Optics education at Eastern Michigan University using a 30-gigawatt high power laser system

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ABSTRACT

In this paper, we introduce the experimental laser physics laboratory recently developed at Eastern Michigan University which houses an exceptional laser facility, including a highly-versatile 30 gigawatt glass laser system. Current practice and future perspective to use the facility for optics education at both undergraduate and graduate levels are discussed in detail.

Keywords: optics education for undergraduates, high power laser system, experimental laser physics, undergraduate and graduate research in optics, research and curriculum development

1. INTRODUCTION

Eastern Michigan University (EMU) is a state-supported multipurpose institution located in Ypsilanti, Michigan. It serves over 25,000 students and was listed as the 50th largest university in U.S. by the 1993 Higher Education Directory. The roots of the university date back to 1849, when the State Legislature designated it as Michigan's first institution to educate teachers to serve the public schools. At that time, the Detroit school system was only ten years old and the transition from one-room schoolhouses had just begun. [1]

EMU is known world-wide nowadays for its educational contributions. It is presently ranked as the number one producer of teachers in U.S. and is at a special position to have an impact on many current and future high school teachers. With this background, the significance of a strengthened education program in optics and optical engineering in the institution can not be over-emphasized, and this is especially true in terms of the long range contribution to the related fields.

In this paper we introduce the experimental laser physics laboratory recently developed at EMU which houses an exceptional laser facility, including a highly-versatile 30 gigawatt glass laser system. The total equipment of the laboratory is worth well above $500,000, acquired through both donations from the former KMS Fusion Inc. and support of the Michigan State Research Excellence Funds and the Physics Department research grant. In the following we will describe in detail the high power laser system, present an outline of the laser laboratory, and discuss our current practice and future perspective to use the high power laser system for optics education at both undergraduate and graduate levels, with emphasis on the research activities which students can actively participate.

2. THE EXPERIMENTAL LASER PHYSICS LABORATORY

The high power laser system donated to EMU by former KMS Fusion Inc. was originally designed for laser fusion studies, and it had a glorious history in inertial fusion research. [2] The major part of the laser system, which is now fully functioning at EMU, is shown in Figure 1. The operational parameters of the laser system are summarized in table 1.

A unique feature of the high power laser system is the combination of its powerfulness, accessibility and flexibility. The laser system is now working with a pulse length of 200 nanoseconds and can work with different output pulse lengths with adjustment, ranging from 100 picoseconds to about one millisecond, which will enable a wide range of contemporary research activities, involving both students and other faculty members.

With the shortest pulse length at the picoseconds range, the output power of the system can reach up to 30 gigawatts. This makes the system an important tool for research and education in modern experimental laser physics, including nonlinear optics, laser-matter interactions, as well as laser-induced plasma and x-ray generations. Research towards this direction has been active and is still growing. The facility gives students an exposure to the fascinating fields of high power laser physics, which are otherwise not available except in very few big laboratories.

With longer pulse lengths, on the other hand, the laser will reduce its peak power but maintain high output energy (currently it produces 75 J/pulse at 200 ns). This makes the system a unique facility for energy management of materials, which is now one of the fields attracting most of the attention of industries. This material-related applied research provides our students with an excellent bridge between the traditional physics courses and the real world applications, making them better prepared for the challenging job market in the late 90's and the next century.

Table 1. Summary of the EMU high power laser performance potential

Final amplifier diameter = 45 mm

Pulse length	Energy (ω) 1.054 μm	Energy (2ω) 0.527 μm
100 ps	2 - 3 J	1 J
1 ns	25 - 30 J	10 J
100 ns - 200 μs	50 - 75 J	–

Final amplifier diameter = 32 mm

Pulse length	Energy (ω) 1.054 μm	Energy (2ω) 0.527 μm
100 ps	1 - 1.5 J	0.5 J
1 ns	10 J	5 J
100 ns - 200 μs	15 J	–

One innovation which has been introduced is to separate the output beam of the laser system into several ones. This has made it possible to use the high power system as several parallel medium power/medium energy subsystems. For materials characterization and research and education in the field of experimental laser physics and modern optics, these subsystems are important basic tools, which otherwise would be too costly to buy from the market. These subsystems give us an excellent opportunity to involve more students in the research and laboratory training activities.

Nondestructive evaluation (NDE) methods based on laser technology are of great importance to materials research as well as industrial development. The applications of nondestructive evaluation ranges from nanometer microelectronic devices to inch-thick mechanical parts for the automotive and aerospace applications. Our laser facilities have offered students a good opportunity to be trained in this growing field.

We are also starting collaborations with local hospitals for laser applications in biological and medical sciences. Our joint effort with Sinai Hospital of Detroit on muliwavelength laser induced nonlinear absorption and damage of human eyes has made great progress recently.

Besides the powerful and flexible high power laser system, the physics department hosts also a 100-milliwatt aircooling Krypton-Argon ion laser, a 10-watt Argon-ion laser, a 5-watt Nd:YAG laser, a 35-milliwatt He-Ne laser and several lower power He-Ne lasers. These facilities will be used for research and education activities in both the experimental laser physics and modern optics laboratories.

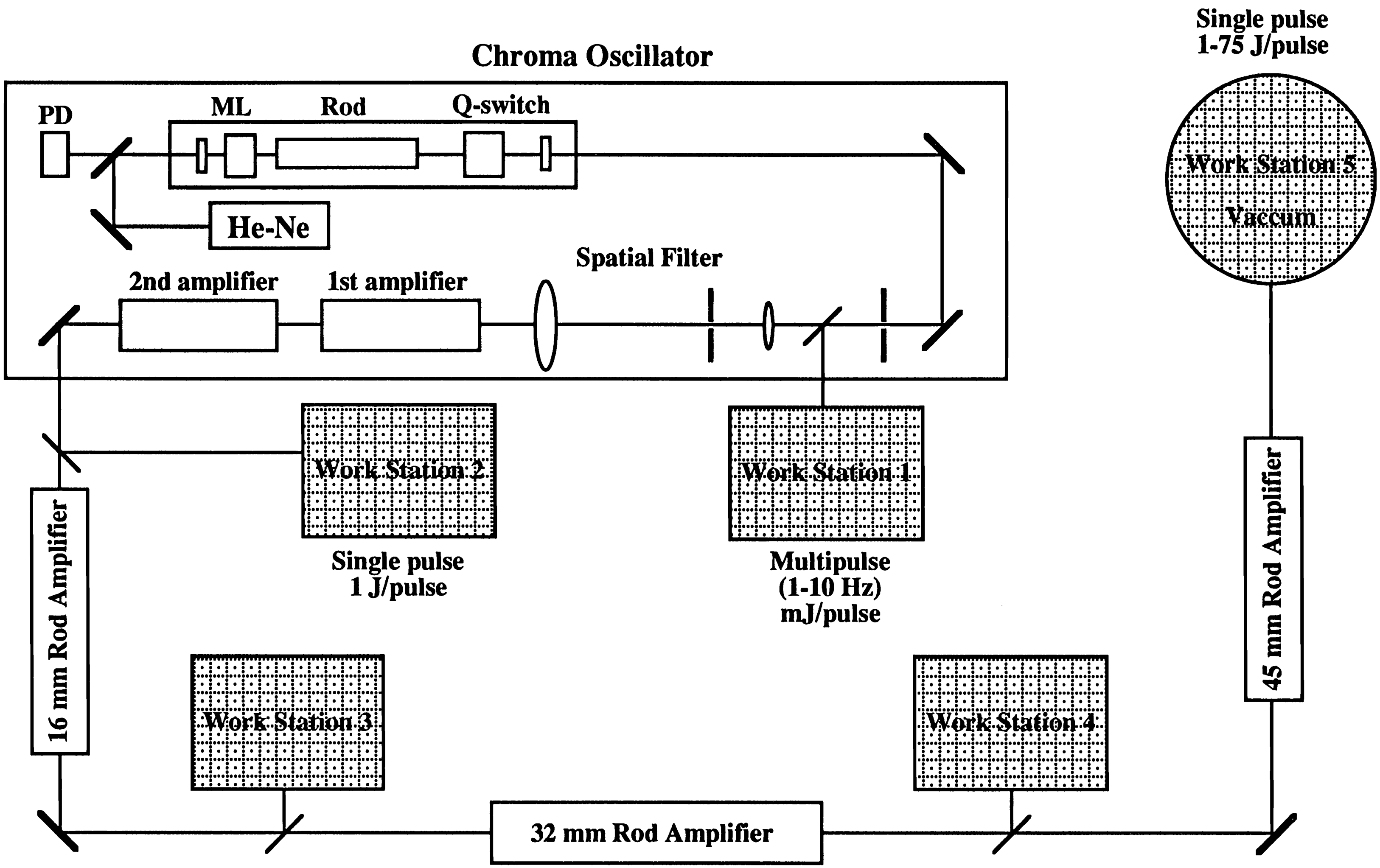

Figure 1. Schematic depiction of the 30 GW high power laser system at the Experimental Laser Physics Laboratory of Eastern Michigan University.

3. WORK STATIONS FOR STUDENT RESEARCH

By splitting the high power laser beam into sub-beams, several work stations have been developed for student research, as shown in Figure 1. At these work stations, both pulsed and cw laser beams are available, depending on the specific experiments to be carried out.

At work station 1, the pulsed laser beam is split from the output of the oscillator of the high power laser system. Its energy level is at the order of 1 to 10 mJ per pulse, and it can be operated at multiple-pulse mode with a repetitive frequency of 0.5 to 10 Hz. Besides the pulsed laser source, at this work station there is also a 10-mw He-Ne laser and a 100-mw Krypton-Argon ion laser. The latter works with eight different visible wavelengths and is an excellent tool for research in biomedical optics. With the low-energy and low-power laser beams, this work station is designed for student research in the following areas: 1. Laser beam characterization (by using traditional laboratory tools as well the novel LAB-100 beam analyzer) [3]; 2. Optical interferometry and holography using pulsed laser source; 3. Materials characterization by using photoacoustic and photothermal phenomena [4]; 4. Nonlinear optics; and 5. Laser-tissue interactions -- biological and medical optics. [5]

At work station 2 the laser is operating at single-pulse mode, and the output energy is in the range of a few tens of mJ to about 1 J per pulse. At this medium-energy / power level, the station is designed mainly for studying laser damage of materials and laser modification of surfaces and thin films. [6,7] The ongoing research projects which involve student effort include in-situ studies of laser damage and laser processing of thin films by using laser-induced ultrasonic and thermal waves.[4]

The pulsed laser beam is working with high-energy and high-power output at work stations 3 and 4. Projects in development for research and education purpose include large area laser processing of materials and large area materials testing using novel nondestructive methods. While many more experiments can be further developed for laser physics and modern optics at these two stations, safety and cost have started to be a concern, which need to be better resolved in future.

Work station 5 includes a vacuum system which was formerly used for laser fusion studies. [2] While this work station is still in construction, it should be pointed out that its direction has not been decided yet. The laser power at this station can be as high as 30-GW, and it can be of value in studying laser-induced shock wave processing of materials, laser-material interactions in vacuum, plasma physics, x-ray laser generation and x-ray physics, and laser fusion. However, it has not been learned yet how to get undergraduates and future high school teachers interested and involved in these studies. And more seriously, how should one deal with the safety and cost problems related to these studies?

4. SUMMARY AND CONCLUSIONS

As an education oriented institution, we are trying to get students involved in all of the on-going research projects in the laser laboratory, and are moving actively to enhance our program of research and education in optics -- primarily for future educators. At the present time student involvement in research is achieved mainly through independent studies and thesis work. In future we plan to expand student activities in the laboratory by hiring more student assistants and developing more laboratory demonstrations. We will also combine our research work with curriculum development. The latter includes developing laboratory and lecture courses of experimental laser physics as well as an interdisciplinary effort on laser applications in materials and biomedical sciences.

The reconstruction of the 30-GW high power laser system has brought to EMU both an excellent opportunity and a serious challenge. Currently the major issue is the cost of the maintenance and operation of the system. The laboratory is now mainly supported by the Michigan State Research Excellence Funds and EMU internal grants, but these supports are not going to last forever. We take this opportunity to express this concern and welcome comments and suggestions for a better use of the laser facility. The laboratory opens its door for collaborations in research and education in all the fields where laser plays a role.

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