Lasers and Applied Optics Course for Industrial Personnel.

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ABSTRACT

Lasers are now critical components in many automated manufacturing systems due to the development of bigger, faster, and more easily-controllable lasers, to the improved understanding of the laser-material interaction, and to advances in fixturing and numerical control. As training courses in industrial laser applications technology are not widespread in engineering undergraduate curricula, management and production-line personnel are not familiar with this rapidly-evolving technology and this may act as a brake on its implementation. A training course for industrial personnel is described the purpose of which is to provide an overview of laser and associated technology. The course is comprised of lectures, video segments, case studies of laser applications in industry and demonstrations of a range of lasers being used for various tasks.

INTRODUCTION

Since the invention of the laser of the in 1960, it was clear that high-power laser beams could be used to deposit large amounts of energy in materials for manufacturing purposes - a possibility that has since become a highly-developed technology[1,2]. In most industrial laser applications, it is the combination of the unique characteristics of the laser beam - high intensity, coherence, directionality, etc. - coupled with computer control of the laser parameters which has improved efficiency and reduced costs. In many industries, laser processing is a competing technology which needs to be assessed. This assessment phase requires a basic knowledge of the advantages and limitations of lasers and the fundamentals of their operation and their interaction with materials. Once implemented, there is a need for retraining of existing personnel in order to exploit fully the benefits of laser technology. These developments have led to the establishment of laser centres which specialise in contract research, feasibility studies and technology transfer. In some centres, a range of training activities are also provided. Based on experience gained in using a wide range of lasers and related instrumentation for scientific research, and in response to requests from industry to provide courses, advice on laser safety, and other back-up services for industrial systems, a national centre for laser applications was established within the Department of Physics in University College, Galway. As part of our services to industry, we have developed a short course on lasers and their applications, which is aimed at personnel in industry who are already using lasers or who foresee applications for laser technology in their plant in the near future. Persons who have a supervisory, planning, production manager or engineering manager role on the factory floor make up most of the attendance at these courses. The aim of the course is to develop an understanding of laser operation, its interactions with matter, and the potential benefits of laser technology. Attendance at the course should enable participants from industry to understand laser specifications and to assess the suitability of lasers for specific tasks.

COURSE CONTENT

A listing of the topics covered in the course is given in Table 1. Each item in the table represents a 1-2 hour period comprising a mixture of lecture, slides, and video segments, and a large number of demonstrations are used to illustrate the course material. There is a natural division of the material covered in sections 1 and 2, with the emphasis in section 1 on providing all the background material required for the more detailed treatments of laser processing which are presented in section 2. Although most of the participants have some technical background, their knowledge of optics was superficial in most cases and the treatment of background topics in optics was particularly welcomed. Good-quality videos[3] and various operating lasers, sensors, and scanners were used to provide many supporting demonstrations to illustrate the lecture material. The material contained in section 2 of the course could be influenced by the interests of the participants. The topics marked by an asterisk were usually presented by specialists from the applications laboratories of the major industrial laser manufacturers and, as the breakdown of the course audience became clear, the content of these presentations was adjusted to reflect the distribution of backgrounds of the audience and were directed towards achieving the goals of the participants.

TABLE 1 : COURSE OUTLINE

Topic	Content
	Section 1
Optics fundamentals	EM radiation, polarization, reflection (specular and diffuse), refraction, absorption. Interference and diffraction. Optical components (active and passive). Radiometry. Optical sources.
"Lasers at work"	Educational video on lasers showing a range of applications.
Basis of laser operation	Stimulated/spontaneous emission. Active media. Population inversion. Resonators. Longitudinal and transverse modes. TEM_{oo} mode propagation. Beam divergence. Worked examples.
Details of laser operation/ construction and types	Pumping and laser efficiency. Threshold conditions. Losses. He-Ne laser. Argon ion laser. CO_2 laser. Excimer laser. Diode laser. Solid-state lasers.
Laser applications	Useful properties of laser light. Review of laser applications in medicine, construction, quality control communications, metrology, non-destructive testing, scientific research.
	Demonstrations of lasers and associated instrumentation in operation (see Table 2)
	Section 2
Laser safety	Biological nature of the hazard. Safety standards and classes. Estimation of MPE. Safety control measures. Nominal optical hazard zone. Eye protection. Worked examples.
Material processing	Mechanisms of laser cutting. Hole drilling. Resistor trimming (case study). Engraving. Scribing. Welding. Soldering (case study). Applications tables.
Laser scanning and modulation./Sensors	Scanning and modulation techniques - mechanical, acousto-optic, electro-optic, holographic devices. Optical detectors - thermal, photoemissive, photovoltaic, photoconductive. Position sensors and CCD arrays. Beam profilers.
Nd:YAG lasers/guided beams	YAG lasers in industry - construction, performance, applications. Q-switching. Computer control. Diode-pumped YAG laser. Beam delivery systems. Optical fibres. Case studies.
CO_2 lasers/machining systems	Slow flow, fast axial flow, and sealed CO_2 lasers. Review of applications. Operation of complex machining systems. Case studies.
Excimer lasers in industry	Mainly video segments showing a range of applications for excimer lasers and the status of current technology.
Considerations for lasers lasers in manufacturing	Economic justification. Potential for new products. Savings. Analysis of successful applications. System specification. Requirements in manpower, space and facilities. Spare parts, maintenance, field service. System evaluation.

TABLE 2

DEMONSTRATIONS.

System	Topics Illustrated.
Argon Ion Laser	All-lines (5W) and single line operation, prism tuning, Brewster windows, output polarisation TEM_{00}, TEM_{01} beam profiles. Applications in spectroscopy and surface characterisation of diamond films using Raman scattering.
CW Dye-laser	Jet-stream dye laser pumped by Ar^+ laser. Tuned by birefringent filter driven by stepper motor. Application in selective excitation of luminescence.
Ti:Sapphire laser	Tunable solid state laser pumped by Ar^+ laser. Application in spectroscopic measurements.
Diode laser	Various (powers up to 5mW). Beam divergence, collimation using lens assembly. Longitudinal mode structure. Application in CD reader head (disassembled).
Q-switched YAG	300 mJ/pulse (1.06 μm), 100 mJ/pulse (0.53 μm). Electro-optic Q-switch. Applications in pumping dye lasers and in lifetime measurement.
Industrial YAG I	CW 65 W (multimode), 15 W (TEM_{00}), Repetitive Q-switch cavity construction, acousto-optic Q-switch, beam expander, galvanometer-mirror scanners, F-Θ lens. Applications in engraving, cutting, scribing, electronic soldering. Beam profiles of output in TEM_{00} and multimode.
Industrial YAG II	Long pulse ($\sim$1 ms) system (2J /pulse). Application to hole-drilling and cutting in metals. Power and energy meters. Control of X-Y stages.
CO_2 laser	Low-power system (25W). Industry surplus. Pulsed operation only. Spare tubes used to show ZnSe optics for output window. Germanium focusing optics. Application to electronic soldering.
CO_2 laser system	50 W system. Demonstration of cutting of thin materials by laser supplier.
Laser printer	First-generation system based on He-Ne. Demonstration of acousto-optic modulation, polygon mirror scanner, collimators, photodiode sensors, F-Θ lens.
Aerosol analysers	Systems based on He-Ne laser used to measure particle size distributions in aerosols. Application to measurement of fume and particulate emission associated with laser soldering.
Safety equipment	Laser protective eyewear, warning labels, door warning lights, interlocks, etc.
Wafer inspection	Use of scanning He-Ne laser for inspection of surfaces.
Miscellaneous	Exhibition of various parts, components, samples of materials which have been cut, welded, soldered, scribed, drilled, etc., using lasers.

DEMONSTRATIONS.

Demonstrations formed a major part of the course structure and the demonstrations of working laser systems were usually added by the laser suppliers to complement those mounted by the laser centre. The point was continuously emphasised that it is the combination of the laser with ancillary devices to either control, scan or modulate the beam, or to move the workpiece with precision, which has made the laser such a useful tool in many industries. As a result, we felt it was important to give an overview of such equipment - laser beam detectors, modulators and scanners, beam profilers, X-Y tables, etc., - and to demonstrate also some of these components in operation. The use of door-warning lights, interlocks, and protective eye-wear was demonstrated as safety aspects[4] of laser use were often a concern for participants who were contemplating the replacement of existing technology with a laser-based alternative. A list of the demonstrations mounted in one running of the course is shown in Table 2. The attendance at this course came from the computer industry mainly and were interested in the applications of lasers in computer manufacturing - soldering, stencil cutting, CD-ROM mastering, functional trimming, etc. These topics were emphasised in that edition of the course. Argon ion lasers, although not widely used as a processing tool, have the advantage of visibility which enables the unique properties of a laser beam to be appreciated. The main research interests of the department are in laser processing, laser spectroscopy, atmospheric studies, and image sharpening techniques applied to astronomy, and all these activities contribute elements to the demonstration section of the course, as indicated in Table 2. The examples chosen provide interesting illustrations of the use of lasers in scientific research. A diode laser mounted in front of a small scanning spectrometer provided a simple and cheap demonstration of longitudinal mode structure[5]. An early model of laser printer was purchased from a surplus house and was cut away to show an acousto-optic modulator, a rotating polygon mirror, and an F-θ lens in operation. In the laser centre, several industrial Nd:YAG lasers were used to demonstrate cutting, engraving, soldering, drilling, etc., and the case histories of feasibility studies carried out by the centre were presented (when this did not interfere with the proprietary nature of the research). Additional case studies of successful applications of lasers were presented by guest speakers from laser equipment manufacturers. Small exhibitions of laser instrumentation were also mounted in conjunction with the running of the course.

CONCLUSION

The implementation of laser technology in various ways in industry has resulted in the need for various education and training courses to enable industrial personnel to assess and specify laser tools for their particular application. Even on safety considerations alone, it is recommended that employees who are not using laser tools but who are working in the vicinity of a high-power laser installation should receive some basic overview of laser technology. This is particularly true of management personnel and safety officers, who have responsibilities in this area[6].

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