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HP 86037B Chromatic Dispersion Test Solution

**Highly accurate and repeatable measurements  
of fiber and gratings in the 1300, 1550, or 1600<sup>+</sup> nm  
wavelength bands**



- L-Band extended wavelength option (up to 1640 nm)
- High resolution and accuracy on narrow-band devices
- Faster measurement capability

## Introduction

This document provides an overview of the HP 86037B version Chromatic Dispersion Test Solution. The 86037B provides accurate characterization of optical fiber cables, dispersion compensating devices and fiber Bragg gratings for manufacturing and R&D. New to the “B” version are extended wavelength operation to characterize components in the L-Band (up to 1640 nm), greater measurement speed control based on accuracy requirements, and an easy to use graphical interface for measuring fiber or gratings. It is a complete, turnkey solution, requiring no further equipment to make chromatic dispersion measurements.<sup>1</sup>

The HP 86037B solution is aimed at applications requiring near-end measurement capabilities (i.e. where there is access to both ends of a test device at the same location). Far-end configurations (i.e. those that are made ship-to-shore or at two geographically separated locations) are not addressed in this document.

## HP 86037B Features and Benefits

The HP 86037B CD Test Solution is ideal for chromatic dispersion measurements in manufacturing as well as R&D environments. It uses the industry-standard modulation phase-shift (MPS) technique for group delay and dispersion measurements.

## L-Band 1600+ nm Extended Wavelength Operation

The HP 86037B features extended wavelength operation up to 1640 nm. This covers the “Long” Band (or L-Band) region of the erbium-doped fiber amplifier (EDFA) transmission window. An extended wavelength tunable laser source and enhanced modulator/receiver hardware in the HP 83427A test set make this possible. This option allows CD measurements to be made from 1510 nm up to 1640 nm with high dynamic range over a wide band.

The standard 1550 nm configuration covers the 1450 to 1590 nm range for “Conventional” and “Short” Bands (C-Band & S-Band) of EDFA transmission, and the 1300 nm system measures dispersion from 1265 to 1350 nm. Further details about wavelength range and options are available in the “Ordering Option” and “Performance and Specifications” sections of this document.

## Faster Measurements

The HP 86037B improves group delay and dispersion measurement speed by offering more flexible network analyzer set up control and by determining measurement accuracy needs. Figure 2 provides an example of speed improvements on a fiber DUT (device under test) compared to the “A” version<sup>2</sup>. Speed is increased by a factor of 1.7 by using 3 points instead of 201 and selecting *normal* sensitivity. A factor of 6 speed increase is achieved when using 3 points (instead of 201) at the *highest* sensitivity setting.

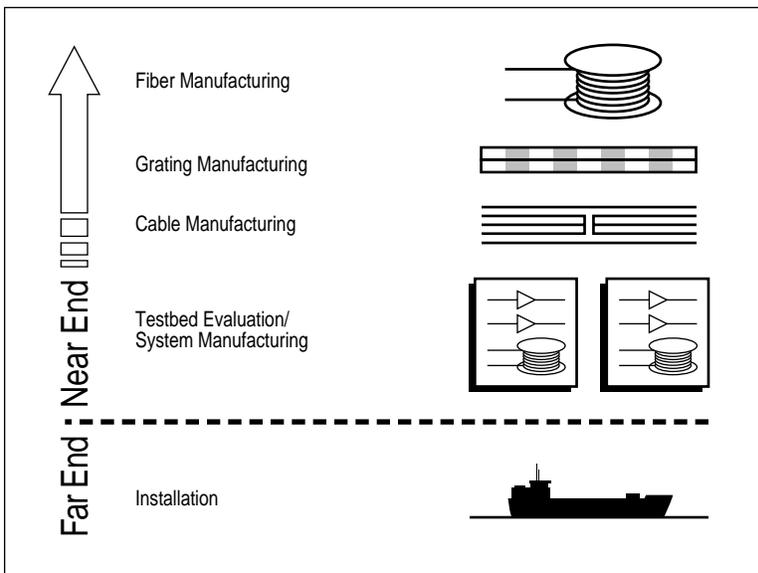


Figure 1. Chromatic dispersion dependent applications

<sup>1</sup> Please contact HP's field staff with any questions or requests for modification or custom configurations.

<sup>2</sup> Testing was done on dispersion shifted fiber spools from 1520 to 1580 nm, +7 dBm TLS power, 60 wavelength steps, gain off, reference wavelength on, wavelength meter on, enhanced TLS mode off.

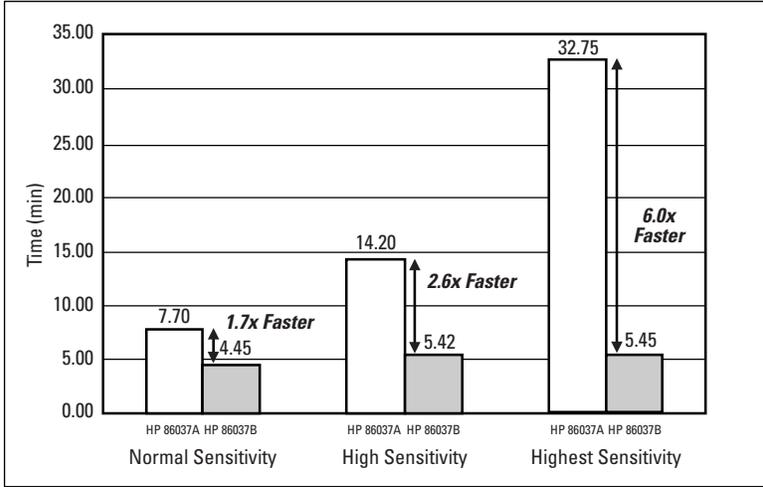


Figure 2. HP 86037B speed improvements

These speed improvements can still maintain high measurement accuracy by using the group delay uncertainty analysis feature available in the “B” version.<sup>3</sup> Users can now understand how much delay uncertainty there is when adjusting the measurement set up parameters. Figure 3 depicts the Group Delay Uncertainty Analysis graph as a function of device loss.

For devices with less than 10 dB loss, very high accuracy can be achieved by using only 3 points and normal sensitivity with fast measurement results. The uncertainty analysis graph shows that using more points and higher sensitivity would not gain any more accuracy but would take more time. With greater losses, speed is dependent on the accuracy requirement of the group delay

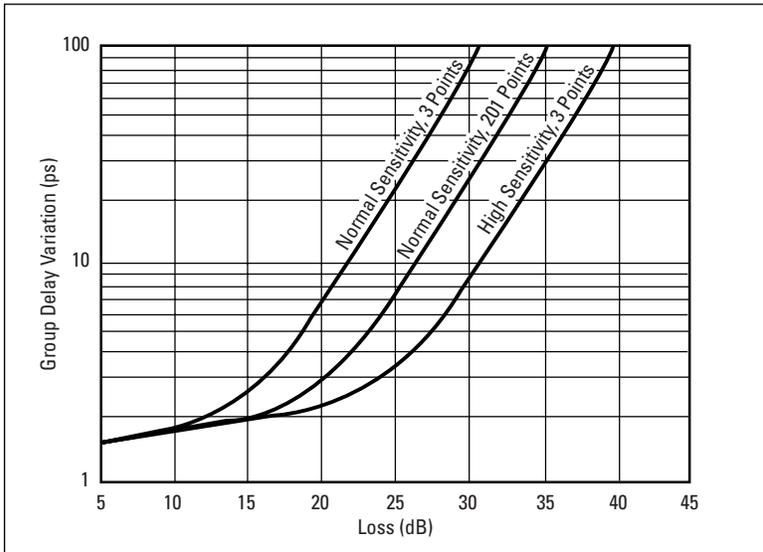


Figure 3. Group delay uncertainty versus loss

measurement. Test times can be significantly reduced if larger group delay uncertainty is tolerated, while very accurate measurements will require additional time. This flexible speed/accuracy control in the HP 86037B allows users to optimize measurement time based on their specific needs.

### Standard Features

Along with the new features, the HP 86037B CD System comes with the following capabilities:

- High wavelength resolution and accuracy
- Wide dynamic range
- High repeatability
- Quadratic, 3-term and 5-term Sellmeier curve fitting algorithms
- Direct calculation from group delay data
- NIST backed and traceable measurements
- Automatic length measurements
- Integrated MS Access™ database storage of measurements
- Spectral gain/loss measurements
- Transmitted and reflected signal strength vs. wavelength measurements
- Windows NT based software
- Remote connectivity
- Remote file interface control capability
- A full range of installation, training and support options

<sup>3</sup> Group delay variation was determined by using the results of Monte Carlo simulations to relate lambda zero standard variations to group delay variations. Lambda zero was determined using quadratic fitting.

## **Product Description**

The HP 86037B CD Test solution is capable of meeting complex dispersion measurement requirements by integrating high performance instruments with robust system software. It has proven performance through extensive testing on very long, amplified lightwave transmission systems with excellent repeatability. The performance of the CD Test solution is possible through the use of high quality Hewlett-Packard instruments, described below:

### **RF Network Analyzer**

An HP RF Network Analyzer is used in the HP 86037B to generate and receive the modulation signal, instead of the typical arrangement of signal generator and voltmeter. This approach results in higher phase accuracy and resolution, faster sweep speeds, and easy length measurements.

### **Choice of HP Tunable Laser Sources**

The HP 86037B offers a choice of tunable sources to measure devices in specific wavelength bands. The standard HP 8168F series covers the 1450 to 1590 nm wavelength range. An enhanced HP 8168F TLS is used to extend the wavelength operation from 1510 up to 1640 nm. HP 8167B tunable laser source is used to characterize dispersion in the 1300 nm region. An HP8168D TLS is a low cost, reduced performance source to measure dispersion

in the 1550nm range. These sources can also be combined for a dual band solution. Further detail is available in the "Ordering Options" section of this document.

Polarization-maintaining (PM) fiber is also used in all tunable laser sources and in the output fiber pigtailed to increase the stability and accuracy of measurements. This is a key element to optimize system operation, accuracy, and repeatability.

### **Wavelength Meter**

Wavelength accuracy is enhanced using the HP 86120C Multi-Wavelength Meter (MWM). The MWM provides a very precise wavelength reference to automatically measure and provide feedback of the Tunable Laser Source's output wavelength. Absolute accuracy of 3 pm can be achieved in the HP 86037B test solution. The HP 86120C is included in the standard configuration, but a low cost CD solution is available that excludes this component (see the "Ordering Options" section).

### **Test Set Module**

The Test Set in the HP 86037B mainly consists of the modulator and optical receiver. The internal modulator converts the RF electrical signal from the network analyzer and modulates the TLS optical signal. The instrumentation-grade receiver is used to ensure stable and accurate recovery of the optical signal back to electrical for phase analysis by the network analyzer.

### **System Controller**

All system elements, measurement procedures, temperature compensation algorithms and computations are performed with an HP PC controller in a 32-bit Windows™ NT operating environment. An intuitive, easy-to use Graphical User Interface (GUI) provides simplified control of any type of measurement. The PC controller also comes with a Digital-to-Analog (DAC) card, used to control the modulator bias, and a LAN card, to take advantage of Windows™ NT's networking capability. The system also comes with a Super VGA monitor, keyboard and mouse.

### **System Software with Easy-to-Use GUI**

A Visual Basic® program running under the Windows™ environment ensures easy-to-use operation and flexibility in adapting the system to user needs. The application's main measurement window (Figure 4) has been enhanced to allow users to easily set up parameters depending on whether the device under test is a fiber or grating. A selectable measurement speed setting (bottom of figure) can control measurement time versus accuracy needs of the user. Speed can be optimized for broadband fiber measurements, or accuracy can be optimized on narrow-band grating measurements. Example measurement results are shown in Figures 5 and 6.

Customers are also able to use the 86037B's remote file interface program to create their own user GUIs to reside on top of the system's own software. Please see Appendix 3: Applications of the Remote File Interface for details.

## Measurement Description

The HP 86037B uses the modulation phase shift technique to make CD measurements. The RF Network Analyzer is used to modulate the optical signal at user-definable modulation frequencies ( $f_m$ ) for any measurement can be selected manually or automatically by the system. The automatic  $f_m$  algorithm selects the highest modulation frequency (Range: 100 MHz to 2.5 GHz) that avoids phase wrap-around errors for a given measurement setting ( $\Delta\lambda$ ) and device characteristics (dispersion and length). Flexibility in choosing this modulation frequency allows measurements of the highest practical accuracy.

The block diagram in Figure 7 shows the 86037B's system configuration. The output of the TLS is transported via polarization maintaining fiber to the modulator in the heart of the test set. There, the signal is modulated and split.

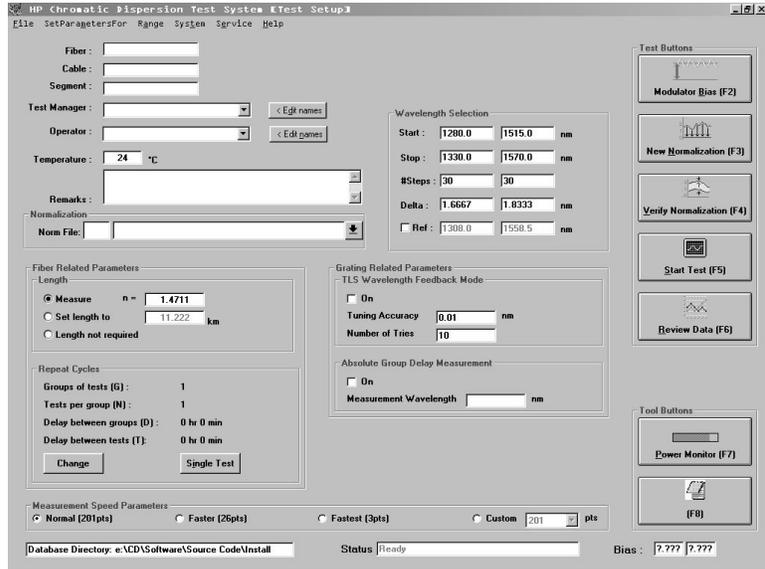


Figure 4. GUI main window

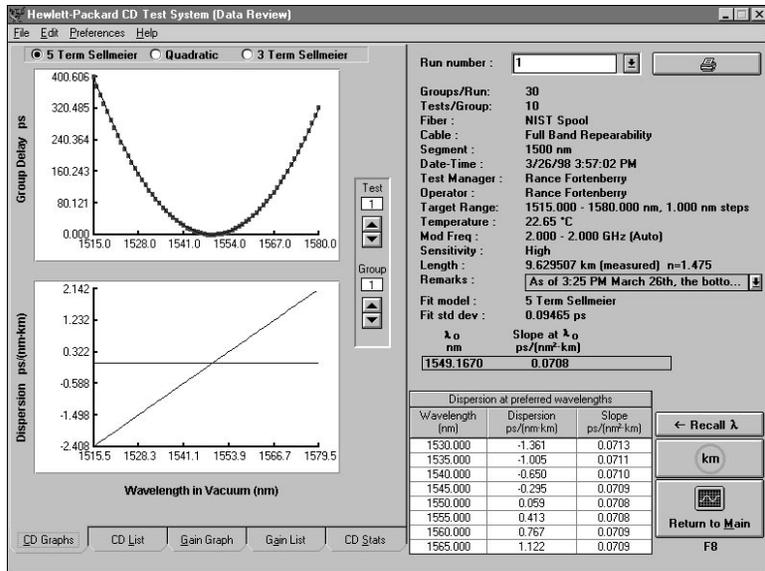


Figure 5. Screen shot of fiber measurement

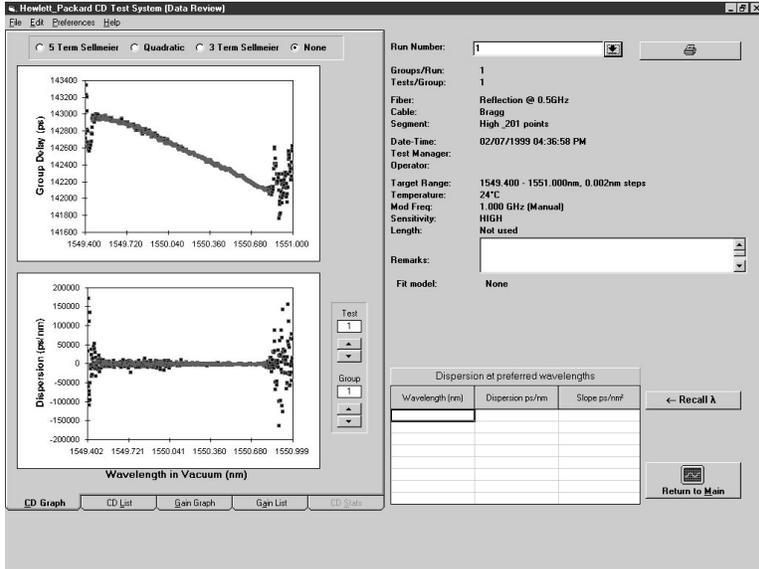


Figure 6. Screen shot of grating measurement

One half is passed through the DUT, detected by the optical receiver, down converted to RF frequencies and compared by the 8753E network analyzer against its own reference signal. The difference in phase between the two signals is used as the basis of all measurements. The second half of the modulator signal is fed straight to the HP 86120C Multi-wavelength meter for attaining wavelength accuracy in measurements. The wavelength meter provides a feedback loop to the laser to ensure the accuracy of the laser's output signal. The whole system operation is controlled by the PC controller via the HP-IB bus.

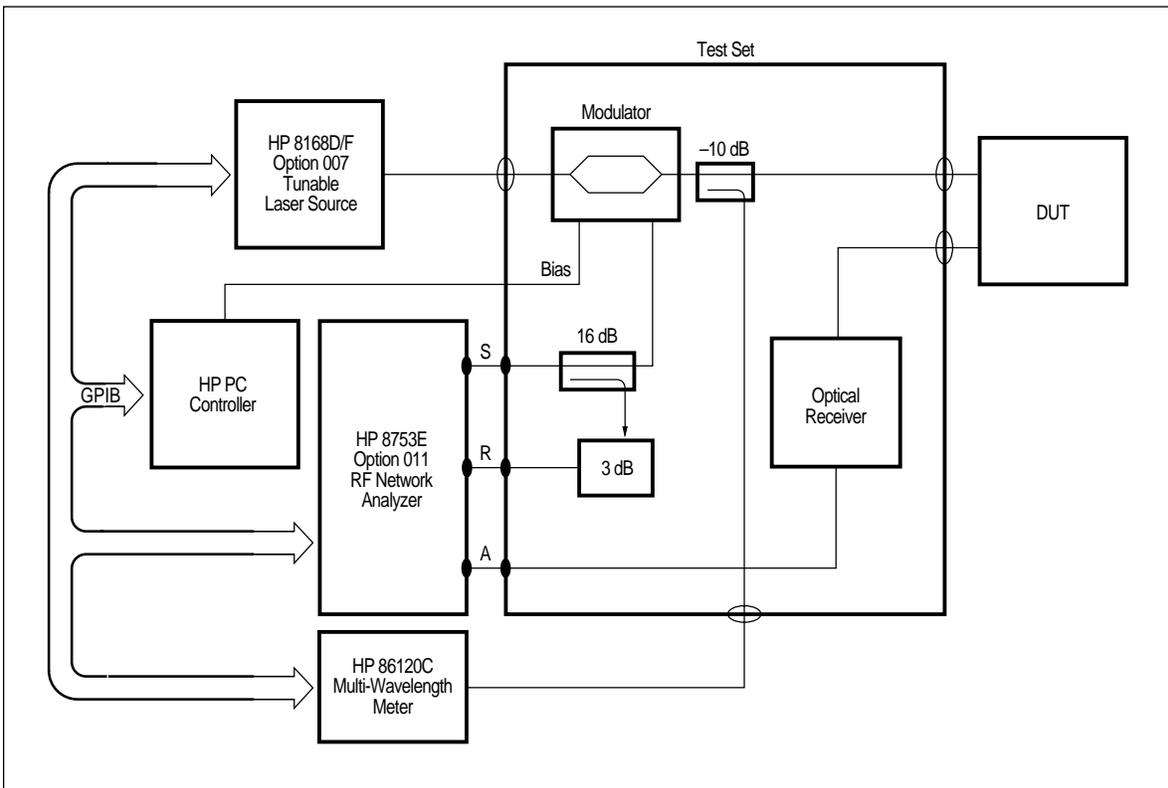


Figure 7. 1550 nm system block diagram

## Ordering Options

The HP 86037B Chromatic Dispersion solution offers many standard options to satisfy customer specific measurement requirements. All configurations start with a basic system mainframe, and customers can select desired options to make

measurements in the 1300 nm, 1550 nm or 1600 nm wavelength ranges. Dual band systems are also available to measure dispersion in the 1300 and 1550 or 1600 nm wavelength bands in a single rack. For budget sensitive customers, a lower cost, reduced performance

configuration uses a lower cost HP 8168D TLS and excludes a wavelength meter. A special option that excludes a TLS is also available for customers who have their own HP tunable source.<sup>4</sup> The complete list of options and accessories is described in Table 1.

**Table 1. HP 86037B ordering options**

<b>Model/Option</b>	<b>Description</b>
<b>HP 86037B</b>	Standard CD Test Solution Mainframe (8753E #011 Network Analyzer, HP PC Controller, E3660A Rack)
<b>Option 111</b>	Standard 1550nm Configuration (add 8618F #007 #021 TLS, 86120C MWM, 83427A Test Set)
<b>Option 112</b>	1600nm Configuration (add 8618F #503 #007 #021 TLS, 86120C MWM, 83427A Test Set)
<b>Option 113</b>	1300nm Configuration (add 8167B #007 #021 TLS, 86120C MWM, 83427A Test Set)
<b>Option 114</b>	Low Cost 1550nm Configuration (add 8168D #007 #021 TLS, 83427A Test Set)
<b>Option 121</b>	Standard 1300/1550nm Dual Band Configuration (add 8168F #007 #021 TLS, 8167B #007 #021 TLS, 86120C MWM, 83427A Dual Band Test Set)
<b>Option 122</b>	1300/1600nm Dual Band Configuration (add 8168F #503 #007 #021 TLS, 8167B #007 #021 TLS, 86120C MWM, 83427A Dual Band Test Set)

All options are only available at the time of initial purchase. Options at any other time are considered upgrades and should be inquired through the HP field staff. Customized solutions may be considered on a case-by-case basis. Contact your local HP field representative or Test and Measurement Services and Consulting Operations for details on feasibility and quotes.

<sup>4</sup> Customer provided HP tunable laser sources must be equipped or retrofitted with the polarization maintaining (PM) fiber option. Contact the HP field sales staff for more information about performing retrofits.

# System Performance and Specifications for the HP 86037B

**Specifications** describe warranted system performance parameters for the temperature range of  $23 \pm 3^\circ\text{C}$  after 2 hours of warm-up. **Supplemental Characteristics** provide non-warranted information about system performance. They are not warranted because (1) there is no viable way to test for this characteristic or (2) there are no recognized standards upon which measurements can be traced. The characteristics provided are based upon analysis and measurements and give HP's most accurate estimate of the performance that can be expected.

## Chromatic dispersion measurements

### Wavelength range:

Option 111 (standard 1550nm): 1450 to 1590 nm  
Option 112 (1600nm): 1510 to 1640 nm  
Option 113 (1300nm): 1255 to 1365 nm  
Option 114 (1500nm): 1490 to 1565 nm  
Option 121 (1300/1550nm): 1255 to 1365 nm  
and 1450 to 1590 nm  
Option 122 (1300/1600nm): 1255 to 1365 nm  
and 1510 to 1640 nm

### Maximum optical power from SOURCE OUTPUT<sup>5</sup>:

Option 111: -1 dBm (optical) (1520 to 1570 nm)  
Option 112: -2 dBm (optical) (1545 to 1620 nm)  
Option 113: -5 dBm (optical) (1310 to 1350 nm)  
Option 114: -12dBm (optical) (1500 to 1565 nm)  
Option 121: -5 dBm (optical) (1310 to 1350 nm)  
-1 dBm (optical) (1520 to 1570 nm)  
Option 122: -5 dBm (optical) (1310 to 1350 nm)  
-2 dBm (optical) (1545 to 1620 nm)

### Optical power range for RECEIVER INPUT: -3 to -45 dBm (optical)

### Modulation frequency range: 100 MHz to 2.5 GHz

### Dispersion measurement range:

0.1 ps/nm to  $D_{\text{max}}$ <sup>6</sup>.

### Group delay uncertainty<sup>7</sup>:

0.5 ps (0.05 ps characteristic)

### Zero dispersion wavelength repeatability<sup>8</sup>:

0.05 nm (0.005 nm characteristic)

### Wavelength Resolution

1 pm (with HP 8168F/8167B TLS)  
0.1 nm (with HP 8168D TLS)

### Wavelength Accuracy

0.003 nm (with wavelength meter)  
0.1 nm (without wavelength meter, except Option 114)  
0.2 nm (Option 114)

## Supplemental characteristics

Repeatability of dispersion slope at zero dispersion wavelength<sup>8</sup> (Characteristic): 0.002 ps/(nm<sup>2</sup> km)

### Measurement Time (Characteristic):

2 seconds per point without wavelength meter  
3 seconds per point with wavelength meter<sup>9</sup>

### System dynamic range (Characteristic)<sup>10</sup>:

Option 111: 43 dB optical (1520 to 1570 nm)  
Option 112: 39 dB optical (1545 to 1620 nm)  
Option 113: 43 dB optical (1310 to 1350 nm)  
Option 114: 30 dB optical (1500 to 1565 nm)  
Option 121: 43 dB optical (1310 to 1350 nm)  
43 dB optical (1520 to 1570 nm)  
Option 122: 43 dB optical (1310 to 1350 nm)  
39 dB optical (1545 to 1620 nm)

### Zero dispersion wavelength accuracy<sup>11</sup>:

$\pm 0.15$  nm (8168F TLS without wavelength meter)  
 $\pm 0.25$  nm (8168D TLS without wavelength meter)  
 $\pm 0.05$  nm (8168F TLS with wavelength meter)

### Relative power accuracy (Characteristic): $\pm 0.25$ dB

## System/fiber length measurement

Range: 0.2 m to 100,000 km<sup>12</sup>

## Supplemental length measurement characteristics

Range resolution<sup>13</sup>: 0.05 mm or 0.1% of measured length, whichever is greater

Group refractive index: 1.0000 to 2.0000 (user-adjustable)

<sup>5</sup> Refer to TLS power specifications other wavelength ranges.

<sup>6</sup> Maximum dispersion,  $D_{\text{max}}$  (in ns/nm), is given by  $25/\Delta\lambda$ , where  $\Delta\lambda$  is the wavelength step size in nm.

<sup>7</sup> Based on noise floor measurement, full output power, reference wavelength on, no averaging, and high sensitivity

<sup>8</sup> One standard deviation for 20 measurements on the same spool of 10 km dispersion-shifted fiber for the wavelength range from 1515 to 1580 nm with power into RECEIVER INPUT at -43 dBm (optical). Parameters refer to curve fit traces using the five-term Sellmeier fit.

<sup>9</sup> This calculation was done for 65 points on a standard spool of 10km fiber using normal sensitivity. Any change of sensitivity will result in a corresponding change in time. As an example, 10 runs of standard fiber with 65 points per run takes one hour.

<sup>10</sup> System dynamic range is calculated by [TLS output power] - [Test Set loss] - [Receiver sensitivity].

<sup>11</sup> These values are based on measurements of NIST Standard Reference Material 2524, Serial No. 0001, using a quadratic fit to 65 point spaced at 1 nm.

<sup>12</sup> For very long lengths of fiber, the use of EDFA amplifiers is assumed. The systems dynamic range is not sufficient to measure long lengths of fiber without amplification.

<sup>13</sup> Range resolution is a measure of the ability to pinpoint the peak of a response in the length measurement.

## General Specifications

### Assembled Dimensions: (H x W x D)

112 cm x 59.5 cm x 143.5 cm (without monitor)

44.1 in x 23.4 in x 56.5 in (without monitor)

### Net Weight

Single band system: 249 kg (548 lbs)

Dual band system: 269 kg (592 lbs)

### Power Requirements

Single band system: 594 watts

Dual band system: 726 watts

## Documentation

The main system documentation is the operating manual that describes how to operate the HP 86037B. Individual instrument manuals will also be supplied with supplemental documentation of any special modifications. All documentation (see Table 2) is shipped with the product but is also available on the HP web site at [www.hp.com/go/lightwave](http://www.hp.com/go/lightwave).

Table 2. HP 86037B test solution documentation

HP 86037B	Operating Note
Instrument level documentation	
Tunable laser	Standard manual with supplement
Network Analyzer	Standard manual
Test Set	Standard manual with supplement
PC Controller	Standard manual. The PC controller is configured with an HP-IB card, DAC board and Windows™, all installed at the factory
HP Monitor	Standard manual

## Warranty

Note—all system warranties and support agreements are dependent upon the integrity of the HP 86037B. Any modification of the system software or hardware will terminate any obligation that Hewlett-Packard may have to the purchaser. Please contact your local HP Field Engineer before embarking in any changes to the system.

## System

Included in the sales price is the standard HP one-year warranty. The standard warranty includes on-site troubleshooting, on-bench functional test of a characterized fiber spool that is shipped with each system, and on-bench instrument calibration (no system level calibration is presently available).

For further details, please refer to Appendix 1: System Repair Strategy.

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In addition to the standard one-year warranty, extended warranty periods, on-site trouble shooting, reduced response times and increased coverage hours can be negotiated under a separate support agreement and will be charged at an extra cost. Such support is strongly recommended for the HP 86037B where up-time is crucial to system operation. Please refer to Appendix 2: System Support Options for a breakdown of available plans.

The system support life period is based on the instrument standard support life period.

### **Instruments and computers**

On-Site, troubleshooting at functional level (PC controller or instrument). Faulty instrument will be repaired following procedure described in Appendix 1.

The instrument standard support life period is five years. Application software is supported only on computer and instrument configurations specified at the time of installation.

### **Software**

90 Days on Media.

### **Instrument level hardware support**

See Appendix 1.

### **Installation and training**

Before shipment of the system, it is recommended that HP personnel perform a site survey and preparation visit to the customer site. The customer should prepare space for an 1100 mm high system rack. A tabletop is also required for the PC monitor and keyboard, although the monitor can also be placed on top of the system rack.

Included in the system price is one day of installation and training by HP personnel. This comprises of four hours for hardware and software installation and acceptance testing<sup>14</sup> and up to four hours of training on system operation for a maximum of four people. Training covers use of the system but not optimization of measurements. Further training can be purchased as needed.

The installation portion will include a System Functional Test using a characterized HP fiber spool, which is shipped with the system. A documented procedure for operational check purposes will be provided as part of the system software. No system level calibration is available. A System Functional Test should always be done after instrument level repair.

Specifications involving power and wavelength will be verified with a wavelength meter and power meter. Measurement repeatability specifications will be verified by performing multiple measurements on the shipped fiber spool.

The instrument calibration cycle is one year from the system shipment date. No system level calibration is available. It is the customer's responsibility to make arrangements with HP for instrument level calibration requirements.

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<sup>14</sup> Performed by a local HP Customer Engineer

## Appendix 1: System Repair Strategy

Diagnostics are provided at the installation site by the HP local support system engineer. If the PC controller is defective, it will be repaired on-site. If the system instrumentation is faulty the System Support Strategy will be applied.

### System Repair Strategy

Table 3: HP 86037B repair strategy

Description	Repair Strategy
Tunable laser source	Return to factory
Network Analyzer	On bench repair
CD test set	Return to factory
HP PC Controller	On bench repair
HP monitor	On bench repair
Multi-wavelength meter	Return to service center

### Comments

On Bench Repair: Unit will be fixed in the HP regional repair center.

Return to Factory: Unit will be returned to the Lightwave Division factory.

## Appendix 2: System Support Options

In addition to the standard one-year HP warranty, the HP 86037B's warranty plan can be tailored to meet customer needs. HP Service Centers offer two options for extending the duration of the standard warranty. Option W31 increases the warranty to three years, and option W51 extends the standard warranty to five years.

HP also offers various support plans, as outlined below:

Table 4: HP 86037B support options

Option	Details
<b>Cooperative</b>	For customers who wish to maintain their own systems and rely on HP for training, replacement parts, diagnostic support tools, repair documentation and remote backup support. Available for customers with specific systems, spares and personnel.
<b>Priority Plus</b>	Repair service 24 hours a day, seven days a week. Customers within 100 miles of a HP support facility receive an on-site visit within four hours.
<b>Priority</b>	On-site coverage from 8:00 am to 9:00 pm Monday through Friday, excluding HP holidays; allows scheduled maintenance to be performed after normal working hours. Customers within 100 miles of a HP support facility receive an on-site visit within four hours.
<b>Standard (Next Day)</b>	Provides next-day coverage from 8:00 am to 5:00 pm Monday through Friday, excluding HP holidays, for customers within 100 miles of a HP support facility.

For further information on availability, implementation and pricing of the various support options, please contact your local Field Engineer.

## Appendix 3: Applications of the Remote File Interface

The HP 86037B has a remote file interface feature that allows a user to run dispersion measurements from a remote location. This is done through the use of a 'parameter file'. This file is a database format that contains the values used by the system to make a measurement. These values include such things as measurement range, step size, name of the database file that measurements are saved to, operator's name and date the measurement was made.

Customers can create their own GUI to read and write to this 'parameter' database. This allows the customer to restrict access to the system, invest less time in training operators and create GUIs in English and other languages (see Figure 8).

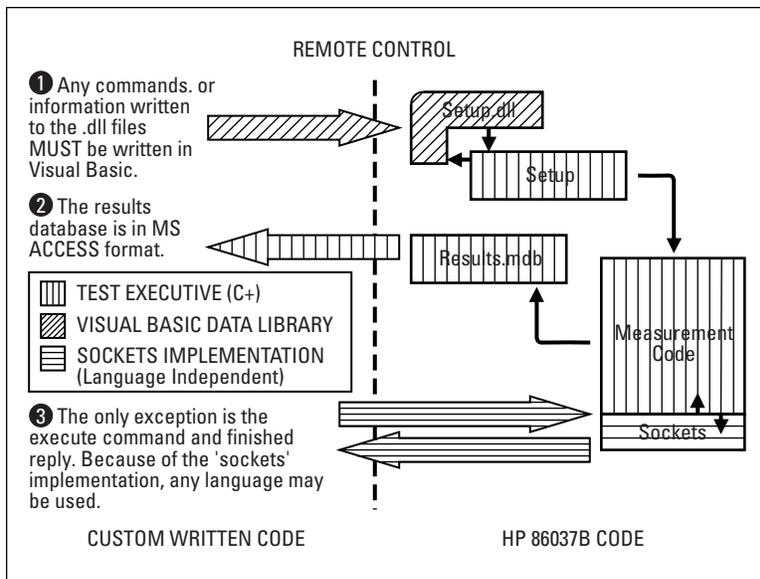


Figure 8. User's own GUI using the Remote File Interface feature

Requests for customization will be considered on an individual basis. Specials can be developed by either HP's Lightwave Division or Test and Measurement Services and Consulting Operations.

For more information about Hewlett-Packard test and measurement products, applications, services, and for a current sales office listing, visit our web site,

<http://www.hp.com/go/lightwave>

**You can also contact one of the following centers and ask for a test and measurement sales representative.**

### United States:

Hewlett-Packard Company  
Test and Measurement Call Center  
P.O. Box 4026  
Englewood, CO 80155-4026  
(tel) 1 800 452 4844

### Canada:

Hewlett-Packard Canada Ltd.  
5150 Spectrum Way  
Mississauga, Ontario L4W 5G1  
(tel) 1 877 894 4414

### Europe:

Hewlett-Packard  
European Marketing Organisation  
P.O. Box 999  
1180 AZ Amstelveen  
The Netherlands  
(tel) (31 20) 547 9999

### Japan:

Hewlett-Packard Japan Ltd.  
Measurement Assistance Center  
9-1, Takakura-Cho, Hachioji-Shi,  
Tokyo 192-8510, Japan  
(tel) (81) 426 56 7832  
(fax) (81) 426 56 7840

### Latin America:

Hewlett-Packard Company  
Latin American Region Headquarters  
5200 Blue Lagoon Drive, 9th Floor  
Miami, Florida 33126, U.S.A.  
(tel) (305) 267-4245  
(305) 267-4220  
(fax) (305) 267-4288

### Australia/New Zealand:

Hewlett-Packard Australia Ltd.  
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