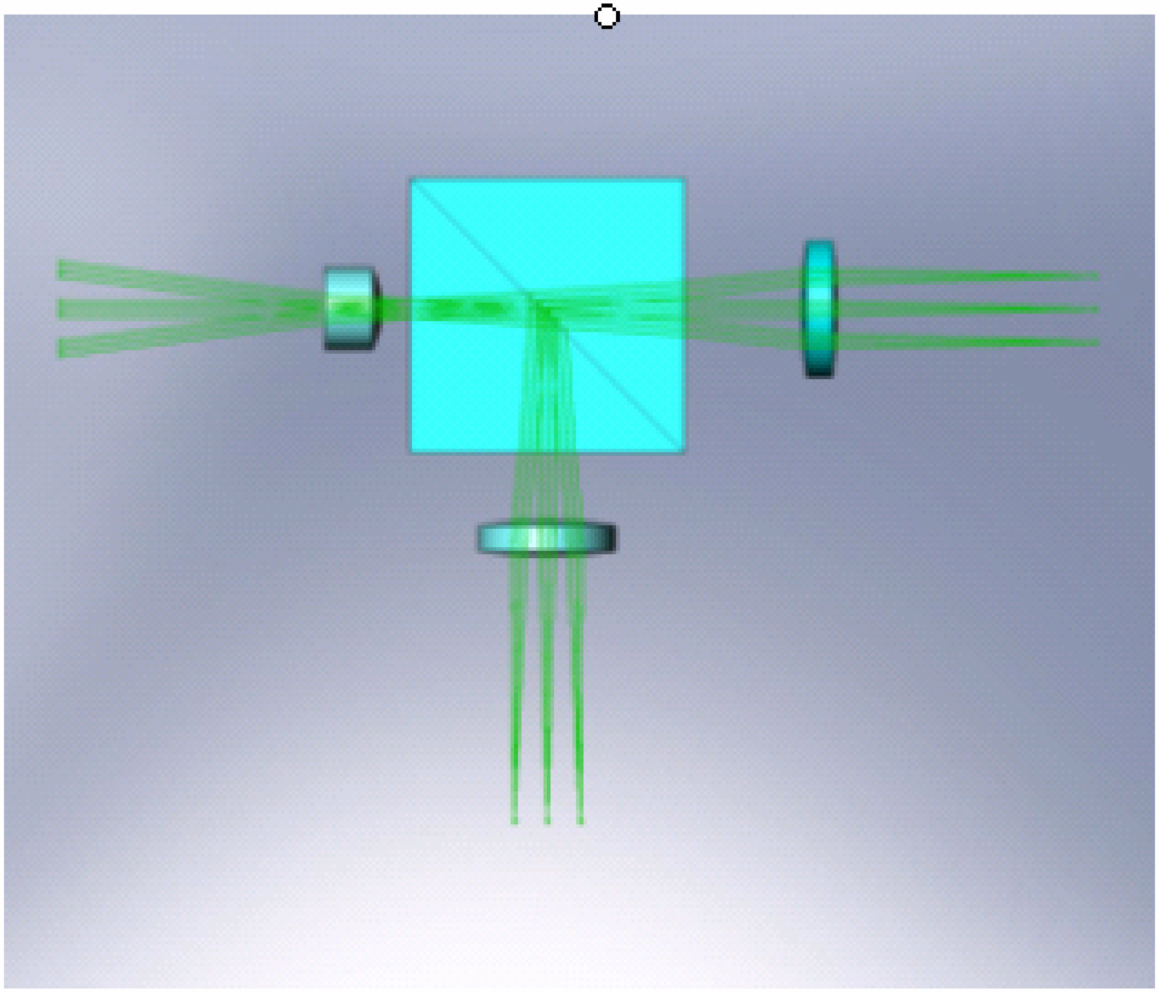


Fig. 12. The 3D SolidWorks model of the ray trace and the optical components of the system shown in figure 4.

System design and top level assembly

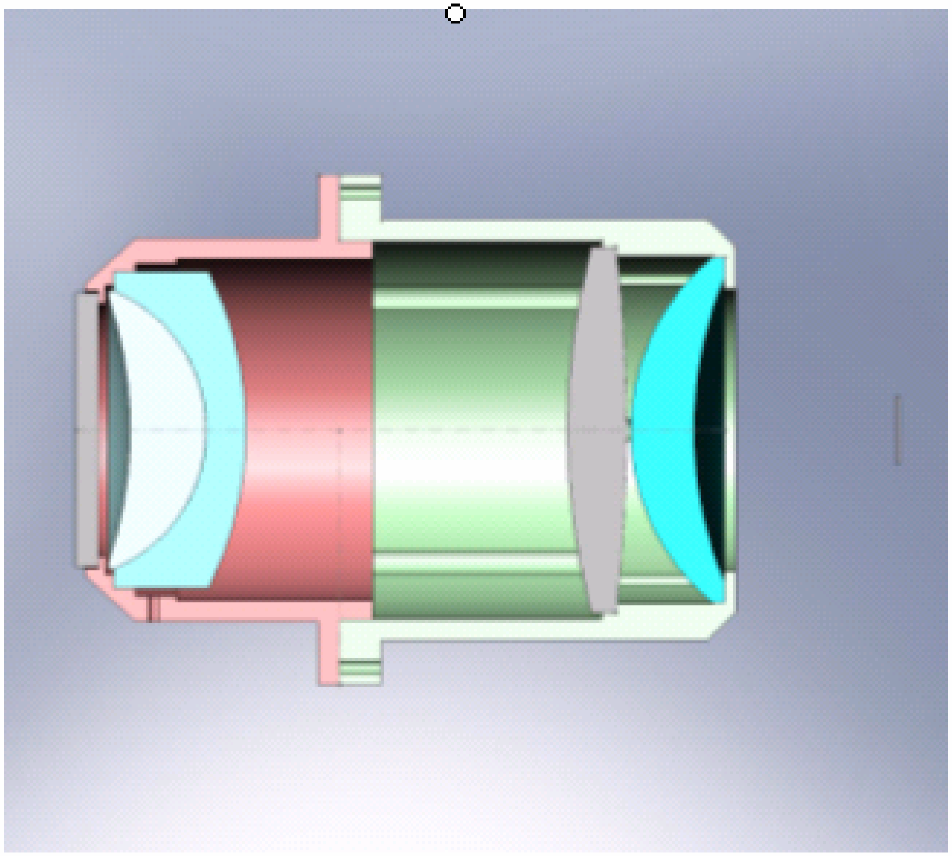


Fig. 13. A lens housing assembly design based on the optical components imported from ZEMAX.

System design and top level assembly

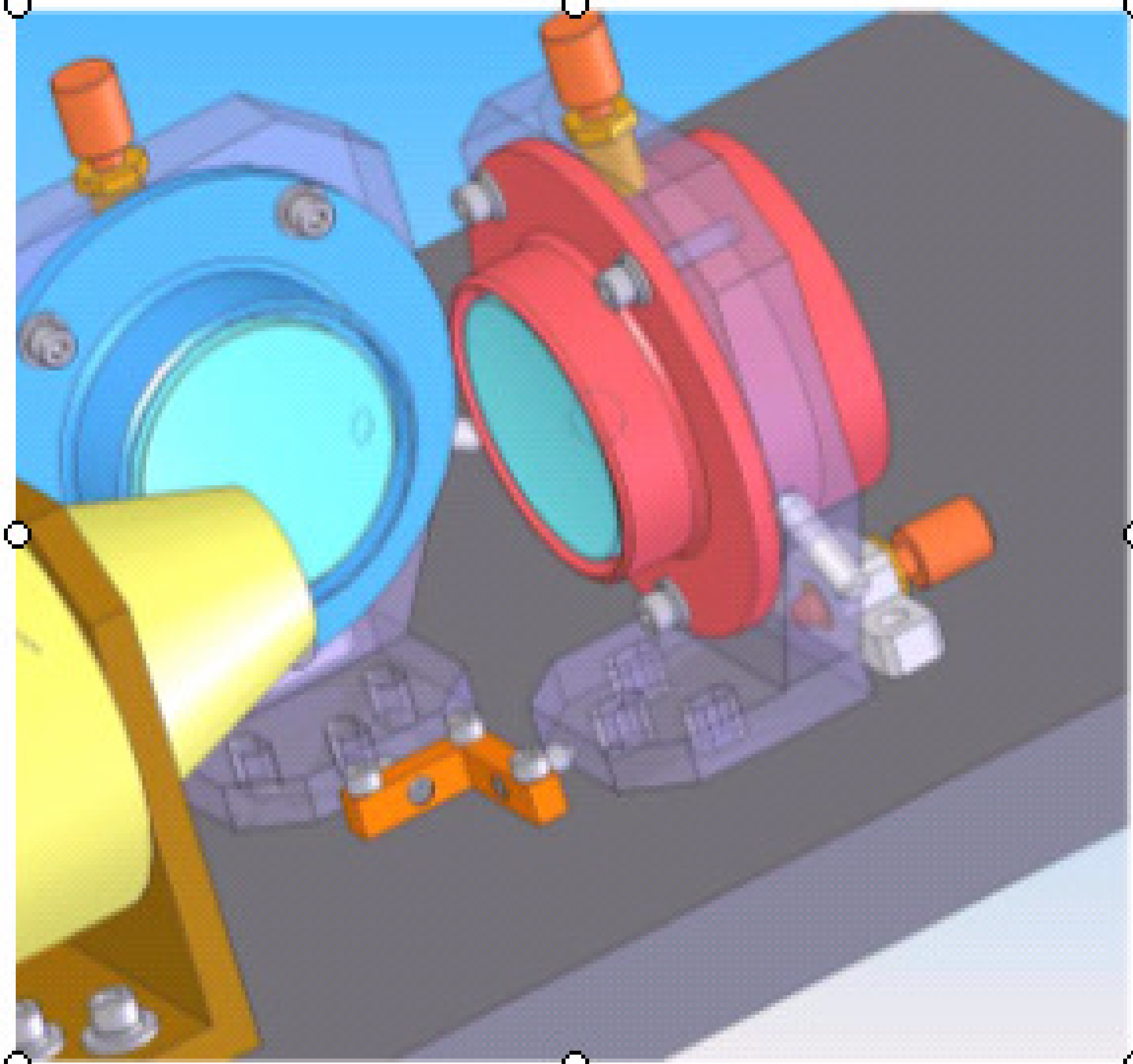


Fig. 14. Top level assembly showing alignment jigs on two lens holders.

Optical Instrument Design Program Conclusions

- Hands-on educational and design experience for students in the optics industry
- Lens design course which provides three basic skills: *manual, design code,* and *design philosophy*
- Advanced optical systems design and analysis beginning with modeling coordinate breaks, multi-configurations and evolving into systems analysis, tolerancing and athermalization.
- Optomechanical systems design and integrates the optical and the mechanical systems to perform effectively.
- Fill the growing needs of local optics companies and companies using optics.

http://oisc.net/SPIE6668-15Aug2007.pdf

Holography – Science & Art

(CACT 130) Jim Trolinger & David Cook

first class Fall 2008 or Spring 2009 - TBD

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Textbook: Practical Holography, 3rd edition, Graham Saxby

(Institute of Physics, Taylor & Francis, Inc., 2003)

Form of photography that allows a 3D image to be viewed

- **Basic optics setup: producing gratings and moiré patterns**
- **Interferometry and diffraction topics**
- **Holography lab setup**
- **What are holograms and types of holograms**
- **Making and viewing holograms**
- **Critiquing holograms and holographic art**
- **Holographic optical elements (HOE)**
- **Holographic interferometry**
- **Applications of holography: advertising, security**

--Class taught without need for a math background--

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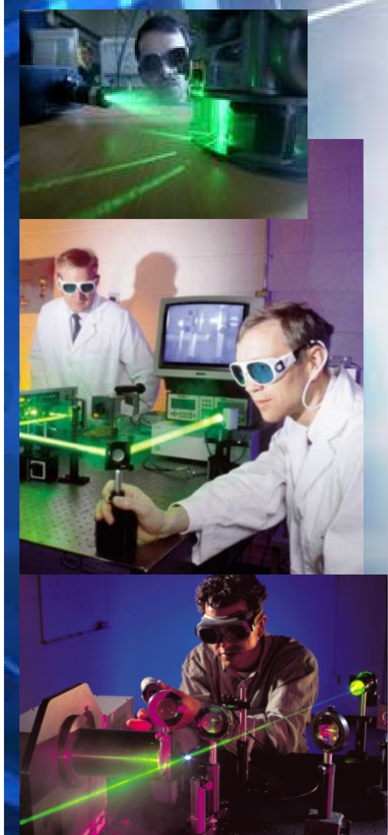
Partnerships



- Commercial Companies
  - Newport Corporation
  - Schott Glass
  - Zygo Corporation
  - Davidson Optronics
  - OptoSigma
  - Mark Optics
- Aerospace Companies
  - Northrop Grumman
  - Raytheon

Newport Corporation

1791 Deere Ave., Irvine, CA 92606

www.newport.com

Newport Puts Light to Work

Newport's Capabilities Cover a Full Spectrum of Customer Needs for Photonic Applications

Make

- Lasers
- Diode Lasers
- Light Engines

Manage

- Optics
- Optical Positioning
- Motion Control
- Vibration

Measure

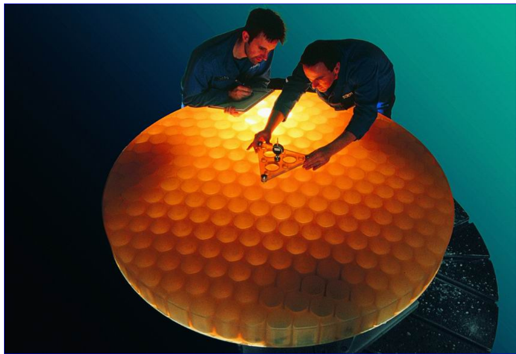
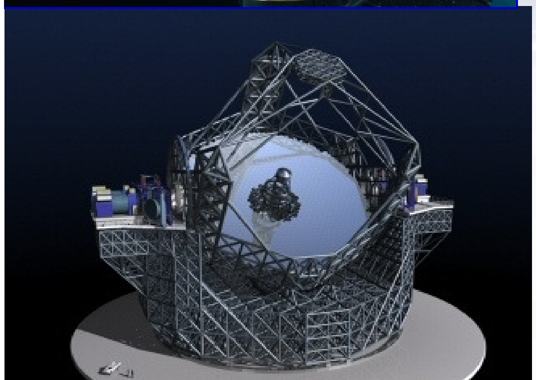
- Detection
- Feedback/Control

Putting Light to Work

Product Category Leaders

Lasers.....Spectra-Physics
Optical / Motion / VC.....Newport
Instrumentation.....Oriel
Automated Systems.....MRSI

Integrated Solutions for High Precision Photonic Applications

Schott Glass

Otto Schott is founder of modern glass technology

Company founded 1884 in Jena, Germany

Advanced materials

--Invented ZERODUR® glass ceramic having near-zero thermal expansion for telescope mirror substrates

Advanced optics

Solar energy

Fiber optics

Lithography

Home technology

--Invented CERAN® glass ceramic cooktop resisting thermal shock up to 700C

Schott Glass

26-ft. **ZERODUR®** mirror blank for
European Space Observatory in Chile.

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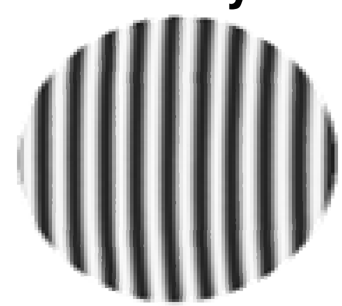
C A C T
Centers for Applied Competitive Technologies

Zygo Corporation

Headquarters in Middlefield, CT
Local Location: Zygo Optical Systems, Costa Mesa, CA

- **GPI family™ of interferometers is the industry standard for <u>noncontact</u> measurement of flat or spherical surfaces, and transmitted wavefront measurement of optical components and assemblies. When combined with Zygo's <u>MetroPro</u>™ software, the GPI systems give a wide range of operational features and data analysis tools.**
- **GPI XP/D uses the precision of *phase modulation* to show fine measurement detail on optical parts with excellent accuracy and repeatability.**

www.zygo.com



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Partnerships

- Professional Societies
  - Optical Society of Southern California, OSSC
  - Optical Society of America, OSA
  - SPIE
- Universities & Colleges
  - UC Irvine
  - UC Davis
- Non-profit Organizations
  - Optics Institute of Southern California, OISC
  - Achievement Institute for Scientific Studies, AISS

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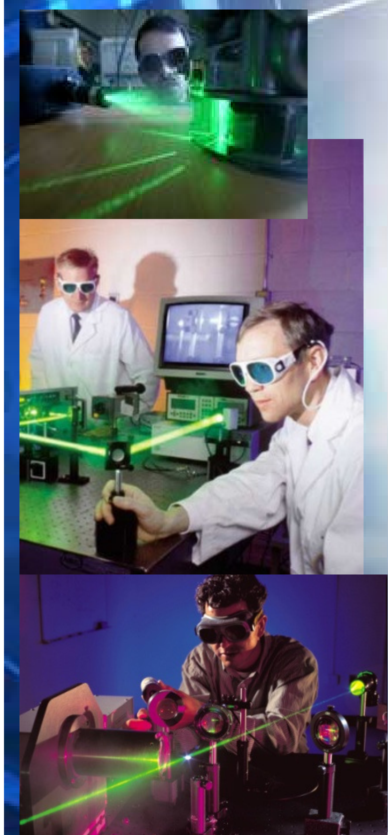
Partnerships



- Industry Advisory Committee
- Company Tours & Invited Speakers
- Donations
  - IBM San Jose
  - Newport Corporation
  - Schott Glass
  - Northrop Grumman
  - OptoSigma
  - CVI Melles Griot

Career Pathways Educational Outreach

- **Memberships**
  - Optics Institute of Southern California
  - Optical Society of Southern California
  - Achievement Institute for Scientific Studies
- **Educational Grants from SPIE**
- ***Optricks Days* at Discovery Science Center in Santa Ana** (5th Annual in March 2008)
- **Industry and University Tours**
- **CACT at ATEP Open House**

Non-profit organizations

Optics Institute of Southern California

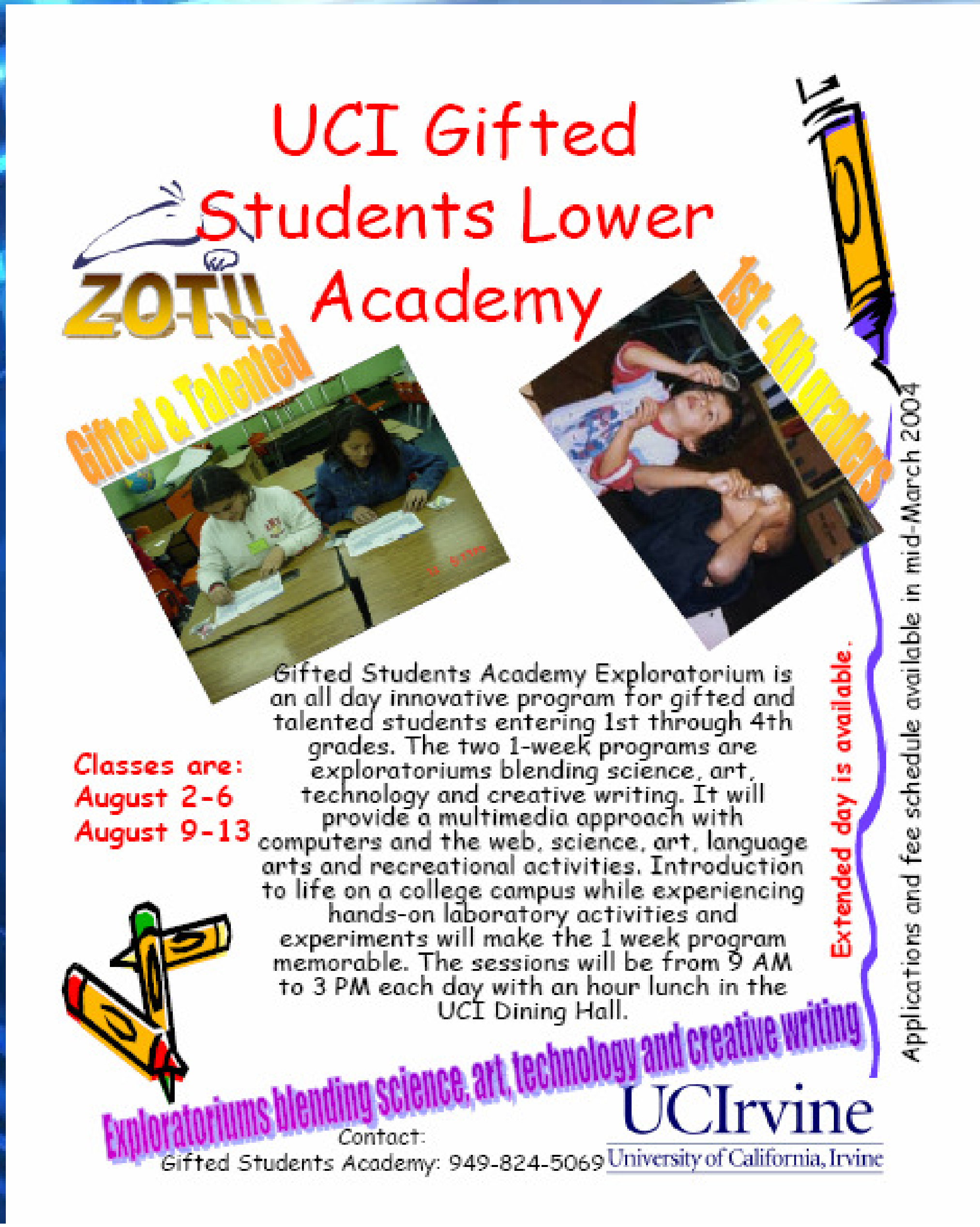
Focus on Science Education Outreach

- K-12 After-School & Summer Programs
  - Think Together, UC Irvine Gifted Student Academy
- Science Center Special Event Days
  - Discovery Science Center – Optricks Days
- Family Day Events
  - UC Irvine Beall Center for Art + Technology

http://oisc.net/SPIE6668-17Aug2007.pdf

The Optics Institute
of Southern California

First grant in 2003 from SPIE to IVC

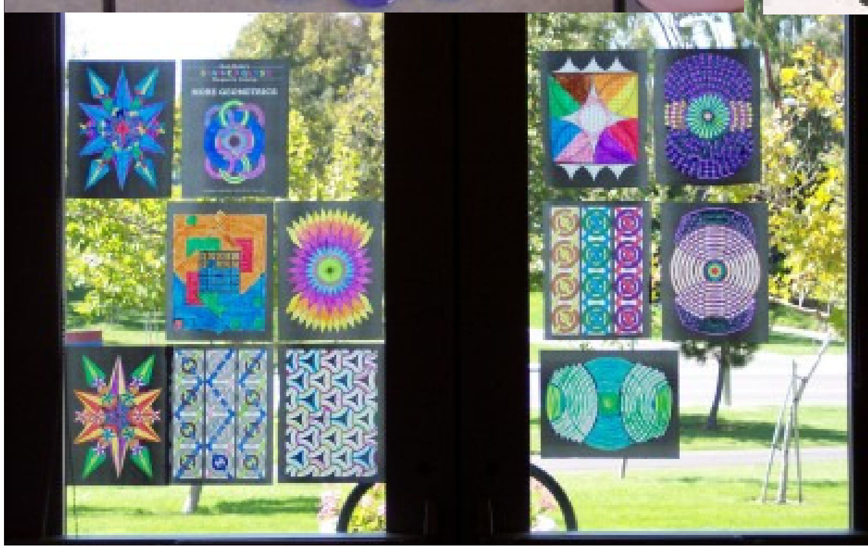


OISC received $5000 SPIE grant through Irvine Valley College to work with UC Irvine's *Gifted Students Academy* to develop and implement a HANDS-ON OPTICS program for gifted students in Grades 1-4.

This complemented the very successful Middle School program and is still going strong today.

OISC has since received other SPIE grants for additional optics programs.

Color My World (UC Irvine Gifted Student Academy)



OPTRICKS Suitcase

An Educational Outreach Presentation Guide

With Inspiration By:

Dr. Murty

The Wizard of Light

OPTICAL SOCIETY OF SOUTHERN CALIFORNIA

The Optics Institute Of Southern California

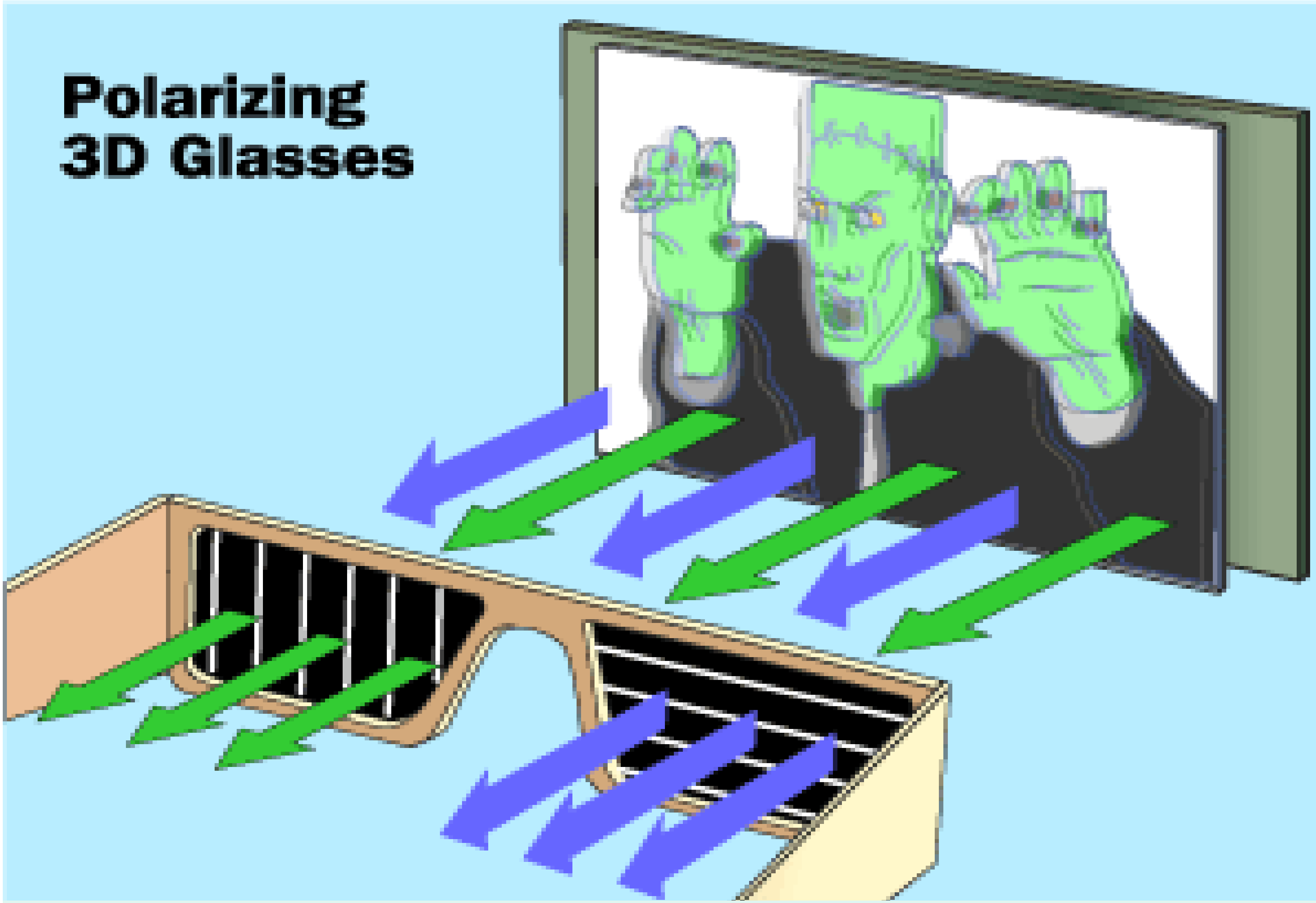
Lenses & The Magic Dots

Young students use to see the Magic Dots that are used to create color images on printed pages.

The Optricks Suitcase

Polarization Filters

Young students use an overhead projector, two linear polarizers and plastic utensils to experience polarization.



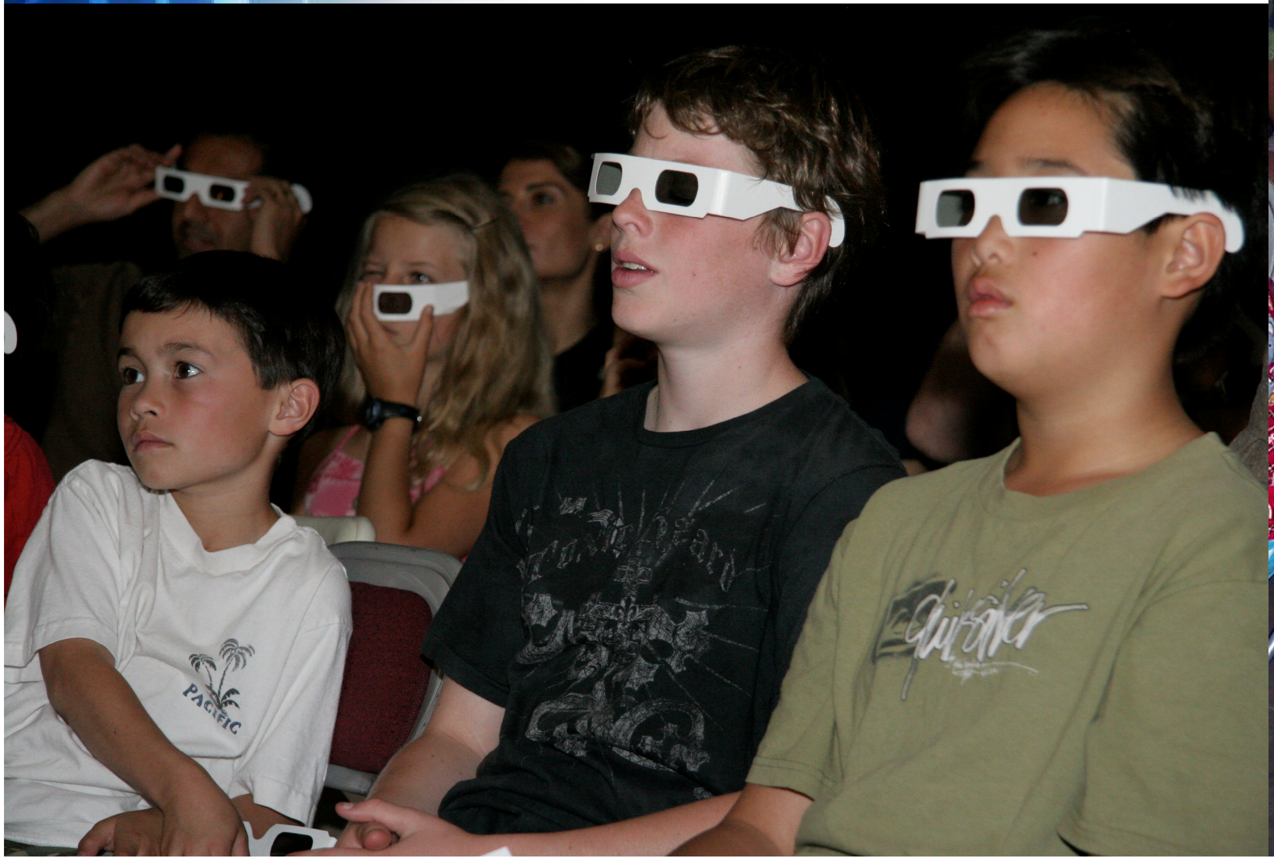
The polarized glasses allow only one of the images into each eye because each lens has a different polarization. Image courtesy of howstuffworks.com

The Optricks Suitcase

Donations from

TACO BELL
DISCOVERY
SCIENCE CENTER

3D Polarizing Glasses



CHOLESTIERIC LIQUID CRYSTALS

Teenagers investigating Cholesteric LCDs.

CHOLESTIERIC LIQUID CRYSTALS

Magic Patch Theme Packet

from the Optricks Suitcase

Diffraction Gratings

Rainbow Peephole Theme Packet from the Optricks Suitcase

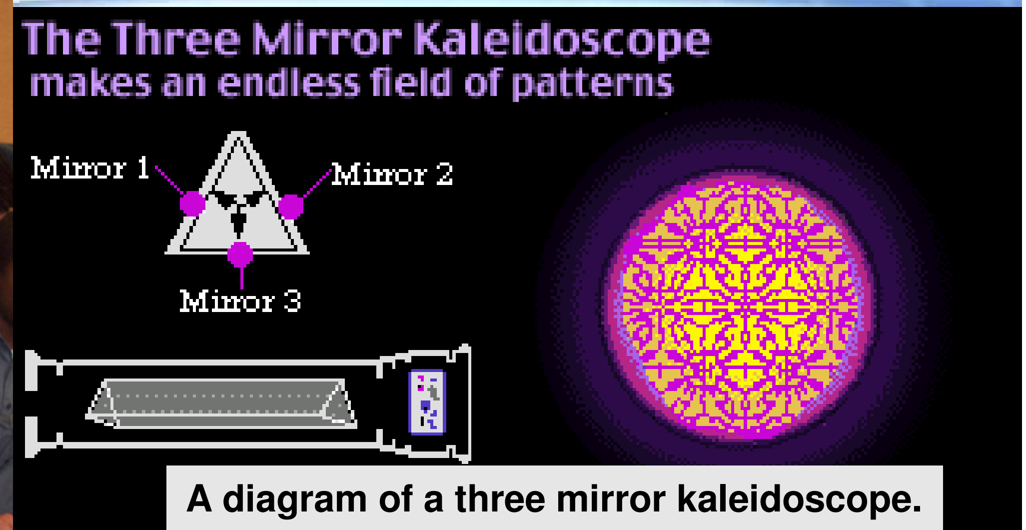
Student using the Rainbow Peephole and light.

Diffraction Gratings

Photograph taken through a Rainbow Peephole.

Kaleidoscopes


A group of Hands-On Optics students with kaleidoscopes they made.



A diagram of a three mirror kaleidoscope.


A large group of Hands-On Optics students with kaleidoscopes they made.


A group of Hands-On Optics students making kaleidoscopes.

Teen Optics Bench

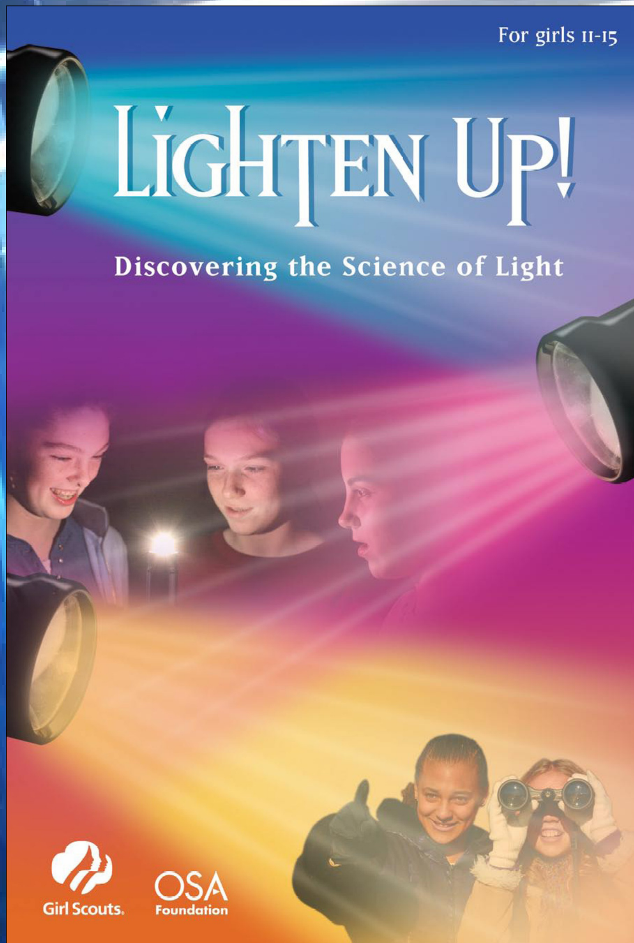
Special activities during Optricks Days @ the Discovery Science Center

An Optricks Apprentice demos the bench

A pack of cub scouts get their hands-on.

Students at a Think Together after school program – the first use of the Teen Optics Bench in 2003 - 2004

OSA & Girl Scouts of America



CHAPTER 1

Light Is

To understand optics, first you need to understand light. Light is a form of energy made up of electric and magnetic fields, called . Light comes from the sun, the stars, camp fires, lightning, flashlights, and even some living creatures like lightning bugs and some deep sea fish. There is light you can see ( ) and light you can't and .

Visible light may look white, but is it? Check out the next activity to find out!

ACTIVITY spinning your (COLOR) wheels

What You

- Pushpin
- Pencil eraser
- Ruler
- Scissors
- Markers or crayons in red, orange, yellow, green, blue, and violet
- Uncoated white paper plate (dessert or lunch size)

What You

- Trim the edge off the plate to create a flat white circle.
- Divide the circle into 6 equal sections, using the ruler and a pencil.
- Color each section a different color.
- Pull the eraser out of the top of the pencil.
- Color side up, stick the pushpin through the circle's center and into the eraser.
- Holding the handle of the pushpin, spin the circle on a hard surface like a top.

Continued...

3

Download free from the OSA or OISC websites

OSA & Girl Scouts of America

GSA Orange County Council invites the Hogwarts School of Optricks Headmaster and Apprentice

Booth Set-up with our banner

Intro to Spinning your color wheels

A big hit at the Harry Potter Carnival

AlphaNumeric Optical Inverter

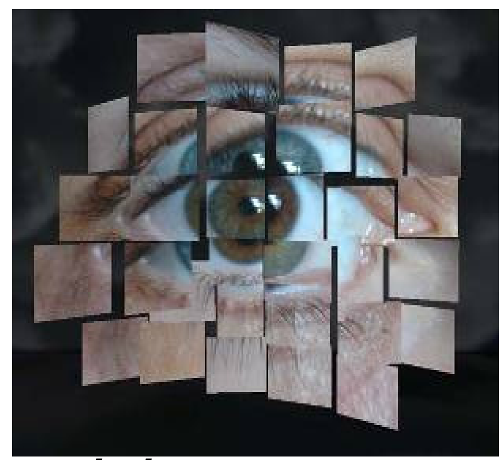
Telescope Challenge – A & B

It's all about the kids!!!

Family Day Events

University of California, Irvine
Beall Center for Art + Technology

The OISC & OSA Student Chapter @ UCI has been providing *Optricks* at the Beall Center's Family Day events since the Fall of 2006



in a thousand drops…refracted glances

Computational Poetics

Family Day February 2nd 11:00 a.m. – 3:00 p.m.

Achievement Institute for Scientific Studies (AISS)

Non-profit Organization for Orange County High Schools

- Academically gifted but economically under represented students (6 high schools involved)
- After-school programs for grades 10-12
- Extension of student's academic studies
- Company sponsored seminars and tours
- Docent training for Discovery Science Center
- Student stipends

CACT is Sponsor and Larry DeShazer is on Board of Directors

MAKING IT IN CALIFORNIA

Irvine CACT

Centers for Applied Competitive Technologies

Optricks Days
@ Discovery Science Center

Fun learning about optics – play with the real thing!!

Students having fun with the Teen Optics Benches

Centers for Applied Competitive Technologies
Assisting California Manufacturers to Compete in a Global Economy
www.irvinecact.com www.atep.us

Center for Applied Competitive Technologies (CACT) in Irvine is one of twelve chosen for the National Center for Photonics Education, a National Science Foundation Center of Excellence

NSF

Providing courses in Optics, Lasers, Fiber optics & related technologies
Irvine CACT is at your service.

The Optics Institute of Southern California
http://oisc.net

Providing Optics, Laser Fiber Optics Education & Science Outreach

ATEP Advanced Technology & Education Park

Advanced Technology & Education Park (ATEP)
15445 Lansdowne Road, Tustin, CA 92782
The OISC is A Community Partners Project

Optricks Days
5th Annual
Sat. & Sun.
March 1st & 2nd, 2008

An Activities Guide

Taco Bell Discovery Science Center

Hogwarts
School of Optricks

With Inspiration By:

Dr. Murty
The Wizard of Light

Optical Society of Southern California

The Optics Institute of Southern California

Funded in part by SPIE & OSA grants

Optricks Days

one weekend every March, since 2004

Optricks Days Activities

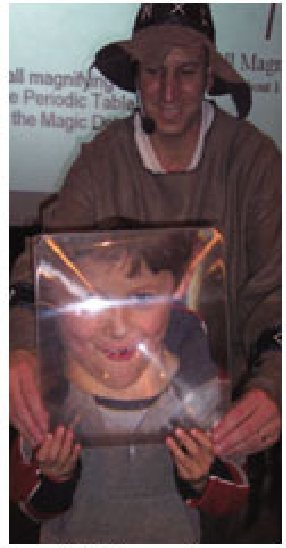
TIME	EVENT	LOCATION
10am – 4pm	Optricks Education Stations	1st Floor Exhibit Areas
11:00am	"The Optricks Suitcase" *Including Take Home Theme Packets* Exploring and applying color & optics all around us!	1st Floor – 4D Theater
12:30pm	*"Hogwarts School of Optics presents – Optics for a Greener World"*	1st Floor – 4D Theater
12:45pm To 3:00pm	*Hogwarts School of Optics Telescope Challenge and Spinning Your (color) Wheels* Teen Optics Bench Workshop *Exploring colored light & more*	2nd Floor Large Challenge Room
3pm (2:30 pm On Sun.)	"The Optricks Suitcase" *Including Take Home Theme Packets* Exploring and applying color & optics all around us!	1st Floor – 4D Theater

TACO BELL DISCOVERY SCIENCE CENTER

Lenses handed out during the Optricks Suitcase presentations have been generously donated by:

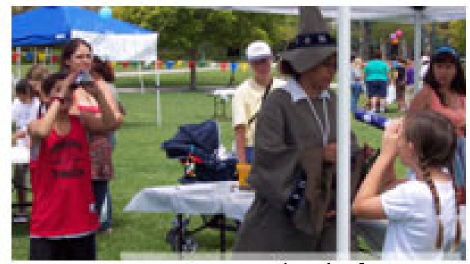
OptoSigma® Your First Source for Precision Optics and Hardware

Discovery Science Center
Main Number: 714-542-CUBE (2823)
Address: 2500 North Main Street Santa Ana, CA 92705



Fun with Fresnel Lenses & the Optricks Apprentice

Young Scouts at an Optricks Education Station



Hogwarts School of Optics Telescope Challenge

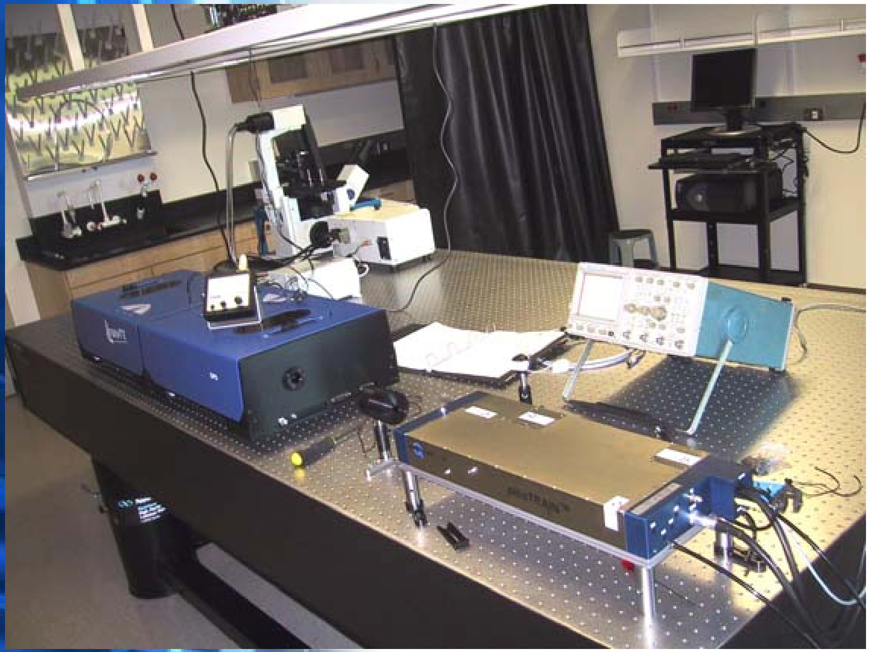
Students making "Spinning Your (color) Wheels"

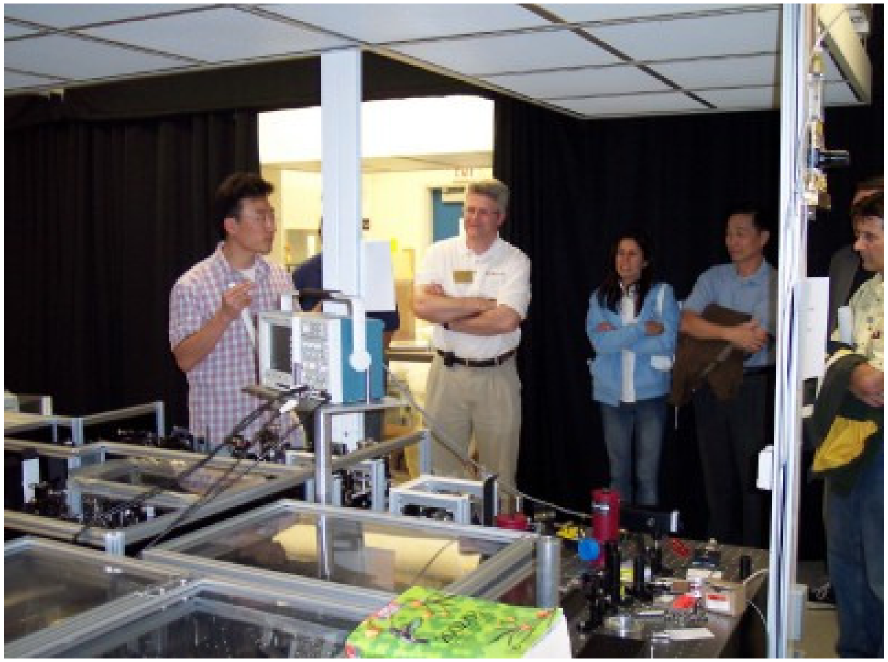
Hogwarts School of Optics Headmaster & Apprentice With new optics students

Industry & University Tours

Examples Include:

- UC Irvine, Laser Spectroscopy Labs
- Cal Tech, NanoPhotonics Labs
- Newport Corp., Advanced Optics Fabrication
- Mark Optics, Precision Optics Fabrication
- Trimedyne, Medical Lasers





Student Tour of Industry
Trimedyne Medical Lasers, Inc.
Students cutting steak with holmium laser (2μm)

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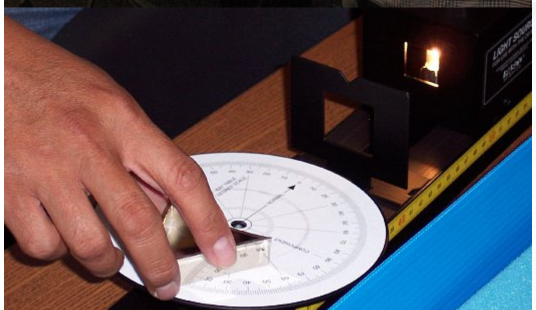

CACT @ ATEP
Open House
Oct. 2007

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IVC President Glenn Roquemore and his wife

Desire Whitmore UCI OSA Student Chapter President with guest

Community Recognition of Optics

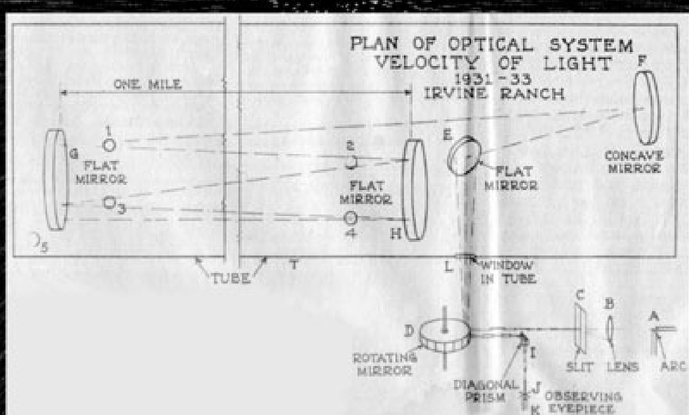
Michelson Speed-Of-Light Exhibit at Irvine City Hall

The Speed of Light

The speed of light was measured by Dr. Albert Michelson at the Irvine Ranch in the early 1930s.

Many modern physics students repeat the experiment in their college laboratory classes.

Light...What is it?
How do you measure it?



Come share a story and begin a journey that will last longer than a lifetime…it will go on for generations!

One of the important experiments in physics and optics was made at Irvine Ranch in 1931, just five blocks from CACT. It was the measurement by Albert Michelson of the speed of light in partial vacuum using an evacuated pipe, one-mile long and three-feet in diameter, in order to eliminate uncertainties in air refraction. Original experiment was parallel to Armstrong Avenue in Irvine.

The month-long exhibit at the Irvine City Hall in Oct 2004 demonstrated a modern version of the experiment using a helium-neon laser with a rotating mirror similar to the one used by Michelson in the Irvine Ranch Experiment.

Special Thanks

We would like to extend a Special Thank You to:

Dr. Larry DeShazer

Director, CACT @ ATEP

Thank You

Time for questions, answers, comments, discussions