ME EN 5960/6960
Laser-based Manufacturing and Materials Processing
Syllabus for Spring 2017 (Draft)

Instructor: Wenda Tan, Ph.D., Assistant Professor
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Lecture time: TBD
Course website: CANVAS
Office Hour: TBD

Textbook:

Background:
Significant advances of lasers have been achieved in the last decades, which has considerably broadened the capability of lasers to process various engineering materials. Therefore, lasers have been widely used in the manufacturing of many industry sectors, including energy, aerospace/aeronautics, automotive, medical, electronics, etc.

Depending on the different power intensity level of the lasers, the irradiated materials can be heated, melted, evaporated, and even ionized, and hence the geometry, properties, and/or appearance of the materials will be modified. Multi-physics, including laser-matter interaction, heat/mass transfer, fluid/solid mechanics, and phase/microstructure change, etc., can occur simultaneously to affect the materials being processed. A good understanding of the complex physics in the laser materials processing is crucial for the improvement of accuracy, efficiency and product properties in these processes.

Objectives:
This course will provide students with a fundamental understanding of the lasers and the physics in various laser-based manufacturing and materials processing techniques. The students will also be exposed to different analytical and numerical models that capture the physics in material processing techniques (not limited to laser-based ones). Opportunities will be created for the students to explore the possibilities of using laser-based techniques in their own research areas.

At the end of the course the students are expected to
- Understand the basics of laser physics, laser optics, and laser-materials interaction;
- Understand the phenomena of heat transfer, fluid/solid mechanics, and phase/microstructure change in typical laser-based manufacturing and materials
processing techniques;

- Understand the basic analytical and numerical methods to investigate the heat transfer, fluid/solid mechanics, and phase/microstructure changes in various manufacturing and materials processing techniques.

**Pre-requisite:**
This course covers various advanced topics in manufacturing and materials processing, so the students must have taken the following pre-requisites:

- MSE 2010 - Introduction to Materials Science and Engineering
- ME EN 2650/4060 – Manufacturing of Engineering Systems

The students will better understand the course contents if they have taken some of the following courses:

- ME EN 2300 - Thermodynamics I
- ME EN 2450 - Numerical Methods for Engineering Systems
- ME EN 3650 - Heat Transfer
- ME EN 3700 - Fluid Mechanics

**Course Structure:**
The course will comprise of classes, homework, term project and exams.

- Classes: In classes, the basic principles and characteristics of selected processes will be discussed through instructor lectures, video demonstrations and in-class discussions.
- Homework: Homework will be assigned on a regular basis. Homework will include short-answer questions, calculations problems and numerical modeling problems.
- Term project: A term project will be assigned to individual students. The deliverables include a written report and an oral presentation to the class. The term project will be in one of the following formats (to be determined).
  a) A literature study of a novel laser-based materials processing technique
  b) A proposal of utilizing an existing laser-based materials processing technique for the current research of the students.
  c) A project to use numerical modeling technique to investigate a specific problem in a selected laser-based materials processing technique.
- Exams: There will be one mid-term during the regular class hour, and one final exam (comprehensive) at the end of the semester.

To accommodate the differences between graduate and undergraduate students, the two groups of students will be assigned different homework, term project and exams.

**Course score and grade:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Homework</td>
<td>25%</td>
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<tr>
<td>Mid-term</td>
<td>15%</td>
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<tr>
<td>Final (comprehensive)</td>
<td>25%</td>
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<tr>
<td>Term project</td>
<td>35%</td>
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<tr>
<td>Total</td>
<td>100%</td>
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</tbody>
</table>
Grades: A (94 and higher), A- (90-93), B+ (87-89), B (83-86), B- (80-82), C+ (77-79), C (73-76), C- (70-72), D+ (67-69), D (63-66), D- (60-62), E (59 and below)

Tentative lecture schedule: (designed based upon 2016 spring calendar, subject to changes)

<table>
<thead>
<tr>
<th>Week 1-T</th>
<th>Introduction of laser-based materials processing</th>
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<tbody>
<tr>
<td>Week 1-Th</td>
<td>Fundamentals of Lasers</td>
</tr>
<tr>
<td>Week 2-T</td>
<td>Laser optics</td>
</tr>
<tr>
<td>Week 2-Th</td>
<td>Laser matter interaction</td>
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<tr>
<td>Week 3-T</td>
<td>Laser matter interaction</td>
</tr>
<tr>
<td>Week 3-Th</td>
<td>Laser hardening: physics, process and applications</td>
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<tr>
<td>Week 4-T</td>
<td>Modeling of solid-state phase transformation</td>
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<tr>
<td>Week 4-Th</td>
<td>Laser bending: physics, process and applications</td>
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<tr>
<td>Week 5-T</td>
<td>Modeling of thermo-mechanical behavior in materials processing</td>
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<tr>
<td>Week 5-Th</td>
<td>Laser annealing: physics, process and applications</td>
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<tr>
<td>Week 6-T</td>
<td>Laser re-crystallization: physics, process and applications</td>
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<tr>
<td>Week 6-Th</td>
<td>Laser direct deposition: physics, process and applications</td>
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<tr>
<td>Week 7-T</td>
<td>Selective laser sintering/melting: physics, process and applications</td>
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<tr>
<td>Week 7-Th</td>
<td>Modeling of thermo-fluid phenomena</td>
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<tr>
<td>Week 8-T</td>
<td>Fundamentals of solidification</td>
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<tr>
<td>Week 8-Th</td>
<td>Modeling of free surface motion in solidification</td>
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<tr>
<td>Week 9-T</td>
<td>Midterm Exam</td>
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<tr>
<td>Week 9-Th</td>
<td>Laser welding: physics, process and applications</td>
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<tr>
<td>Week 10-T</td>
<td>Spring break</td>
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<tr>
<td>Week 10-Th</td>
<td>Spring break</td>
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<tr>
<td>Week 11-T</td>
<td>Laser drilling/cutting: physics, process and applications</td>
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<tr>
<td>Week 11-Th</td>
<td>Modeling of free interface motion in laser additive manufacturing, welding, drilling and cutting</td>
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<tr>
<td>Week 12-T</td>
<td>Laser shock peening: physics, process and applications</td>
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<tr>
<td>Week 12-Th</td>
<td>Laser forming: physics, process and applications</td>
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<tr>
<td>Week 13-T</td>
<td>Laser micro-machining: physics, process and applications</td>
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<tr>
<td>Week 13-Th</td>
<td>Numerical modeling of plasma physics</td>
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<tr>
<td>Week 14-T</td>
<td>Laser surface texturing: physics, process and applications</td>
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<tr>
<td>Week 14-Th</td>
<td>Term project presentations</td>
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<tr>
<td>Week 15-T</td>
<td>Term project presentations</td>
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<tr>
<td>Week 15-Th</td>
<td>Review for final exam</td>
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