

Advanced Laser Manufacturing Experience in China

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ABSTRACT: We report our trip to China for advanced laser manufacturing in the Laboratory for Laser Intelligent Manufacturing at the Institute of Mechanics, Chinese Academy of Sciences, Beijing. Both the PI and the graduate student had extensive interactions with the researchers in the host institution during the IREE program. The PI was invited for a lecture in laser nanomanufacturing and the graduate student conducted 11-week research in laser direct fabrication of metallic parts in free-form in the host institution. This experience will enhance our current NSF award by learning new laser manufacturing processes, systems, and applications. From this experience, we plan to launch larger programs like organizing US-China workshops in laser manufacturing by inviting leading researchers in this field from both countries, and establishing a long-term exchange programs in collaboration.

INTRODUCTION

The objective of current NSF award is to develop an efficient, accurate, and low-cost laser direct-write process for fabricating a sub-micron dent array on precision components to enhance fatigue performance. A synergistic experimental, theoretical, and computational study is being conducted. The research approach is to develop a massively parallel laser direct-write process for fabricating a sub-micron dent array on precision surfaces, and create a finite element analysis model to capture mechanical behaviors at pertinent small scales to understand the mechanisms of laser/material interactions and predict dent geometry, transient and residual stress, and surface material properties. The broad impact includes an efficient and cost-effective surface treatment process for making micro surface structures with high efficiency, high accuracy, and low cost to meet production needs. The research supports the economy by improving the U.S. position in the manufacturing industry.

This IREE award support international research experiences for a graduate student, Wei Wang and the PI in the *Laboratory for Laser Intelligent Manufacturing* at the Institute of Mechanics, Chinese Academy of Sciences, Beijing, China. Dr. Chen's travel dates are from June 8 to July 18, 2007. Wei Wang's travel dates are June 1 to August 21, 2007.

Laboratory for Laser Intelligent Manufacturing (LLIM) is at the Institute of Mechanics, Chinese Academy of Sciences. The Institute of Mechanics (IMECH) is a flagship research institution devoted to the study of various branches of theoretical and applied mechanics including materials and mechanics issues in laser manufacturing. At present, there are 350 staff members in the Institute, including 240 professionals and technicians, among which there are 8 members of Chinese Academy of Sciences and Chinese Academy of Engineering (Academicians), 50 research professors, and 110 associate research professors and senior engineers.

The *Laboratory for Laser Intelligent Manufacturing (LLIM)* is one of the leading research laboratories for intelligent laser manufacturing in China, led by Professor Gang Yu (http://english.imech.ac.cn/research/5_technology.htm). The focus of LLIM's research is on laser manufacturing systems while the PI's group concentrates on laser manufacturing processes especially in small scales. Research collaboration between these two groups will definitely leverage the complementary strengths for research in advanced laser manufacturing.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION

The PI and the foreign partner, Professor Gang Yu at IMECH have established initial contact in the past year. In June 2005, the PI visited Prof Yu and his *Laboratory for Laser Intelligent Manufacturing (LLIM)* in China. As part of the visit, the PI gave an invited seminar in LLIM and IMECH. As a return, Professor Yu visited the PI's laboratory from February 11 to 17, 2006 as a visiting professor. Professor Yu offered a lecture on laser intelligent manufacturing during this visit. The PI has given a lecture in LLIM during the visit and signed an Agreement for further collaboration between the two groups as a result of this visit. The graduate student, Wei Wang spent 11 weeks in LLIM, working on direct laser fabrication (DLF) of metallic parts with Prof. Yu's researchers. He also attended weekly group meetings of LLIM.

Direct laser fabrication (DLF) is an advanced manufacturing technology, which developed from laser cladding and rapid prototyping techniques. During the fabrication process, metal powder is injected from a powder feeder into the molten pool on a substrate to form laser claddings and layers along former designed filling paths. Then the successive claddings and layers are metallurgic fusion bonded to the substrate layer by layer. The DLF technique can fabricate near net-shape metal parts with complex geometry. Wei's research activities include two components:

- (1) Setting up the direct laser fabrication system, which includes a HLD 1001.5 laser, CNC-machine, powder feeder and a coaxial nozzle.
- (2) Studying the fabrication method for large scale metal part using stainless steel 316 L.

The fabrication system included a 5-axes CNC-machine, an Nd:YAG laser HLD 1001.5 with a maximum output power of 1 kW. The deposition was carried out with stainless steel 316 L powders onto C45 carbon steel plates using coaxial powder feeding method. Figure 1 shows the CNC-machine, the coaxial nozzle and powder feeder.

Experimental material and parameter:

- The material used in the experiment is stainless steel 316, with the chemical composition as shown below:

Table 1. Chemical composition of the stainless steel material

Material	Ni	Cr	Mo	Fe
Stainless steel 316	12 ~ 14	16 ~ 18	2 ~ 3	others

- Laser power: 700W, diameter of the laser spot: 3mm, the height of each layer(z-increment Δz): 0.25mm, table feeding rate v : 500 mm/min.

We have successfully fabricated a large scale (200mm×150mm×3mm) metal part using the fabrication method. We will measure the mechanical properties (tensile strength, percentage elongation, etc.) of the metal part. We will also study the effects of experiment parameters for large scale metal parts fabricated by direct laser fabrication.

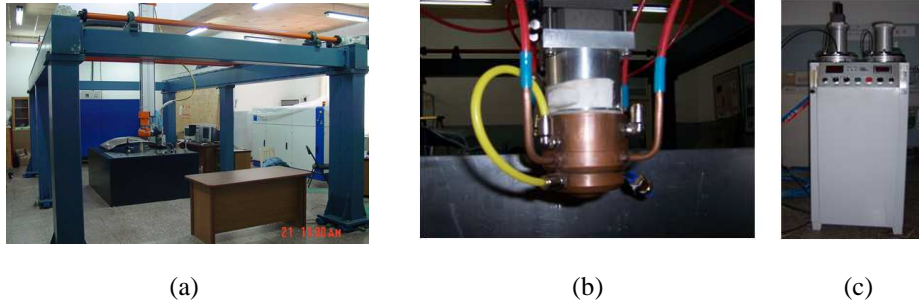


Figure 1. (a) The CNC-machine in LLIM, (b) The coaxial nozzle, (c) powder feeder for DFL.

The participating graduate student, Wei Wang used this IREE opportunity to learn the components of laser intelligent manufacturing in LLIM, including laser systems, computer control, materials analysis, and the numerical simulation codes developed in LLIM. These experiences will be very useful for the NSF funded project: “CMMI 0555275-Massive Parallel Laser Direct-Write of Sub-micron Dent Array for Quantum Leap of Fatigue Performance”.

BROADER IMPACTS OF THE INTERNATIONAL TRAVEL

As China is becoming the global factory for manufacturing, this IREE experience is just-in-time to learn advanced laser manufacturing. It will expand the original scope of the current award by looking at larger scale direct laser manufacturing of metallic parts of net

shapes. This trip will lay down the foundation for future collaboration between Dr. Chen's group and this leading laser manufacturing group in China. We plan to use this trip as a steppingstone and in the future we would like to have the following events:

- Co-organize US-China workshops in laser manufacturing in Beijing, China by inviting other leading researchers in laser manufacturing from both China and US.
- Establish a long-term exchange program between the two groups by sharing laser equipment and exchanging researchers.

DISCUSSION AND SUMMARY

In summary, this IREE trip has been a wonderful experience for both the graduate student and the PI. The graduate student learned a lot in laser direct fabrication of metallic parts in freeform in the leading laser manufacturing group in China. This experience will enhance our current NSF award in laser texturing metals in a micro and nanoscale. More importantly, this IREE program will allow us to build a long-term, strong collaboration between our two groups. We will use this experience as a steppingstone for future larger scale efforts in international collaboration.

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BRIEF BIOGRAPHIES OF RESEARCHERS

Shaochen Chen received the Ph.D. degree in Mechanical Engineering from the University of California, Berkeley, in 1999. Currently, he is an Associate Professor with the Mechanical Engineering Department at the University of Texas at Austin. His research interest lies in nano/micro-scale laser materials processing, biomaterials and nanomedicine, nanophotonics, and MEMS/NEMS. Dr. Chen received a CAREER Award from the National Science Foundation in 2001, an Outstanding Young Manufacturing Engineer Award from the Society of Manufacturing Engineers in 2002, and a Young Investigator Award from the Office of Naval Research in 2004. He received AIAA Best Paper award in 2006. He is a committee member of the ASME Nanotechnology Institute and IEEE Nanotechnology Council. Dr. Chen is an Associate Editor of ASME *Journal of Manufacturing Science and Engineering* and *Journal of Biomedical Nanotechnology*. He is an editor of a book – “*Nanomanufacturing*” (American Scientific Publishers, 2007) and serves on the Editorial Board of a journal – *Nanomedicine*. He was as a Guest Editor in 2003 for *IEEE Transactions on Advanced Packaging: Special Issue on NEMS/MEMS Packaging*. Dr. Chen is a Fellow of ASME.

Wei Wang received the BS in Control from Tsinghua University in 2006. Currently he is a graduate student in the Department of Mechanical Engineering at the University of Texas at Austin. His research interests include laser and optics for manufacturing, nanophotonics, and plasmonics.