

The Bentham Fibre Spectral Loss System is modular in nature and consists of chopped light sources, monochromators, launch optics, detector and lock-in amplifier. The whole system is controlled by a PC which also calculates loss in dB/km as a function of wavelength.



Cut back method

Spectral loss in fibres is usually measured by the cut-back method. Modulated white light is passed through a monochromator before being launched into one end of the fibre under test. The light emitted from the other end of the fibre is collected by a large area indium gallium arsenide or silicon detector and the resulting signal amplified by a lock-in amplifier. The detector end of the fibre is then cut back by a known length and the cleaved end reinserted in the detector assembly. The spectral loss of the fibre is calculated from the two stored curves as follows:

$$\text{Spectral Loss (dB/km)} = 10 \log_{10} (\text{short/long})/\text{cutback}$$

Prime system requirements

- Light throughput of the monochromators
- Stability of light output
- Mechanical stability

Light throughput of the monochromator

The final signal-to-noise ratio and hence speed and accuracy of measurement is dominated by the level of light reaching the detector. In all real systems this light level is limited by the efficiency and light throughput of the monochromators.

When comparing various commercially available monochromators, you find that most have an f number in the region of 4. It is a common misconception to assume that light throughput can be assessed by comparing f number alone. This is not the case. For a given spectral bandwidth, a large $f/4$ monochromators (long focal length, large mirrors and gratings) will operate with wider slits than a small $f/4$ unit. The wider slit allows more power through and into the fibre.

The Bentham system uses a 300mm focal length, $f/4$ monochromators to launch 5nW or -53dBm (cw) into a single mode fibre (1300nm, 10nm bandwidth).

Fibre spectral loss system

Stability

Due to the sequential nature of the measurement, both optical and mechanical stability over the period of the two spectral runs is of critical importance.

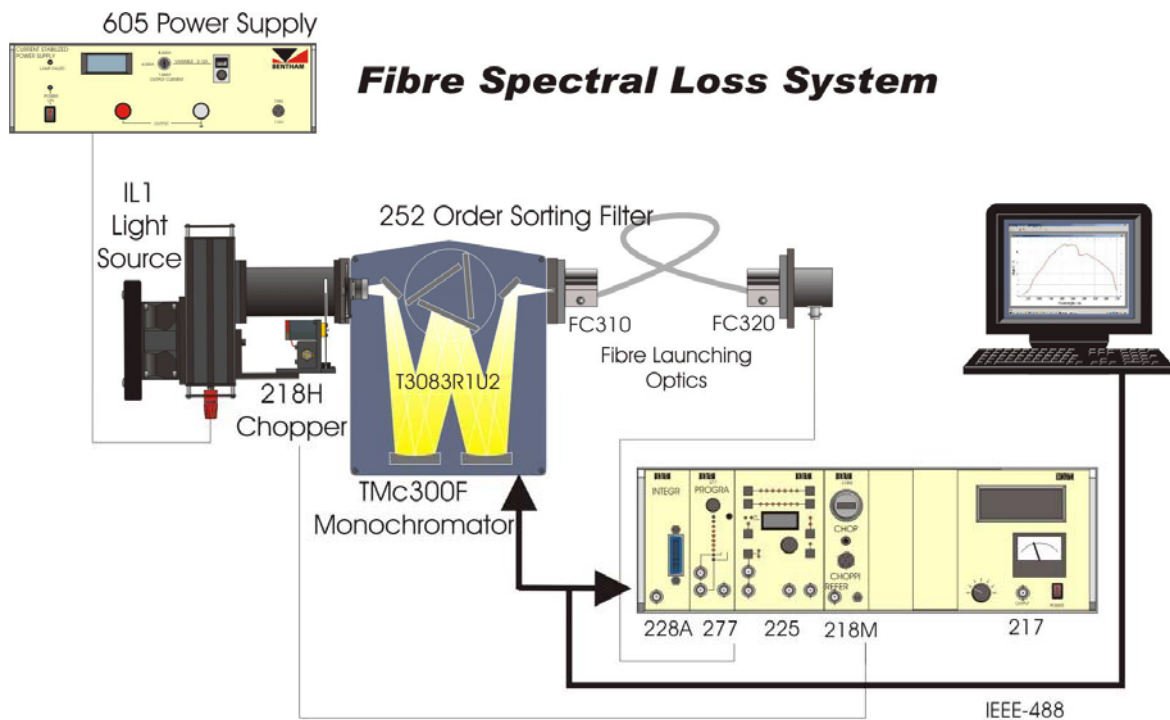
For the Bentham system, optical stability is ensured by the IL1 light source, which uses a 100W quartz halogen lamp controlled by a highly stabilised constant current power supply. This power supply is at least 10 times more stable than a normal laboratory stabilised supply.

Mechanical instability in such systems results in short or long term wander of the focused spot over the end of the fibre at the launched end. In the Bentham system the light source and launch optics are bolted firmly to the monochromator which is constructed from a single rigid casting.

Software

Our software controls the entire system via the IEEE/488 bus. The operator may select the start and finish wavelengths for the scan as well as spectral resolution and signal averaging period.

Automatic zero routines deal with any drift in electronic offset by making a zero level measurement prior to each spectral run. Complete spectral loss files may be stored in ASCII format, allowing easy transfer to other software packages.



- 228A: Integrating A-D converter
- 277: Programmable current pre-amplifier
- 225: Fully programmable lock-in amplifier
- 218M: Optical chopper with modular control electronics
- 217: Single height bin, power supply and display

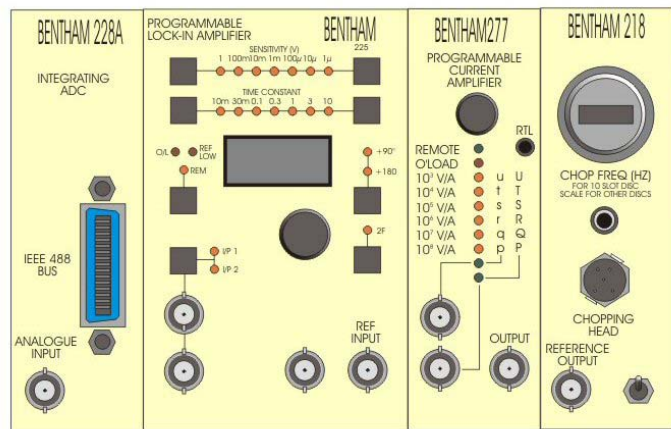
Fibre spectral loss system

Lock-in amplifier system

The lock-in amplifier system uses the 277 system programmable current pre-amplifier followed by the 225 programmable voltage sensitive lock-in module and 228A integrating analogue to digital converter.

Controlling the sensitivity in the current pre-amplifier is better from a signal-to-noise point of view than the more conventional approach, where the current pre-amplifier has fixed gain and is followed by a lock-in with programmable voltage sensitivity.

The 228A integrating analogue to digital converter, which digitises the lock-in output and passes it to the computer, makes maximum use of the signal information available and allows digital averaging in the computer, a far better technique than analogue averaging in the time constant circuit of the lock-in.



Fibre launch optics

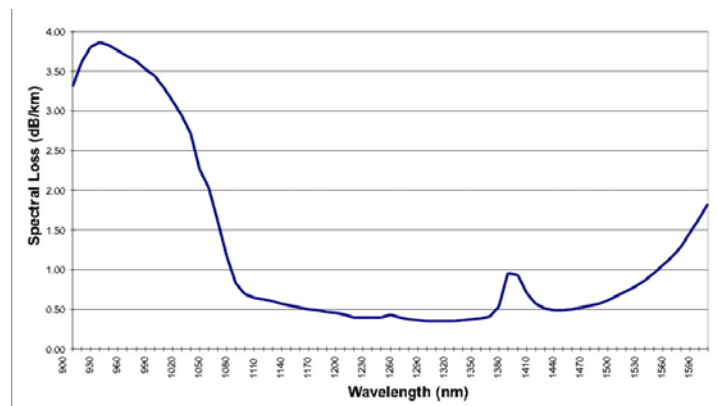


Flexibility

The modular nature of the Bentham system leads to a degree of flexibility which is unobtainable with other systems. Some of the more common adaptations which our existing customers have made are:-

- Changing light source, grating and detector to cover other wavelength ranges from UV to beyond 5 microns
- Positioning the launch optics at the entrance and the detector at the exit of the monochromators to analyse the output of LED's and lasers with fibre pigtails
- Measuring transmission of filters and other fibre components

Typical results



Fibre spectral loss system specifications

Light source

100W quartz halogen source with aspheric lens controlled by constant current supply at 8.5A. Built-in variable frequency chopper.

Stability of light output: $\pm 0.1\%$ over 8-hour period
 Power supply stability: 0.02% for $\pm 10\%$ variation in line supply and $0.01\%/K$.

Monochromator

- 300mm focal length Czerny Turner mount with 69mm x 69mm mirrors and gratings.
- Variable slits adjustable from 0.01mm to 5.5mm.
- Stepping motor controlled wavelength selection.
- Stepping motor controlled order sorting filter wheel and shutter.
- Interchangeable gratings.

Grating dependent specification

Grating [lines/mm]	600	900	1200	300
Resolution (optical) [nm]	0.7	0.5	0.35	1.4
Min. wavelength step [nm]	0.15	0.1	0.075	0.3
Range of bandwidth [nm]	0.7-30	0.5-22.5	0.35-15	1.4-60
Usable wavelength range [μ]	0.8-2.5	0.5-1.8	0.3-1.1	1.5-5.5
Scan speed [nm/sec]	60	40	30	120
Reciprocal dispersion [nm/mm]	5.4	3.6	2.7	10.8
Wavelength accuracy [nm]	± 0.4	± 0.3	± 0.2	± 0.8

Order sorting filter wheel/shutter

Six position stepping motor controlled filter wheel. Five positions available for filter. Position 6 is shutter. Long wavepass filters available with insertion wavelengths of 400nm, 70nm, 1250nm, 200nm, 3800nm, 700nm and 12000nm.

Lock-in amplifier

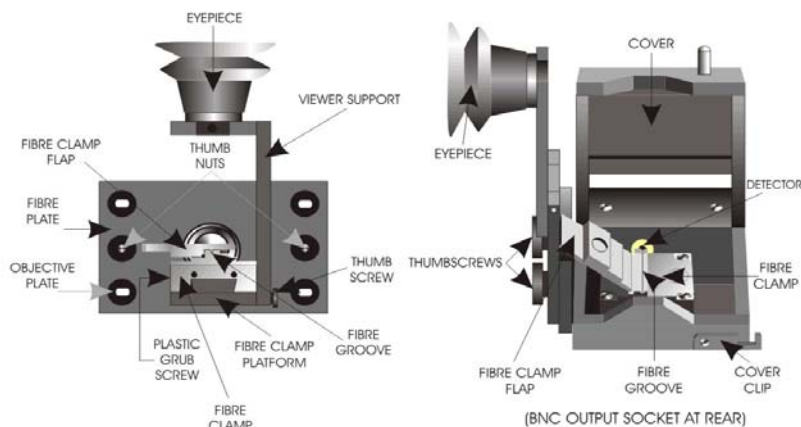
Current pre-amplifier with programmable transimpedance of $10^3V/A$ to $10^8V/8$ followed by lock-in module with manually selectable gain of 10 to 10^6 . Analogue output is digitised by Bentham's 228A Integrating ADC with 4.5 digit resolution.
 Gain stability: 100ppm/K

Launch optics

Slit mounted launch optics with x20 microscope objective with NA of 0.4.

Fibre is held in bare fibre chuck capable of holding fibres with diameters from zero to 250 microns. Alternative chucks for fibres up to 1mm diameter and for recognised fibre connectors also available.

Fibre chuck is manually adjusted x,y,z stage giving sub-micron positioning resolution.



Detector

A 2mm diameter InGaAs photodiode in housing with adapter for fibre chuck. Detector can also be mounted at exit slit of monochromators.

Peak responsivity : 0.9A/W at 1700nm
 Responsivity at 1300nm: 0.7A/W
 Typical shunt resistance: 0.9M Ω

A 5mm diameter silicon photodiode is available for measurements in the 300nm to 1100nm range.

System

Wavelength range with standard grating and detector:	800 to 1.7 microns
Dynamic range:	30dB single mode fibre 48dB multimode fibre
Repeatability:	<0.01dB (10nm bandwidth)
Power into single mode fibre:	2.5nW with 10nm bandwidth and chopper running at 1300nm
Wavelength range with 1200g/mm grating and silicon detector:	300nm to 1100nm