

# Development and Practice on Cultivation of Graduate Students in Optical Engineering

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## ABSTRACT

We provide an overview of the development and current structure for cultivating the success of graduate student in Optical Engineering at Beijing University of Technology. Using the educational environment for graduate students in Advanced Laser Manufacturing as an example, we present the environment, the curriculum and some specific programs which demonstrate a multifaceted strategy combining production, study and research, including international cooperation, applications engineering and technology-based research. The programs are tightly linked to the national economic goals and specifically to development of the manufacturing industry which has a critical need for highly skilled and motivated graduates.

**Key Words:** cultivation of graduate students, advanced laser manufacturing, multidisciplinary, productive education system, internationalization

## 1. INTRODUCTION

Photons, as energy carriers, interact with materials in laser processing, causing a series of physical and chemical changes in the material so that we are capable of realizing manufacture, formation, connection, removal and modification of materials. In comparison with the traditional fire, force, heat, and electrical material processing, laser manufacturing is characterized by non-contact processing, high energy concentration, high-efficiency. It is highly flexible and efficient. As one of the most advanced manufacturing technologies, laser manufacturing has the advantages in quality and environmentally-friendly manufacturing, and has been hailed as “a common processing method in future manufacturing system” [1]. Since the birth of high power laser devices in the 1970s, dozens of applications have sprung up, such as laser welding, laser cutting, laser drilling, laser surface treatment, laser alloying, laser cladding, laser marking, laser 3D printing, laser micro-nano fabrication, laser irradiation modification and so on. Constant breakthroughs and innovation will continue to appear.

At present, laser manufacturing has the following characteristics: firstly, the laser manufacturing industry is flourishing, and is widely used, especially in the fields of automobile, information, shipbuilding, energy, metallurgy. <sup>[1-4]</sup> Annual sales of laser processing equipment in China is growing at

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the speed of more than 20% per year, which is more than 10 billion yuan in 2011. Secondly, being irreplaceable, laser manufacturing is playing an increasingly significant role in national defense, aerospace and aviation, and the field of high-tech laser technology has been listed as one of the key tasks in national medium and long-term development. Thirdly, research teams and their academic influence on laser manufacturing has increased greatly. The most important international conference is “International Forum on Laser and Optoelectronic Technology” hosted by the Laser Association of American, more than 500 people attended the 33rd Forum in 2012<sup>[4]</sup>. National Conference on Laser Processing has been hosted ten times by Laser processing professional committee of Chinese Optical Society since 1992, with the attendance of nearly 300 people in 2012. Finally, and most importantly, high-level innovative talent in the field of laser manufacturing is in critically short supply.

Graduate-level education in Laser manufacturing is faced with the following problems: firstly, there is no corresponding major at the undergraduate level, resulting in relatively poor disciplinary background, and a weak sense of identity in the discipline. Secondly, it is interdisciplinary, involving physics, materials science, mechanics, industrial controls, electronics, chemistry, biology and much more. Due to the postgraduate students and supervisors possessing different educational backgrounds, they come view the basic requirements for the degree with different levels of understand. Thirdly, it requires strong, hand-on practice. Postgraduates require not only theoretical knowledge, but also extensive development of experimental skills in laser manufacturing. Fourthly, because the technology of laser manufacturing is widely used in diverse ways, the technology evolves quickly, so to stay abreast of the latest developments in related fields so as to update our knowledge base. Based on our exploration and experience in graduate education in laser manufacturing for more than 20 years, we have developed a general guideline for constructing a graduate education curriculum and practical experience which nurture excellence in the field of laser manufacturing. This system is characterized by an enhanced combination of learning, manufacturing and research, extended international exchange and cooperation and encouragement of innovation and teamwork for improving the quality of graduate education.

## **2. IDEOLOGY**

The basic idea of graduate education in laser manufacturing is to be consistent in providing a core curriculum and dedicated to fostering best practices. The educational system for graduates in laser manufacturing is composed of five parts which are laying a solid foundation, strengthening industry-university-research cooperation, expanding international exchanges and cooperation, encouraging innovation, and facilitating teamwork. Laying a solid foundation consists of building a core curriculum for graduate education in laser manufacturing, to produce a series of textbooks on advanced laser manufacturing, employing distinguished professors to teach the curriculum and offering experimental and research courses in advanced laser manufacturing. Strengthening cooperation between industry and universities requires cultivation of a pool of industry experts working directly with the students on projects which yield true enterprise scholarship. Strengthening international cooperation and academic exchange programs requires developing a network of international partners, both in industry and at top universities worldwide for joint training and research projects. We encourage innovation by providing an atmosphere of independent thought and a well-equipped environment which encourages self-directed research.

## **3. MEASURES AND IMPLEMENTATIONS**

### **3.1 Constructing a graduate curriculum in Laser Manufacturing**

Major research specialties in Laser Manufacturing include: advanced laser manufacturing technology, micro-nano optics, new laser and optoelectronics technologies, biomedical photonics, and much more. Fundamental degree courses for Academic Masters include introduction to laser science and

engineering, optoelectronics, advanced optics, numerical analysis, mathematical statistics and stochastic process, etc., requiring at least 6 credits; Professional degree courses including: experimentation with advanced laser manufacturing, laser micro-nanofabrication technologies, laser technology and devices, non-linear optics and so on, requiring at least 4 credits. Elective courses include: laser safety and radiation protection, laser joining technique, laser processing materials metallurgy, laser rapid prototyping technique, laser material processing technique, semiconductor laser technology, laser parameters test techniques, ultrashort laser pulse technique, biophotonics, all-solid-state laser technology, scientific literature retrieval and applications and technical writing for engineers and so on, requiring at least 10 credits. For the purpose of constructing the above courses, we edit a series of textbooks for postgraduates in the field of laser manufacturing, including: *Advanced Manufacturing Technology in the 21st Century ---Laser Technology and Engineering*, *Laser Welding of High Strength Aluminum Alloy*, *Laser Manufacturing Technology*, *Laser Manufacture Process*, *Laser Principles and Technology*, *Laser Frequency Conversion and Extension*, *Advanced Laser Manufacturing Experiment*, among which three of them are listed as “Excellent Textbooks” in Beijing higher education.

### 3.2 Strengthen the industry-university-research cooperation

The National Industry-university Research Center for Laser Technology was constructed in 1995, which was authorized by the State Commission of Economy and Trade, the State Commission of Education and the Chinese Academy of Sciences. It includes more than ten laser manufacturing experiment halls (shown below), laser processing for non-metallic materials laboratory, high power semiconductor laser technology laboratory, the high power fiber laser technology laboratory, excimer laser micro-processing laboratory, femtosecond laser micro processing laboratory, joint research center for advanced manufacturing technology established by BJUT and Bluestar Chemical Machinery co., Ltd. (Beijing), picosecond laser technology joint laboratory established by BJUT and Beijing G&K Laser Technology co., Ltd. It is orientated as a research and development center for laser manufacturing technology and systems, a demonstration center on laser manufacturing engineering, a service center for laser manufacturing technology, a center of moving laser manufacturing laboratory work into the industrial sector of, a talent training center for laser manufacturing technology.



Fig.1 Experimental Hall of Laser Manufacturing

On the basis of the industry-university-research cooperation, we combine talent cultivation and basic research with major engineering projects for technical transformation in enterprise. For example, Prof. Zuo Tiechuan had led a key project Theory and Technology for High-power CO<sub>2</sub>&YAG Laser 3D Welding and Cutting supported by National Science Foundation and in the meantime she cooperated with China First Automobile Group corporation and developed 3D laser processing technology for coating parts of the car body. Developing from high-power laser transmission theory, they completed the design of the long-span 3D laser processing system. Through independent development and application of 3D laser processing CAM software, they realized the automatic programming and control of the laser 3D processing track on the coating parts of the car. With the help of a

self-developed laser processing expert system, the technicians in enterprise can easily guarantee the quality of 3D laser welding.

Through this technological innovation, they greatly reduced the original number of molds needed to develop a new model and shortened the development cycle, making it flexible enough to produce a variety of automobile styles.

With Four doctoral students and three master students being assigned to the front line of the project, both teachers and students worked and studied together during the research, not only enhancing their innovative abilities, but also improving their engineering qualifications and practical engineering abilities.

### **3.3 To boost international exchanges and cooperation**

We are devoted to setting up international cooperation research bases. In 2001, approved by the Ministry of Science and Technology in China and Federal Ministry of Education in Germany, we established the Chinese-German Center of Laser Technology in Beijing University of Technology, which is designed to be a center of application in laser science and technology and a research center of international cooperation, an academic exchange center, a technical training and consulting service center and an equipment exhibition center as well.

BJUT-IPG Fiber Laser Application Eesearch Center was founded in 2009, which focuses research on optical fiber laser and its application and talents cultivation in related fields. In addition, we have established stable cooperation with several laser research centers, among which are Fraunhofer-Institut für Lasertechnik-ILT and Laser Zentrum Hannover in Germany, Cavendish Laboratory in University of Cambridge and Laser Institutions in University of Manchester in Britain. We undertook an ITER project (International Thermonuclear Experimental Reactor), titled “Research on ITER correction SCC Coil Box of Laser Welding Technology.” In addition, a number of Sino-German cooperation projects of science and technology are being carried out.

Every year we invite more than ten internationally recognized scholars in the field of laser manufacturing to give academic lectures and more than twenty graduate students annually receive grants to participate in international academic conferences. No less than thirty graduate students have been invited abroad, funded by China-Germany Laser Technology Center, international Cooperation Projects and the China Scholarship Council. Through all these measures, the graduate students broaden their international perspectives, and move to the forefront of international laser manufacturing while improving their ability to engage in and contribute to the international dialog on laser manufacturing technology..

### **3.4 Encouraging Innovation**

Inspirational Education. We introduce the life story of the Nobel Prize winners in the field of lasers on display boards and publicize the significant milestones and distinctive contributions of scientists. We host more than 80 academic lectures, such as Frontiers of Laser Technology and its Applications, Frontiers of Optical Science and Engineering and Engineering Master Forums. Under such circumstances, postgraduates form the habit of taking part in the advanced academic lectures. We also host Doctors and Masters Forums, supporting graduates’ participation in national Doctoral Forums and Academic Conferences.

Building a platform---The Laser Art Production Laboratory encourages graduate students’ independence and innovative spirit. This laboratory is autonomous and multi-discipline oriented. Autonomy means that students will form groups, select topics, explore and manage by themselves. Multidiscipline refers to synergetic innovation in the fields of Optical Engineering, Art Design, Control Science and Engineering, Material Science and Engineering, Management and Engineering and more, developing a series of crafts based on laser technology. We carry forward a pioneering spirit of working

hard, fostering unremitting self-improvement, a pragmatic spirit of engineering orientation and a union of knowledge and action, a spirit of teamwork---openness and inclusiveness, while striving for the top.

### **3.5 Constructing the academic team**

Through direct invitation and cultivation, we have developed a network of scholars and professors listed in the National Thousand Talents Program, in National New Century 10 Million Talents Project of the Ministry of Education and in the Beijing Overseas Talent Project, on the basis of which we make a great effort to construct a cross-disciplinary, well-structured and innovative academic team with advanced academic leaders. We require that teaching faculty join the teams, research areas belong to disciplines and equipment be included in the platform. We invite talents, operate, construct and assess on the basis of teamwork. With the mode of teamwork, we try to improve the team, undertaking significant scientific research project, setting a higher standard and promoting communication and cooperation. Currently there are 72 full-time teachers, 86% of whom have acquired doctor's degree and 70% of whom have studied abroad. We have formed two Beijing Higher Educational Innovative Teams--- the Laser Manufacturing Academic Team and Energy Photoelectron Technology Team.

## **4. CONCLUSION**

The admission of graduates majoring in laser manufacturing has increased greatly from only a few post-graduates in 1994 to sixty-five Master's degree students and twenty doctoral students in 2013. In these twenty years, we have cultivated more than five hundred Master's degree students, sixty-one doctoral students and, twelve post-doctoral students. Immediate employment rate for graduate students stays above 95%. In addition, we have trained more than one hundred distinguished people for the enterprises in the field of laser manufacturing.

One doctoral dissertation was nominated for the National Outstanding Doctorate Dissertation, and another doctoral dissertation was named Beijing Municipal Outstanding Doctorate Dissertation. Two graduate students won "Wang Dahang Optical Awards for College Students". Of our students, seventeen have won Excellent Thesis Awards in international or national academic conferences.

Graduates are usually employed in well-recognized academies and enterprises, such as: General Electric Company, IPG Photonics Corporation, China Aerospace Science and Technology Corporation, China Aviation Industry Group, Academy of Chinese Weapon Science, Institute of Semiconductors of the Chinese academy of sciences, Institute of Physics and Chemistry of the Chinese academy of sciences, Beijing Benz auto co., LTD., Beijing Fine Instrument Group, North Microelectronics Group, China Baogang Group, Datang Telecom, BOE Technology Group Co., LTD., institutions of higher Education, and so on. A majority of our graduates have grown into research scholars, chief engineers, presidents and professors, playing a increasingly leading role in the field of laser manufacturing.

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