MECHANICAL & AEROSPACE ENGINEERING

Course: ME 297-1 –Optomechanical Systems Engineering: For KLA Tencor

Course Code: OME-SJSU-MAE-KT

Semester: Fall 2011. Sept. 13 through Nov. 22

Prerequisites: Enrollment in SJSU COE masters degree program.

Credit Units: 3 Lecture

Instructor: Nayer Eradat, Ph.D.

Class: Tuesdays 4-8 PM at KLA-Tencor Bldg #1, Room 2301-Confosious

Office Hours: Tuesdays 3-4 PM at KLA-Tencor Bldg #1, Room 2301-Confosious
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Description: Application of mechanical engineering design principles to the area of optical systems engineering.
Issues and methods for defining the requirements and their relation to design of precision optomechanical systems.
Discussion of the effect of various environments into which optical systems are deployed or operated.

Course Goals:

1. To learn the <u>major principles</u> of optomechanical systems engineering
2. To learn techniques used and challenges when designing <u>athermal optical systems</u>
3. To learn <u>material characteristics</u> for use in optomechanical systems
4. To learn techniques used and challenges in <u>optical system alignment</u>.
5. To understand <u>stray light affects</u>, <u>suppression techniques surface finish selection</u>, and other system parameters affected by the <u>optomechanical interface</u>
6. <u>To design both optical and mechanical parts of a simple optomechanical system and develop an alignment system for mounting the optical components in the mechanical parts</u>

Course Format A project-based and hands on approach. Homework assignments and exams will be real problems from the industry that the students are currently working in.
Each class meeting include

- A 50-minute introductory lecture based on the reading assigned and notes prepared by the instructor, tutorials, standards, etc.
- 10 minute brake
- A 2-hour activity session including learning software and creating designs, discussions for design ideas, design reviews, etc.
- A 10 minute brake
- A 50-minute lecture on in-depth analysis of the activity and design procedure.

Student Learning Objectives:

1. An ability to create a simple optical design based on the specifications required, generate a performance report for the design using optical design software
2. An ability to create a simple mechanical design to mount a simple optical component and generate mechanical drawings.
3. An ability to combine an optical design with a mechanical design
4. An ability to understand <u>optical tolerancing</u> and <u>error budgets</u> in optomechanical systems, determine sensitivities and choose compensators.
5. An ability to develop an alignment plane and procedure.
6. An ability to <u>specify optical mounting systems</u>
7. An ability to guide <u>materials selection</u> based on advance figures of merit
8. An ability to <u>define and develop system design parameters</u> to meet various environmental conditions

9. An ability to create reports that include proposed design, and relevant reviews

Required Text: **Y: Opto-Mechanical Systems Design, by Paul Yoder. CRC Press**
V: Introduction to Opto-Mechanical Design By D. & S. Vukobratovich (out of print in process of getting permission from the author for in-class handouts)
CV: CodeV Introductory User's Guide
LN: Online Lecture Notes (available at http://www.erbion.com/courses.htm)

Course website: **All the lecture notes, HW assignments and supplementary learning resources will be available from the course website at: http://www.erbion.com/courses.htm**

Required Software: **Code V Educational License + CodeV Introductory User's Guide**
SolidWorks or AutoCAD Educational License

References: Handbook of Optomechanical Engineering, by Anees Ahmad, CRC.
Modern Optical Engineering, by Warren Smith, McGraw Hill
Mounting Optics in Optical Instruments, by Paul Yoder, SPIE Press
Optical Systems Design, second edition, by .Fsher, Tadic-Galed, and Yoder. SPIE Press 2008
Introduction to Opto-Mechanical Design By D. & S. Vukobratovich

Grading:

Homework	30%
Midterm project / report	30%
Final project / report	40%

College and Departmental Policies

Academic Integrity Statement

University's Academic Integrity Policy is available at http://www.sa.sjsu.edu/download/judicial_affairs/Academic_Integrity_Policy_S07-2.pdf. Your own commitment to learning, as evidenced by your enrollment at San Jose State University and the University's integrity policy, require you to be honest in all your academic course work. Faculty members are required to report all infractions to the office of Student Conduct and Ethical Development. The website for Student Conduct and Ethical Development is available at http://www.sa.sjsu.edu/judicial_affairs/index.html . Instances of academic dishonesty will not be tolerated. Cheating on exams or plagiarism (presenting the work of another as your own, or the use of another person's ideas without giving proper credit) will result in a failing grade and sanctions by the University. For this class, all assignments are to be completed by the individual student unless otherwise specified. If you would like to include in your assignment any material you have submitted, or plan to submit for another class, please note that SJSU's Academic Policy F06-1 requires approval of instructors.

Campus policy in compliance with the Americans with Disabilities Act

"If you need course adaptations or accommodations because of a disability, or if you need special arrangements in case the building must be evacuated, please make an appointment with me as soon as possible, or see me during office hours. Presidential Directive 97-03 requires that students with disabilities register with the DRC to establish a record of their disability."

Dropping and Adding

Students are responsible for understanding the policies and procedures about add/drops, academic renewal, etc. Information on add/drops are available at http://info.sjsu.edu/web-dbgen/narr/soc-fall/rec- 298.html . Information about late drop is available at http://www.sjsu.edu/sac/advising/latedrops/policy/ **.** Students should be aware of the current deadlines and penalties for adding and dropping classes.

Tentative Course Topics and Schedule:

Week: wk; Number of hours: h; Workshop: ws; Lecture: lec

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Yoder: Y; Online lecture notes: LN; CodeV introductory user guide: CV; Vukobratovich: V

wk Date	hrs	Class / content / knowledge	Reading & Assignment	Objectives /Skills
1 9/13	1h lec	Course overview and structure Teaching method Student learning objective Expectations for technical reports. Intro to Optomechanical Engineering (OME)	Y1 (means Yoder chapter 1) LN1 (Lecture notes 1)	Understand role of the optomechanical engineer (OME) in general Write quality, concise technical reports Understand key issues to be addressed in a technical report
	2h lec	Optical system terminology refresher Nature of light and basic laws First order optics of lenses & mirrors, ray tracing	LN2	Dual nature of light, harmonic wave properties, index of refraction, dispersion, Abbe number, Snell's laws, definition and purpose of optical systems, OPL, wavefront, phase, ray tracing, diffraction, matrix methods, cardinal points and planes, object, image, cardinal point relationships, system LOS, magnification, image orientation, thin prisms
	1h ws	Ordering and installation of the software Overview of the CODE V	CV1 & CV2 Creating a simple optical design using a ray trace program	Software intro and how to purchase
2 9/20	0.5h lec 20 min Talk	Basic optics terminology (continued) Clear aperture, vignetting, Aberrations Optomechanical System requirements and design guidelines at KLA-Tencor by Guest Speaker	LN2	field of view, apertures & stops, Understand role of the optomechanical engineer (OME) and how is it done at your company
	2h ws	Analyzing performance of a simple optical design, Aberrations	CV2 Optical analysis of simple optical system using ray trace program	Understand Aberrations Reporting the performance
	1h lec	Beam walk, Image motion, optical invariant, introducing misalignment & error	LN3	Calculate image shift for 6 degrees of freedom motion of lens, mirror, window Decompose rotation about one point to rotation about another point plus translation Calculate image shift for rotation of optical system about an arbitrary point for object at infinity. Calculate image shift for a general case of any element motion
3 9/27	1h lec	Prisms: names, properties, and applications of common prisms, definitions for technical reports	LN5 Y7.1-3	Determine elliptical beam footprint onto a tilted plane (like a mirror); Tunnel diagrams
	2h ws	Optical vs. misalignment sources of aberrations System line of sight (LOS) and Root Sum Square (RSS) Error budgets and tolerances in optomechanical systems	LN4 CV3 Analysis of aberrations and m alignments in a ray tracing program,	Understand issues for RSS combination Estimate RSS combination for large number of parameters Error analysis and error budgeting for coupled and independent sources of error.
	1h lec	Mirror Matrices: definition of mirror matrices	LN6 Y8.1-2	calculate mirror matrix for set of reflections determine mirror matrix from inspection apply mirror matrices to determine effects of prism rotations
4 10/4	1h lec	Machining and measurements Common machining methods – limitations Common measuring methods –	LN7 Videos of mechanical processing techniques	Calculate effects of Abbe offset

		limitations		
	2h ws	Tolerancing Optical Systems Systems engineering approach to tolerancing Tolerancing and ray tracing	LN8; CV4 & 5 Tolerance analysis of simple optical system using ray trace program	Build tolerance table, adjust for performance Define compensator for tolerancing Use rules of thumb for initial mechanical tolerancing
	1h lec	Preparation of the report for the midterm on tolerancing		
5 10/11	2h ws	Tolerancing of Optical components Relationship between optical element specifications and system performance Lens centration, wedge what it means and how it relates to manufacturing	LN9; CV6 & 8 Tolerance analysis of a optical component in relation to system performance using ray trace program	Specify lens wedge Specify optical surfaces Specify optical glass Specify scratch/dig for surfaces Apply rules of thumb for setting requirements
	2h	**Midterm report /discussion Discussion and review of the tolerancing**	Report on tolerncing a simple optical design project	Presenting a quality professional report on tolerancing.
6 10/18	1h lec	Technical drawings Understand the use of datum surfaces, used for reference	LN10	Create three-view orthographic projections Use center lines, leaders, callouts, Correctly specify dimensions and tolerances on drawings sketch isometric layout for simple solids
	1h lec	Optomechanical drawing standards ANSI Y14.5 convention GD&T conventions ISO 10110	LN11	Use ANSI Y14.5 convention to specify tolerances for straightness, flatness, roundness, profile, perpendicularity, parallelism, concentricity, position, and runout. Specify basic dimensions and tolerances using GD&T conventions Know how optical components are specified with ISO10110
	2h ws	Mechanical design Creating engineering drawings	Installation and getting started with AutoCAD	
7 10/25	1h lec	Optomechanical design introduction Statics Definition of force, moment, static equilibrium Familiarity with methods of joints and sections for frames and machines	LN12	Statics Create free body diagram Apply static equilibrium to determine reaction forces Determine constraint conditions for simple cases
	2h ws	Intro to mechanical design software	Final project proposal introduction Design of a simple mount for one or two optical components	
	1h lec	Kinematic constraints Understand principles of kinematic constraint Understand usefulness and limitations of semi-kinematics Stress and strain Understand normal and shear stress and strain, Poisson effect Definition of material properties E, G, E_B , ν, σ_y , σ_{PEL} σ_{ULT}	LN13 Y2-3 LN14 Y7.4-7 Y4-13	Kinematic Constraints S Define kinematic and semi-kinematic interfaces S Calculate stiffness and stress for point contacts Stress and Strain Calculate elongation due to normal loads Determine effective stiffness for combination of series – parallel load paths Use bulk modulus to determine stiffness of constr layer
8 11/1	1h lec	Deflections under loading Understand solid mechanics of deformations for beams with simple loading – axial, shear, torsion, bending	LN15 Proposal review and discussion / approval	Calculate I, J for simple geometry, look it up for more general cases Use tables to determine angular and lateral deflections of beams for simple loading Use superposition to determine beam deflections for more general cases

				Use superposition to solve problems that have overconstraint Apply Maxwell's reciprocity to simple cases Calculate stiffness for simple geometry, determine resonant frequency Assess stability for Euler buckling
	1h lec	<u>Thermal Distortions</u> Understand thermal expansion Know about materials with very low CTE	LN16 Y14.5 V pp 81-95	Calculate thermal distortion for simple cases Apply material conductivity to determine thermal gradient, heat flux Apply thermal diffusivity to determine conductive time constant Athermalize using different materials, geometry
	0.5h lec	<u>Optical materials and athermalization</u> Know approximate values of all common material constants for BK7 Familiarity with special issues for common classes of materials,	LN17 Y3 Y15.1-6	Calculate change in focus due to temperature for simple optical systems Athermalize mechanical distances, optical systems
	0.5h lec	<u>Mechanical Materials</u> Know approximate values of all common material constants for aluminum Familiarity with special issues for common classes of materials knowledge of important constants	LN18 V pp 6-48 Y3.4	
	0.5h lec	<u>Fasteners</u> Definitions of metric and English fasteners Familiarity with types and sources of specialty hardware	Will post later	Use tables to find dimensions and torque settings for common fasteners Find and procure fasteners and specialty hardware
	0.5h lec	<u>Adhesives</u> Familiarity with classes of adhesives, issues, methods	LN21 V pp 6-48 &121-129 Y3.5	Calculate stiffness for elastomeric adhesives Calculate thermally induced stress for simple bonded joints
9 11/8	1h lec	<u>Shock and Vibration</u> Dynamic response for Mass-spring-damper system Definition of PSD, acceleration spectrum	LN19 V pp 96-113 Y pp 45-54	Estimate performance of vibration isolation system Estimate shock loading for simple case
	1h lec	<u>Flexures and adjustments</u> Understand 6 DoF constraints, adjustments Understand use of flexures to constrain some and allow other degrees of freedoms Use of flex pivots, blade flexures Use of geometry, differential flexure for small motions.	LN22	Specify use of shims, preloaded screws push-pull screws for adjustments Use liquid pinning for stable connection Choose materials for flexures Calculate stiffness for simple flexures
	1h lec	<u>Stages and motion control</u> Understand elements of any translation or rotation stage Understand geometry of hexapod for motion control	LN23 V pp 117-161	Calculate effect of angle coupled through Abbe offset Trade off different issues and be able to choose stages - linear stage - rotary stage - tilt stage
	1h ws		Project progress check	
10 11/15	1h lec	<u>Concepts for mounting optical elements</u> Understand how to define 6 DoF constraints Understand issues for choosing glass-metal interface - control of position and geometry, coupled with manufacturing tolerance - limit stress due to thermal and shock loading	LN24 V: PP166-311	Choose between mounting concepts: clamping and bonding Estimate thermal survival for bonded joints

	1h lec 1h ws	<u>Mounting of lenses</u> Separate the functions of the mount: safe constraint and dimensional precision. Understand the techniques used to achieve tolerances that are tighter than the machining precision <u>Mounting of windows</u> Mounting techniques for windows	Y4 & 5 Developing an alignment plan for an optomechanical system	Design simple lens barrel for multiple lenses Understand difference between mechanical and optical surfaces of a lens and how to mount them with required accuracy Calculate stresses for pressure windows
	1h	<u>Mirror mounts</u> Understand basics for controlling mirror errors - fully constrain the rigid body degrees of freedom - not over constrain and distort the mirror - allow thermal expansions - avoid applying moments Sources of error for mirror mounts	Y8 V: pp 243-311	Defining simple bonded or clamped mount for small mirror Estimating performance of simple bonded or clamped mirror mount
11 11/22	1h lec	<u>Stray light analysis</u> Description of stray light and scattered light. Introduction to suppression techniques. Optical black finishes. Reflectance and BRDF		How to minimize the stray light, Ability to interpret the effect of the stray light in system performance data.
	1h lec	<u>Optomechanical Systems</u> Familiarity with system-level design, tradeoffs Familiarity with incorporation of assembly and alignment plan as part of system design	Y14 Final stages of the design, reviews, generating repots	
	2h	Overview and wrap up. Concluding remarks. Course evaluation	Final exam report / Final interview and presentations in design review format	Reporting and presentation, managing a design review.