

# Unit 22:        Laser Technology and its Industrial Applications

Learning hours:    60

NQF level 4:        BTEC Higher National — H1

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## Description of unit

This unit will enable learners to understand the physical fundamentals that determine the characteristics of different laser systems. Learners will gain a thorough grounding in the aspects of laser safety and handling. The importance of different laser properties for various industrial applications will be emphasised. Learners will gain an understanding of the benefits of lasers to society as a whole and industry in particular. Examples will be drawn from the medical, scientific, telecommunications, entertainment and industrial sectors.

Quantum mechanical energy level diagrams will be used to determine the laser wavelength.

This unit will begin with a thorough examination of the principles of laser safety and handling. It will continue by developing the necessary concepts to characterise the different types of lasers and their properties, and the relationship of these properties to various industrial applications. The various benefits of lasers in modern society will be discussed in detail.

## Summary of learning outcomes

To achieve this unit a learner must:

- 1 Investigate and apply the fundamentals of **laser safety** and beam handling
- 2 Investigate the **relationship of laser properties to applications and calculate laser properties** from fundamentals of the laser medium and design
- 3 Explain the physical principles of **holography** and its applications
- 4 Explore **key applications** of lasers in industry and their benefits to society

# Content

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## 1 Laser safety

*Exposure:* calculation of maximum permissible laser exposure

*Eye protection:* effect of lasers on the eye; retina damage (compare with laser eye surgery); use of coloured safety goggles (ie reflect laser frequency); prevention of accidental exposure with warnings and interlocks

*Beam handling:* equipment (eg waveguides, mirrors, screens); fibreoptic cable; delivery systems; detectors

*Code of Practice:* Laser Safety BS EN60825

## 2 Relationship of laser properties to applications and calculate laser properties

*Laser properties:* monochromatic, unidirectional, intense, coherent light; the wavelength and power of the beam as determined by the laser design

*Laser medium:* effect of energy level arrangement; stimulated vs spontaneous emission (predominantly stimulated emission gives high amplification and low losses); properties of typical laser media (eg ruby, He/Ne, CO<sub>2</sub>, GaAs, dye)

*Population inversion and pumping:* generation of large population of excited electrons and lower energy holes; energy source required to achieve inversion (eg electrical discharge, lamp); bias current (laser diode)

*Resonant cavity:* spacing and reflectivity of mirrors; selection of frequency; generation of standing waves; multiple reflection in cavity

*Laser interaction mechanisms:* cutting, welding and drilling

*Critical factors for applications:* frequency (red, green, infra red and tunable lasers); power (for heavy industrial uses); pulsed/continuous; cost (always a factor, laser diode vs laser)

## 3 Holography

*How holography works:* split beam; scattering off target; reading with reference beam from original direction; transmission/reflection holography

*Applications:* medicinal/dental microscopy; micromasurement (crack detection, design, measurement of mechanical vibrations)

*Displays:* security; forgery prevention; barcode scanners

#### **4 Key applications**

*Medical:* treatment of tumours; cutting/cauterizing blood vessels; dental drilling; eye surgery (corrective and repair of detached retinas)

*Telecommunications:* modulated beams transmitted along optical fibres; signal densities; telephone, radio, television, computer and broadband internet applications

*Miscellaneous:* eg entertainment (CD/DVD, red and blue laser DVD technology), military (range finding), surveying, printing, art, chemical characterisation (infrared, Raman and surface enhanced Raman spectroscopy), influencing chemical reactions

## Outcomes and assessment criteria

| Outcomes  | Assessment criteria for pass<br><br>To achieve each outcome a learner must demonstrate the ability to:   |
|---|--|
| 1 Investigate and apply the fundamentals of <b>laser safety</b> and beam handling   | <ul style="list-style-type: none"> <li>• Calculate maximum permissible laser exposure</li> <li>• Explain the effect of lasers on the eyes and skin</li> <li>• Design suitable beam handling and safety systems for different types of laser</li> </ul>   |
| 2 Investigate the <b>relationship of laser properties to applications and calculate laser properties</b> from fundamentals of the laser medium and design | <ul style="list-style-type: none"> <li>• Explain the effect of the energy level arrangement of the laser media on the laser properties</li> <li>• Draw energy level diagrams for laser action in different media</li> <li>• Perform calculations using the physical parameters of lasers eg calculate frequency, steady state population inversion from pump power</li> <li>• Design appropriate resonant cavities for different laser applications</li> </ul> |
| 3 Explain the physical principles of <b>holography</b> and its applications   | <ul style="list-style-type: none"> <li>• Explain the recording and viewing of a holographic image</li> <li>• Design a hologram recorder (practical experiment or schematic diagram)</li> <li>• Explain applications of holography</li> </ul>   |
| 4 Explore <b>key applications</b> of lasers in industry and their benefits to society   | <ul style="list-style-type: none"> <li>• Identify the key applications of lasers in society</li> <li>• Explain the selection of laser type for different applications</li> <li>• Critically compare and evaluate different types of lasers including laser diodes</li> </ul>   |

## Guidance

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### Delivery

It may be necessary to review work concerning the wave/particle dual nature of light, which was covered in unit 1.

The content may be delivered mainly through lectures, physical demonstrations and tutorial sessions but where possible, practical work should be used to consolidate the theoretical concepts.

A discussion of laser technology in fiction (eg James Bond) and its many exciting applications (eg Star Wars, holograms, discos, accurately measuring the distance from the Earth to the moon, etc) will stimulate and motivate learners.

Two-thirds of the time allocated to this unit could be used for lectures/demonstrations and the remaining third could be allocated to tutorial work. Where individual or small-group practical work is possible, three to five two-hour practical sessions should allow for sufficient development of skills and consolidation of knowledge.

Centres are expected to ensure that practical work is undertaken only after all aspects of laser safety have been covered and, as far as is feasible, at or near the same time as the teaching of the corresponding theoretical work.

### Assessment

Evidence can be generated through a variety of means, depending on the resources available locally. In general, all outcomes can be met through the use of written assignments involving interpretation of datasheets or specifications, calculation-type problems and analysis of case studies drawn from commercial and industrial applications. Reports based on practical investigations or analysis of experimental data or individual research can also generate appropriate evidence.

### Links

This unit has links with *Unit 1: Quantum Systems and the Atom* and *Unit 10: Optical Technology*. It could link with *Unit 6: Project* and *Unit 8: Work-based Assignment*.

### Resources

Ideally, a low-powered Helium/Neon or LED laser should be available for individuals or small groups of learners to carry out practical investigations. Local universities, hospitals or companies would be beneficial for providing demonstrations of laser technology.

## Support materials

### Textbooks

- Ready, J — *Industrial Applications of Lasers* (Academic Press, 1997)  
ISBN: 012583960 X
- Hecht, E — *Optics (International Edition)* (Addison Wesley, 2003)  
ISBN: 0201116111.
- Steen, W — *Laser Material Processing* (Springer-Verlag, 1998)  
ISBN: 0387196706.
- Koechner, W — *Solid State Laser Engineering* (Springer-Verlag, 1999)  
ISBN: 0387187472.
- Rubahn, H — *Laser Applications in Surface Science and Technology* (John Wiley and Sons Ltd, 1999) ISBN: 0471984507.
- Chow, W and Koch, W — *Semiconductor-Laser Fundamentals: Physics of the Gain Materials* (Springer-Verlag Berlin and Heidelberg GmbH, 1999) ISBN: 3540641661