Guide to HP Labs ROFL/OFL Fiber Measurements from 12/15/97 – 12/19/97

Lew Aronson and Lisa Buckman

INTRODUCTION

At the request of Del Hanson and David Cunningham, we at HP Labs Palo Alto constructed a system to do field measurements of multimode fiber bandwidth to support the IEEE 802.3z Gigabit Ethernet Standard effort. In particular, measurements of the fiber bandwidth using the recently defined radially overfilled launch (ROFL) as well as the standard overfilled launch (OFL) methods were requested. The purpose of these measurements was to test the bandwidth and in particular the details of the differential mode delay (DMD) of installed multimode fiber.

We constructed a system, which will be fully described later, to do these measurements based on a time domain technique. Our system transmits very short optical pulses (< 30 – 40 ps) at 850 or 1300 nm wavelength as desired using a given launch type. At the receiving end, a high-speed photodetector would receive the pulse, amplify it and display the results on a high speed sampling scope. The complete system (lasers, detector amplifier chain and scope) had an impulse response of 70 – 80 ps. The measured received signal as well as a number of comments were recorded on a laptop computer and stored in a text file. The purpose of this document is to quickly summarize what fiber measurements were made, and to provide a guide to the understanding of the data file nomenclature and structure. This document does not contain any reduction of the data or accurate calculations of the fiber bandwidth.

SUMMARY OF MEASUREMENTS

Five days of measurements were conducted at Lawrence Berkeley National Labs (LBL), Lawrence Livermore National Labs (LLNL) and Sandia National Labs. We measured as many fibers as possible in the available time and were often limited by logistical issues imposed by our hosts and the nature of the facility. In all, a total of 78 fibers were tested: 34 at LBL, 24 at LLNL and 20 at Sandia. All of the fibers at LBL and LLNL were 62.5/125 MMF and all of the fibers at Sandia were 50/125 MMF. The lengths of the fibers measured ranged from 320 – 610 m with most between 320 and 460 m. Appendix A contains a list of all of the fibers measured including an 8 or less character unique ID which was assigned in the field as well as as much descriptive data on the fiber as we know. The lengths of these fibers were measured by OTDR in the field by a group from Siecor. All of our measurements list the fiber length from bulkhead to bulkhead as they exist in the installation. This length does not include the patchcords which connect our system to the installed fiber however our data files note the patchcord length on each side and calibration files were done with these patchcords connected back to back so any small effect can be factored out. This fiber table is also contained in the Excel 97 file "Fibertab.xls".

Two other teams conducted measurements on the same general group of fibers that we measured. Howard Frazier and others from Cisco conducted packet loss measurements using a number of different transceiver modules. A group led by Jonathan Thatcher from IBM did eye diagram measurements using different transceivers. We still need to consult with the other groups to reconcile our fiber labeling system. We believe we measured all of the fibers on which eye diagram measurements were made, but there may have been a few fibers on which packet loss data was measured which we didn't cover. Cetainly, we measured all fibers on which actual packet loss was recorded.

For each fiber, 8 or 9 measurements were made. In all cases, three types of ROFL launches (0.5 dB, 1.0 dB and 2.0 dB) and one OFL launch were done at the short and long wavelength regions. In many cases, single mode launch was done at long wavelength because this seemed like a good approximation of what a 1000LX transceiver would launch.

As mentioned above, our system would save a text file for each measurement. Additionally, a summary file described below was automatically kept in which one line was entered for each measurement. This line of data contains enough information to identify the fiber, describe where the detailed data is stored, and to identify exactly which test was performed. It also contains the manual estimate of DMD for each measurement that is further described below.

IMPORTANT NOTE ON STATISTICS: Great care should be taken if our data is to be used for developing an estimate of the statistical distribution of fibers with poor DMD. There are two reasons for this. First, we were directed to one subset of fibers at LBL (noted in Appendix A) <u>because they were known to have problems</u>. The problems with these particular fibers were actually known by LBL before any GigabitEthernet testing. In fact, LBL had independently measured some of these fibers to have OFL bandwidth worse than the manufacturer's specification. Additionally, there were severe installation deficiencies noted for these fibers (sharp bends, etc). Some of the other fibers in this rack had been specifically installed by the manufacturer as replacement fibers for the poor fibers mentioned. It is our opinion that fibers which would not pass the basic definition of the fiber specification of the GBE standard, due to manufacturers error or installation problems, are not part of the group of bad fibers which we are striving to identify.

There is a second more subtle, but important, statistical issue which should also be considered. We always attempted to measure all fibers in a given subgroup. Nevertheless, we would only test "dark fibers" and never disconnect an installed link (for obvious reasons). The fibers which were in use were often not # 1,2,3 etc. of a cable but seemingly randomly

distributed. It may very well be the case that when links were set up, that if a link performed poorly, the network administrators would switch to another fiber in the cable. Thus, the fibers we tested may exclude particularly good fibers (which were used for working links) and include particularly bad fibers (which failed attempts to use in links).

ESTIMATED DMD

At the request of David Cunningham, a measured value we call estimated DMD was recorded for each measurement. This was supposed to be the time delay between the outer peaks of a received pulse. We attempted to measure this and record the data each time however, it is easy to see how this can be a subjective measurement. Received pulses are found to be almost any shape in practice. In many cases there are two well-defined peaks of similar amplitude and the estimated DMD is straightforward. Even in this case, however, questions easily arrive. What if there is a small peak outside the two main peaks. At what relative amplitude do you assume it defines the DMD? Also, you can easily have one smooth peak or a main peak with a "shoulder" to one side. We used the following rules:

1) If the received pulse consisted of separate peaks we recorded the time between the outermost peaks which have amplitude at least 10% of the main peak. Shoulders in the data were also considered if they were the outermost feature larger than 10%. If a measurement was based on peaks it was designated with a "p" at the end of the filename.
2) If the pulse really was one smooth peak, the full width half max (FWHM) was recorded and an "f" placed at the end of the filename.
3) If the data was especially ambiguous, a "c" for comment was attached to the filename and comments were included within the file. In these cases, the actual data should be examined.

Even with this system, the estimated DMD number should be treated carefully as estimates of this 10% rule were only estimates. Moreover, two different measurements with very similar pulses could have very different estimated DMDs if in one case an outer peak was just under the 10% rule and in the other an outer peak was just over.

SUMMARY FILE

As mentioned above, a summary file was generated with a line for each test or calibration run. This file (which we name "Summary.dat") is a TAB delimited text file which is easily viewed in EXCEL. It is located with all of the individual trace files in the zip file described below. The first lines of this file are shown in Figure 1 below. In this case, the first 10 entries are calibration runs and the next eight are tests on the first fiber measured, 155c1. As shown, the first column is the filename where the detailed data from the test is stored. The nomenclature for the filenames will be discussed below. The 2nd column is the code letter explaining the DMD measurement (p,c or f) . The 3rd column is what we call the fiber ID (155c1 for the first fiber measurements shown). This is a unique 8 character or less ID that we assigned the fiber in the field. For a full description of the fiber see the Fiber Table file or Appendix A or examine the detailed data file for a given test. The 4th column is the length of the fiber in meters. The 5th column is **50** or **62** representing 50MMF or 62 MMF fiber. The 6th column is the launch type: This is either **0.5 dB ROFL, 1.0 dB ROFL, 2.0 dB ROFL** or **OFL**. In some cases, this column says **Calibration** when referring to a fiber measurement. We used this designation for single mode launch into a multimode fiber. The 7th column indicates the wavelength: **SX** for our 850 nm source and **LX** for our 1310 nm source. The last column is the estimated DMD in picoseconds. For calibration files this was listed as –1.

Filename	DMD comment	Fiber ID	Fiber Length	Multimode Type	Launch Type	Wavelength	Estimated DMD
cal15000S0.dat		cal15	6	62	0.5 dB ROFL	SX	-1
cal15000S1.dat		cal15	6	62	1.0 dB ROFL	SX	-1
cal15000S2.dat		cal15	6	62	2.0 dB ROFL	SX	-1
cal15000S3.dat		cal15	6	62	OFL	SX	-1
cal15000L0.dat		cal15	6	62	0.5 dB ROFL	LX	-1
cal15000L1.dat		cal15	6	62	1.0 dB ROFL	LX	-1
cal15000L2.dat		cal15	6	62	2.0 dB ROFL	LX	-1
cal15000L3.dat		cal15	6	62	OFL	LX	-1
cal15000L4.dat		cal15	2	62	Calibration	LX	-1
cal15000S4.dat		cal15	2	62	Calibration	SX	-1
155c1000S0.dat		155c1	399	62	0.5 dB ROFL	SX	713
155c1000S1.dat		155c1	399	62	1.0 dB ROFL	SX	719
155c1000S2p.dat	p	155c1	399	62	2.0 dB ROFL	SX	724
155c1000S3c.dat	c	155c1	399	62	OFL	SX	989
155c1000L0p.dat	p	155c1	399	62	0.5 dB ROFL	LX	167
155c1000L1p.dat	p	155c1	399	62	1.0 dB ROFL	LX	157
155c1000L2p.dat	p	155c1	399	62	2.0 dB ROFL	LX	157
155c1000L3f.dat	f	155c1	399	62	OFL	LX	146

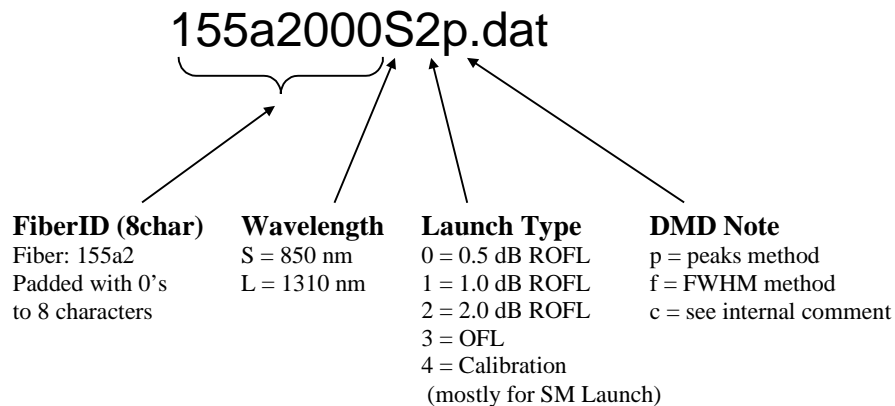**Figure 1. First lines of Summary.dat file.**

CALIBRATION FILES

For the purpose of calibrating out the impulse response of the system itself, a number of calibration measurements were done. These have filenames like **cal15000S0.dat**. These tests consisted of connecting the transmitter unit directly to the receiver through the multimode patchcords (3m on each end typically) which were normally used to connect to fibers under test. Thus, the pulses recorded in these files include the pulse response of the laser, detector, amplifiers and scope as well as any small DMD in the patchcords. Calibration tests were done three times during the week. Files beginning in **cal15...** indicate a calibration on Decemeber 15th, **cal18...** are December 18th and **cal19...** are December 19th. Calibration tests were done through each type of launch condition accounting for 8 of the files on each date (nomenclature in next section). Additionally, short and long wavelength calibration files were made with the TX and RX units connected with 2m of single mode fiber (this will let you note any effect from the MMF). On the 18th, two calibration runs were done with direct single mode launch at each wavelength into the MMF patchcords (files **cal18MMFS4.dat** and **cal18MMFL4.dat**). Please also note that for the Sandia tests, 6m of multimdoe patchcord was required on the RX end. This is reflected in the cal19 files which used the 9m of multimode patchcords used in the Sandia tests. Also note that all tests at LBL and LLNL were on 62MMF, and the calibration files (cal15 and 18) used the same patchcords. At Sandia, 50MMF was used in the tests and calibration (cal19).

As discussed in the section on data reduction below, most data was recorded with the scope set on 200 ps/div. Occasionally, the DMD was so large that 500 ps/div had to be used. Unfortunately, all the calibration files were done at 200 ps/div that may pose some problems when normalizing the Fourier transforms. If desired, we will run calibrations at 500ps/div after we return January 5th.

DATA FILES

For each fiber tested, 8 or 9 measurements were made. For each measurement, data about the fiber, the location, the test type, the estimated DMD and other comments were recorded as well as XY data downloaded from the scope. All of this data was recorded in a single text file for each measurement. Calibration runs have the same format as do data files. Including calibration runs, there are over 700 individual data files of about 18 – 21KB each. There is a specific nomenclature used for these filenames which is also reflected in the entries of the Summary file which are meant to aid automated data reduction as well as rapidly allowing one to open the file of interest. Figure 2 describes meaning of each position in the filename.

FiberID (8char)	Wavelength	Launch Type	DMD Note
Fiber: 155a2	S = 850 nm	0 = 0.5 dB ROFL	p = peaks method
Padded with 0's	L = 1310 nm	1 = 1.0 dB ROFL	f = FWHM method
to 8 characters		2 = 2.0 dB ROFL	c = see internal comment
		3 = OFL	
		4 = Calibration	
		(mostly for SM Launch)	

Figure 2. Data filename nomenclature.

The structure of the file is fixed, again for automated data reduction. Figure 3 shows the first lines of a typical data file. While the data file is a text file, items in a given line are TAB delimited which allows the file to easily be opened in EXCEL. The First line contains the test date and time. The second is the full file name as originally stored. Thus, for automated data reduction, it would be helpful to place the files in a directory names **C:\Field Test Data** . The next line is labeled repitition and consists of a single character entered by the operator. This was used as the DMD note described in Figure 2. Next comes information about the fiber, then info about the launch type, followed by up to three lines of comments. After line showing the number of averages is the data itself. The data is in two columns, time in picoseconds and amplitude in mV. The time is referenced to 0 for the start of the data. In all cases, there are 1026 data points which was a default value for the scope. In most cases, the horizontal scale was set for 200 ps/div which is a total span of 2 ns This results in a point spacing of about 1.95 ps. In some cases, the received pulse could not be fully contained in this span and 500ps/div was used. This was noted in the comments when it occurred. It should be noted that the pulses were transmitted every 10ns and the data was AC coupled into the scope. Thus, there are often small negative values for some points. This is discussed further in the section on data reduction.

Because the structure of the file is fixed, a trace may be easily graphed in EXCEL by selecting cells A19:B1045 and using the graph tool.

Multimode Fiber Bandwith Test:		12/15/97	16:53:09
Filename:	C:\Field Test Data\155a2000S2p.dat		
Repetition:	p		
Fiber ID:	155a2		
Fiber Info 1:	Node 1 cabinet 4 to bldg 55		
Fiber Info 2:	Corning?		
Test Location:	LBL		
Fiber Length (m):		399	
Fiber Type:	62 MMF		
Launch Type:	2.0 dB ROFL		
Wavelength:	850 nm		
Estimated DMD (ps):		677	
Comments:			
Number of Averages:		64	
Time (pS)	Amplitude (mV)		
0		0.1194	
1.953125		0.2395	
3.90625		0.1002	

.
.
.

Figure 3. Initial lines of a typical data file.

NOTES ON DATA REDUCTION

It is likely that the main task of reducing this data will be to do FFTs on the received pulse data for each test and to normalize the spectra using the Fourier transform of the relevant calibration file. The resulting curve can than be examined to find the 3 dB point and, along with the fiber length, calculate the fiber bandwidth in MHz km. We have tried to arrange the data, summary file and filenames so that this process can be completely automated. There are a few points worth making about how this reduction should be done.

1) **Selection of calibration file for each tests**
   As stated in the section above, calibration data was taken for each launch type and for each site tested. In point of fact, these data files are quite similar since there is very little DMD introduced by the patchcord regardless of the launch type. It may be worthwhile using calibration files taken at each wavelength for the corresponding data files since the lasers at each wavelength had measurably different pulse widths. Thus, for example, **cal15000S4.dat** would serve well for all short wavelength tests and **cal15000L4.dat** would be used for all long wavelength tests.

2) **Centering of data and timespan.**
   When recording the data, the scope was generally set so that the pulse filled the vertical scale with no clipping and the trigger delay set to show the entire received pulse. While not always perfectly done, we tried to have about 1 division of "zero data" before each received pulse and to use a long enough span (500ps/div when necessary) to capture all of the pulse. When using the longer span, some small glitches after the pulse are occasionally seen (due to amplifier reflections) at about 3 -4 ns after the pulse.

3) **Doing the FFT.**
   Since in most cases the total span is only 2 ns, a straightforward FFT of 1024 of the data points would give a spectra point spacing of 500MHz (first data point at 500 MHz) which may be too high. It would be perfectly reasonable to pad the data with "zeros" (after scaling the data so the minimum data point is 0) to a total of 4096 or more points spanning 8ns or more so that the point spacing of the spectra is 125 MHz or less. This is reasonable because made sure there was no pulse energy outside the span recorded. Scaling the data so that the minimum amplitude point is 0 is also important so that the spectra has an accurate DC value and thus the 3 dB point is accurate.

Appendix A: List of fibers tested
This data is stored in file FiberTab.xls

HP Fiber ID	Starting Location	Ending Location	Fiber Number/Label	Site	Length(m)	Type	Nom. Cell	Manufacturer	Comment
155c1	Node 1, cabinet 4	Bldg. 55	c1	LBL	399	62/125	200/500?	ATT Lightguide	
155c2	Node 1, cabinet 4	Bldg. 55	c2	LBL	399	62/125	200/500?	ATT Lightguide	
155c3	Node 1, cabinet 4	Bldg. 55	c3	LBL	399	62/125	200/500?	ATT Lightguide	
155c4	Node 1, cabinet 4	Bldg. 55	c4	LBL	399	62/125	200/500?	ATT Lightguide	
155c5	Node 1, cabinet 4	Bldg. 55	c5	LBL	399	62/125	200/500?	ATT Lightguide	
155c6	Node 1, cabinet 4	Bldg. 55	c6	LBL	399	62/125	200/500?	ATT Lightguide	
155b6	Node 1, cabinet 4	Bldg. 55	b6	LBL	399	62/125	200/500?	ATT Lightguide	
155b5	Node 1, cabinet 4	Bldg. 55	b5	LBL	399	62/125	200/500?	ATT Lightguide	
155b4	Node 1, cabinet 4	Bldg. 55	b4	LBL	399	62/125	200/500?	ATT Lightguide	
155a1	Node 1, cabinet 4	Bldg. 55	a1	LBL	399	62/125	200/500?	ATT Lightguide	
155a2	Node 1, cabinet 4	Bldg. 55	a2	LBL	399	62/125	200/500?	ATT Lightguide	
155b3	Node 1, cabinet 4	Bldg. 55	b3	LBL	399	62/125	200/500?	ATT Lightguide	
727	Bldg. 7	Node 2, Cabinet 3	7	LBL	320	62/125	200/500?	ATT Lightguide	(a)
728	Bldg. 7	Node 2, Cabinet 3	8	LBL	320	62/125	200/500?	ATT Lightguide	(a)
729	Bldg. 7	Node 2, Cabinet 3	9	LBL	320	62/125	200/500?	ATT Lightguide	(a)
72ten	Bldg. 7	Node 2, Cabinet 3	10	LBL	320	62/125	200/500?	ATT Lightguide	(a)
7211	Bldg. 7	Node 2, Cabinet 3	11	LBL	320	62/125	200/500?	ATT Lightguide	(a)
7212	Bldg. 7	Node 2, Cabinet 3	12	LBL	320	62/125	200/500?	ATT Lightguide	(a)
725	Bldg. 7	Node 2, Cabinet 3	5	LBL	320	62/125	200/500?	ATT Lightguide	(a)
726	Bldg. 7	Node 2, Cabinet 3	6	LBL	320	62/125	200/500?	ATT Lightguide	(a)
7214	Bldg. 7	Node 2, Cabinet 3	14	LBL	320	62/125	200/500?	ATT Lightguide	(a)
7215	Bldg. 7	Node 2, Cabinet 3	15	LBL	320	62/125	200/500?	ATT Lightguide	(a)
7216	Bldg. 7	Node 2, Cabinet 3	16	LBL	320	62/125	200/500?	ATT Lightguide	(a)
72b1	Bldg. 7	Node 2, Cabinet 3	"bonus" 1	LBL	325	62/125	200/500?	ATT Lightguide	(b)
72b2	Bldg. 7	Node 2, Cabinet 3	"bonus" 2	LBL	325	62/125	200/500?	ATT Lightguide	(b)
72b3	Bldg. 7	Node 2, Cabinet 3	"bonus" 3	LBL	325	62/125	200/500?	ATT Lightguide	(b)
72b4	Bldg. 7	Node 2, Cabinet 3	"bonus" 4	LBL	325	62/125	200/500?	ATT Lightguide	(b)
7213	Bldg. 7	Node 2, Cabinet 3	13	LBL	320	62/125	200/500?	ATT Lightguide	(a)
2524	Bldg. 25, Cabinet 1	Node 2, Cabinet 2	4	LBL	419	62/125	200/500?	ATT Lightguide	
2525	Bldg. 25, Cabinet 1	Node 2, Cabinet 2	5	LBL	419	62/125	200/500?	ATT Lightguide	
2526	Bldg. 25, Cabinet 1	Node 2, Cabinet 2	6	LBL	419	62/125	200/500?	ATT Lightguide	
2527	Bldg. 25, Cabinet 1	Node 2, Cabinet 2	7	LBL	419	62/125	200/500?	ATT Lightguide	
2528	Bldg. 25, Cabinet 1	Node 2, Cabinet 2	8	LBL	419	62/125	200/500?	ATT Lightguide	
25213	Bldg. 25, Cabinet 1	Node 2, Cabinet 2	3	LBL	419	62/125	200/500?	ATT Lightguide	
LG010407	Node 1 (Bldg. 256)	Bldg. 451	LGUM0104-07	LLNL	407	62/125		ATT Lightguide ?	
LG010408	Node 1 (Bldg. 256)	Bldg. 451	LGUM0104-08	LLNL	407	62/125		ATT Lightguide ?	
LG011105	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-05	LLNL	457	62/125		ATT Lightguide ?	
LG011107	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-07	LLNL	457	62/125		ATT Lightguide ?	
LG011106	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-06	LLNL	457	62/125		ATT Lightguide ?	
LG011108	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-08	LLNL	457	62/125		ATT Lightguide ?	
LG011113	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-13	LLNL	457	62/125		ATT Lightguide ?	
LG011141	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-41	LLNL	457	62/125		ATT Lightguide ?	
LG011142	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-42	LLNL	457	62/125		ATT Lightguide ?	
LG011114	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-14	LLNL	457	62/125		ATT Lightguide ?	
LG011115	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-15	LLNL	457	62/125		ATT Lightguide ?	
LG011116	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-16	LLNL	457	62/125		ATT Lightguide ?	
LG010401	Node 1 (Bldg. 256)	Bldg. 451	LGUM0104-01	LLNL	407	62/125		ATT Lightguide ?	
LG010402	Node 1 (Bldg. 256)	Bldg. 451	LGUM0104-02	LLNL	407	62/125		ATT Lightguide ?	
LG010405	Node 1 (Bldg. 256)	Bldg. 451	LGUM0104-05	LLNL	407	62/125		ATT Lightguide ?	

LG010406	Node 1 (Bldg. 256)	Bldg. 451	LGUM0104-06	LLNL	407	62/125		ATT Lightguide ?	
LG011137	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-37	LLNL	457	62/125		ATT Lightguide ?	
LG011117	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-17	LLNL	457	62/125		ATT Lightguide ?	
LG011118	Node 1 (Bldg. 256)	Bldg. 451	LGUM0111-18	LLNL	457	62/125		ATT Lightguide ?	
LG091904	Bldg. 430	Bldg. 415	LGUM0919-04	LLNL	610	62/125	160/500?	Siecor	
LG091903	Bldg. 430	Bldg. 415	LGUM0919-03	LLNL	610	62/125	160/500?	Siecor	
LG091905	Bldg. 430	Bldg. 415	LGUM0919-05	LLNL	610	62/125	160/500?	Siecor	
LG091906	Bldg. 430	Bldg. 415	LGUM0919-06	LLNL	610	62/125	160/500?	Siecor	
LG091907	Bldg. 430	Bldg. 415	LGUM0919-07	LLNL	610	62/125	160/500?	Siecor	
N05A1102	Bldg. 912	Bldg. 904	912BN05-904FA11 #02	Sandia	457	50/125	400/400?	Siecor	
N05A1103	Bldg. 912	Bldg. 904	912BN05-904FA11 #03	Sandia	457	50/125	400/400?	Siecor	
N05A1104	Bldg. 912	Bldg. 904	912BN05-904FA11 #04	Sandia	457	50/125	400/400?	Siecor	
N05A1105	Bldg. 912	Bldg. 904	912BN05-904FA11 #05	Sandia	457	50/125	400/400?	Siecor	
N05A1106	Bldg. 912	Bldg. 904	912BN05-904FA11 #06	Sandia	457	50/125	400/400?	Siecor	
N05A1108	Bldg. 912	Bldg. 904	912BN05-904FA11 #08	Sandia	457	50/125	400/400?	Siecor	
N05A1107	Bldg. 912	Bldg. 904	912BN05-904FA11 #07	Sandia	457	50/125	400/400?	Siecor	
N05A1110	Bldg. 912	Bldg. 904	912BN05-904FA11 #10	Sandia	457	50/125	400/400?	Siecor	
N05A1111	Bldg. 912	Bldg. 904	912BN05-904FA11 #11	Sandia	457	50/125	400/400?	Siecor	
N05A1112	Bldg. 912	Bldg. 904	912BN05-904FA11 #12	Sandia	457	50/125	400/400?	Siecor	
N05A1109	Bldg. 912	Bldg. 904	912BN05-904FA11 #09	Sandia	457	50/125	400/400?	Siecor	
N05A1101	Bldg. 912	Bldg. 904	912BN05-904FA11 #01	Sandia	457	50/125	400/400?	Siecor	
N03A0909	Bldg. 912	Bldg. 904	912BN03-904FA09 #09	Sandia	457	50/125	400/400?	Siecor	
N03A0910	Bldg. 912	Bldg. 904	912BN03-904FA09 #10	Sandia	457	50/125	400/400?	Siecor	
N03A0911	Bldg. 912	Bldg. 904	912BN03-904FA09 #11	Sandia	457	50/125	400/400?	Siecor	
N03A0912	Bldg. 912	Bldg. 904	912BN03-904FA09 #12	Sandia	457	50/125	400/400?	Siecor	
N04A1001	Bldg. 912	Bldg. 904	912BN04-904FA10 #01	Sandia	457	50/125	400/400?	Siecor	
N04A1002	Bldg. 912	Bldg. 904	912BN04-904FA10 #02	Sandia	457	50/125	400/400?	Siecor	
N04A1005	Bldg. 912	Bldg. 904	912BN04-904FA10 #05	Sandia	457	50/125	400/400?	Siecor	
N04A1006	Bldg. 912	Bldg. 904	912BN04-904FA10 #06	Sandia	457	50/125	400/400?	Siecor	

Notes

HP Fiber ID:	8 or less character unique ID for Filenaming purposes
Fiber Number/Label	Number listed on tray/rack/cabinet
Site	LBL = Lawrence Berkeley National Labs
	LLNL = Lawrence Livermore National Labs
	Sandia = Sandia National Labs
Length(m)	Installed Fiber Length (bulkhead to bulkhead) as verfied by OTDR
Type	50 or 62 multimode fiber
Nom. Cell	On site guess of manufacturers fiber bandwidth cell
Manufacturer	Best estimate of fiber original manufacturer
Comment (a)	These fibers were selectively tested because of previously known problems
	LBL measurements of some fibers showed OFL bandwidth below spec
Comment (b)	Fibers in same rack as (a) but installed later as replacements for bad fibers
Note on Statistics	In some cases (a), (b), fibers tested because of known problems which may be below building cabling specs.
	In general, only unused fibers tested, which may have been unused because of problems