OPTOSCI
...OPTOELECTRONIC SYSTEMS, COMPONENTS, INSTRUMENTATION...

SPECIFICATIONS OF OPTOSCI EDUCATOR KITS

Principles of Physical Optics ED-OPTICS (Modular)

1. FEATURES

- Comprehensive laboratory education kit investigating the fundamental properties of light and the principles of physical optics.
- Incorporates four separate modules, which can be set up sequentially in the laboratory, to address: polarisation, reflection & refraction, diffraction, and interference & coherence
- Modular design enables users to purchase only particular parts of the complete package of immediate interest and leaves open the possibility of future upgrading by the addition of further modules.
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments sequentially.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address applications of optics, such as: optical waveguiding, metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics

2. MODULE DESCRIPTIONS

Polarisation

The polarisation module enables students to carry out the following experimental investigations: confirmation of Malus' law; investigation of the properties of half and quarter wave plates (alignment, axes identification, polarisation characteristics); measurement of the state of polarisation of a light wave; investigation of quarter and arbitrary waveplates (Stokes parameters, the polarisation ellipse and the Poincaré sphere); examination of strain birefringence and its application to strain sensing.

Reflection & Refraction

With this module students undertake the necessary measurements to confirm Snell's law; determination of the reflection coefficient of both an internal and external optical interface for both the vertical and horizontal polarisation configurations; experimental confirmation of the Fresnel equations and identification of such features as Brewster's angle, the critical angle and total internal reflection. From the measurements they determine the refractive index of an optical element.

Diffraction

The diffraction module enables investigation of near and far field diffraction patterns for apertures and slits of various dimensions (Fraunhofer and Fresnel diffraction); confirmation of the width of various known slits and apertures and determination of the width of unknown slits and apertures; experimental investigation of diffraction at a reflective grating, including the basic grating equation (confirmation of grating line density), multiple order diffraction, the Littrow configuration, and grating resolution and resolving power as a function of incidence angle and diffraction order using two wavelengths; determination of the wavelength of a second laser, diffraction through a transmission grating and measurement of line spacing.

Interference & Coherence

Here students construct a Michelson interferometer and investigate its multiple and single fringe alignment configurations. They then assess the surface quality of three different optical elements inserted into one arm of the interferometer and calculate the wedge angle for one of the elements. They proceed to investigate the coherence function of a He-Ne laser and then a Fabry-Perot cavity laser, as well as examining the coherence length of the Fabry-Perot

cavity laser as the laser's drive current is varied. The students then determine the coherence length of the laser and measure its cavity length.

Principles of Physical Optics ED-OPTICS (Modular)

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments in each module sequentially.

Description	Qty/Unit
HARDWARE	
1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
1mW Laser Diode (λ TBD) with integral drive electronics, holder and 6V power supply	1
1mW 633nm He-Ne Laser, holder and power supply	1
Remotely mounted Si detector head with battery powered bench top receiver unit displaying detected power on an integral panel meter.	1
Linear Photodiode Array	1
Linear Translation Stage	1
50mm Beamsplitter mount with precision angular adjustment	1
25mm mirror mount with precision angular adjustment mounts	2
Graduated table and indicator arm	1
Spacer for graduated table	2
470mm Optical Rail	2
25mm Carriers with Post Holders	8
50mm Carrier	2
Graduated Rotating Polariser Mounts	6
Right Angle Post Clamp	1
Post Collars	18
95mm posts	20
Plate Clamp	1
Spring Clamp	1
Allen Keys	3
25mm λ/10 Mirrors	2
50mm λ/10 Circular Beamsplitter	1
Glass Semi-Cylindrical Element with mounting plate	1
Half Waveplate	1
Quarter Waveplates	2
Arbitrary Waveplate	1
Diffraction Grating (Reflection) with mount	1
Transmission Grating	1
Test optical elements	3
Perspex Sheet	2
25mm Polariser / Analyser	2
Mounted Pinholes (various diameters)	3
Mounted Air Slits (different widths)	2
Mounted Concave Lens	2
Mounted Convex Lens	1
DC Voltage Control Unit	1
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	4
Student Laboratory Manual describing the relevant background theory and experimental procedure.	4
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on the Fundamentals of Physical Optics covering the principles of all the issues dealt with in the laboratory exercises	1

CD with student literature for ED-OPTICS (signed agreement required) 1

4. ADDITIONAL EQUIPMENT REQUIRED

- A two channel laboratory oscilloscope with a minimum bandwidth of 20MHz is required for some of the experiments.

5. OPTIONAL EXTENSIONS & ACCESSORIES

- The kit can be readily upgraded to the complete ED-OPTICS educator kit enabling the tutor to set up each of the four fundamental modules (i.e. Reflection & Refraction, Polarisation, Diffraction, and Interference & Coherence) simultaneously in the laboratory.
- An add-on application module investigating optical waveguiding is also available.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Principles of Physical Optics ED-OPTICS (Complete)

1. FEATURES

- Comprehensive laboratory education kit investigating the fundamental properties of light and the principles of physical optics
- Incorporates four complete modules, which can be set up simultaneously in the laboratory, to address: polarisation, reflection & refraction, diffraction, and interference & coherence
- Modular design enables users to purchase only particular parts of the complete package of immediate interest and leaves open the possibility of future upgrading by the addition of further modules
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments simultaneously.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address applications of optics, such as: optical waveguiding, metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics

2. MODULE DESCRIPTIONS

Polarisation

The polarisation module enables students to carry out the following experimental investigations: confirmation of Malus' law; investigation of the properties of half and quarter wave plates (alignment, axes identification, polarisation characteristics); measurement of the state of polarisation of a light wave; investigation of quarter and arbitrary waveplates (Stokes parameters, the polarisation ellipse and the Poincaré sphere); examination of strain birefringence and its application to strain sensing.

Reflection & Refraction

With this module students undertake the necessary measurements to confirm Snell's law; determination of the reflection coefficient of both an internal and external optical interface for both the vertical and horizontal polarisation configurations; experimental confirmation of the Fresnel equations and identification of such features as Brewster's angle, the critical angle and total internal reflection. From the measurements they determine the refractive index of an optical element.

Diffraction

The diffraction module enables investigation of near and far field diffraction patterns for apertures and slits of various dimensions (Fraunhofer and Fresnel diffraction); confirmation of the width of various known slits and apertures and determination of the width of unknown slits and apertures; experimental investigation of diffraction at a reflective grating, including the basic grating equation (confirmation of grating line density), multiple order diffraction, the Littrow configuration, and grating resolution and resolving power as a function of incidence angle and diffraction order using two wavelengths; determination of the wavelength of a second laser, diffraction through a transmission grating and measurement of line spacing.

Interference & Coherence

Here students construct a Michelson interferometer and investigate its multiple and single fringe alignment configurations. They then assess the surface quality of three different optical elements inserted into one arm of the interferometer and calculate the wedge angle for one of the elements. They proceed to investigate the coherence function of a He-Ne laser and then a Fabry-Perot cavity laser, as well as examining the coherence length of the Fabry-Perot

cavity laser as the laser's drive current is varied. The students then determine the coherence length of the laser and measure its cavity length.

Principles of Physical Optics ED-OPTICS (Complete)

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments in each module simultaneously.

Description	Qty/Unit
Reflection & Refraction Module	
HARDWARE	
1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
Remotely mounted Si detector head with battery powered bench top receiver unit displaying detected power on an integral panel meter.	1
Graduated table and indicator arm	1
Spacer for graduated table	2
470mm Optical Rail with supports	1
25mm Carriers with Post Holders	3
Graduated Rotating Polariser Mount	1
Right Angle Post Clamp	1
Post Collars	2
95mm posts	3
Spring Clamp	1
M6 Allen Key	1
Glass Semi-Cylindrical Element with mounting plate	1
25mm Polariser	1
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on the Fundamentals of Physical Optics covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature for ED-OPTICS (signed agreement required)	1
Polarisation Module	
HARDWARE	
1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
Remotely mounted Si detector head with battery powered bench top receiver unit displaying detected power on an integral panel meter.	1
470mm Optical Rail with supports	1
25mm Carriers with Post Holders	7
Graduated Rotating Polariser Mount	6
Post Collars	8
95mm posts	9
Allen Keys	3
25mm Polariser / Analyser	2
Plate Clamp	1
Perspex Sheet	2
Half Waveplate	1
Quarter Waveplates	2
Arbitrary Waveplate	1
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1

3. CONTENTS LIST CONTINUED...

Diffraction Module

HARDWARE

1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
1mW Laser Diode (λ TBD) with integral drive electronics, holder and 6V power supply	1
Linear Photodiode Array	1
Graduated table and indicator arm	1
470mm Optical Rail	1
Translation Stage	1
25mm Carriers with Post Holders	3
Post Collars	5
95mm posts	5
Plate Clamp	1
Allen Keys	2
Diffraction Grating mounted on plate	1
Transmission Grating	1
Mounted Pinholes (various diameters)	3
Mounted Air Slits (different widths)	2

LITERATURE

Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1

Interference & Coherence Module

HARDWARE

1mW 633nm He-Ne laser with holder and power supply	1
1mW Laser Diode with integral drive electronics, holder and 6V power supply	1
Linear Photodiode Array	1
Linear Translation Stage	1
50mm angular beamsplitter mount	1
470mm Optical Rail	2
25mm Carriers with Post Holders	8
50mm Carrier	2
Post Collars	8
95mm posts	9
Plate Clamp	1
Allen Keys	2
25mm mirror mounts with angular adjustment	2
25mm λ/10 Mirrors	2
λ/10 Circular Beamsplitter	1
Mounted Concave Lens	2
Mounted Convex Lens	1
DC Voltage Control Unit	1
Test Optical Elements	3

Interference & Coherence Module continued...

LITERATURE

Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1

4. ADDITIONAL EQUIPMENT REQUIRED

- A two channel laboratory oscilloscope with a minimum bandwidth of 20MHz is required for the experiments which use the Linear Photodiode Array (*Diffraction* and *Interference & Coherence*). Thus 2 oscilloscopes will be required.

5. OPTIONAL EXTENSIONS & ACCESSORIES

- An add-on application module investigating optical waveguiding is also available.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Reflection & Refraction Module R&R

1. FEATURES

- Comprehensive laboratory educational package examining reflection and refraction characteristics at an internal and external optical interface.
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address other aspects of fundamental optics, such as: polarisation, diffraction, and interference & coherence.
- To extend the capability of R&R and enable students to appreciate how the fundamental principles examined in R&R are applied, an add-on module, optical waveguiding (WAVE), is available investigating mode propagation in multimode and singlemode waveguides.

2. MODULE DESCRIPTION

Reflection & Refraction
With this module students undertake the necessary measurements to confirm Snell's law; determination of the reflection coefficient of both an internal and external optical interface for both the vertical and horizontal polarisation configurations; experimental confirmation of the Fresnel equations and identification of such features as Brewster's angle, the critical angle and total internal reflection. From the measurements they determine the refractive index of an optical element.

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments.

Description	Qty/Unit
Reflection & Refraction Module	
HARDWARE	
1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
Remotely mounted Si detector head with battery powered bench top receiver unit displaying detected power on an integral panel meter.	1
Graduated table and indicator arm	1
Spacer for graduated table	2
470mm Optical Rail with supports	1
25mm Carriers with Post Holders	3
Graduated Rotating Polariser Mount	1
Right Angle Post Clamp	1
Post Collars	2
95mm posts	3
Spring Clamp	1
M6 Allen Key	1
Glass Semi-Cylindrical Element with mounting plate	1
25mm Polariser	1
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on the Fundamentals of Physical Optics covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. OPTIONAL EXTENSIONS & ACCESSORIES

- Add-on modules are available to address other aspects of fundamental optics, such as: polarisation, diffraction, and interference & coherence and an extension module is available examining optical waveguiding.

5. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

OPTOSCI
...OPTOELECTRONIC SYSTEMS, COMPONENTS, INSTRUMENTATION...

Polarisation Module POL

1. FEATURES

- Comprehensive laboratory educational package investigating polarised light and its generation and manipulation as it passes through various optical elements.
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address other aspects of fundamental optics, such as: reflection & refraction, diffraction, and interference & coherence, and their associated application areas, like: optical waveguiding, metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics.

2. MODULE DESCRIPTION

Polarisation
The polarisation module enables students to carry out the following experimental investigations: confirmation of Malus' law; investigation of the properties of half and quarter wave plates (alignment, axes identification, polarisation characteristics); measurement of the state of polarisation of a light wave; investigation of quarter and arbitrary waveplates (Stokes parameters, the polarisation ellipse and the Poincaré sphere); examination of strain birefringence and its application to strain sensing.

Polarisation Module POL

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments.

Polarisation Module

HARDWARE

1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
Remotely mounted Si detector head with battery powered bench top receiver unit displaying detected power on an integral panel meter.	1
470mm Optical Rail with supports	1
25mm Carriers with Post Holders	7
Graduated Rotating Polariser Mount	6
Post Collars	8
95mm posts	9
Allen Keys	3
25mm Polariser / Analyser	2
Plate Clamp	1
Perspex Sheet	2
Half Waveplate	1
Quarter Waveplates	2
Arbitrary Waveplate	1

LITERATURE

Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Fundamental Optics and Polarisation covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. OPTIONAL EXTENSIONS & ACCESSORIES

- Add-on modules are available to address other aspects of fundamental optics, such as: reflection & refraction, diffraction, and interference & coherence.
- An add-on application module investigating optical waveguiding is also available.

5. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Diffraction Module DIFF

1. FEATURES

- Comprehensive laboratory educational package investigating diffraction phenomena and the characteristics of diffractive elements.
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address other aspects of fundamental optics, such as: polarisation, reflection & refraction, and interference & coherence, and their associated application areas, like: waveguiding, metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics.

2. MODULE DESCRIPTION

Diffraction
The diffraction module enables investigation of near and far field diffraction patterns for apertures and slits of various dimensions (Fraunhofer and Fresnel diffraction); confirmation of the width of various known slits and apertures and determination of the width of unknown slits and apertures; experimental investigation of diffraction at a reflective grating, including the basic grating equation (confirmation of grating line density), multiple order diffraction, the Littrow configuration, and grating resolution and resolving power as a function of incidence angle and diffraction order using two wavelengths; determination of the wavelength of a second laser, diffraction through a transmission grating and measurement of line spacing.

Diffraction Module DIFF

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments.

Diffraction Module

HARDWARE

1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
1mW Laser Diode (λ TBD) with integral drive electronics, holder and 6V power supply	1
Linear Photodiode Array	1
Graduated table and indicator arm	1
470mm Optical Rail	1
Translation Stage	1
25mm Carriers with Post Holders	3
Post Collars	5
95mm posts	5
Plate Clamp	1
Allen Keys	2
Diffraction Grating mounted on plate	1
Transmission Grating	1
Mounted Pinholes (various diameters)	3
Mounted Air Slits (different widths)	2

LITERATURE

Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Fundamental Optics and Diffraction covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- A two channel laboratory oscilloscope with a minimum bandwidth of 20MHz is required for some of the experiments.

5. OPTIONAL EXTENSIONS & ACCESSORIES

- Add-on modules are available to address other aspects of fundamental optics, such as: polarisation, reflection & refraction, and interference & coherence.
- An add-on application module investigating optical waveguiding is also available.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Interference & Coherence Module I&C

1. FEATURES

- Comprehensive laboratory educational package investigating coherence and interference phenomena.
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address other aspects of fundamental optics, such as: polarisation, reflection & refraction, and diffraction, and their associated application areas, like: waveguiding, metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics.

2. MODULE DESCRIPTION

Interference & Coherence
Here students construct a Michelson interferometer and investigate its multiple and single fringe alignment configurations. They then assess the surface quality of three different optical elements inserted into one arm of the interferometer and calculate the wedge angle for one of the elements. They proceed to investigate the coherence function of a He-Ne laser and then a Fabry-Perot cavity laser, as well as examining the coherence length of the Fabry-Perot cavity laser as the laser's drive current is varied. The students then determine the coherence length of the laser and measure its cavity length.

Interference & Coherence Module I&C

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments.

Interference & Coherence Module

HARDWARE

1mW 633nm He-Ne laser with holder and power supply	1
1mW Laser Diode with integral drive electronics, holder and 6V power supply	1
Linear Photodiode Array	1
Linear Translation Stage	1
50mm angular beamsplitter mount	1
470mm Optical Rail	2
25mm Carriers with Post Holders	8
50mm Carrier	2
Post Collars	8
95mm posts	9
Plate Clamp	1
Allen Keys	2
25mm mirror mounts with angular adjustment	2
25mm λ/10 Mirrors	2
λ/10 Circular Beamsplitter	1
Mounted Concave Lens	2
Mounted Convex Lens	1
DC Voltage Control Unit	1
Test Optical Elements	3

Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Fundamental Optics and Interference and Coherence covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- A two channel laboratory oscilloscope with a minimum bandwidth of 20MHz is required for some of the experiments.

5. OPTIONAL EXTENSIONS & ACCESSORIES

- Add-on modules are available to address other aspects of fundamental optics, such as: polarisation, reflection & refraction, and diffraction.
- An add-on application module investigating optical waveguiding is also available.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Principles of Optical Waveguiding ED-WAVE

1. FEATURES

- Comprehensive laboratory educational package investigating the propagation of light in dielectric media and waveguides, saving the tutor 2 to 3 years of course, literature and hardware development.

- First module examines reflection and refraction characteristics at a dielectric optical interface, while the second module investigates the characteristics, modal properties and design of step index and graded index planar waveguide structures

- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments sequentially.

- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.

- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.

- Upgradable to address other aspects of fundamental optics, such as: polarisation, diffraction, and interference & coherence, and their associated application areas, like: metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics.

2. MODULE DESCRIPTIONS

Reflection & Refraction

With this module students undertake the necessary measurements to confirm Snell's law; determination of the reflection coefficient of both an internal and external optical interface for both the vertical and horizontal polarisation configurations; experimental confirmation of the Fresnel equations and identification of such features as Brewster's angle, the critical angle and total internal reflection. From the measurements they determine the refractive index of an optical element.

Optical Waveguiding

Using prism coupling techniques and m line investigations, the students measure the mode spectrum, modal effective indices and polarisation dependence of various step index and graded index waveguides. From these results they determine the refractive index profile and depth of the waveguides under study and predict the design conditions for fabricating single mode waveguides. Single mode operation is then confirmed experimentally.

Principles of Optical Waveguiding ED-WAVE

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments in each module sequentially.

Description	**Qty/Unit**
HARDWARE	
1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
Remotely mounted Si detector head with battery powered bench top receiver unit displaying detected power on an integral panel meter.	1
Linear Translation Stage	1
Z axis translation stage	1
Rotation stage with vernier scale and 1 arc/min micrometer	1
Graduated table and indicator arm	1
Spacer for graduated table	2
470mm Optical Rail with supports	1
25mm Carriers with Post Holders	3
Graduated Rotating Polariser Mount	1
Right Angle Post Clamp	1
Post Collars	3
95mm posts	6
Spring Clamp	1
M6 Allen Key	1
High index prism coupling assembly	2
Glass Semi-Cylindrical Element with mounting plate	1
25mm Polariser	1
Mounted DCX Lens	1
Multimode and singlemode step index planar waveguides	1 set
Multimode and singlemode graded index planar waveguides	1 set
LITERATURE	
Operator's Manual for the Reflection & Refraction and Optical Waveguiding modules with full sample results for all experiments and exercises.	2
Student Laboratory Manuals describing the relevant background theory and experimental procedure for these modules.	2
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Fundamental Optics and Optical Waveguiding covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. OPTIONAL EXTENSIONS & ACCESSORIES

- ***SWAN(MIC)****:* Excel based optical waveguide analysis software for use with ED-WAVE allowing the user to study planar optical waveguides experimentally and theoretically.
- ***Fibre Optics (FIB Ext.)*** add-on to ED-WAVE allows students to investigate: free space coupling of light into optical fibres, output mode patterns, fibre NA, axial misalignment, connector loss, bend loss & attenuation in optical fibres.

5. REMARKS

- Warranty: 12 months from date of delivery

- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Optical Waveguiding Module WAVE

1. FEATURES

- Comprehensive laboratory educational package investigating the characteristics, modal properties and design of step index and graded index planar waveguide structures
- To enable rapid installation in the laboratory the package includes all of the necessary optical, optoelectronic and optomechanical hardware required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Upgradable to address aspects of fundamental optics, such as: reflection & refraction, polarisation, diffraction, and interference & coherence, and their associated application areas, like: metrology, instrumentation, sensing, electro-optics, non-linear optics, and Fourier optics.

2. MODULE DESCRIPTION

Optical Waveguiding
Using prism coupling techniques and m line investigations, the students measure the mode spectrum, modal effective indices and polarisation dependence of various step index and graded index waveguides. From these results they determine the refractive index profile and depth of the waveguides under study and predict the design conditions for fabricating single mode waveguides. Single mode operation is then confirmed experimentally.

Optical Waveguiding Module WAVE

3. CONTENTS LIST

- Includes all of the optical, optoelectronic and optomechanical hardware required to perform the experiments.

Description	Qty/Unit
HARDWARE	
1mW 633nm Laser Diode with integral drive electronics, holder and 6V power supply	1
Linear Translation Stage	1
Z axis translation stage	1
Rotation stage with vernier scale and 1 arc/min micrometer	1
470mm Optical Rail with supports	1
25mm Carriers with Post Holders	3
Graduated Rotating Polariser Mount	1
Post Collars	3
95mm posts	3
M6 Allen Key	1
High index prism coupling assembly	2
25mm Polariser	1
Mounted DCX Lens	1
Multimode and singlemode step index planar waveguides	1 set
Multimode and singlemode graded index planar waveguides	1 set
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Fundamental Optics and Optical Waveguiding covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. OPTIONAL EXTENSIONS & ACCESSORIES

- ***SWAN(MIC)****:* Excel based optical waveguide analysis software for use with WAVE allowing the user to study planar optical waveguides experimentally and theoretically.
- Add-on modules are available to address other aspects of fundamental optics, such as: reflection & refraction, polarisation, diffraction, and interference & coherence.

5. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

OPTOSCI
...OPTOELECTRONIC SYSTEMS, COMPONENTS, INSTRUMENTATION...

Optical Waveguiding Extension (to R&R)

1. FEATURES

- Add-on extension to Reflection & Refraction module investigating the characteristics, modal properties and design of step index and graded index planar waveguide structures

- To enable rapid installation in the laboratory the Optical Waveguiding Extension includes all of the additional optical, optoelectronic and optomechanical hardware required to perform the waveguiding experiments, when used with an existing Reflection and Refraction Module.

- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.

- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by additional lecture notes on optical waveguiding (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.

2. MODULE DESCRIPTION

Optical Waveguiding
Using prism coupling techniques and m line investigations, the students measure the mode spectrum, modal effective indices and polarisation dependence of various step index and graded index waveguides. From these results they determine the refractive index profile and depth of the waveguides under study and predict the design conditions for fabricating single mode waveguides. Single mode operation is then confirmed experimentally.

Optical Waveguiding Extension (to R&R)

3. CONTENTS LIST

- The Optical Waveguiding Extension includes all of the additional optical and optomechanical hardware required to perform the waveguiding experiments, when used with an existing Reflection and Refraction Module.

Description	**Qty/Unit**
HARDWARE	
Linear Translation Stage	1
Z axis translation stage	1
Rotation stage with vernier scale and 1 arc/min micrometer	1
High index prism coupling assembly	2
Mounted DCX Lens	1
Multimode and singlemode step index planar waveguides	1 set
Multimode and singlemode graded index planar waveguides	1 set
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Additional Lecture Notes on Optical Waveguiding covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. OPTIONAL EXTENSIONS & ACCESSORIES

- ***SWAN(MIC)****:* Excel based optical waveguide analysis software for use with WAVE allowing the user to study planar optical waveguides experimentally and theoretically.
- Add-on modules are available to address other aspects of fundamental optics, such as: polarisation, diffraction, and interference & coherence.

5. REMARKS

- Warranty: 12 months from date of delivery

- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Fibre Optic Communications ED-COM

1. FEATURES

- Comprehensive laboratory educational package in optical fibre communications, saving the tutor 2 to 3 years of course, literature and hardware development.
- Enables students to characterise all of the major components of an optical fibre communications link (i.e. transmitter (both LED and laser), optical fibre and receiver).
- Allows students to experimentally investigate the key issues of attenuation and dispersion (both material and modal) and to determine how these factors limit the overall performance of a fibre communications system in terms of: the upper limits on the link length, analogue bandwidth, and digital bit rate.
- To enable rapid installation in the laboratory the package includes all of the necessary optical components and optoelectronic instrumentation required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.

2. EDUCATOR KIT DESCRIPTION

The Fibre Optic Communications Educator Kit enables students or trainees to characterise all of the major components of a fibre optic communications link (i.e. the transmitter, the optical fibre and the receiver); to build a 1, 2 & 3 km point to point fibre optic link and to compare the overall system performance using both a laser diode and LED source. In the course of the investigation the students measure the P-I characteristics of the transmitters; the launched powers; connector loss, length of fibre link, the receiver noise and sensitivity; the fibre attenuation coefficients; the material and intermodal dispersion coefficients (from the overall system response in both the frequency and time domain); and the bit rate / bandwidth.distance products. This enables them to determine upper limits on the link length, bandwidth and bit rate as determined by attenuation and dispersion in the fibre. Exercises which are included allow them to compare the performance of this system with state of the art installed systems and to carry out various system design and performance assessment analyses.

Fibre Optic Communications ED-COM

3. CONTENTS LIST

- Includes all of the optical components and optoelectronic instrumentation required to perform the experiments

Description	Qty/Unit
HARDWARE	
850 nm ST connectorised LED transmitter with adjustable drive current (current reading displayed on an integral panel meter) and modulation signal input	1
790 nm ST connectorised laser diode transmitter with adjustable drive current (current reading displayed on an integral panel meter) and modulation signal input	1
ST connectorised Si photodiode receiver with detected power displayed on an integral panel meter	1
1 km reel of ST connectorised graded index multi-mode optical fibre	1
2 km reel of ST connectorised graded index multi-mode optical fibre	1
1m lengths of ST connectorised optical fibre patchcord	2
ST bulkhead connector	1
A waveform generator which can be switched between a 4 MHz square wave pulse generator and a variable frequency (1 to 25 MHz) sine wave generator	1
BNC cables	3
BNC Tee-Piece	1
Mains Power Lead	1
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises	1
Student Laboratory Manual describing the relevant background theory and experimental procedure	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Fibre Optic Communications covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- A two channel laboratory oscilloscope with a minimum bandwidth of 50MHz is required for some of the experiments.

5. OPTIONAL EXTENSIONS & ACCESSORIES

- A complete add-on module to ED-COM is available to extend this system to investigate the Eye Diagrams and BER in optical communication systems - BER(COM)

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

BER in Optical Communications BER(COM) (add-on to ED-COM)

1. FEATURES

- Add-on extension to the Fibre Optic Communications educator kit (ED-COM) providing a comprehensive laboratory educational package in Eye Diagrams and Bit Error Rates (BER) and saving the tutor significant course, literature and hardware development.

- Enables students to generate and evaluate eye diagrams and investigate the effects of noise, attenuation and dispersion on eye diagrams and BER for the many communication system permutations allowed by OptoSci's ED-COM educator kit.

- To enable rapid installation in the laboratory the package includes all of the specialised additional components required to perform the experiments.

- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.

2. MODULE DESCRIPTION

The BER(COM) add-on module to ED-COM enables students or trainees to generate and evaluate eye diagrams and investigate the effects of noise, attenuation and dispersion on eye diagrams and BER for the many communication system permutations allowed by OptoSci's ED-COM educator kit. In the course of the investigation the students generate and observe the appearance of eye patterns at various bit rates directly from BER(COM) and then, using the ED-COM LED and laser transmitters, measure and compare rise/fall times, pulse width and jitter using various fibre link lengths (1 to 5km) and bit rates (1 to 40Mbits/s). They then measure noise amplitudes from the eye patterns for both transmitters over various fibre link lengths and bit rates and estimate and compare BER using Q-factors derived from the noise amplitude measurements. Using the statistical analysis software supplied they estimate and compare the Q-factors and BER derived from signal level (eye pattern) histograms for both transmitters over various fibre link lengths and bit rates. Exercises then encourage them to examine the results in relation to attenuation and dispersion measurements made previously with ED-COM.

BER in Optical Communications BER(COM) (add-on to ED-COM)

3. CONTENTS LIST

- The BER(COM) extension to ED-COM includes all of the specialised additional components required to perform the eye diagram and BER experiments, when used with an existing ED-COM educator kit.

Description	Qty/Unit
HARDWARE	
Benchtop instrument including PRBS Generator with variable bit rate (1 - 40Mbit/s) and data, clock and impulse outputs	1
2 km reel of ST connectorised graded index multi-mode optical fibre	1
ST uniter	1
BNC cables (1m)	2
USB Cable	1
Null Modem Cable	1
Mains Power Lead	1
SOFTWARE	
Q-factor Analysis Software to determine Q-factors and BER from the eye pattern histograms generated via BER(COM).	1
LITERATURE	
BER(COM) Instructors Manual	1
BER(COM) Student Laboratory Manual	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- ED-COM educator kit.
- A two channel digital storage oscilloscope (DSO) with a USB output, minimum bandwidth of 50MHz, and minimum *real time* sampling rate of 500MSa/s (see DSO recommendations below).
- The Q-factor analysis software requires a PC running Windows XP, 7, 8 or 10 and is currently designed to be compatible with Tektronix DSO's (TBS 1000 series, USB output) and also Keysight (Agilent) DSO's (InfiniiVision 2000 X-Series, USB Output).

5. BER(COM) use with ED-WDM Series

The PRBS and Q-factor software supplied with BER(COM) can also be used for experiments with OptoSci's ED-WDM Series of kits. When used with ED-WDM Series, BER(COM) enables examination of system crosstalk effects on Eye Diagrams / BER in DWDM systems and chromatic dispersion measurements in singlemode fibre at 1310nm & 1550nm (see *BER Experiments for WDM* specification sheet for more details).

6. REMARKS

- Warranty: 12 months from date of delivery

- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Optical Network Analysis (without OTDR unit) ED-NET

Note that the Optical Network Analysis sheet describes the hardware contents and experiments which can be performed with the ED-NET system when the educator kit is used with a 1310nm / 1550nm singlemode mini-OTDR and trace analysis software (see additional equipment required).

1. FEATURES

- Comprehensive laboratory educational package in optical fibre network analysis and optical time domain reflectometry (OTDR), saving the tutor 2 to 3 years of course, literature and hardware development.

- Investigates the fundamental properties of OTDR, loss mechanisms along fibre links, characteristics of optical fibre components and optical networks, and performs fault analysis on sample optical networks.

- To enable rapid installation in the laboratory the package incorporates all of the necessary optical networks and fibre components required to perform the experiments when used with a commercial dual wavelength OTDR instrument with trace analysis software.

- Single system is a cost effective means of incorporating a new experiment into a teaching laboratory, since students can acquire the network traces relatively quickly using the OTDR, save them to a floppy, and then analyse their results remotely on a PC using the trace analysis software supplied with the system, thus allowing the next group to use the OTDR instrument.

- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.

- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.

2. EDUCATOR KIT DESCRIPTION

With ED-NET, students investigate the fundamental properties of Optical Time Domain Reflectometry (dead zone, distance and spatial resolution, dynamic range, etc.), identify events and determine their location along a fibre link. Various loss mechanisms along the link are then examined and measured at both 1310nm and 1550nm (i.e. Rayleigh scattering, Fresnel reflection, different connectors, standard splice, splices between standard to dispersion shifted singlemode fibre, and fibre bends). The students then measure the response of optical fibre components (fibre coupler and wavelength division multiplexer), characterise multi-branched optical networks, and perform fault location and analysis on a series of networks with deliberately introduced faults. Bi-directional OTDR measurements on the networks are also feasible. Note that ED-NET is designed for use with a commercial OTDR (singlemode 1310nm / 1550nm mini-OTDR), and traces acquired on the OTDR can be analysed remotely on a PC using the trace analysis software supplied with the system.

Optical Network Analysis (without OTDR unit) ED-NET

3. CONTENTS LIST

- Includes all of the optical networks, fibre optic components and support literature required to perform the experiments when used with a commercial OTDR & trace analysis software.

Description	Qty/Unit
HARDWARE	
A network box containing three test singlemode optical fibre networks. The networks include various elements, such as; optical fibre directional couplers, simulated faults, splices, standard & non-zero dispersion shifted singlemode fibre, different fibre connectors, extra fibre lengths and a 1310 / 1550nm wavelength division multiplexer. Access is provided to the ports at each end of the optical networks to allow bi-directional OTDR measurements if desired.	1
2 km reel of connectorised single mode optical fibre	1
All required interconnecting fibre patchcords & uniters	1 set
Bend loss device	1
LITERATURE	
Series of 12 network fault traces for analysis either, as a paper study, or using trace analysis software, as appropriate	1
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure for these modules.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on OTDR and Fibre Optic Components covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- OTDR: Commercial OTDR instrument operating with dual wavelength 1310nm and 1550nm singlemode optical source module (standard dynamic range >24dB) with SC (or FC) output and USB storage or floppy disc drive (a list of suitable OTDR's to consider is available upon request).
- Trace Analysis Software: Ideally the OTDR should be supplied with some Trace Analysis Software to also allow remote analysis of the OTDR traces on a PC.

5. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Erbium Doped Fibre Amplifiers ED-AMP

1. FEATURES

- Comprehensive laboratory educational package investigating the principles and characteristics of erbium doped fibre amplifiers (EDFAs), saving the tutor 2 to 3 years of course, literature and hardware development.
- Examines the gain characteristics under small signal and large signal conditions.
- Investigates the noise properties and its effect on the received signals.
- To enable rapid installation in the laboratory the package includes all of the necessary optical components and optoelectronic instrumentation required to perform the experiments.
- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.
- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.
- Can be extended to examine a full set of Laser experiments with the add-on module LASE.

2. EDUCATOR KIT DESCRIPTION & EXPERIMENTS

The EDFA educator kit enables students to investigate the full gain and noise characteristics of an in line fibre optic amplifier as used in long distance optical communications links and optical networks. The ED-AMP experiments include:

- Measurement of the gain characteristics of the EDFA as a function of input signal power for various pump powers.
- Investigation of small and large signal gain, gain saturation, point of transparency, gain gradient and gain efficiency.
- Measurement of pump saturation and saturated output power
- Measurement of the amplified spontaneous emission (ASE) levels as a function of input signal level over a range of pump powers.
- Investigation of ASE-ASE beat noise, Signal-ASE beat noise and noise figure under various pump and signal conditions.
- Using an optical filter module (available separately) to investigate the filter's impact on the ASE and noise levels of the amplifier.

Erbium Doped Fibre Amplifiers ED-AMP

3. CONTENTS LIST

- Includes all of the optical components and optoelectronic instrumentation required to perform the experiments.

Description	Qty/Unit
HARDWARE	
A connectorised erbium doped fibre amplifier pumped by a 980nm laser diode to provide small signal gains of the order of 25dB. The amplifier contains two optical isolators and has angle polished connectors to limit positive feedback and suppress oscillation (i.e. laser action)	1
A 1550nm DFB laser source to provide the input signals. The source has been specially designed to provide signal levels in a range from approximately -40dBm up to -3dBm (0.5mW) without degradation of its coherence properties (i.e. its linewidth). This is required to enable the investigation of small and large signal gain with gain saturation.	1
A custom designed photodiode detection system for measuring the input signal levels over a large (40dB) dynamic range. The unit also allows the measurement of the amplified AC signal power super imposed on a high quasi DC level of ASE.	1
Fixed 15dB Build-Out optical attenuator	1
Fibre patchcords to connect between the various units of the system	1 set
BNC cables	2
Mains Power Lead	2
LITERATURE	
Operator's Manual with full sample results for all the EDFA experiments and exercises.	1
Student Laboratory Manual describing the relevant EDFA background theory and experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on EDFAs and their applications covering the principles of all the issues dealt with in the laboratory exercises.	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- A two channel laboratory oscilloscope with a minimum bandwidth of 20MHz is required for some of the experiments.

5. OPTIONAL EXTENSIONS & ACCESSORIES

- Laser safety spectacles with OD3+ at 1550nm are available directly from OptoSci.
- An optical filter module enables investigation of the filter's dramatic impact on the ASE and noise levels of the amplifier.
- A complete add-on module to ED-AMP is available to extend this system to investigate the principles and characteristics of lasers (LASE).

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Lasers Module - LASE (add-on module to ED-AMP)

1. FEATURES

- LASE is an add-on extension module to the Erbium Doped Fibre Amplifiers (ED-AMP) educator kit providing a comprehensive laboratory educational package investigating the principles and characteristics of lasers, saving the tutor significant course, literature and hardware development.

- Determines the gain characteristics of the EDFA laser gain medium

- Measures the lasing threshold and slope efficiency as a function of output coupling ratio, intra cavity attenuation and pump power.

- Examines laser dynamics as a function of output coupling ratio, intra cavity attenuation and pump power.

- To enable rapid installation in the laboratory the LASE module includes all of the necessary optical components and optoelectronic instrumentation required to perform the laser experiments, when used with an existing ED-AMP kit.

- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.

- To assist with the preparation of the corresponding lecture course, the module is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.

2. MODULE DESCRIPTION & EXPERIMENTS

The LASE Lasers Module is available as an extension module to the ED-AMP kit, using the EDFA as the laser gain medium. Optical feedback and laser action is provided by a series of fused fibre couplers which are used in turn to connect the amplifier output to its input, thus forming a series of uni-directional fibre ring lasers. The LASE Module experiments include:

- Measurement of power / pump characteristic of the laser for several output coupling ratios and various levels of intra-cavity loss.
- Investigation of the variation of threshold and slope efficiency with output coupling ratio and intra-cavity loss.
- Measurement of relaxation oscillations for different pump powers, levels of intra-cavity loss and coupling ratios
- Investigation of the square of the relaxation oscillation frequency versus pump power in order to derive the excitation lifetime.
- Examination of laser onset time delay as a function of different pump powers, levels of intra cavity loss and output coupling ratios.

Lasers Module - LASE (add-on module to ED-AMP)

3. CONTENTS LIST

- The Lasers extension module to ED-AMP includes all of the optical components required to perform the laser experiments, when used with an existing ED-AMP educator kit.

Description	Qty/Unit
HARDWARE	
Fibre couplers with angle polished connectors to allow investigation of the laser output coupling ratio in steps from 20%, 40%, 60% and 80%	2
In-line band pass filter with angle polished connectors to stabilise operating wavelength	1
In-line variable attenuator to adjust the intra-cavity attenuation in the range 0-30dB	1
Fibre patchcords to connect between the various units of the system	1 set
LITERATURE	
Operator's Manual with full sample results for all the fibre ring laser experiments and exercises.	1
Student Laboratory Manual describing the relevant fibre ring laser background theory as well as the experimental procedure.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Lasers covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

- An ED-AMP educator kit
- A two channel digital storage oscilloscope (DSO), minimum bandwidth of 20MHz

For the laser dynamics experiments:

- a signal / function generator capable of producing a square-wave modulation at 10Hz and 100Hz, with an amplitude of 0 to +5V, and with DC offset capability

5. OPTIONAL EXTENSIONS & ACCESSORIES

- Laser safety spectacles with OD3+ at 1550nm are available directly from OptoSci.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

Principles of Lasers ED-LASE

1. FEATURES

- Comprehensive laboratory educational package investigating the principles and characteristics of lasers based on an Erbium Doped Fibre Ring Laser, saving the tutor 2 to 3 years of course, literature and hardware development.

- Measures the lasing threshold, slope efficiency and laser dynamics as a function of output coupling ratio, intra cavity attenuation and pump power

- To enable rapid installation in the laboratory ED-LASE includes all of the necessary optical components and optoelectronic instrumentation required to perform the laser experiments.

- To eliminate any time consuming and expensive preparation for the tutor extensive literature support is provided including: student manuals which describe the relevant background theory and experimental procedures, and an instructor's manual with sample results for all experiments and exercises.

- To assist with the preparation of the corresponding lecture course, the educator kit is accompanied by a comprehensive set of lecture notes (incorporating examples, design studies, and tutorial questions and solutions) detailing the underlying principles behind the laboratory experiments.

2. EDUCATOR KIT DESCRIPTION

The Principles of Lasers educator kit enables students to investigate the principles and characteristics of lasers using an Erbium Doped Fibre Ring Laser. An EDFA is used as the gain medium with optical feedback and laser action provided by a series of fused fibre couplers which are used in turn to connect the amplifier output to its input, thus forming a series of uni-directional fibre ring lasers. In the course of the experiments the students measure the pump power characteristic of the laser for several output coupling ratios and various levels of intra-cavity loss. They then investigate the variation of lasing threshold and slope efficiency as a function of output coupling ratio, intra-cavity attenuation and pump power. In addition the pump laser in the EDFA is fitted with an external modulation input to allow the examination of laser dynamics. In particular the students investigate and measure the laser relaxation oscillation frequencies for different pump powers, levels of intra cavity loss and output coupling ratios, and proceed to examine the square of the relaxation oscillation frequency versus pump power in order to derive the excitation lifetime. They then explore the laser onset time delay as a function of different pump powers, levels of intra cavity loss and output coupling ratios.

Principles of Lasers ED-LASE

3. CONTENTS LIST

- The Principles of Lasers educator kit provides all of the optical components required to perform the laser experiments.

Description	Qty/Unit
HARDWARE	
A connectorised erbium doped fibre amplifier designed to provide small signal gains of the order of 25 dB.	1
70mW 980nm pump laser diode with adjustable drive current, external modulation input and LCD power readout	1
Fixed 15dB optical attenuator	1
Fibre couplers with angle polished connectors to allow investigation of the laser output coupling ratio in steps from 20%, 40%, 60% and 80%	2
In-line band pass filter with angle polished connectors to stabilise operating wavelength	1
In-line variable attenuator to adjust the intra-cavity attenuation in the range 0-30dB	1
Fibre patchcords to connect between the various units of the system	1 set
An InGaAs photoreceiver module for output power measurements.	1
BNC cables	3
BNC Tee-Piece	1
Mains Power Lead	1
LITERATURE	
Operator's Manual with full sample results for all experiments and exercises.	1
Student Laboratory Manual describing the relevant background theory and experimental procedure for these modules.	1
Comprehensive set of tutorial questions and solutions	1
Extensive Lecture Notes on Lasers covering the principles of all the issues dealt with in the laboratory exercises	1
CD with student literature (signed agreement required)	1

4. ADDITIONAL EQUIPMENT REQUIRED

For the laser dynamics experiments:

- a signal / function generator capable of producing a square-wave modulation at 10Hz and 100Hz, with an amplitude of 0 to +5V, and with DC offset capability
- A two channel digital storage oscilloscope (DSO), minimum bandwidth of 20MHz

5. OPTIONAL EXTENSIONS & ACCESSORIES

- Laser safety spectacles with OD3+ at 1550nm are available directly from OptoSci.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.

WDM Components, WDM Systems & Bragg Gratings ED-WDM Series

1. FEATURES

- ED-WDM Series is a modular range of kits consisting of a base unit Wavelength Division Multiplex (WDM) Components, and three extension modules, Dense WDM (DWDM) Systems, 1310/1550nm WDM Systems & Bragg Gratings.
- Comprehensive laboratory educational package investigating, analysing and characterising WDM components, WDM systems and Bragg Gratings, which saves the tutor significant preparation time and the associated cost of course, literature and dedicated hardware development.
- To enable rapid installation in the laboratory WDM COMPONENTS include all of the necessary optical components and optoelectronic instrumentation required to perform the experiments. The extension units include all of the additional optical components and optoelectronic instrumentation needed to extend the experiments.
- To eliminate any time consuming and expensive preparation for the tutor, extensive literature support is provided including: student manuals describing the relevant background theory and experimental procedures, and an instructors manual with sample results for all experiments and exercises. Furthermore the manual includes background notes on fibre optic components and WDM systems covering the principles of the issues dealt with in the laboratory exercises.
- Driver & display software for optional PC control & monitoring of instrument via USB interface.
- 3U 19" rack style modules allow flexible unit combination, future upgrade options and expansion of the kit when appropriate.

2. EDUCATOR KIT DESCRIPTION

ED-WDM Series consists of a base kit, WDM COMPONENTS, and three extension modules, DWDM Ext, 1310/1550 WDM Ext and BRAGG Ext.

WDM COMPONENTS:
During the course of their investigations with WDM COMPONENTS, the students measure insertion losses, backreflection / return loss, for: a fused biconical taper (FBT) coupler, a FBT WDM, an isolator, a circulator, an Optical Add/Drop Multiplexer (OADM), and backreflection from PC and APC connectors. They then continue to determine the isolation/extinction ratios for an isolator, circulator and OADM and characterise & examine the narrowband wavelength response of Bragg grating and DWDM modules. Using the dedicated driver and display software supplied, the student can then measure and plot the variations in LVI characteristics of an ITU Grid DFB laser with operating temperature.

DWDM Ext:
With the addition of the DWDM Ext module the experiments are extended to investigate and characterise a two channel DWDM system and examine channel add / drop and measure system crosstalk / channel isolation. The students then examine the effect of wavelength drift on DWDM System cross-talk, and (using BER(COM)) the influence of system crosstalk on Eye Diagrams / BER in DWDM systems.

1310/1550 WDM Ext:
The addition of the 1310/1550 WDM Ext module expands the experiments to measure insertion loss and backreflection/return losses for various components supplied with WDM COMPONENTS at 1310nm to compare with 1550nm measurements. Students then determine fibre attenuation and link length and estimate the chromatic dispersion of singlemode fibre using pulsed lasers at 1310nm & 1550nm. Finally they assemble and characterise a two channel 1310nm & 1550nm WDM system.

BRAGG Ext:
The BRAGG Ext module allows examination of temperature tuning effects on a Bragg grating and subsequently its role as a temperature sensor.

3. CONTENTS LIST

- Includes all of the optical components and optoelectronic instrumentation required to carry out the experiments.

Description	Qty/Unit
HARDWARE WDM COMPONENTS	
ITU Grid DFB laser with integrated precision current and temperature driver and LCD display (tuning range ±0.8nm, 10pm resolution; SMB modulation input)	1
InGaAs optical power meter with integral LCD display (60dB dynamic range)	2
Various in-line fibre component Modules: FBT coupler, FBT WDM, isolator, circulator, OADM (SC connectors)	1 set
Fibre Bragg grating Module (SC connectors)	1
PC & APC Connector Module	1
3U 19" rack enclosure for passive modules and all required interconnect fibre patchcords	1
3U 19" rack enclosure with integrated power supply, USB interface, and all required electrical interconnects and RF cables.	1
All required interconnect fibre patchcords	1 set
SOFTWARE WDM COMPONENTS	
CD with driver and display software to provide computer control / monitoring of the appropriate hardware modules in ED-WDM Series. • Allows examination of laser LVI characteristics, automatic wavelength scanning of the laser sources and readout of optical power meters to enable narrowband characterisation of WDM components. • LVI and optical component Wavelength Scan plots can be viewed on screen and the data saved in CSV format for export to standard spreadsheet packages.	1
LITERATURE WDM COMPONENTS	
Instructors Manual with full sample results for all experiments and exercises as well as background notes on WDM fibre optic components and WDM systems covering the principles of all the issues dealt with in the laboratory exercises.	1
Student Laboratory Manual describing the background theory and experimental procedure, with associated exercises to encourage the student to discuss the implications of their results.	1
CD with student literature for WDM Series modules (signed agreement required)	1
HARDWARE DWDM Ext	
Additional ITU Grid DFB laser with integrated precision current and temperature driver and LCD display (tuning range ±0.8nm, 10pm resolution; SMB modn input)	1
InGaAs Photoreceiver with BNC outputs (Bandwidth ~ 100MHz) *	2
Fixed Optical Attenuator *	2
Variable Optical Attenuator with panel mounted control - up to 30dB attenuation	1
OADM module (SC connectors)	1
All required interconnect fibre patchcords	1 set
LITERATURE DWDM Ext	
Operators Manual Supplement with full sample results for all experiments & exercises	1
Student Laboratory Manual Supplement describing any additional background,	1

experimental procedure and exercises.

HARDWARE 1310/1550 WDM Ext

DFB laser module (λ_c=1310±10nm) with integrated precision current and temperature driver and LCD display (SMB modulation input)	1
InGaAs Photoreceiver with BNC outputs (bandwidth ~ 100MHz) *	2
Fixed Optical Attenuator *	2
FBT WDM module (SC connectors)	1 set
4km connectorised singlemode fibre reel (SC connectors)	1
All required interconnect fibre patchcords	1 set

LITERATURE 1310/1550 WDM Ext

Operators Manual Supplement with full sample results for all experiments and exercises	1
Student Laboratory Manual Supplement describing any additional background, experimental procedure and exercises.	1

HARDWARE BRAGG Ext

Fibre Bragg grating module with integrated Peltier thermoelectric device	1
Thermoelectric Controller Module allowing front panel adjustment of set temperature (in 0.1°C increments). Integral LCD displays set and actual temperature.	1

LITERATURE BRAGG Ext

Operators Manual Supplement with full sample results for all experiments and exercises	1
Student Laboratory Manual Supplement describing any additional background, experimental procedure and exercises.	1

** Note that both the 1310/1550 WDM Ext and DWDM Ext require a dual photoreceiver plug-in module and attenuators. As only one dual photoreceiver module and set of attenuators is required for the experiments, if you order both the 1310/1550 WDM Ext and the DWDM Ext for use with one WDM COMPONENTS kit then only one dual photoreceiver plug-in module and set of attenuators will be supplied.*

4. ADDITIONAL EQUIPMENT REQUIRED

- Most experiments in the kits can be performed using the front panel controls on the instrument modules. However, external computer control and readout of the instrument modules using the driver software supplied will require a PC with USB support.

Performance of the full series of experiments in the DWDM Ext and 1310/1550 WDM Ext modules requires:

- A two channel digital storage oscilloscope (DSO) with USB output, minimum bandwidth of 50MHz, and (for the BER experiments) a minimum *real time* sampling rate of 500Msamples/sec (Recommended compatible oscilloscopes: Tektronix DSO's (TDS 2000 series, USB output) and also Keysight (Agilent) DSO's (InfiniiVision 2000 X-Series, USB Output)).
- A laboratory signal generator (up to 10V p-p output, frequency up to at least 2MHz, 10MHz preferable)
- An OptoSci BER(WDM) module for certain DWDM Ext and 1310/1550 WDM Ext experiments (see separate BER(WDM) specification sheet for full details).

5. OPTIONAL EXTENSIONS & ACCESSORIES

- The 3U 19" rack style module design also offers the potential of making a custom kit combination – please contact OptoSci to discuss your requirements further.
- ***4-Ch.DWDM Ext*** is an add-on to the DWDM Ext module and includes two additional ITU Grid DFB laser modules and DWDM components to assemble & investigate a 4-Channel DWDM system. Please contact OptoSci if you would like more details.
- An OSA is not required for any of the ED-WDM Series of experiments but, if available in the laboratory, could of course be used to examine the WDM system and component response over a broader wavelength range.

6. REMARKS

- Warranty: 12 months from date of delivery
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals
- Since OptoSci are committed to continuously improving the design and performance characteristics of our products, these specifications are subject to change without notice.

BER Experiments for WDM — BER(WDM) (add-on to ED-WDM Series)

1. FEATURES

- Add-on module to ED-WDM Series which enables students to generate and evaluate eye diagrams and investigate the effects of system cross talk on eye diagrams and BER due to tuning the emission wavelength of ITU Grid DFB lasers. In addition it allows chromatic dispersion measurements, and fibre link length estimation, using the requisite modules of OptoSci's ED-WDM Series educator kit.

- To enable rapid installation in the laboratory the package includes all of the specialised additional components and literature required to perform the experiments.

2. MODULE DESCRIPTION

The BER(WDM) add-on module to ED-WDM Series enables students or trainees to generate and evaluate eye diagrams in WDM and DWDM systems. In the course of the investigation the students generate and observe the appearance of eye patterns at various bit rates directly from BER(WDM) and then, using the ED-WDM Series modules, examine system crosstalk effects on Eye Diagrams / BER in DWDM systems (using the DWDM Ext. Module). Using the statistical analysis software supplied students/trainees estimate and compare the Q-factors and BER from signal level (eye pattern) histograms for the transmitters over various equivalent fibre link lengths (simulated using an in-line attenuator) and at different bit rates.

The BER(WDM) also provides an impulse output which may be used with specific configurations/options of the ED-WDM Series of educator kits to enable students to perform chromatic dispersion measurements in a singlemode fibre link between 1310nm & 1550nm and determine the fibre link length.

3. CONTENTS LIST

- The BER(WDM) add-on module to ED-WDM Series includes all of the specialised additional components required to perform the eye diagram and BER experiments, when used with requisite modules of the existing ED-WDM series educator kit.

Description	Qty/Unit
HARDWARE	
Benchtop instrument including PRBS Generator with variable bit rate (.01 - 40Mbit/s), Least Count 1 bps, with front-panel LCD display, and data (5V p->p at 50 ohms), clock and impulse outputs	1
4 km reel of SC/APC connectorised step index single-mode optical fibre (λ_c ~ 1210-1250 nm)	1
BNC cables (1m)	1
Null Modem Cable/ USB cable	1
Mains Power Lead	1
SOFTWARE	
Q-factor Analysis Software to determine Q-factors and BER from the eye pattern histograms generated via BER(WDM).	1
LITERATURE	
Operators Manual Supplement with full sample results for all experiments and exercises	1
Student Laboratory Manual Supplement describing any additional background, experimental procedure and exercises.	1

4. ADDITIONAL EQUIPMENT REQUIRED

- ED-WDM Series educator kit (required modules: WDM Components with 1310/1550 WDM Ext and/ or DWDM Ext.).
- A two channel digital storage oscilloscope (DSO) with a USB output, minimum bandwidth of 50MHz, and minimum *real time* sampling rate of 500MSa/s (see DSO recommendations below).
- The Q-factor Analysis Software requires a PC running Windows XP, 7, 8 or 10 and is currently designed to be compatible with Tektronix DSO's (TBS 1000 series, USB output) and also Keysight (Agilent) DSO's (InfiniiVision 2000 X-Series, USB Output).

5. BER(COM) use with ED-COM

The PRBS and Q-factor software supplied with BER(COM) can also be used for experiments with OptoSci's ED-COM kit. When used with ED-COM, BER(COM) investigates the effects of noise, attenuation and dispersion on eye diagrams and BER for the many communication system permutations allowed by OptoSci's ED-COM educator kit (see BER(COM) *BER in Optical Communications* specification sheet for details).

6. REMARKS

- The goods are fully guaranteed for a period of 12 months from date of delivery.
- Full instructions for installation and use of the equipment is provided in the associated instructor and student manuals.