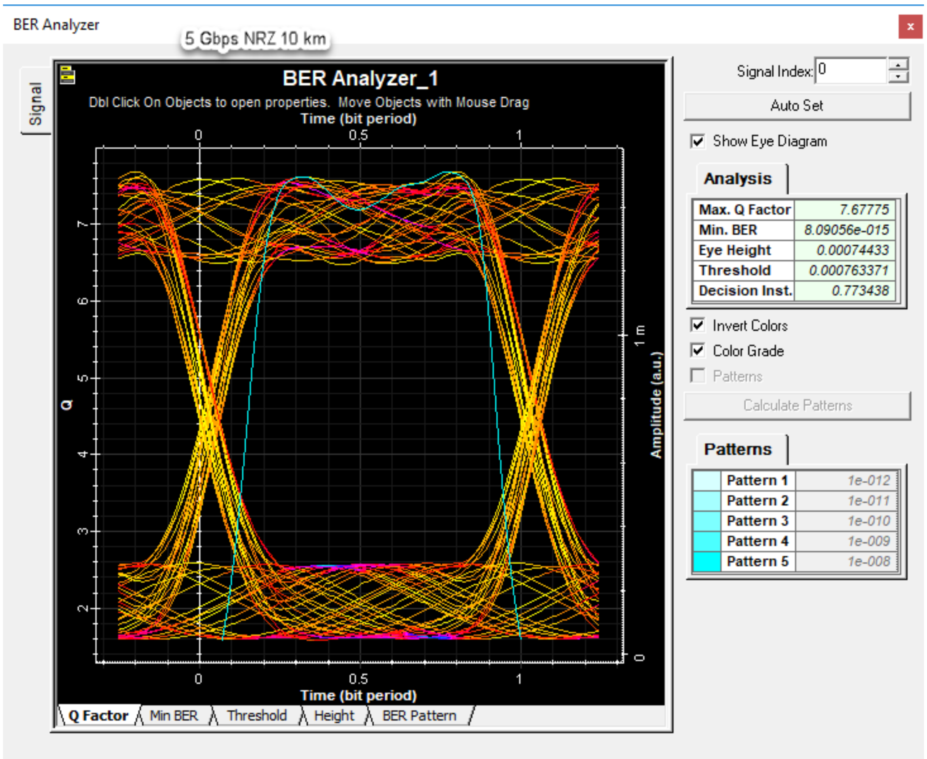
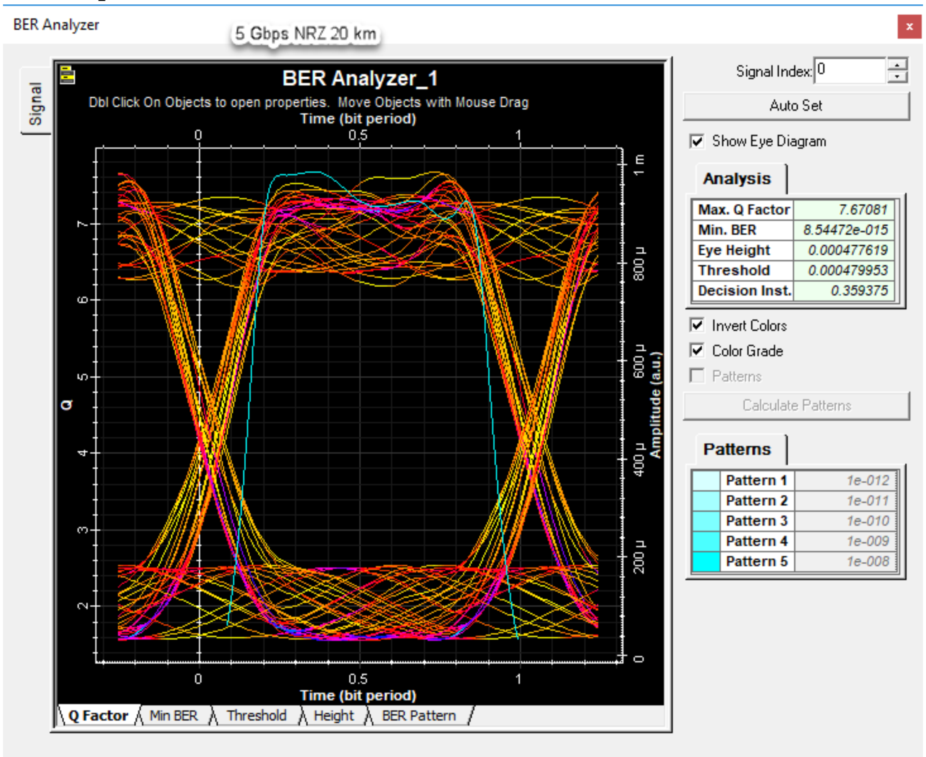
LAMPIRAN

Lampiran 1 *Eye Pattern*

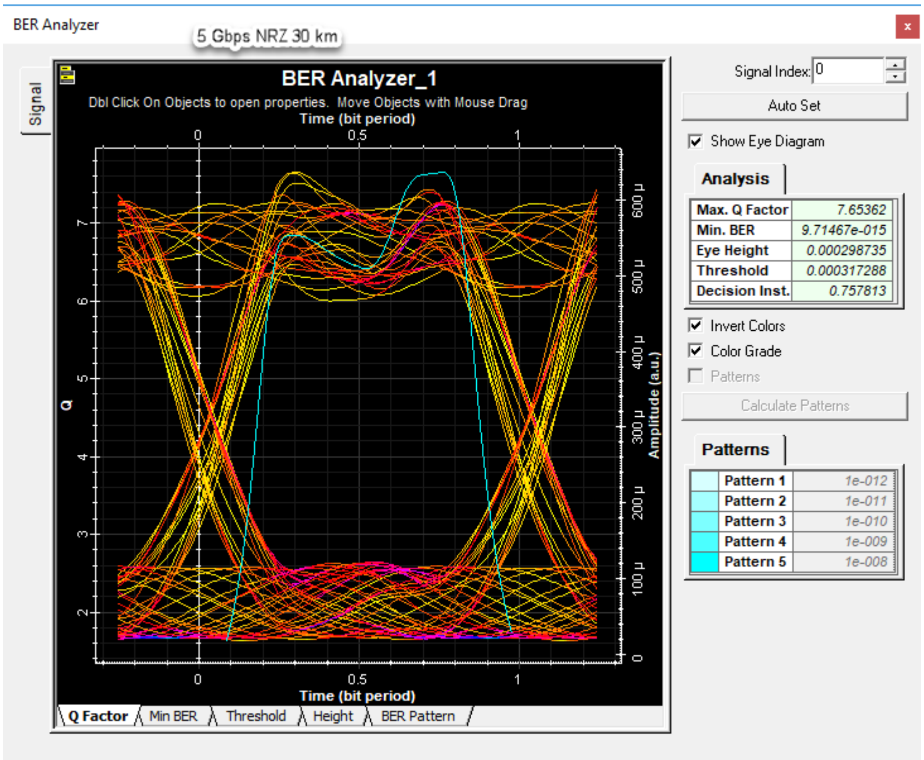
1. 5 Gbps NRZ 10 km



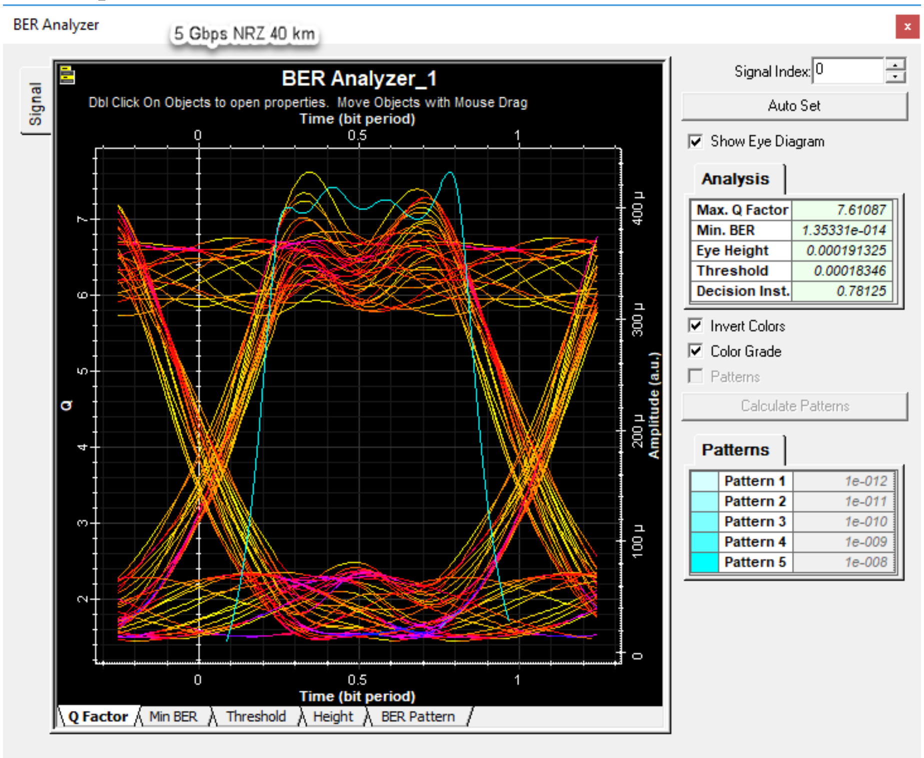
2. 5 Gbps NRZ 20 km



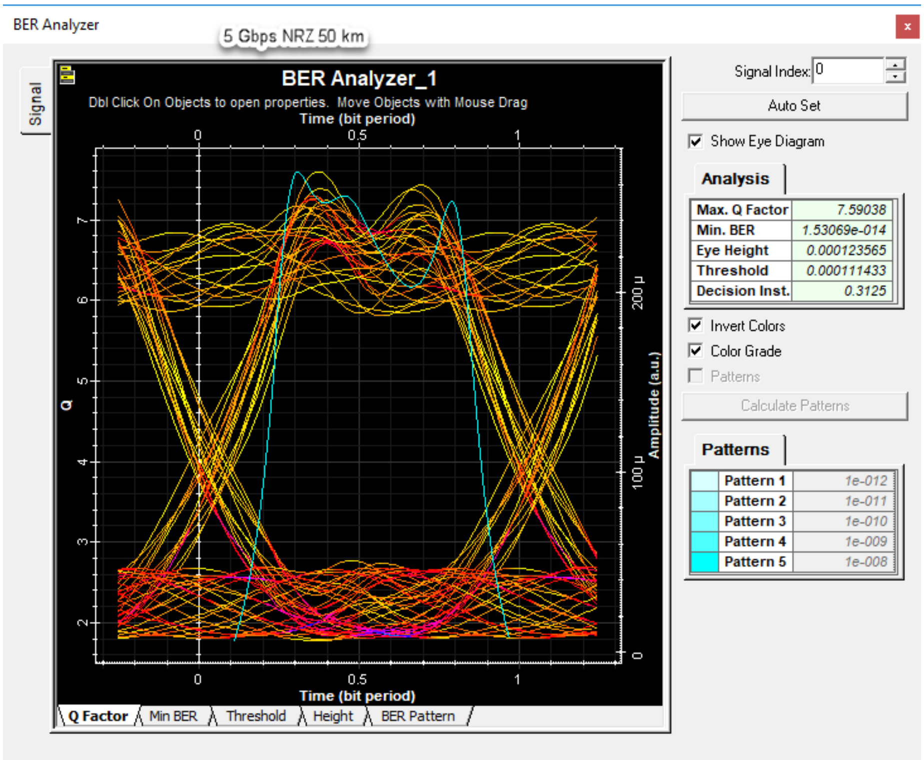
3. 5 Gbps NRZ 30 km



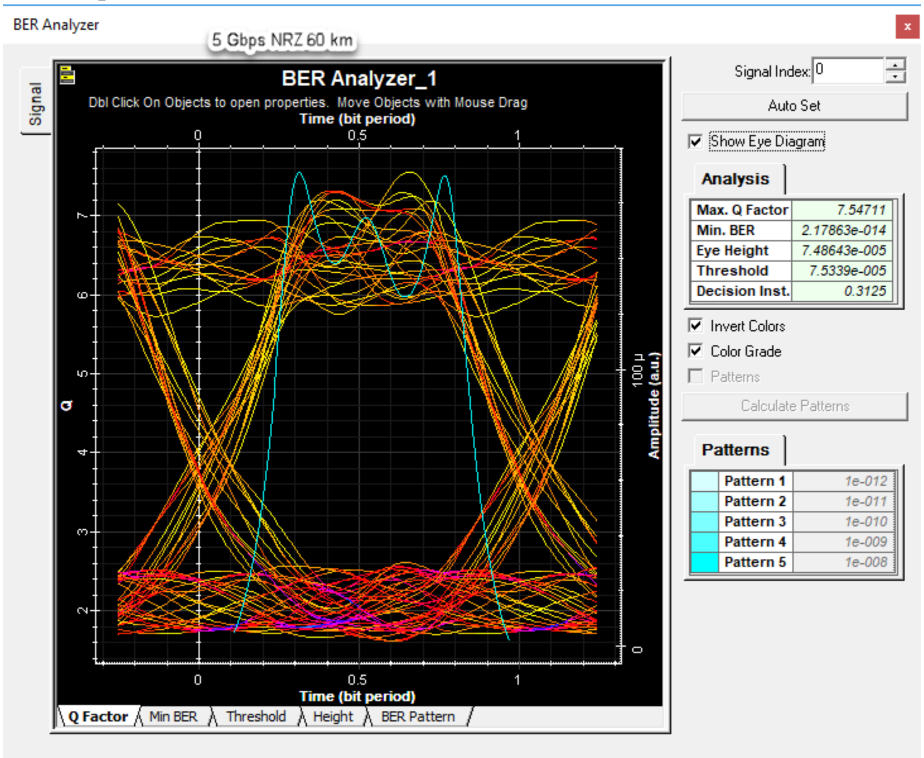
4. 5 Gbps NRZ 40 km



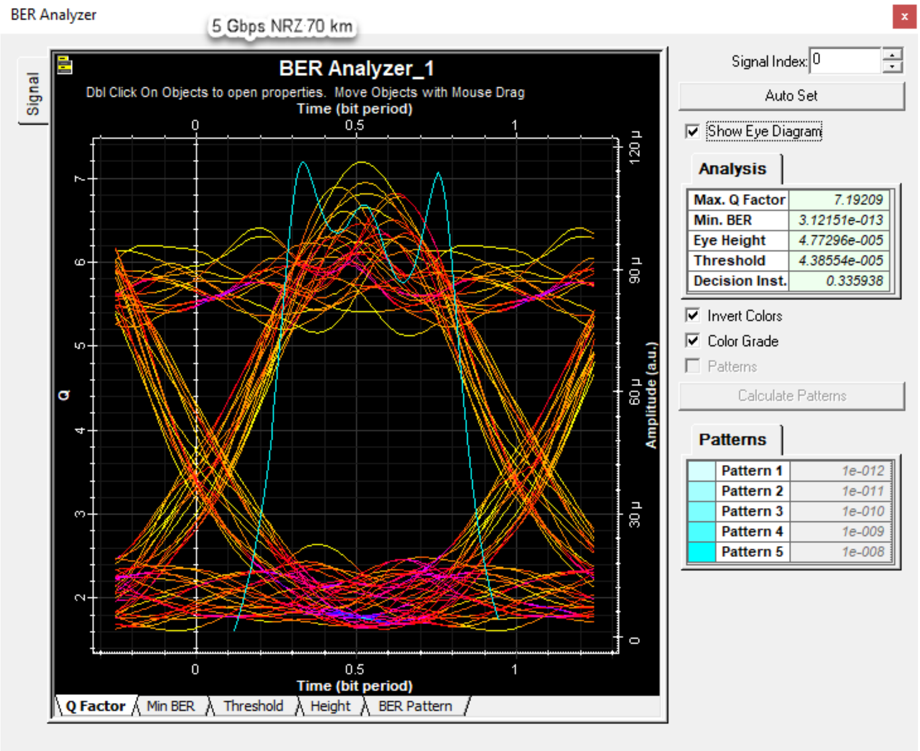
5. 5 Gbps NRZ 50 km



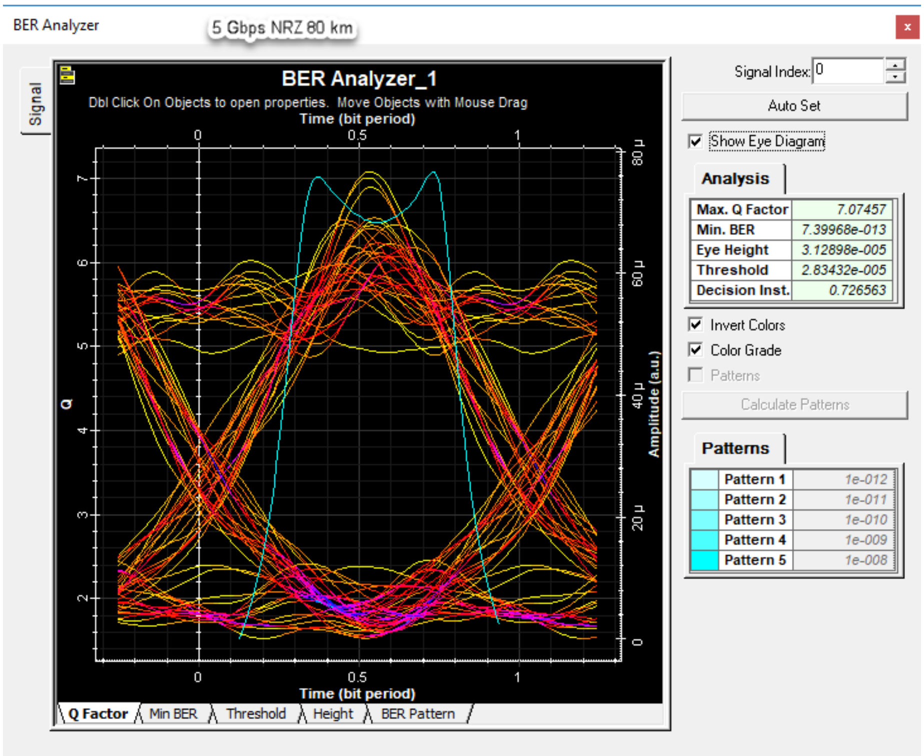
6. 5 Gbps NRZ 60 km



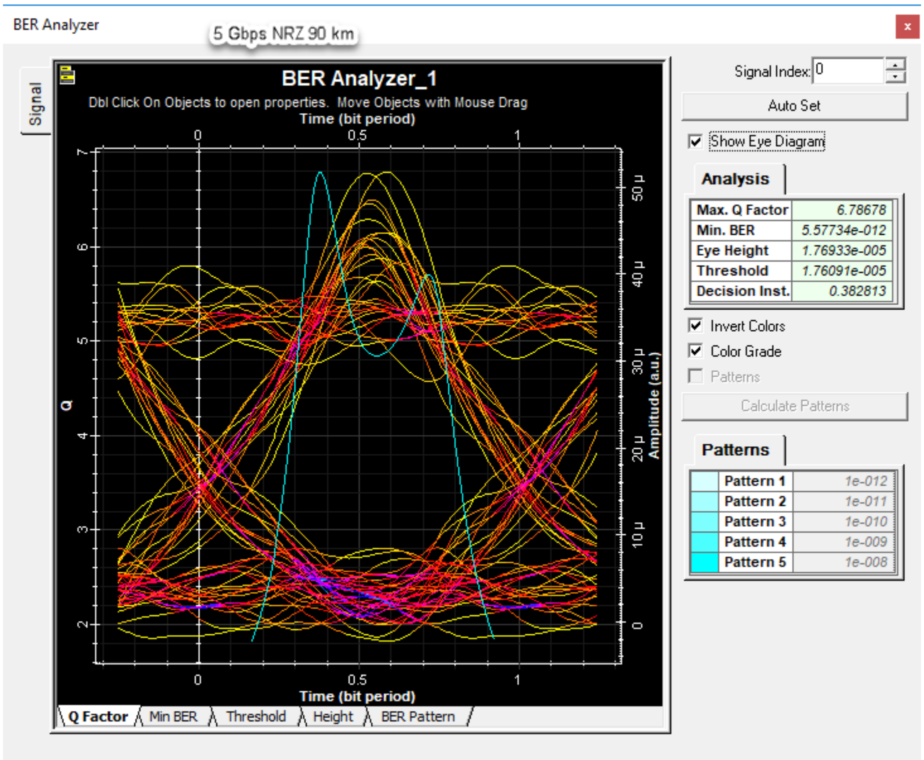
7. 5 Gbps NRZ 70 km



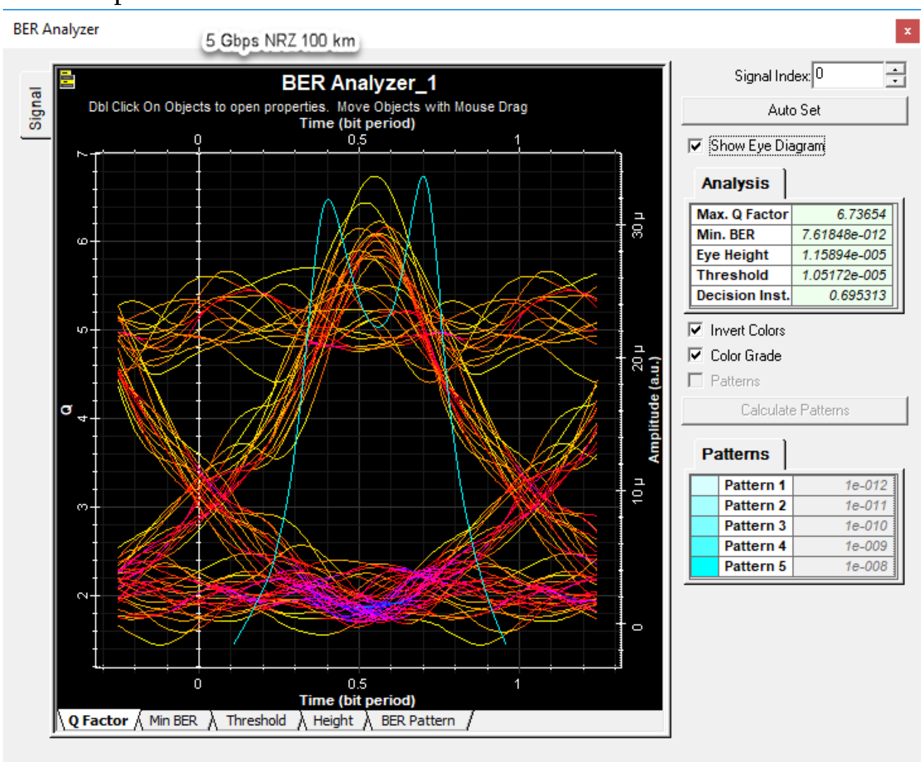
8. 5 Gbps NRZ 80 km



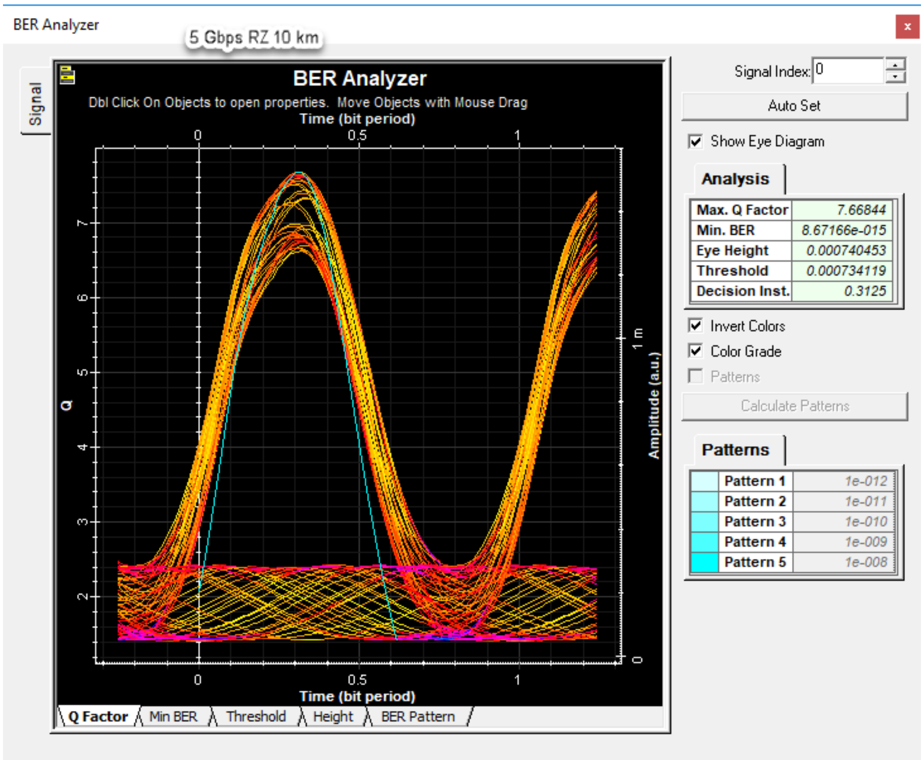
9. 5 Gbps NRZ 90 km



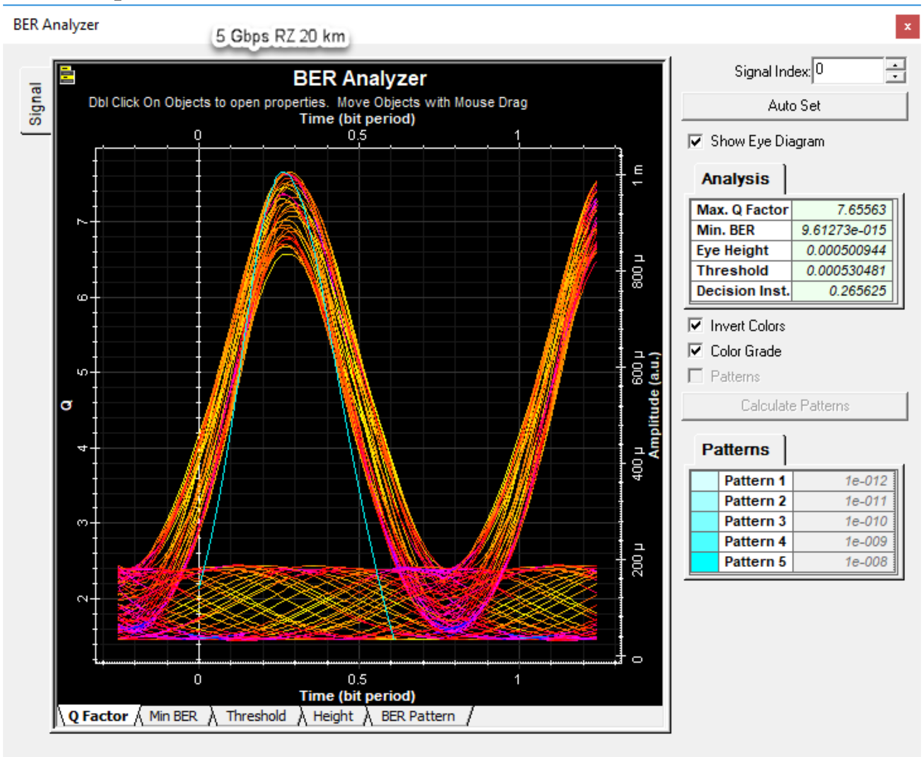
10. 5 Gbps NRZ 100 km



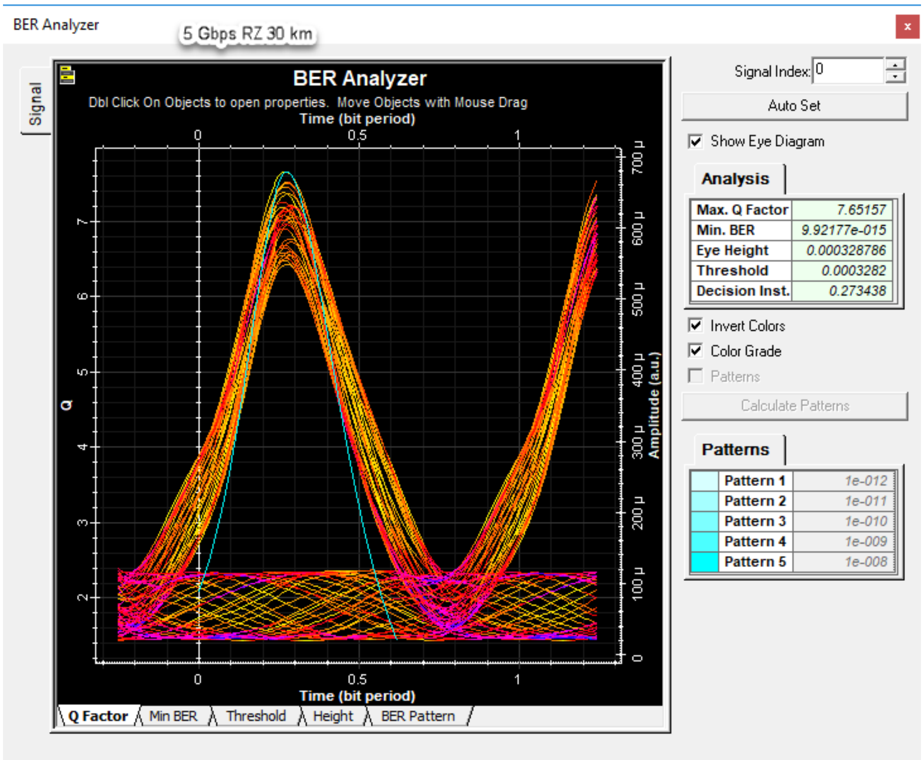
11. 5 Gbps RZ 10 km



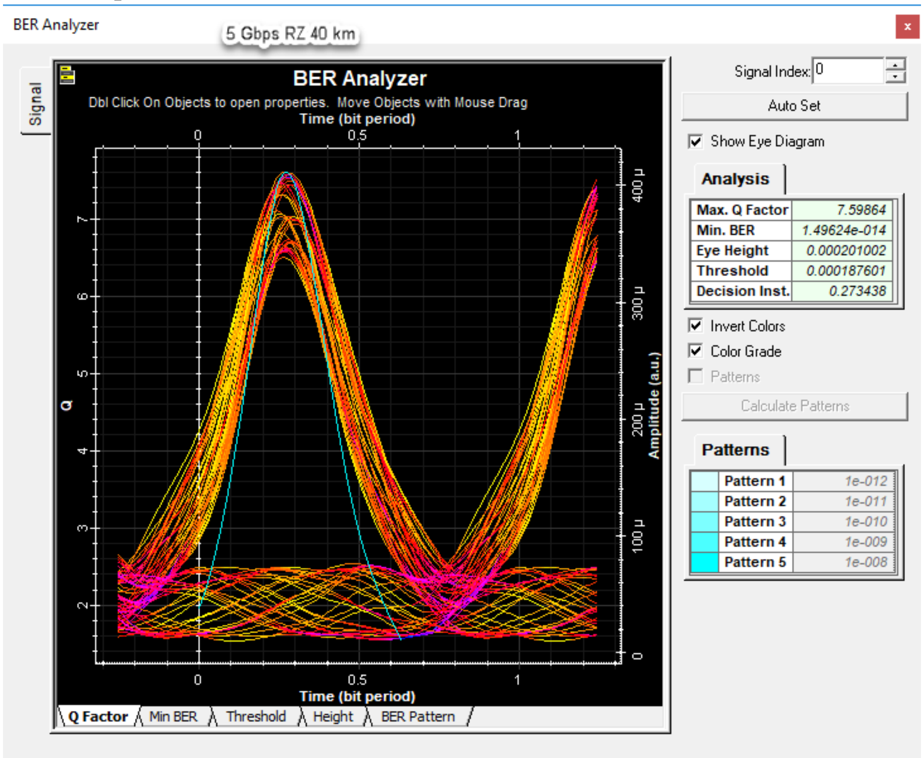
12. 5 Gbps RZ 20 km



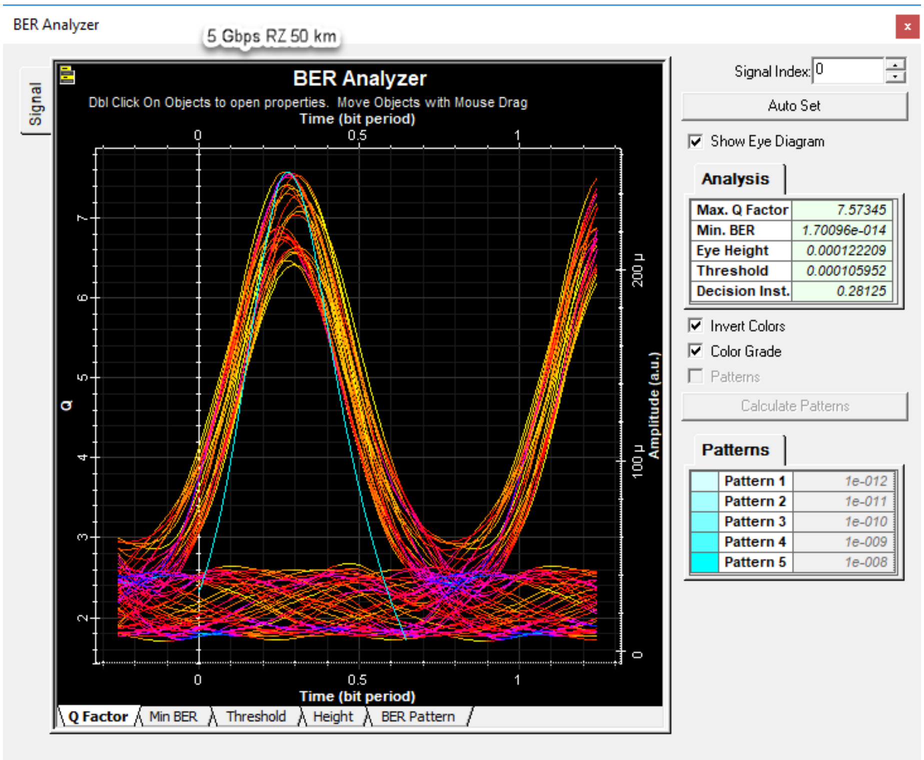
13. 5 Gbps RZ 30 km



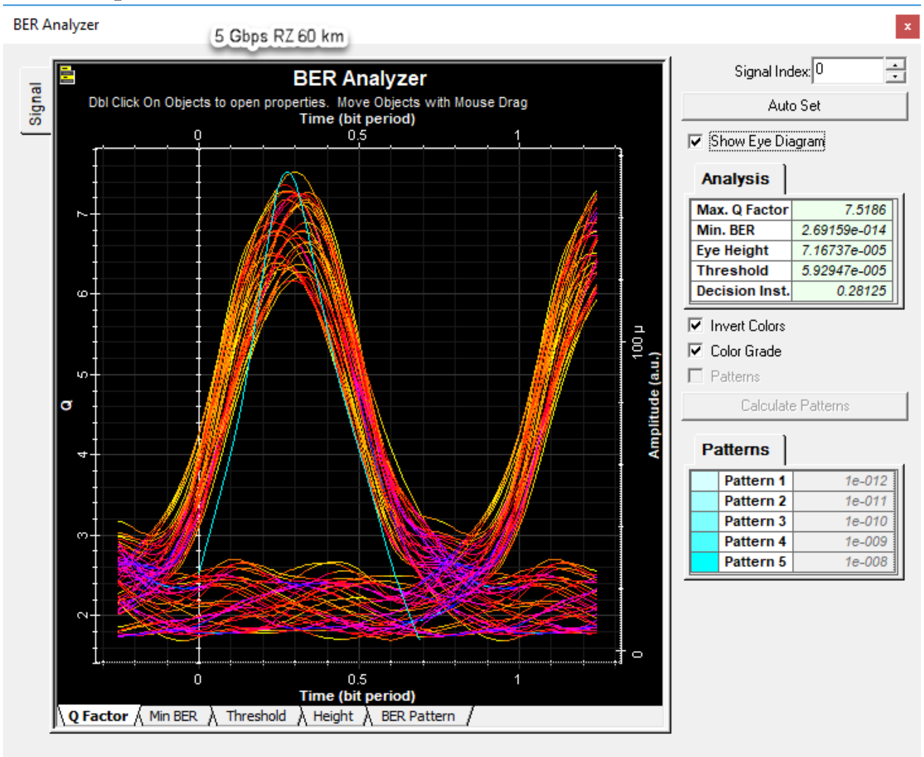
14. 5 Gbps RZ 40 km



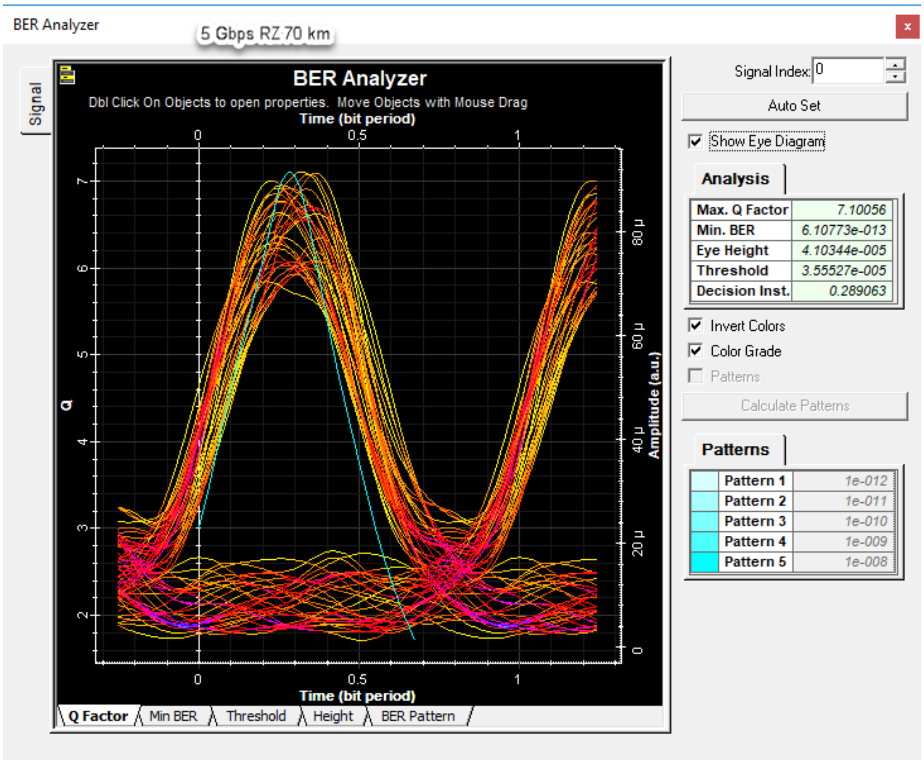
15. 5 Gbps RZ 50 km



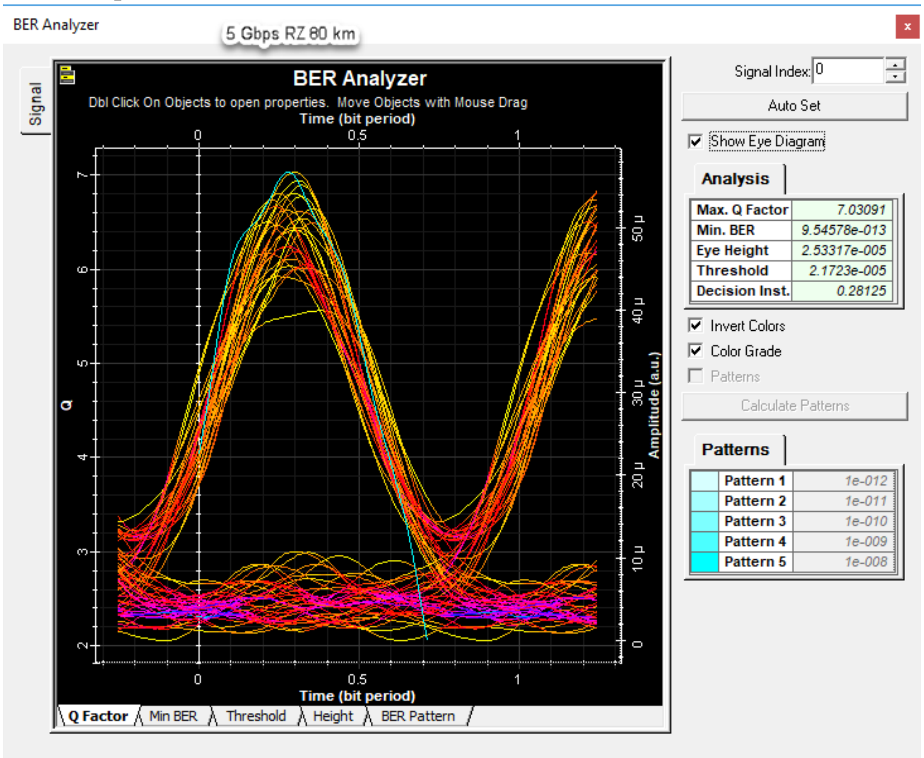
16. 5 Gbps RZ 60 km



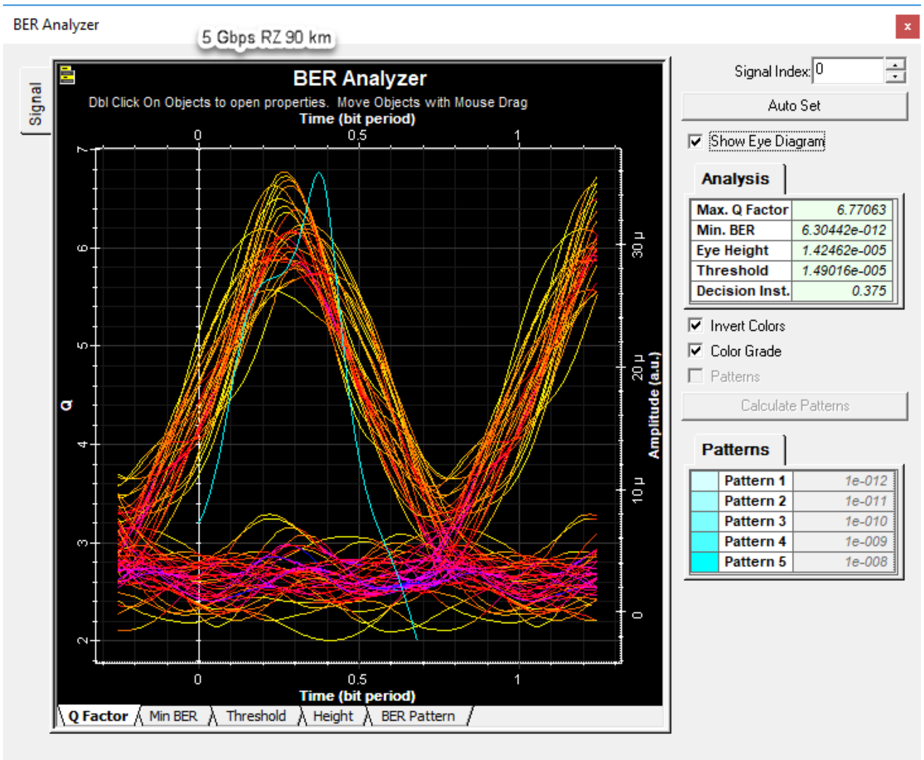
17. 5 Gbps RZ 70 km



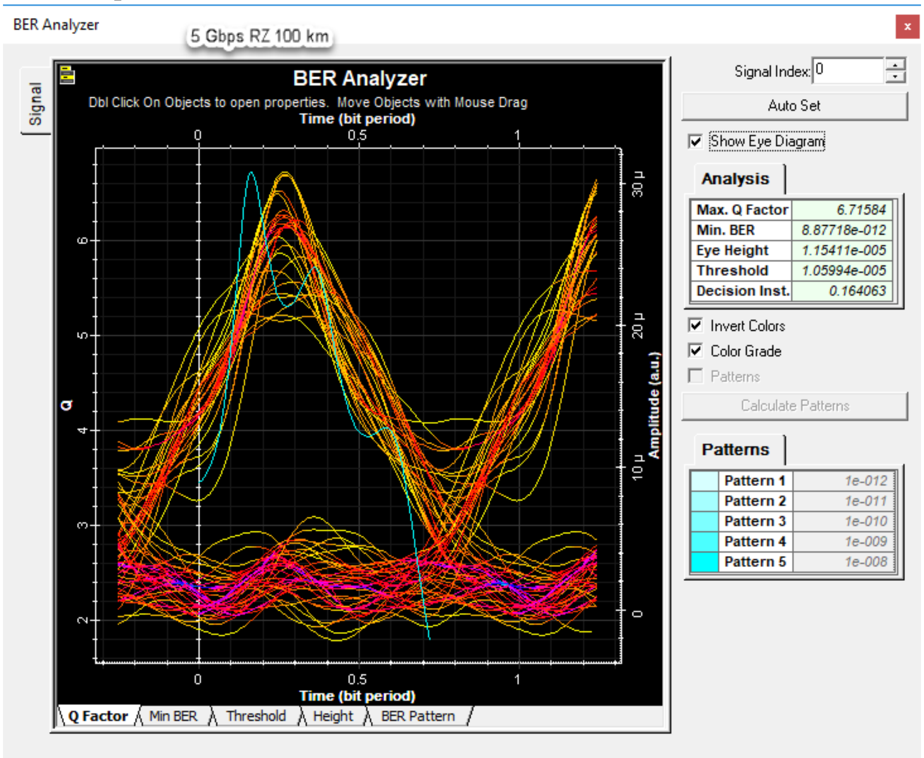
18. 5 Gbps RZ 80 km



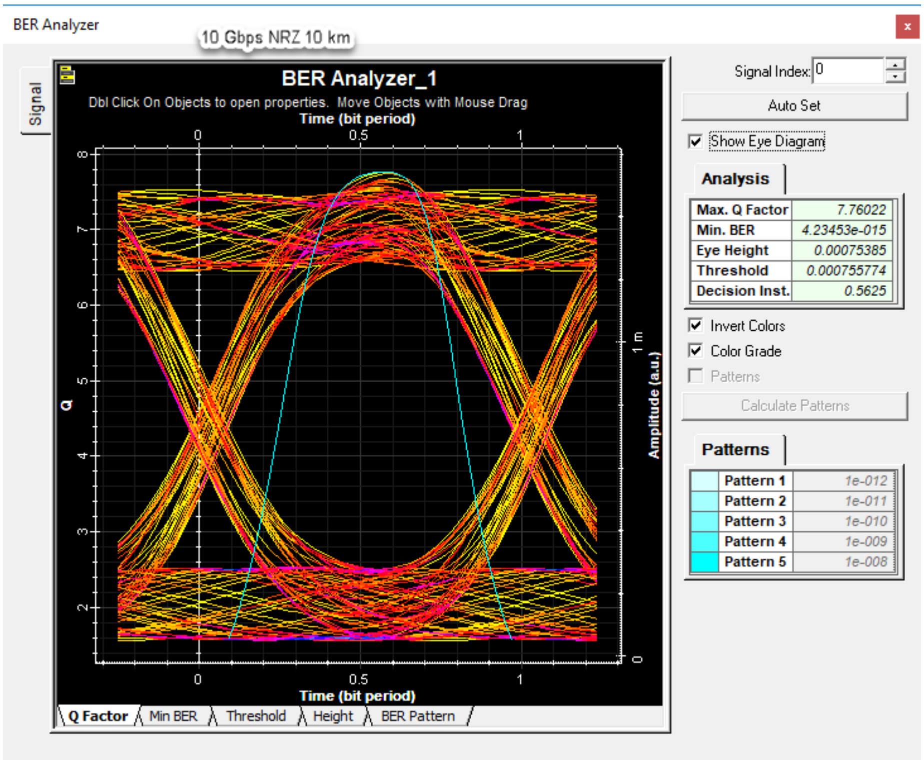
19. 5 Gbps RZ 90 km



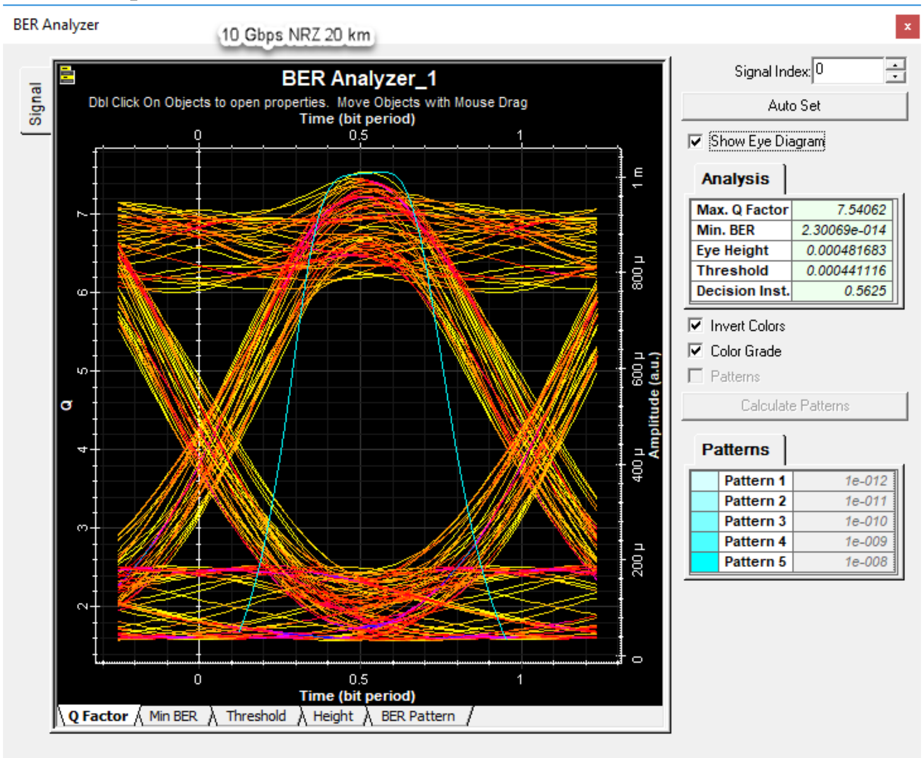
20. 5 Gbps RZ 100 km



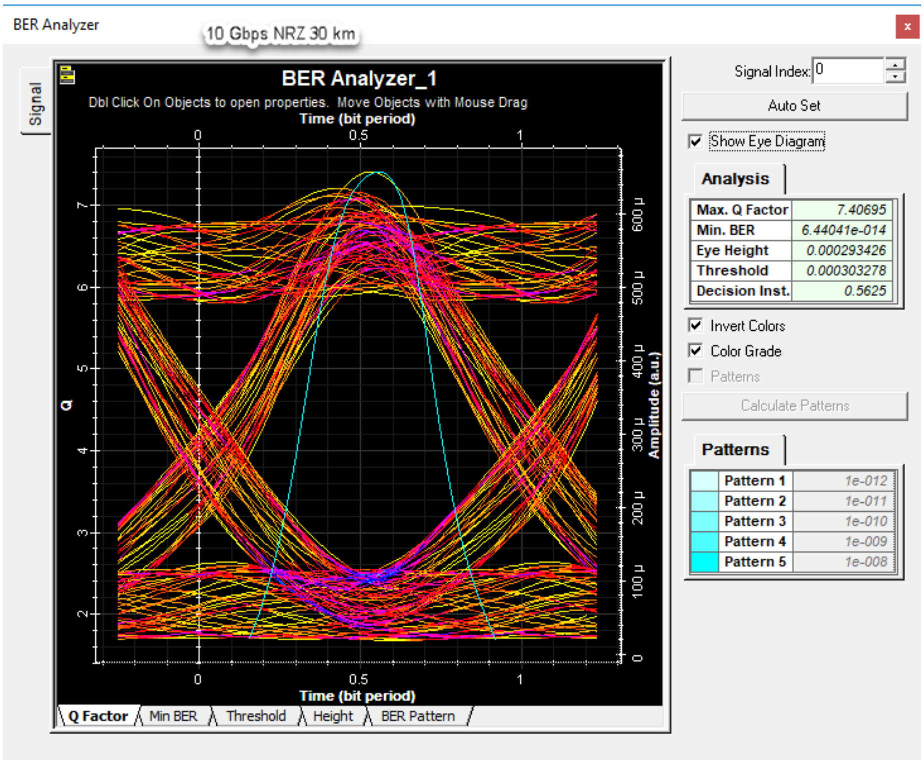
21. 10 Gbps NRZ 10 km



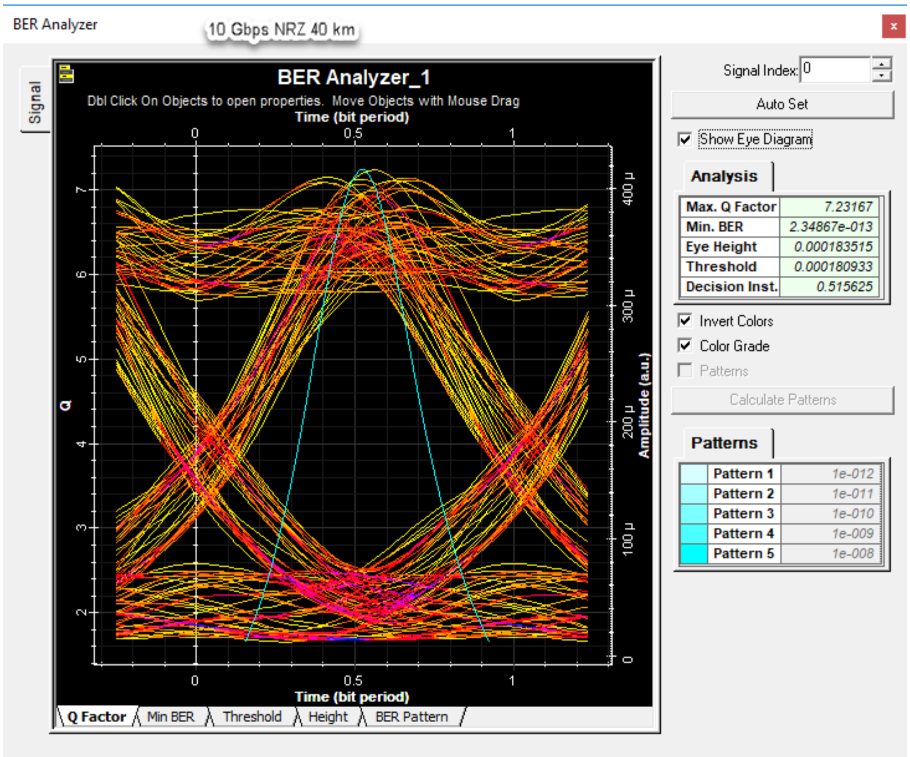
22. 10 Gbps NRZ 20 km



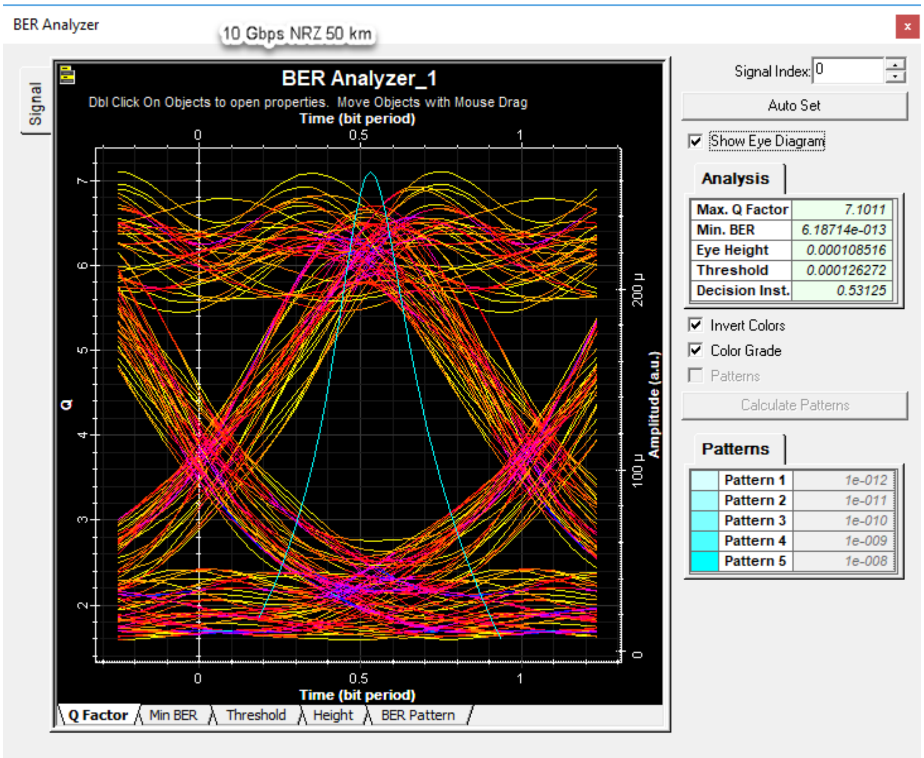
23. 10 Gbps NRZ 30 km



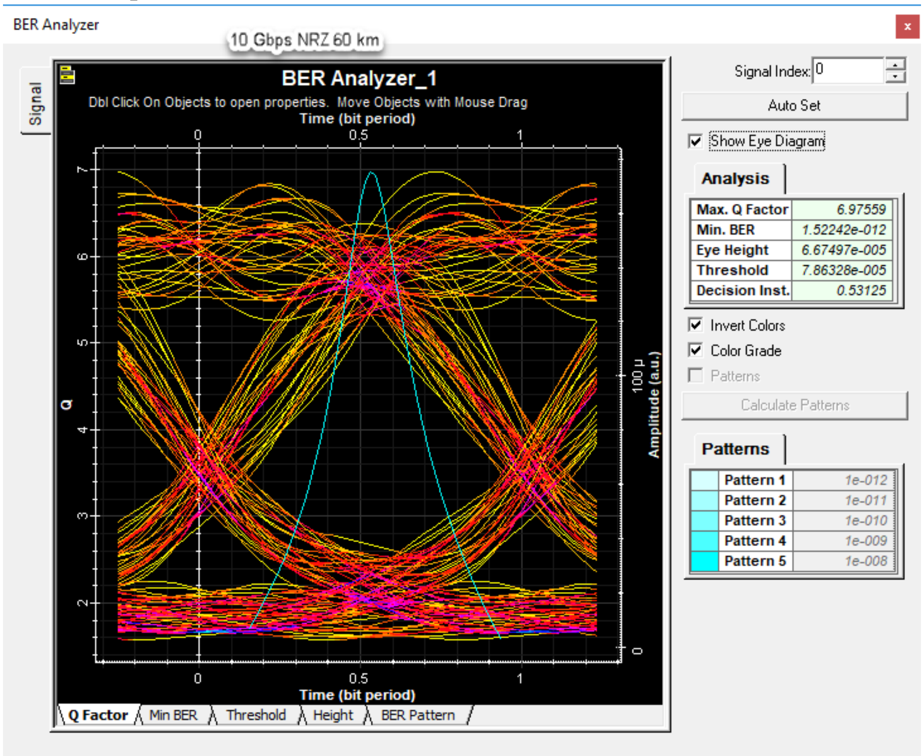
24. 10 Gbps NRZ 40 km



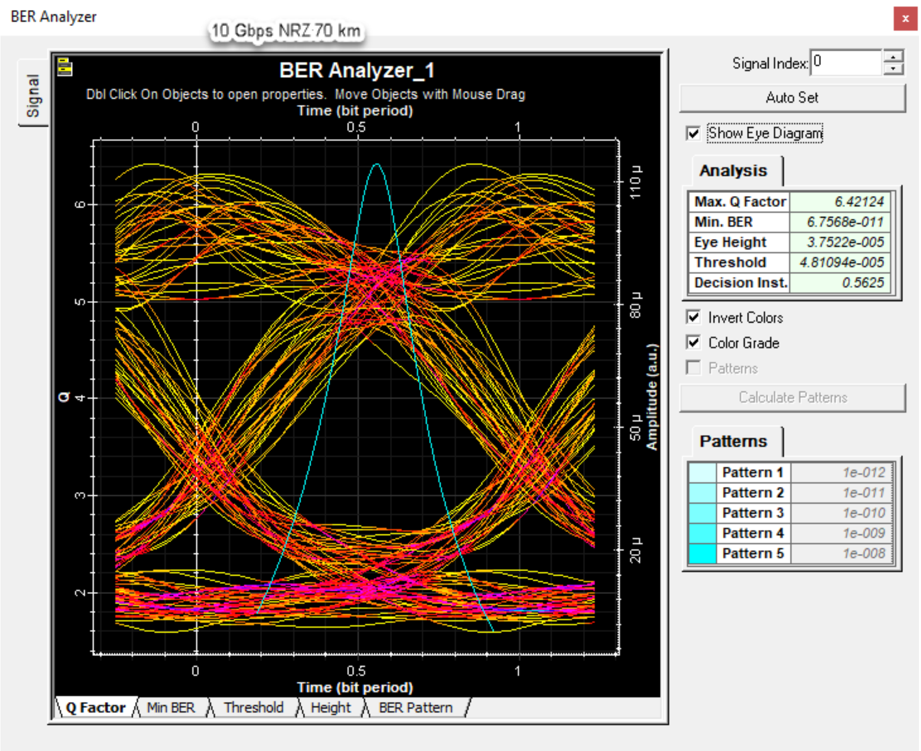
25. 10 Gbps NRZ 50 km



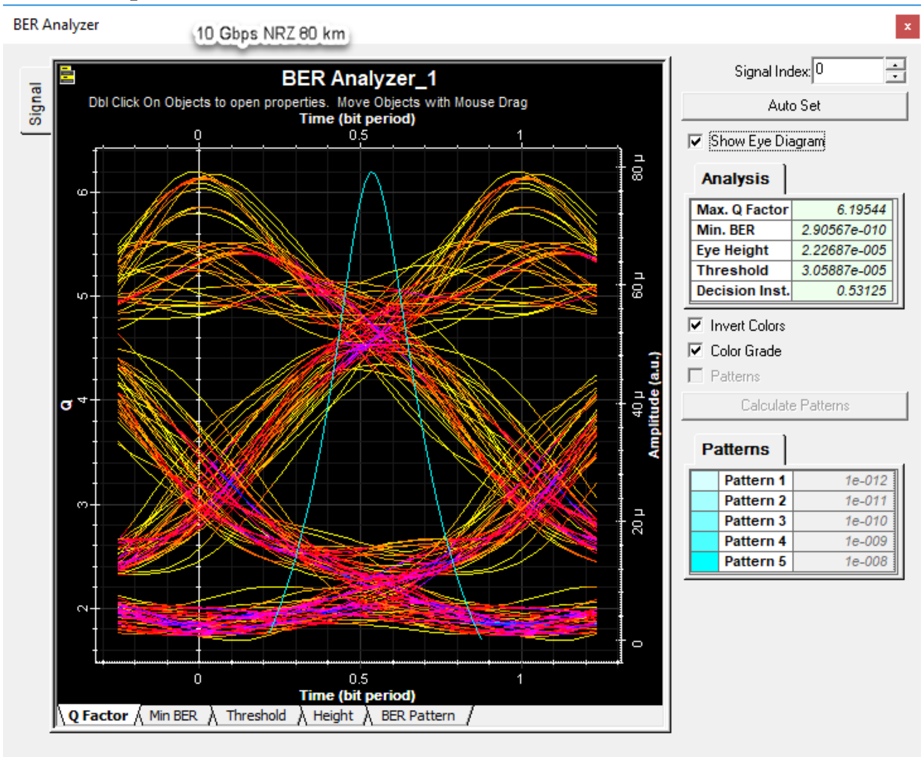
26. 10 Gbps NRZ 60 km



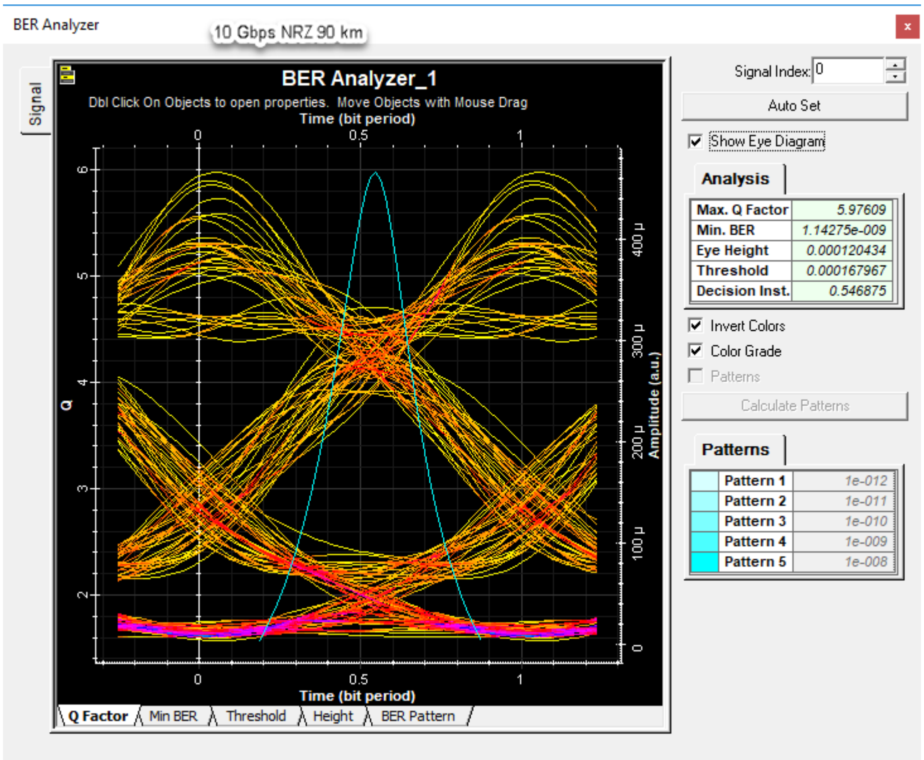
27. 10 Gbps NRZ 70 km



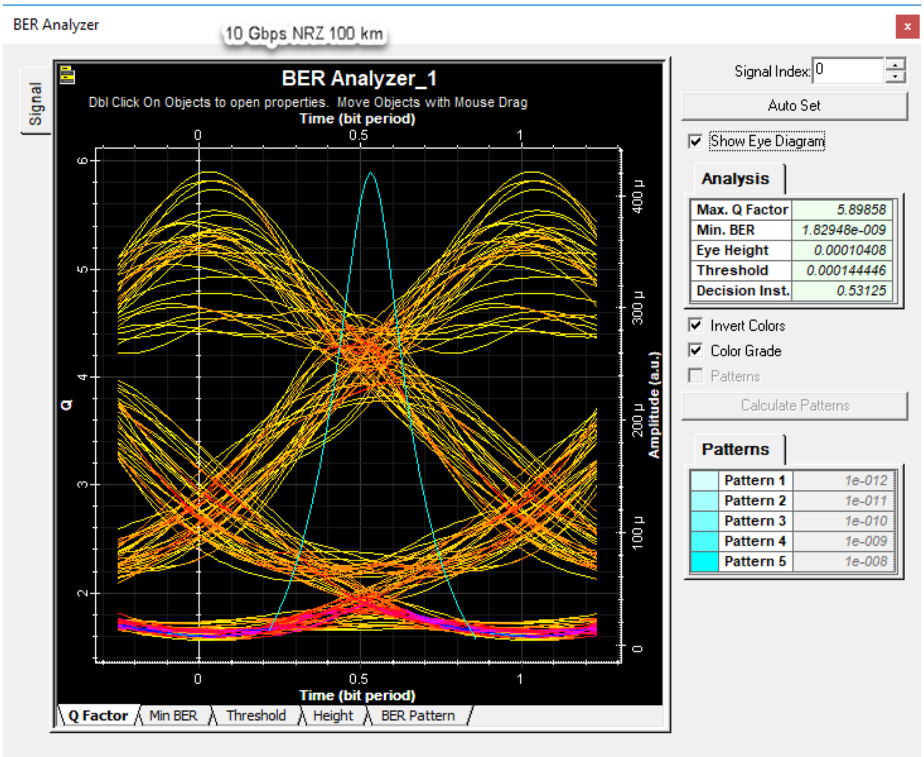
28. 10 Gbps NRZ 80 km



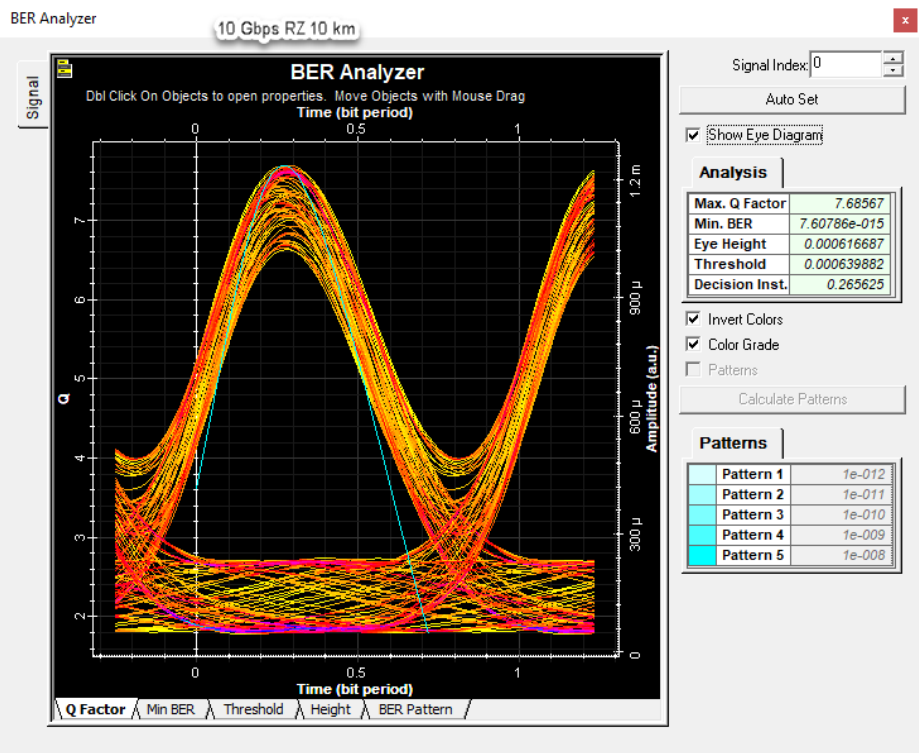
29. 10 Gbps NRZ 90 km



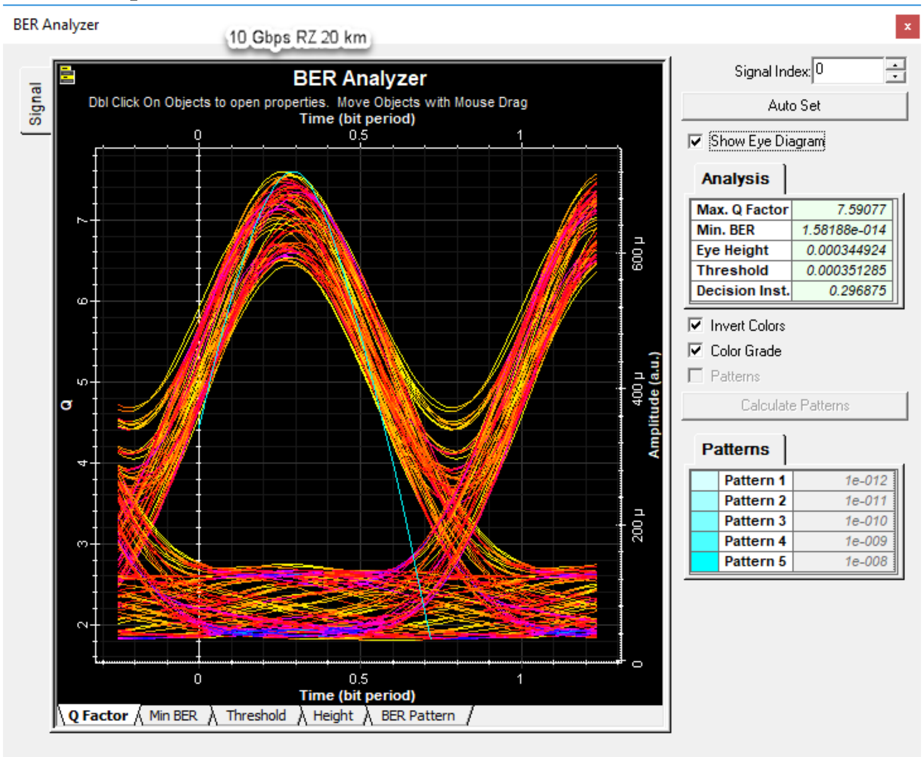
30. 10 Gbps NRZ 100 km



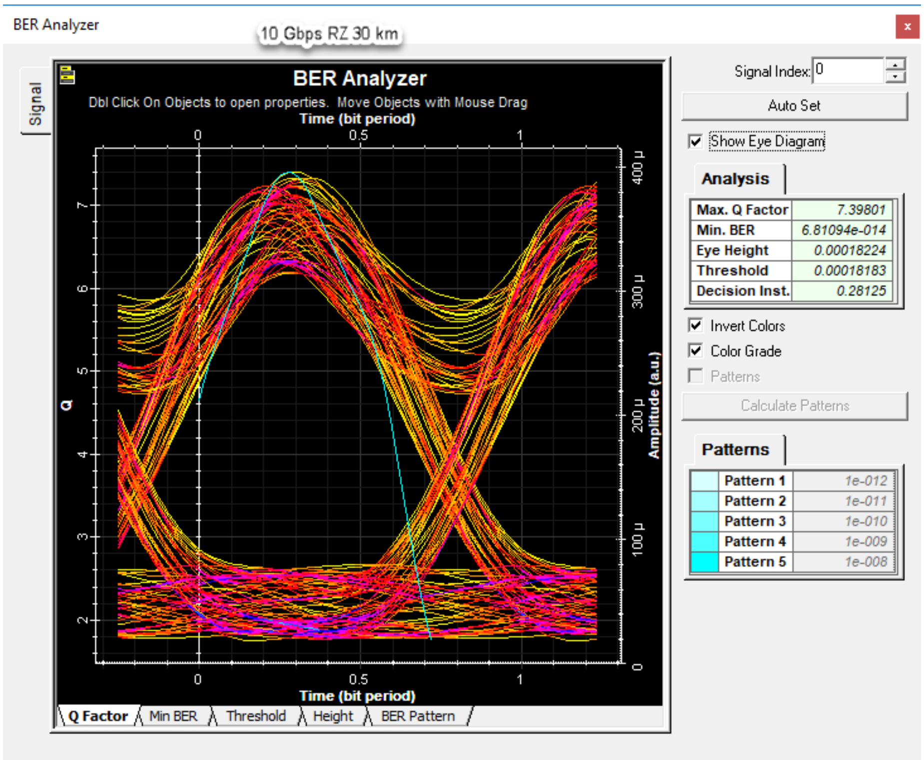
31. 10 Gbps RZ 10 km



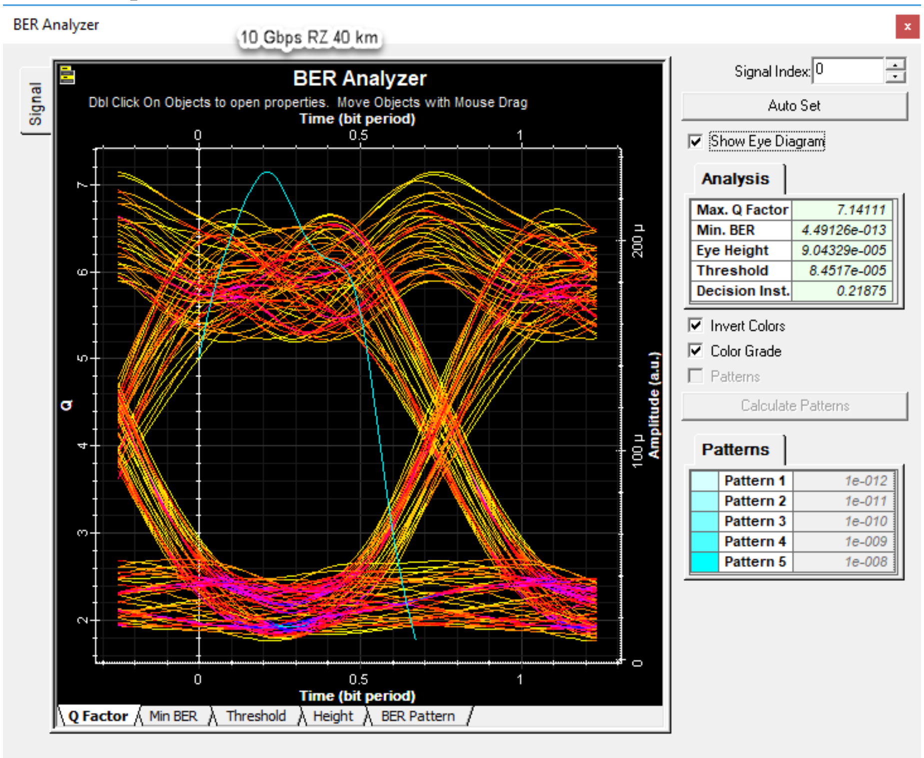
32. 10 Gbps RZ 20 km



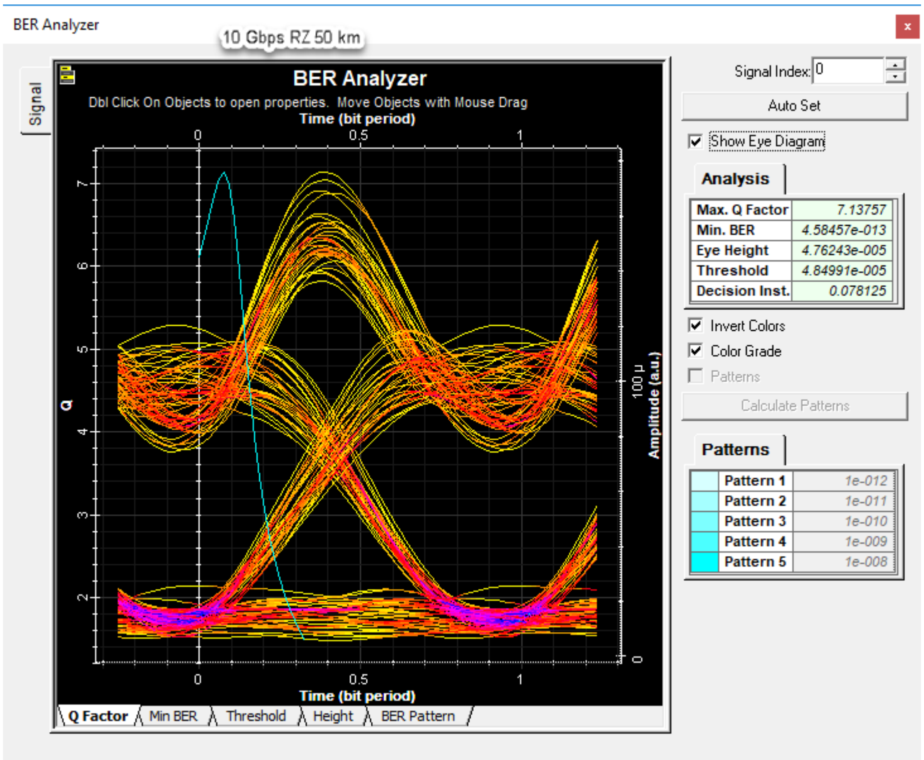
33. 10 Gbps RZ 30 km



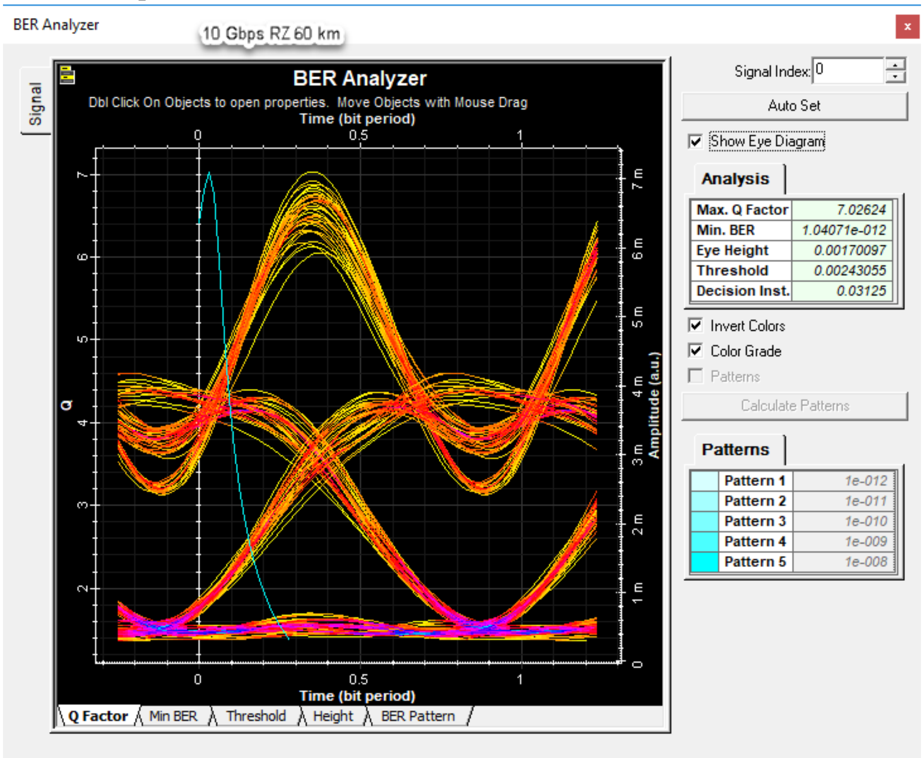
34. 10 Gbps RZ 40 km



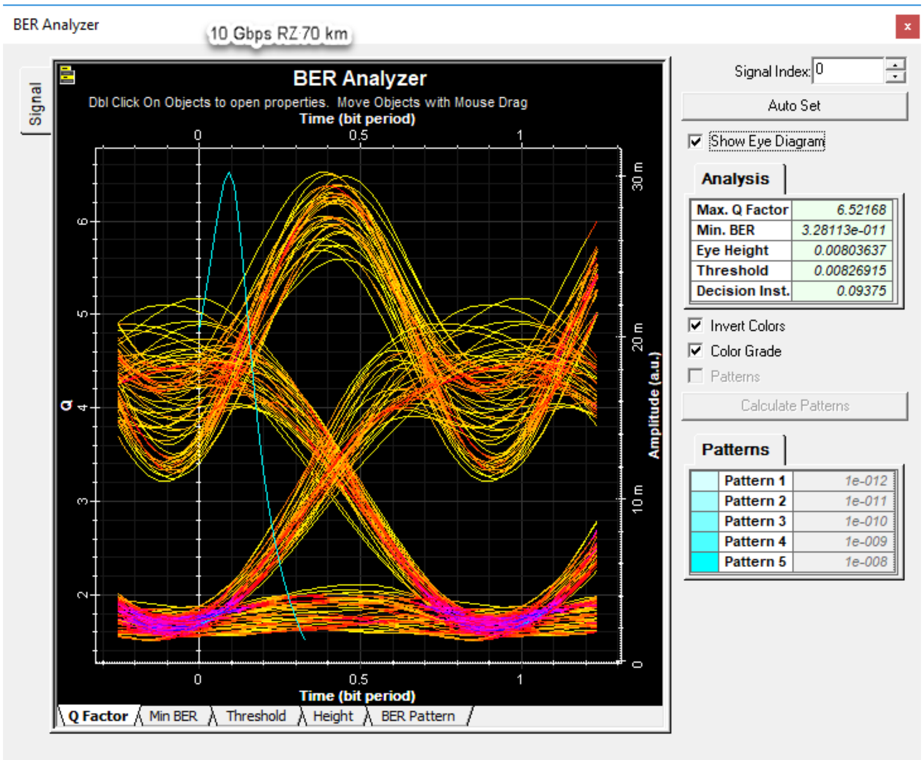
35. 10 Gbps RZ 50 km



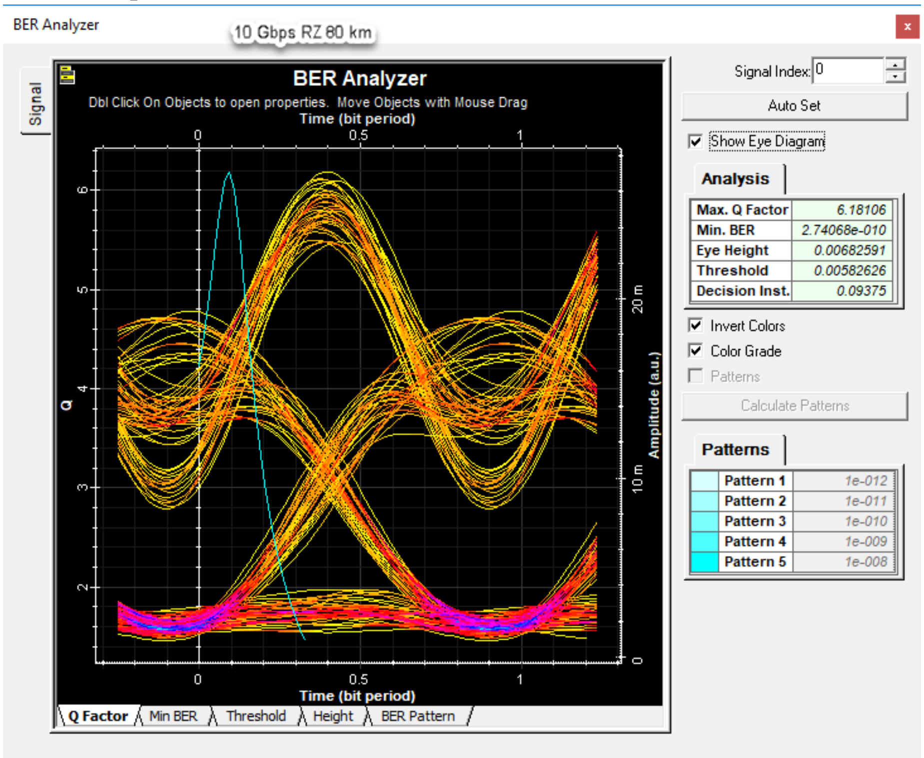
36. 10 Gbps RZ 60 km



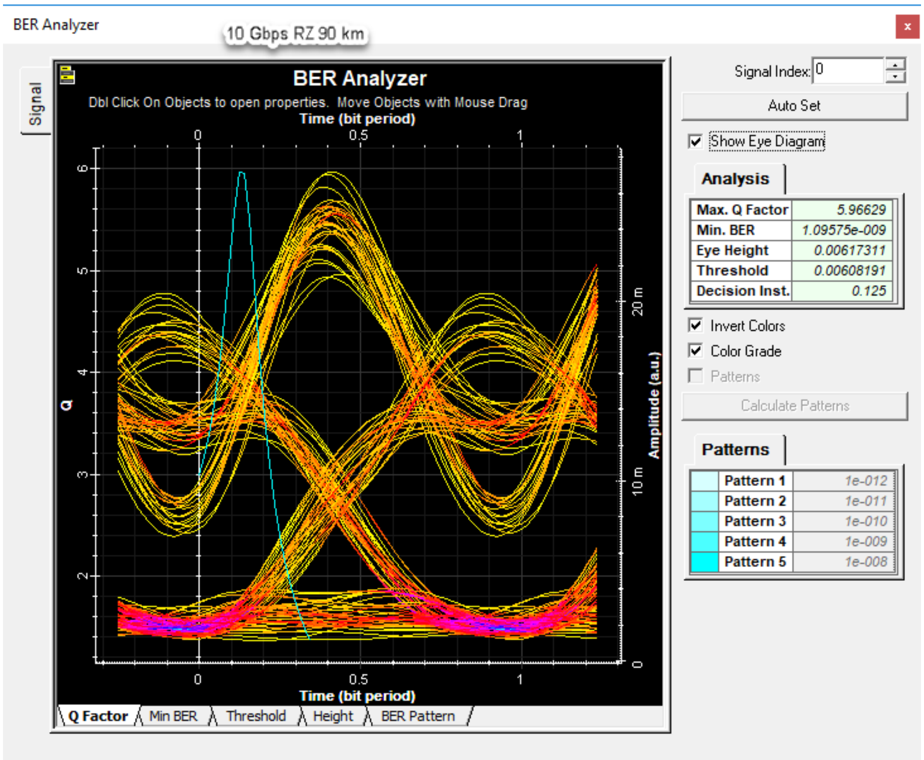
37. 10 Gbps RZ 70 km



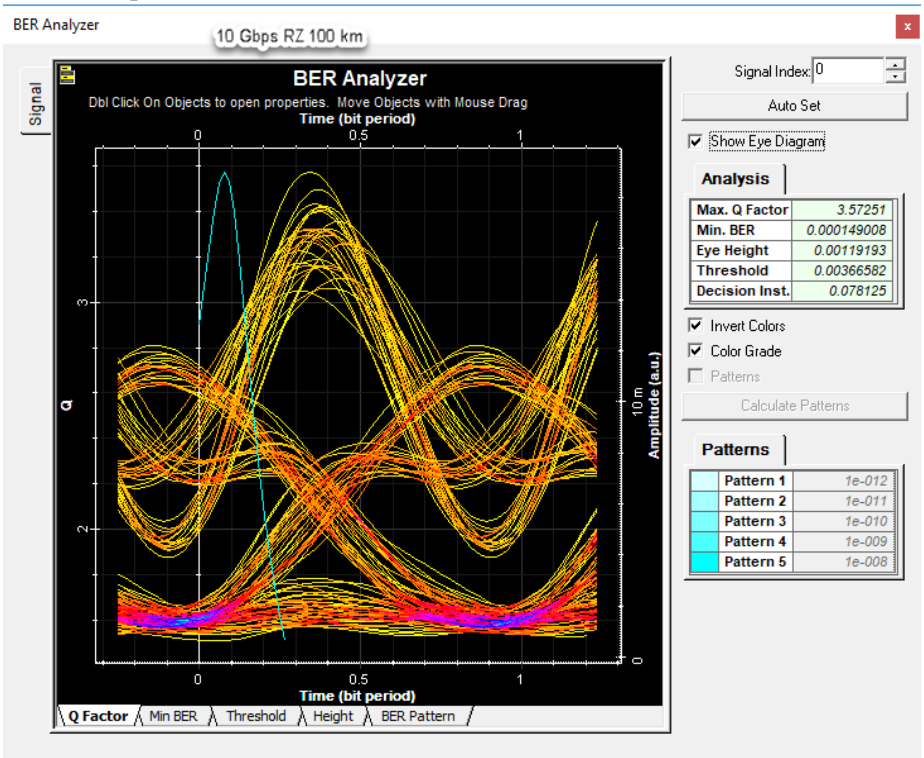
38. 10 Gbps RZ 80 km



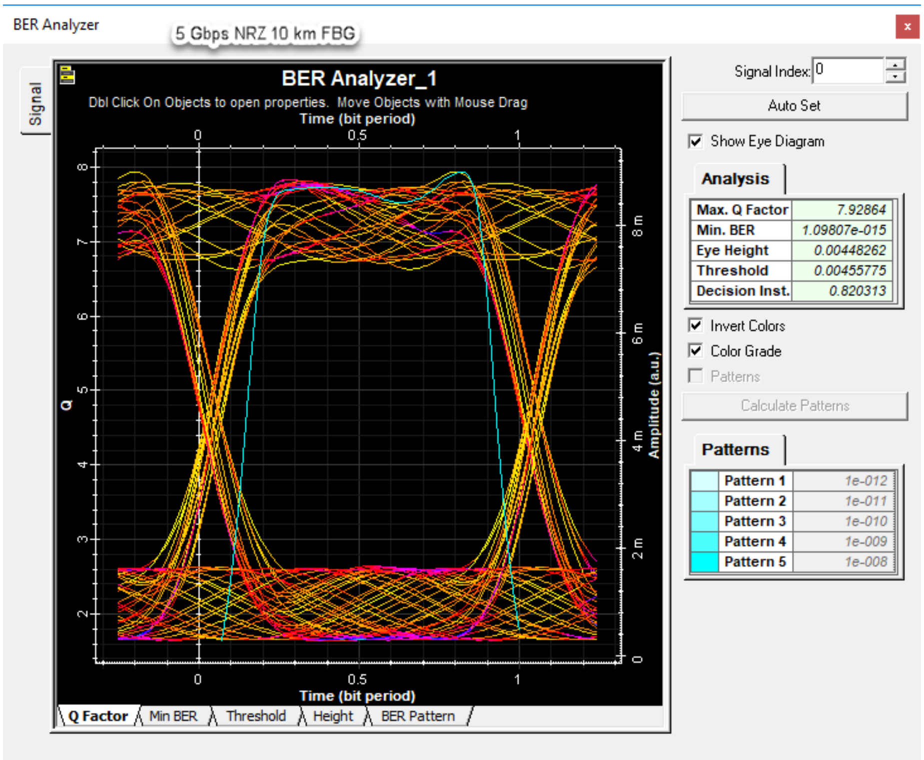
39. 10 Gbps RZ 90 km



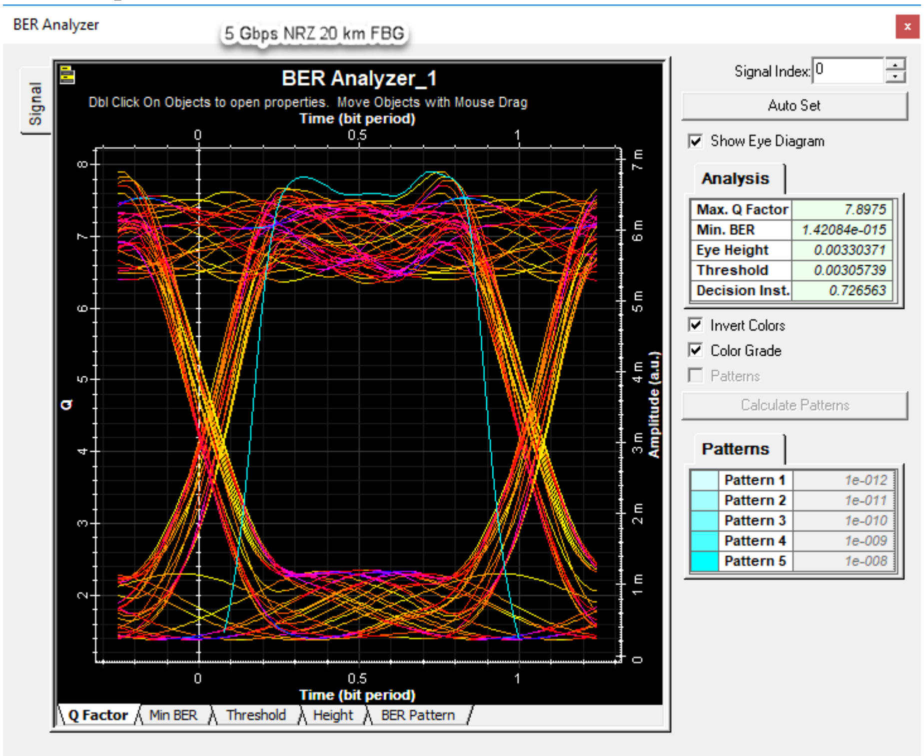
40. 10 Gbps RZ 100 km



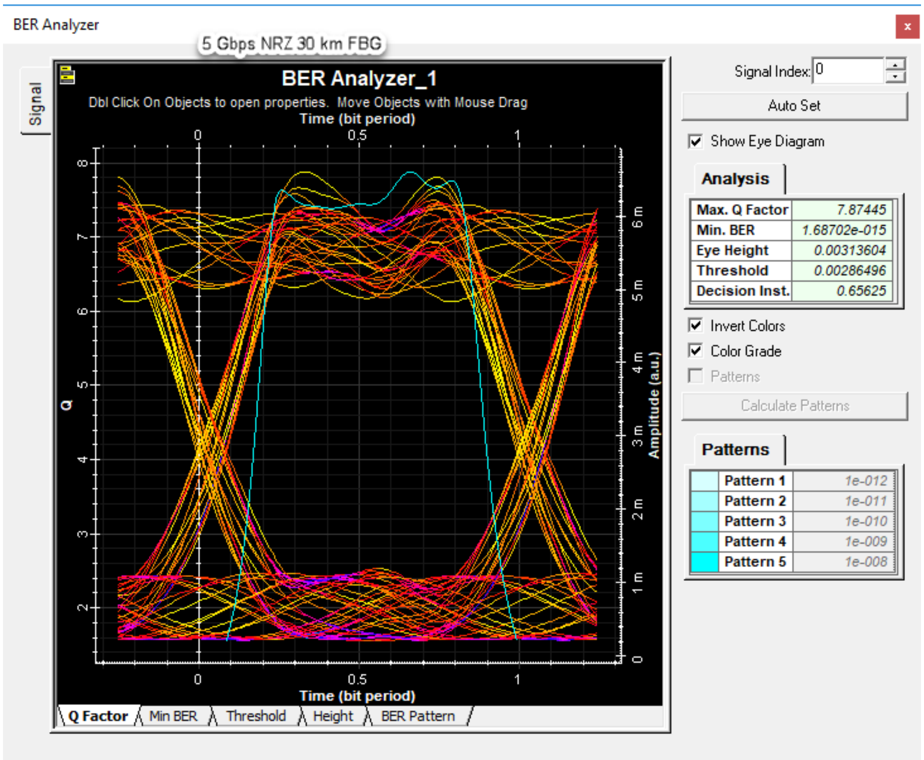
41. 5 Gbps NRZ 10 km FBG



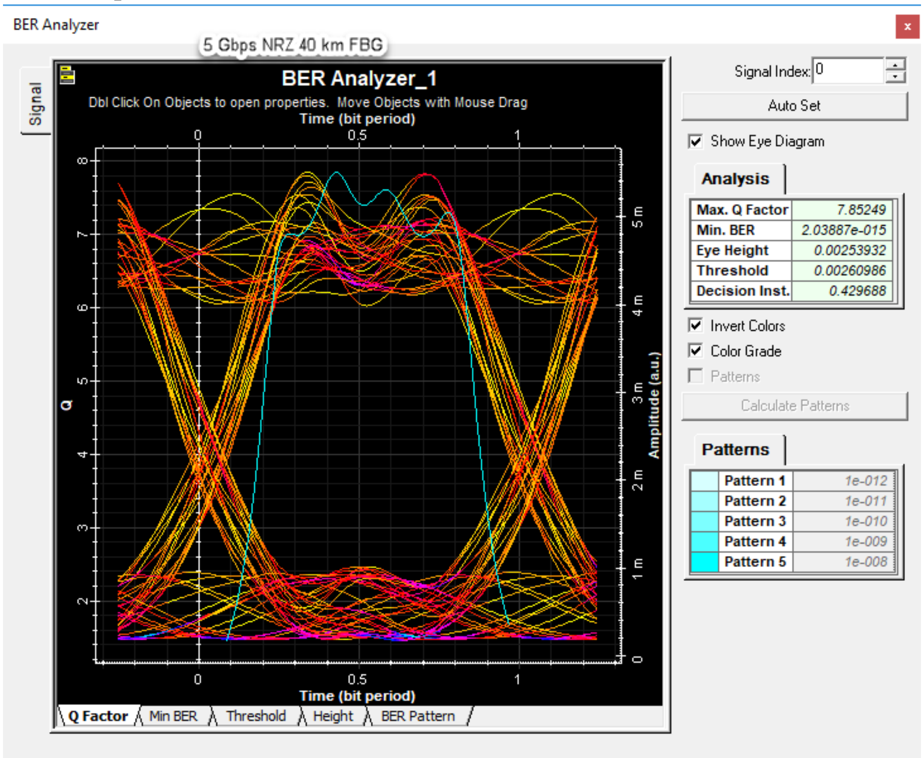
42. 5 Gbps NRZ 20 km FBG



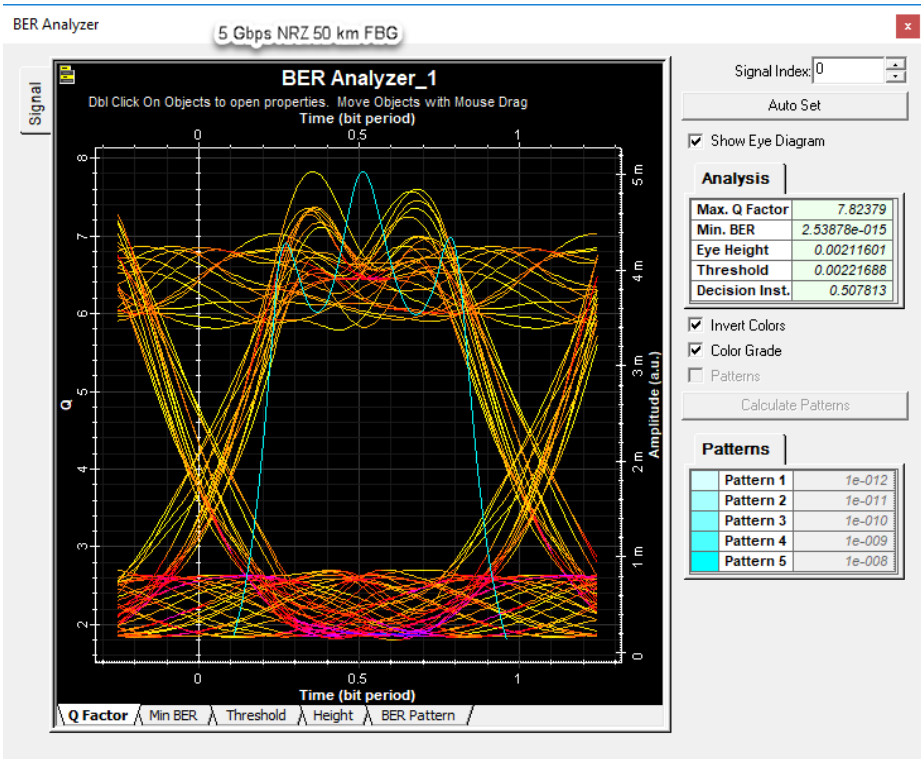
43. 5 Gbps NRZ 30 km FBG



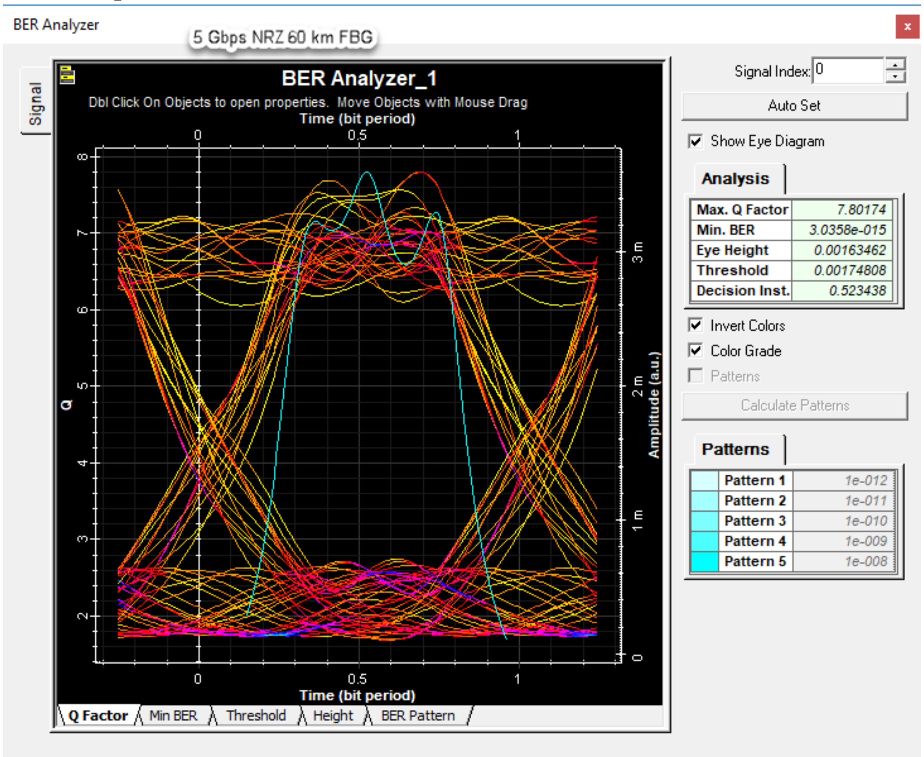
44. 5 Gbps NRZ 10 km FBG



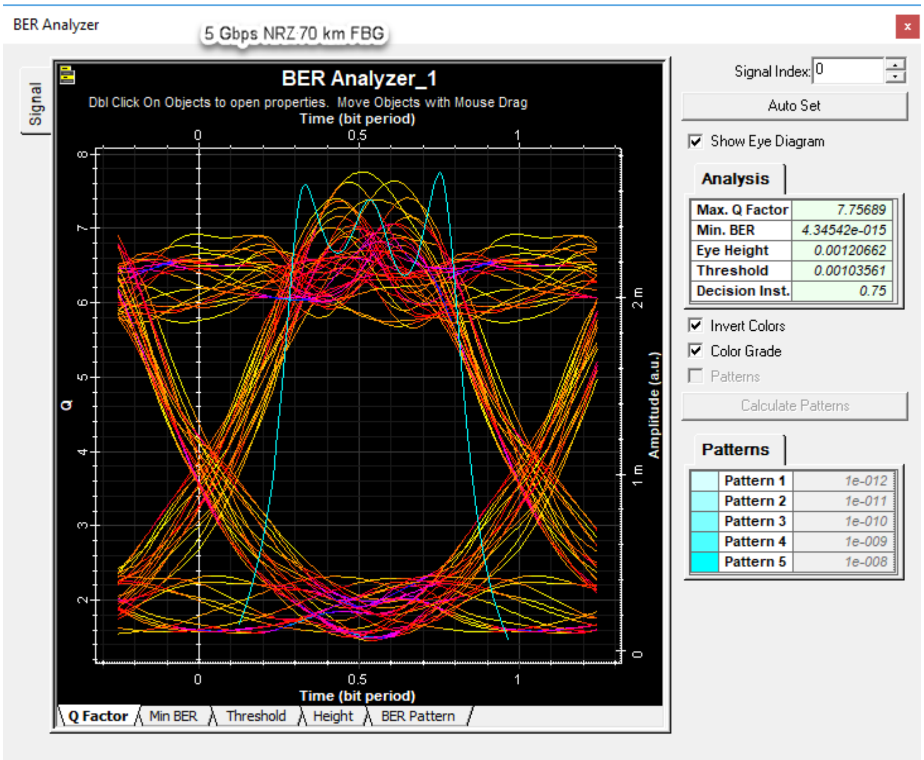
45. 5 Gbps NRZ 50 km FBG



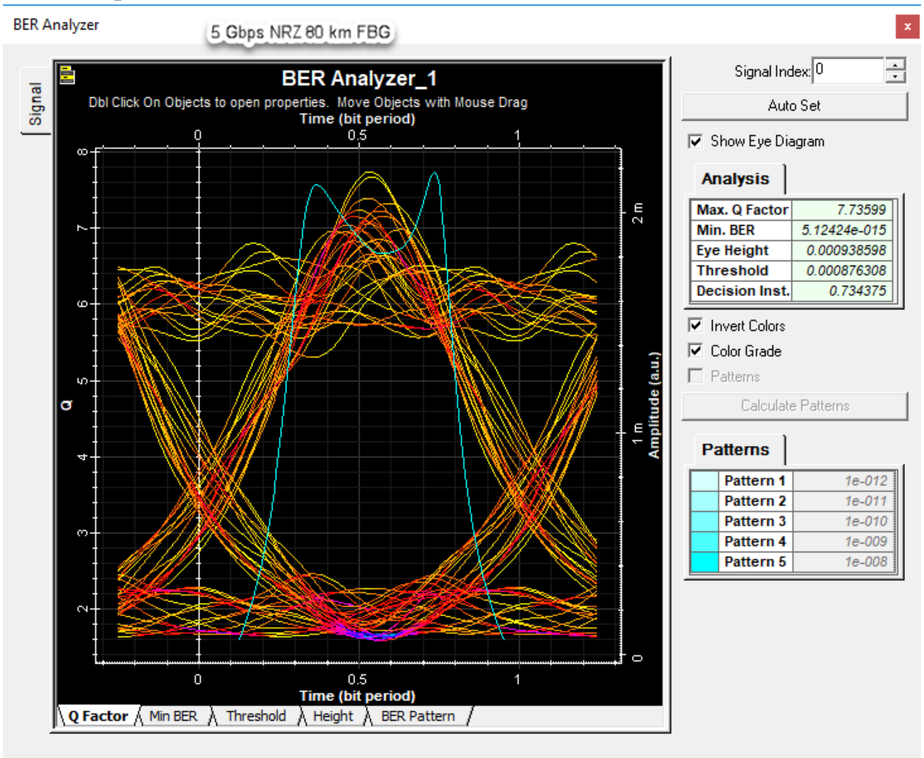
46. 5 Gbps NRZ 60 km FBG



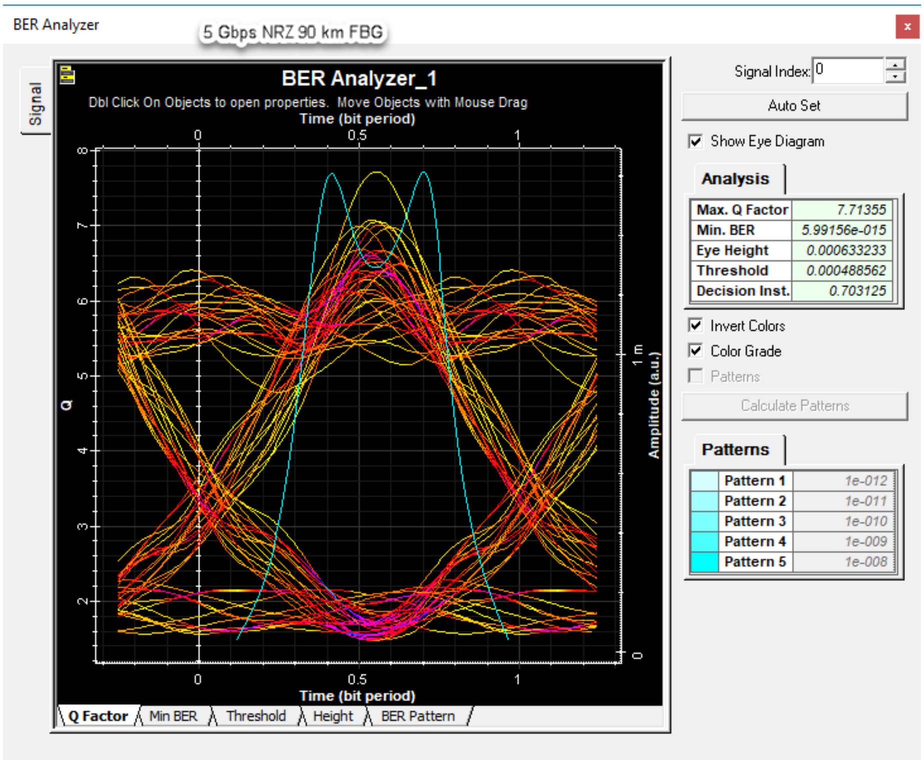
47. 5 Gbps NRZ 70 km FBG



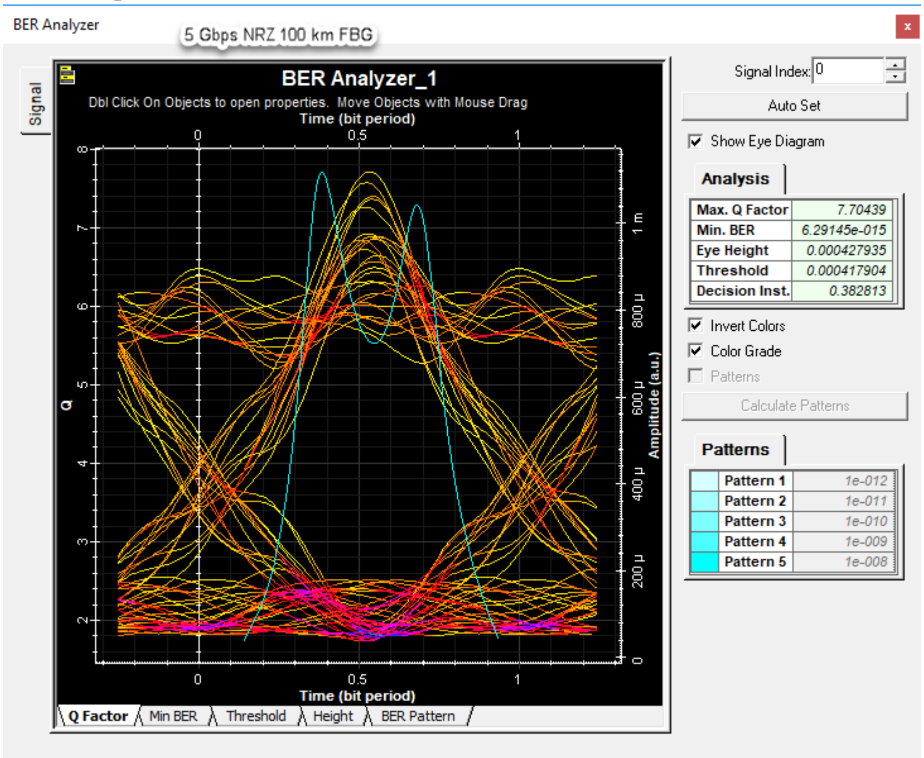
48. 5 Gbps NRZ 80 km FBG



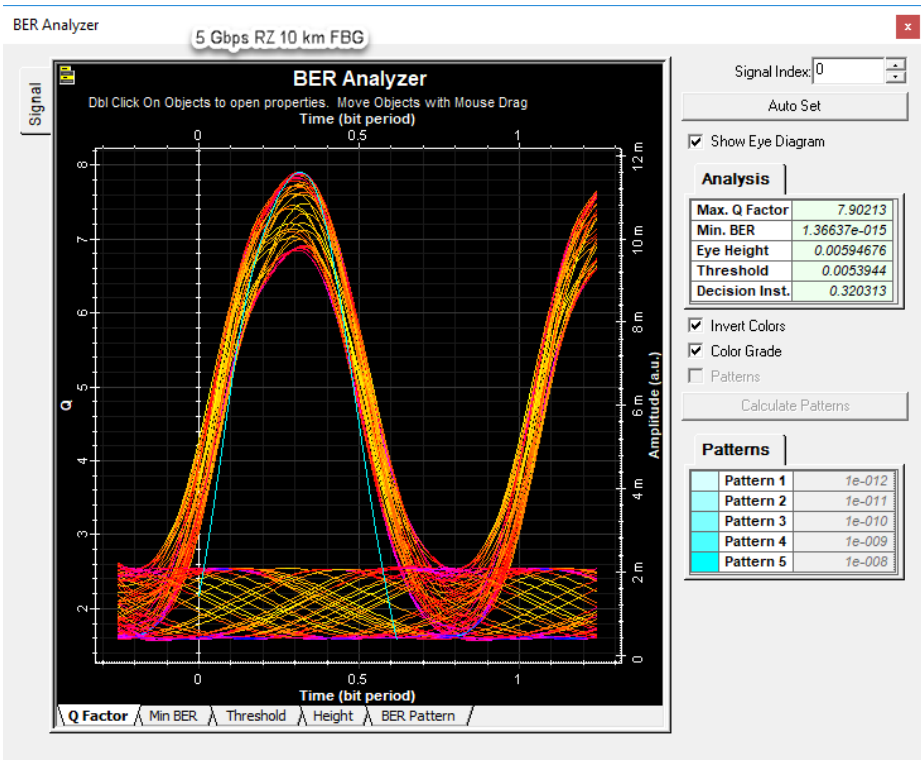
49. 5 Gbps NRZ 90 km FBG



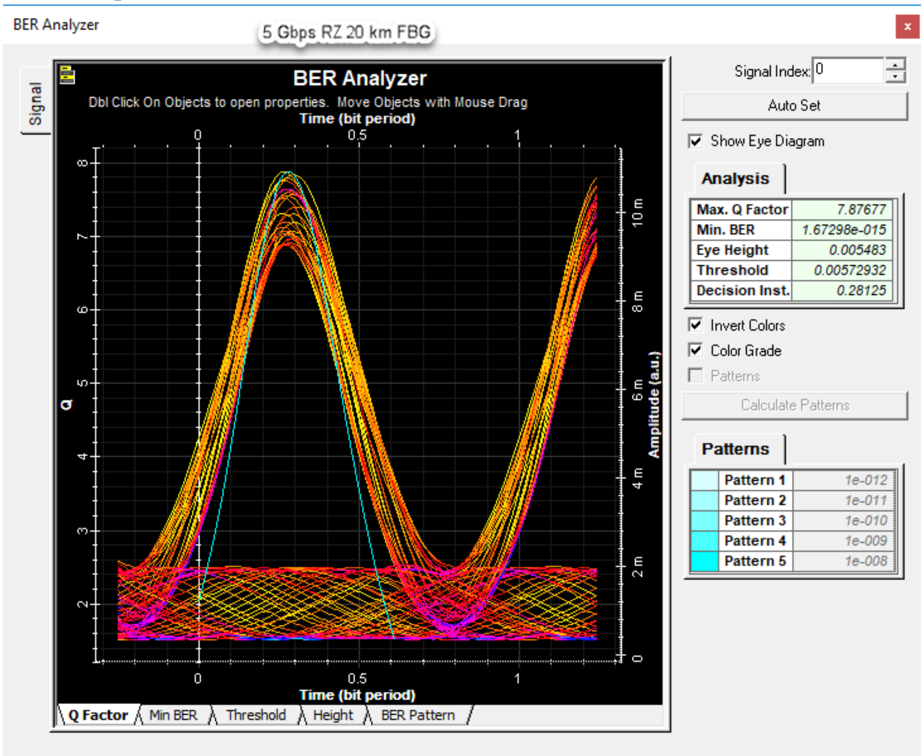
50. 5 Gbps NRZ 100 km FBG



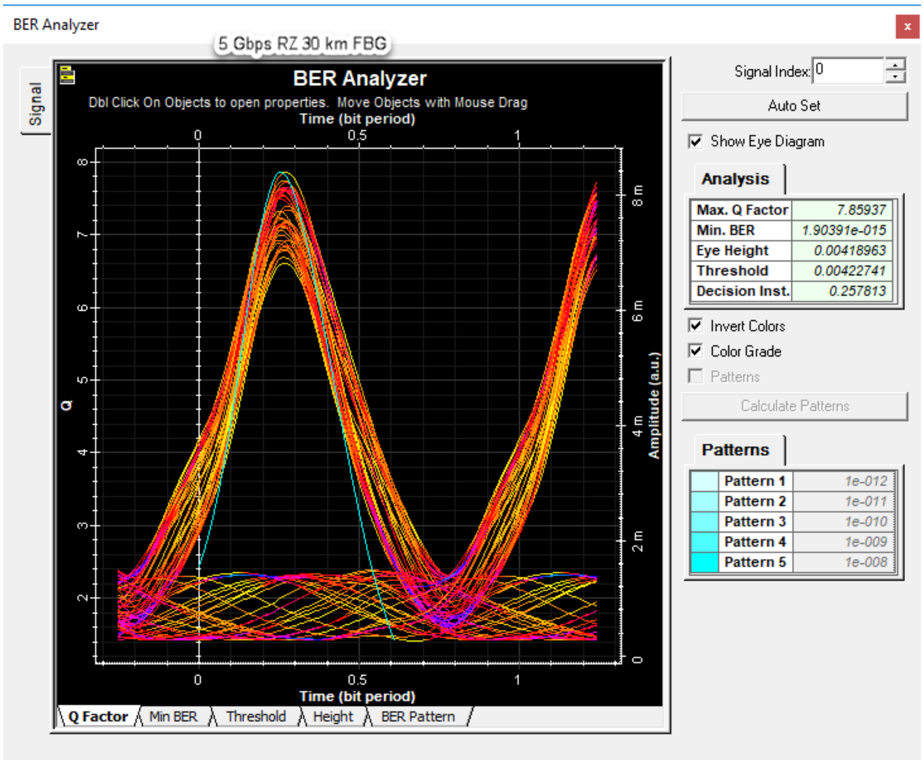
51. 5 Gbps RZ 10 km FBG



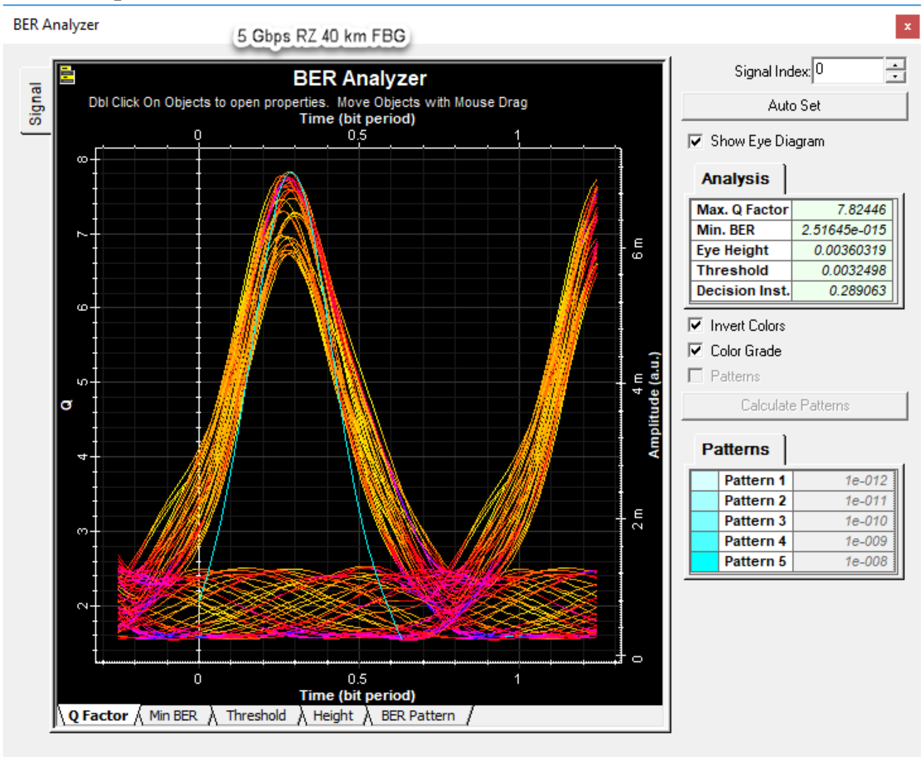
52. 5 Gbps RZ 20 km FBG



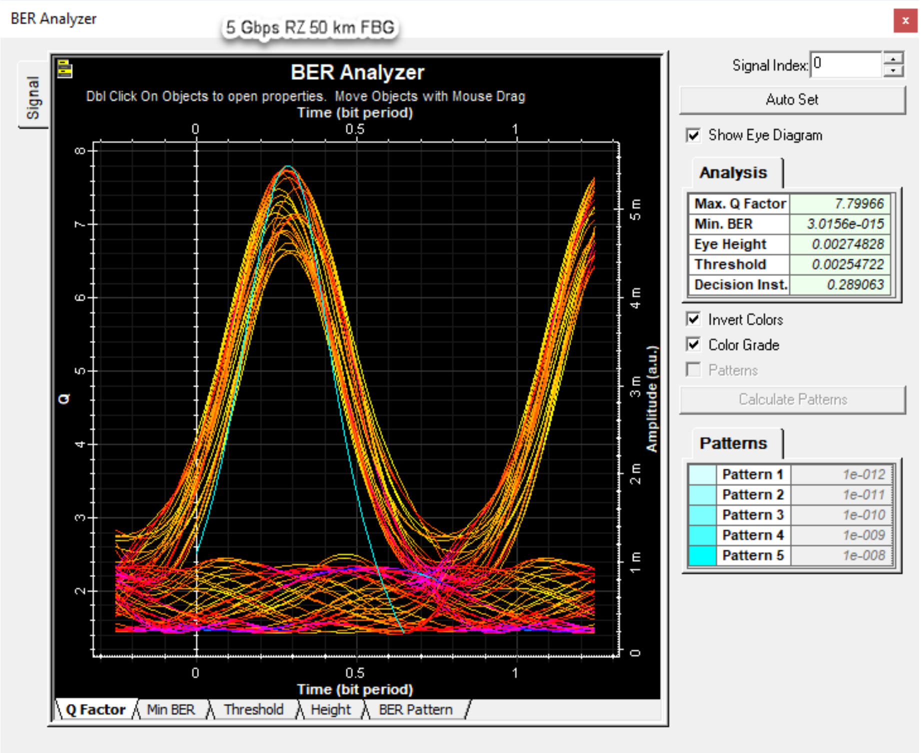
53. 5 Gbps RZ 30 km FBG



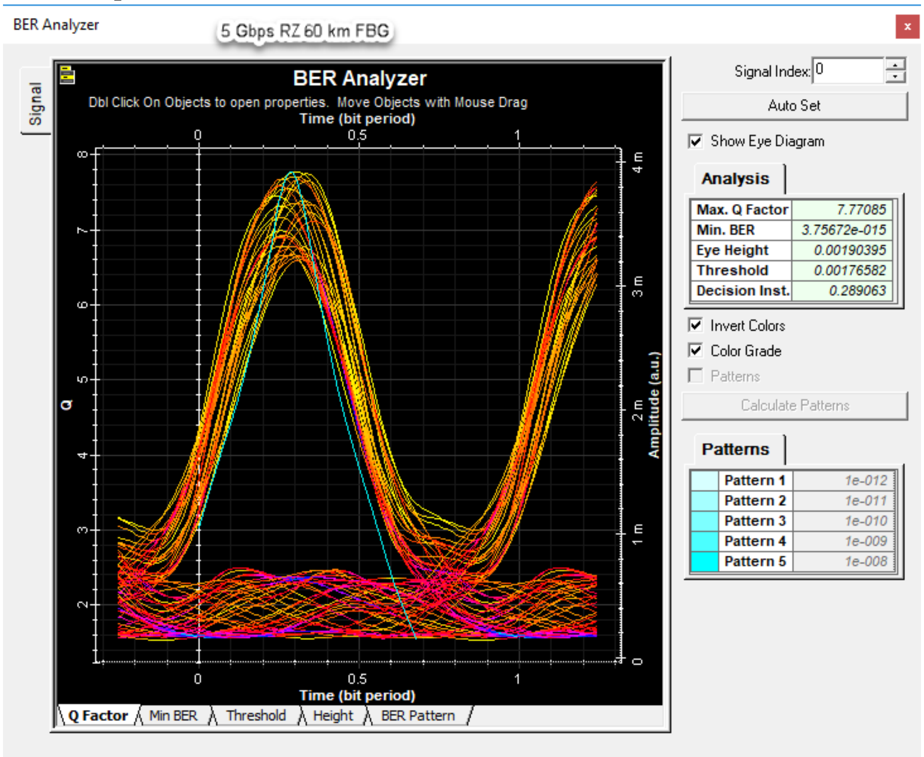
54. 5 Gbps RZ 40 km FBG



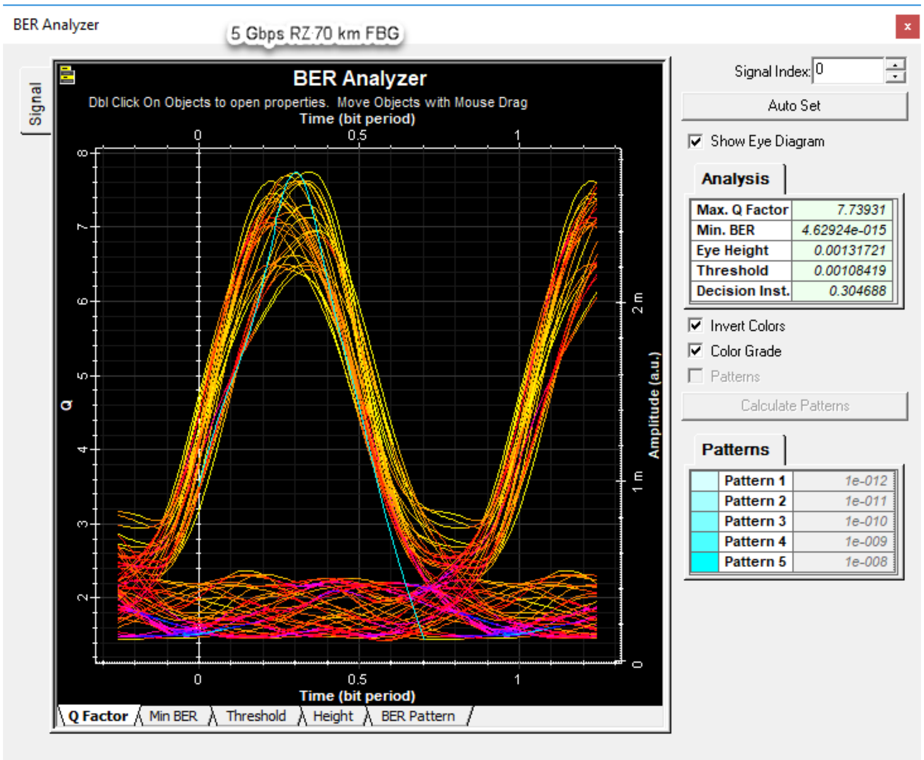
55. 5 Gbps RZ 50 km FBG



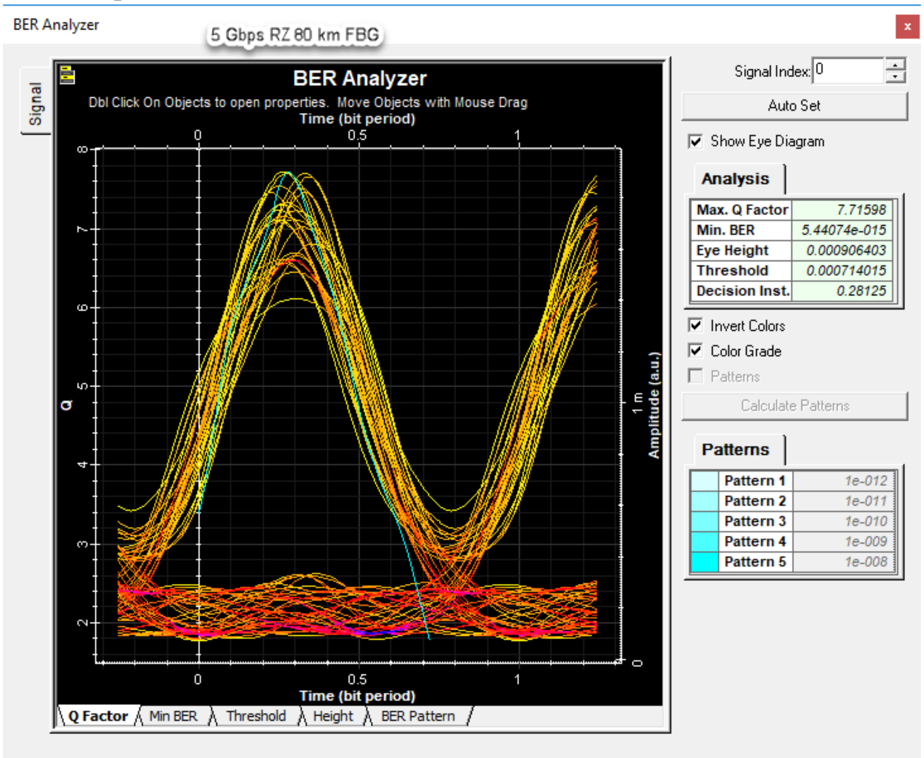
56. 5 Gbps RZ 60 km FBG



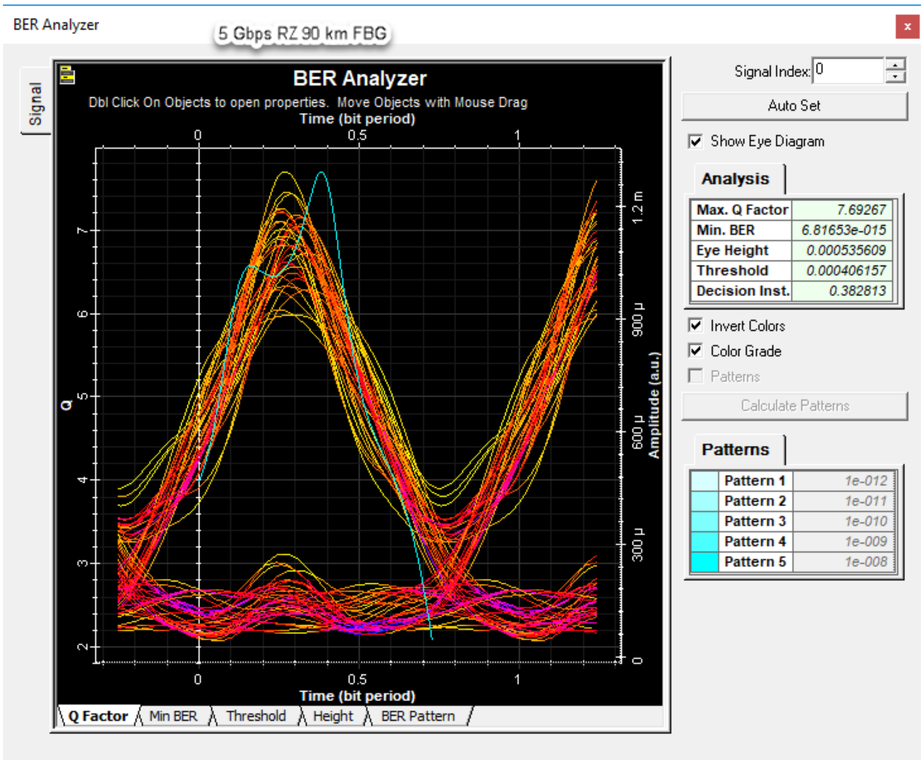
57. 5 Gbps RZ 70 km FBG



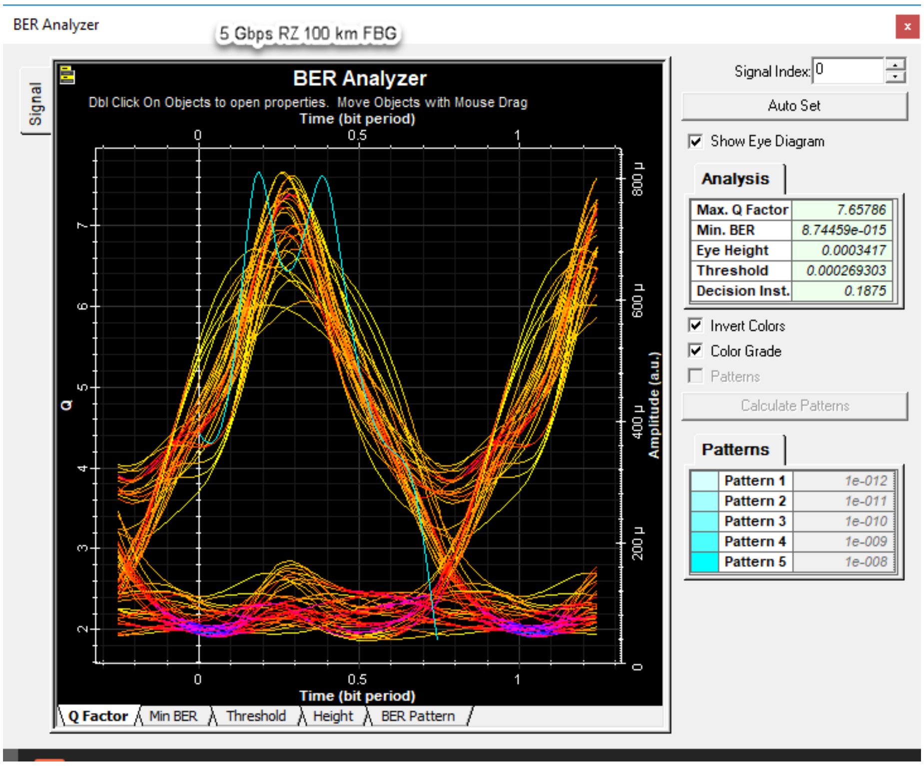
58. 5 Gbps RZ 80 km FBG



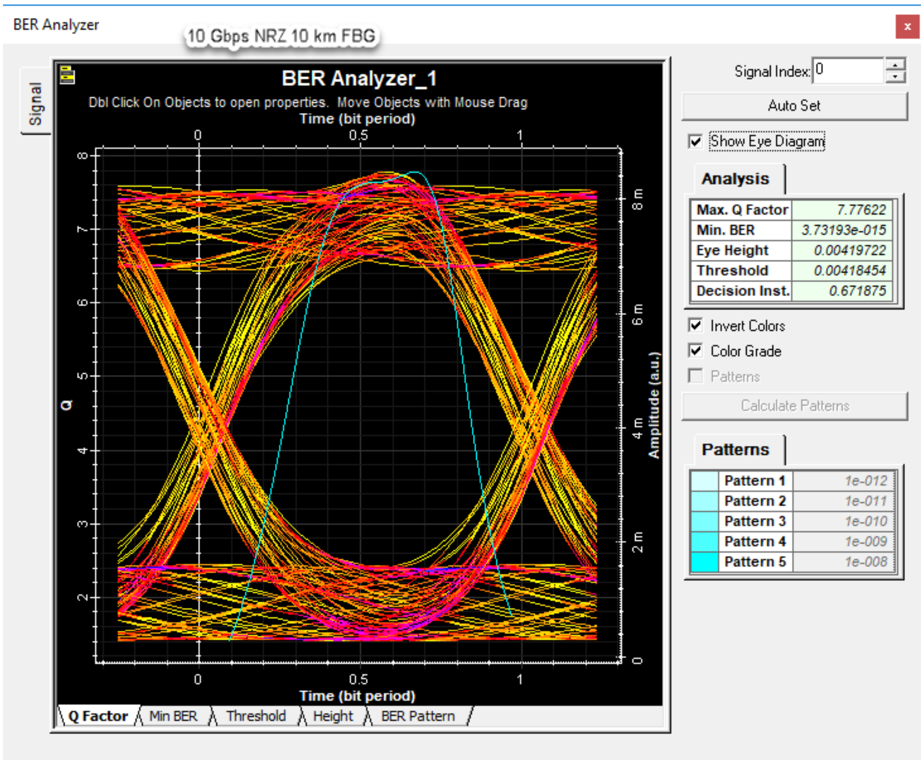
59. 5 Gbps RZ 90 km FBG



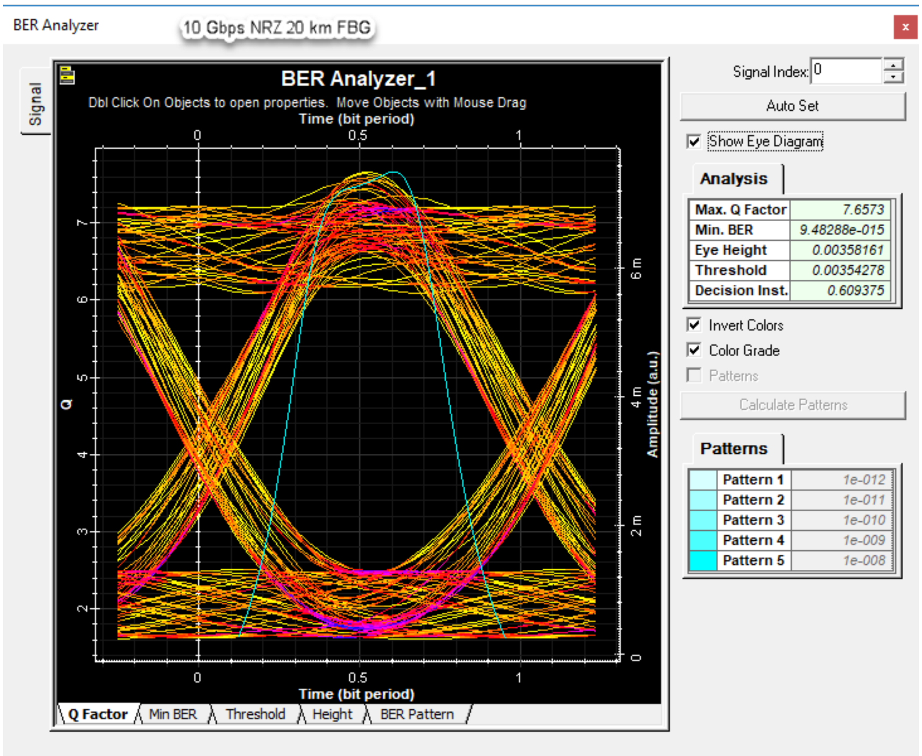
60. 5 Gbps RZ 100 km FBG



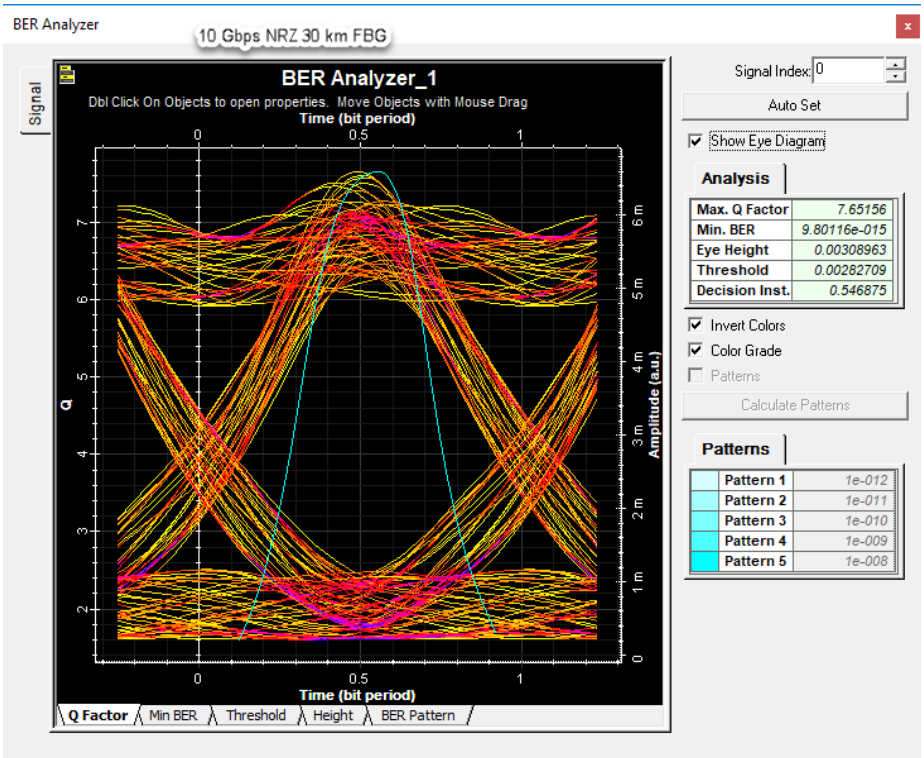
61. 10 Gbps NRZ 10 km FBG



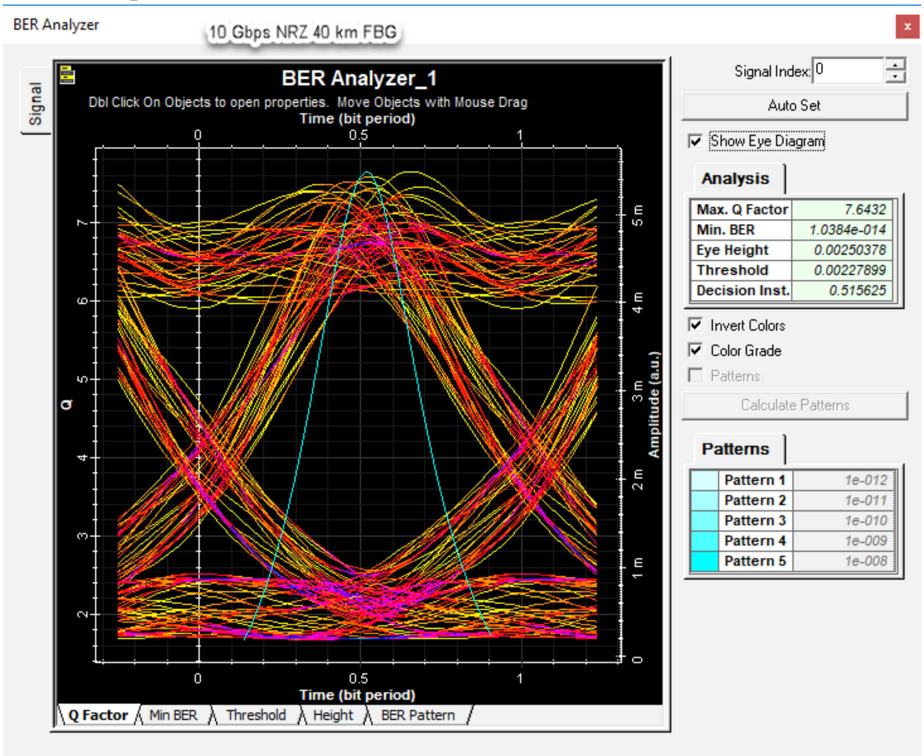
62. 10 Gbps NRZ 20 km FBG



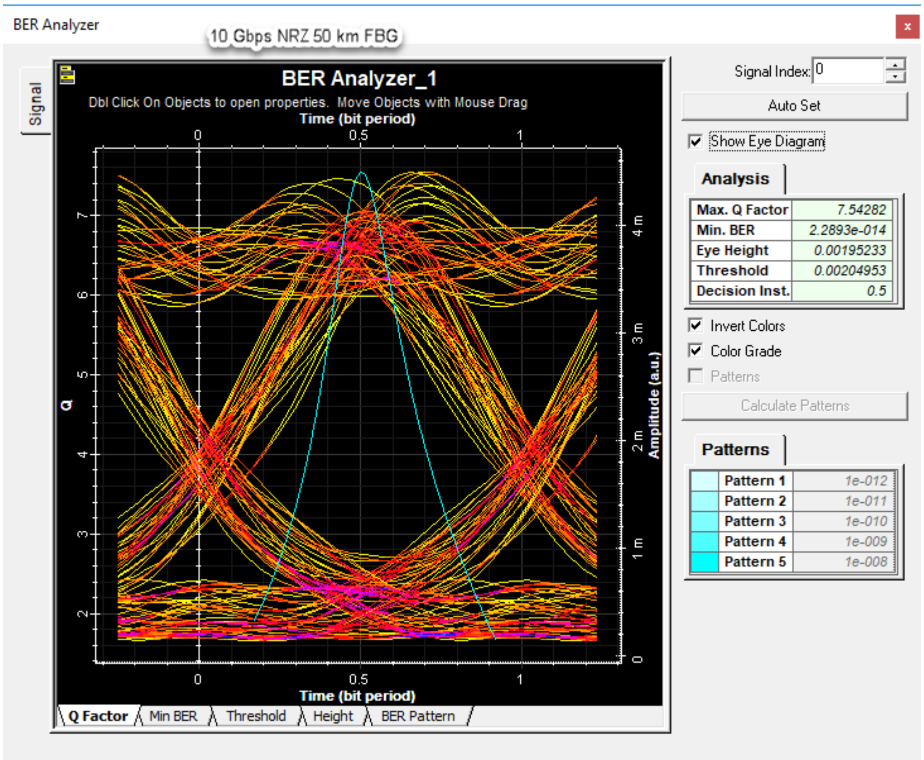
63. 10 Gbps NRZ 30 km FBG



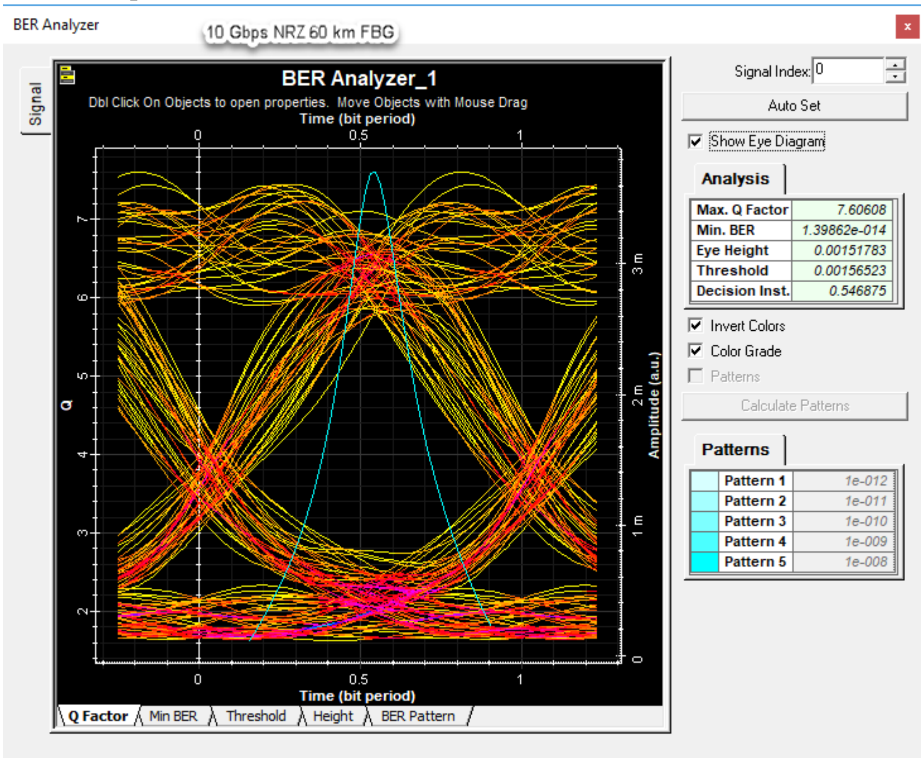
64. 10 Gbps NRZ 40 km FBG



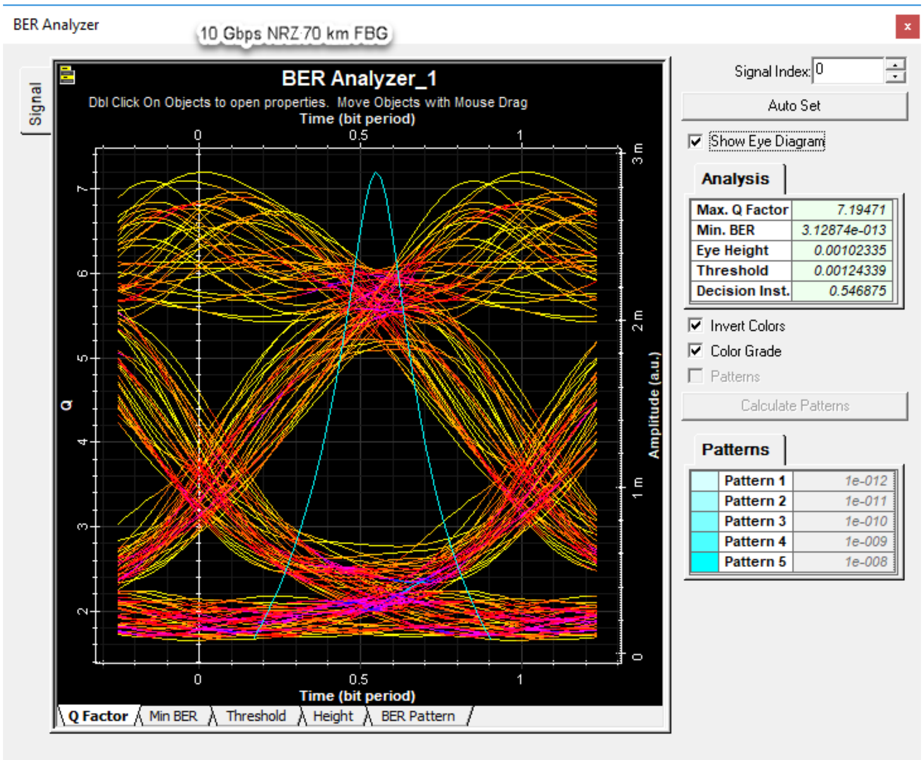
65. 10 Gbps NRZ 50 km FBG



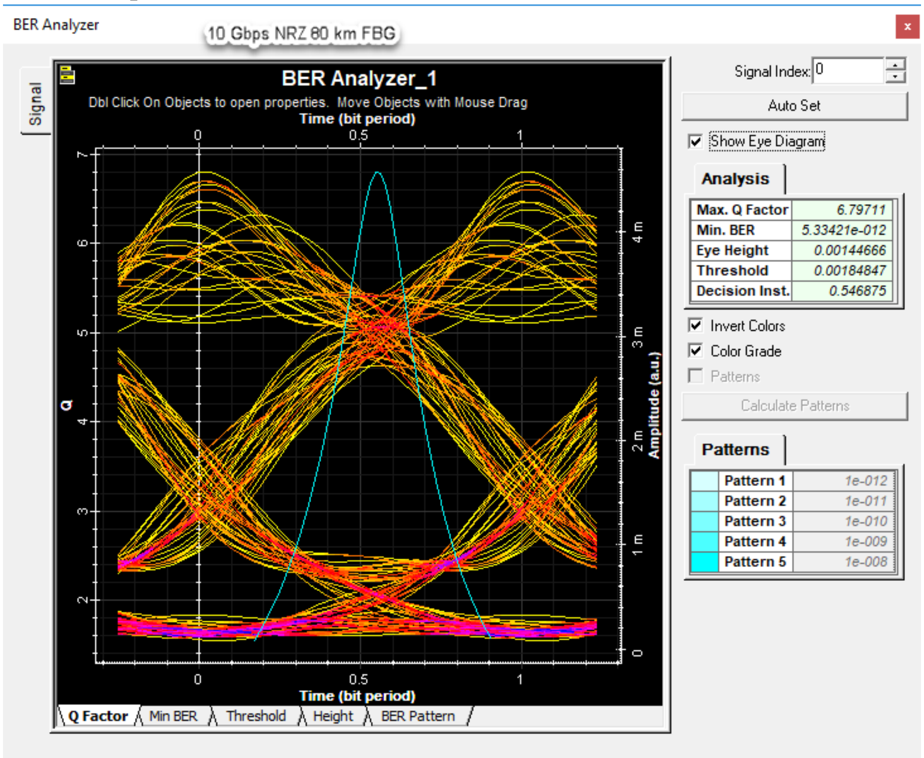
66. 10 Gbps NRZ 60 km FBG



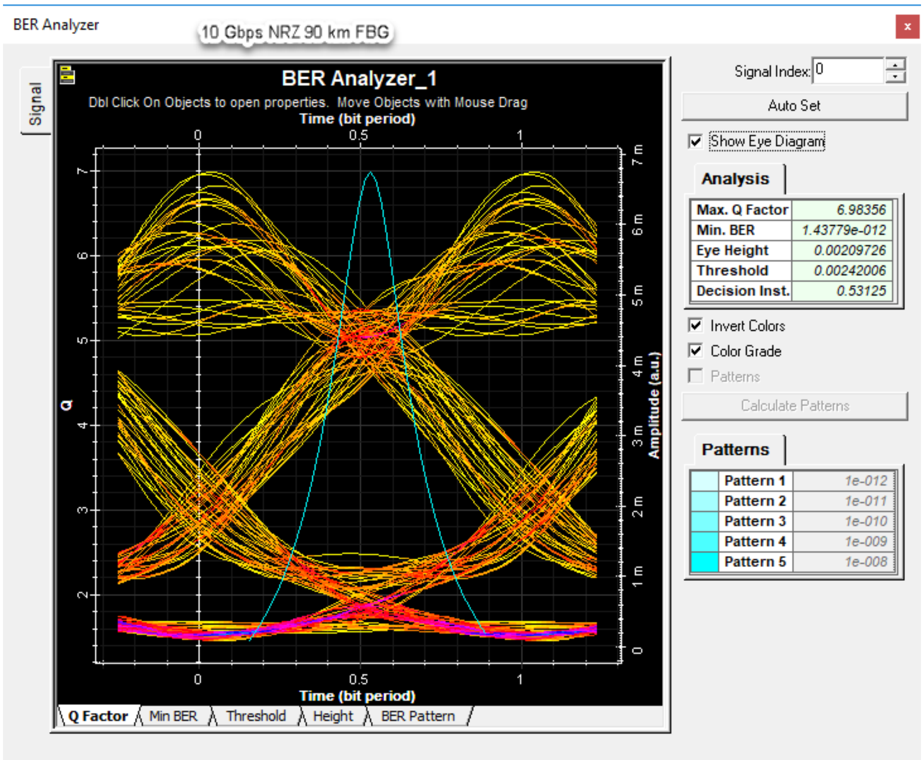
67. 10 Gbps NRZ 70 km FBG



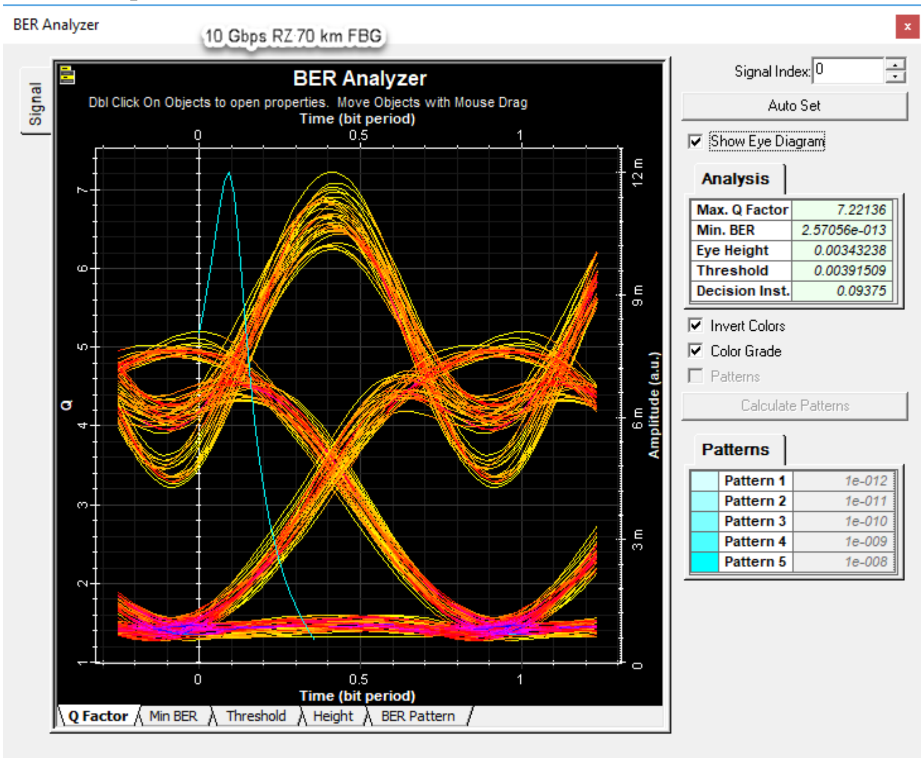
68. 10 Gbps NRZ 80 km FBG



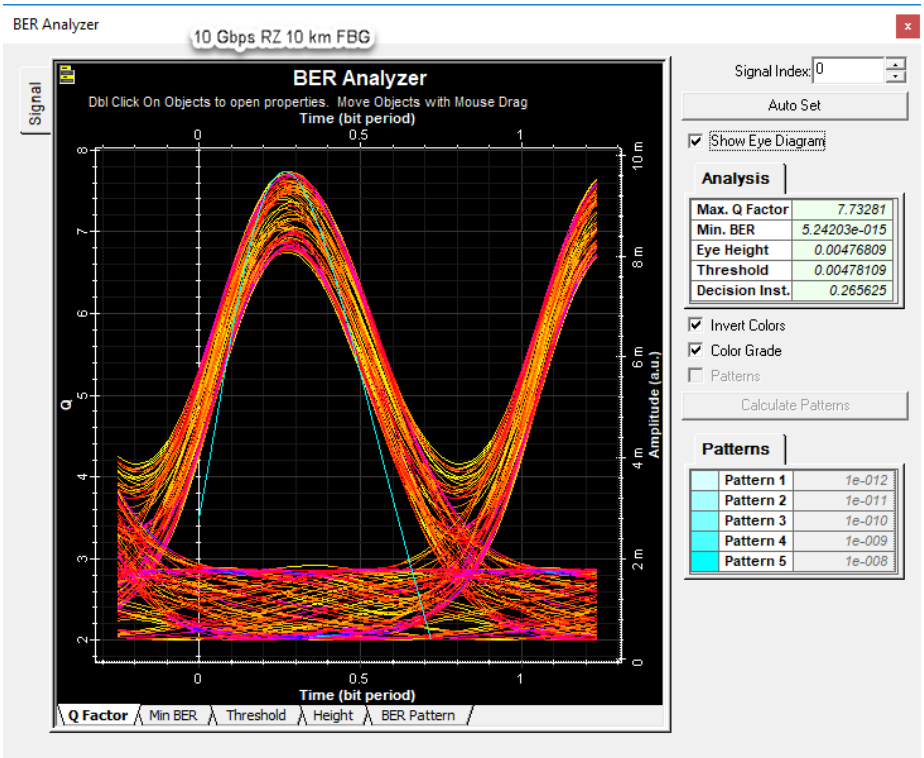
69. 10 Gbps NRZ 90 km FBG



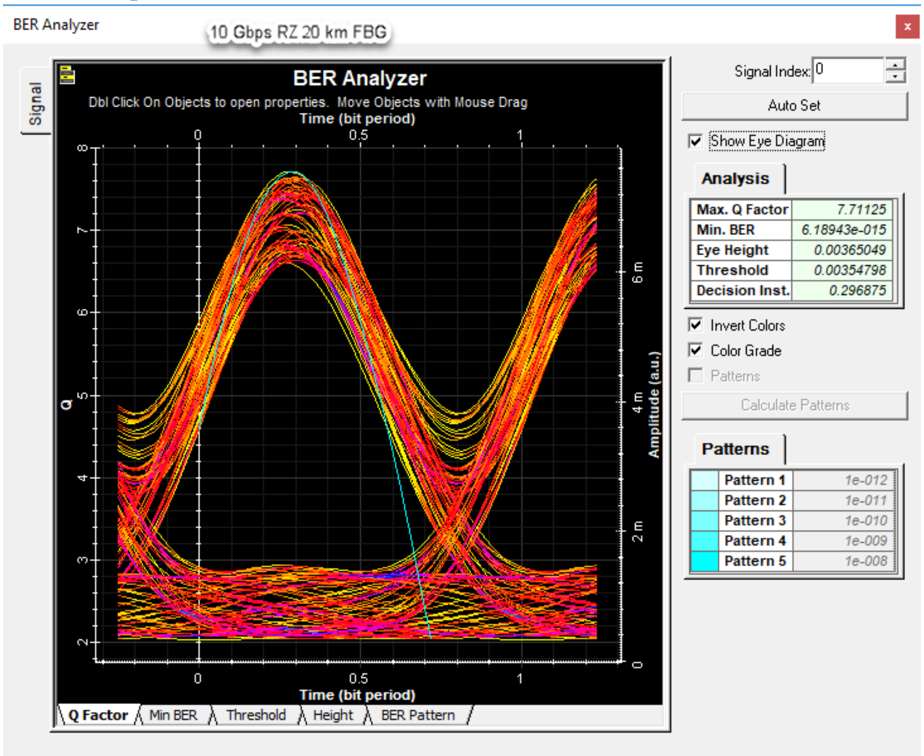
70. 10 Gbps NRZ 100 km FBG



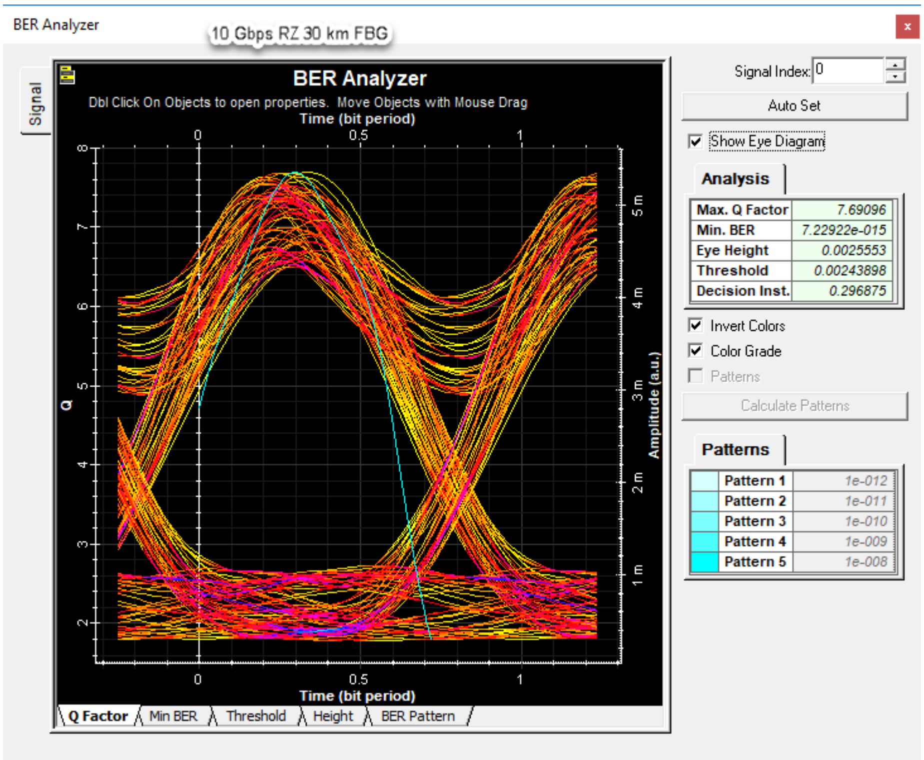
71. 10 Gbps RZ 10 km FBG



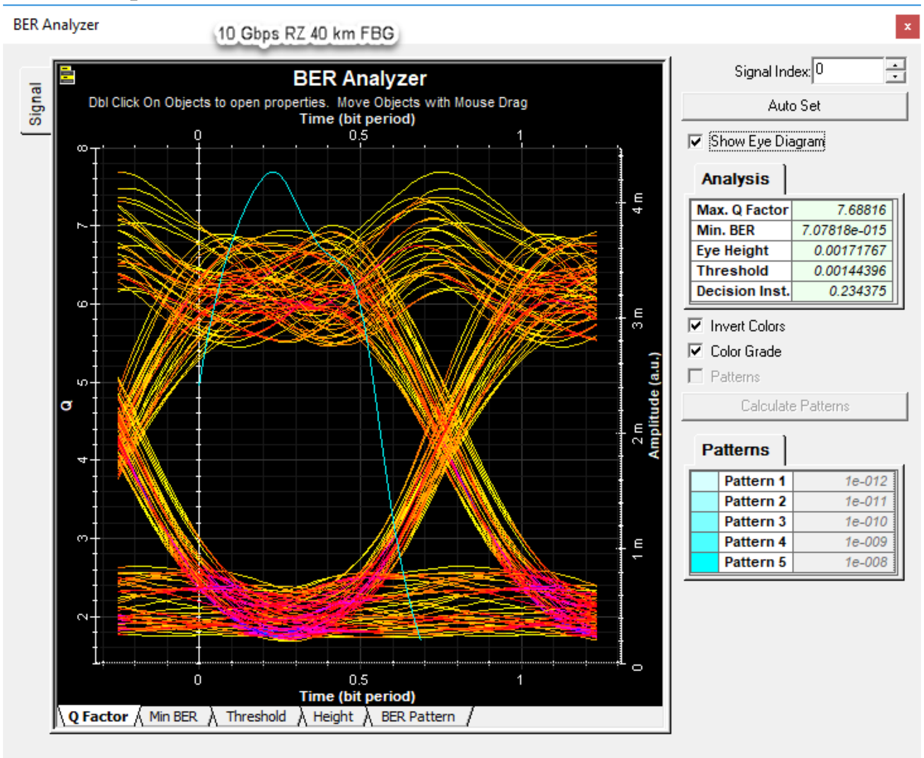
72. 10 Gbps RZ 20 km FBG



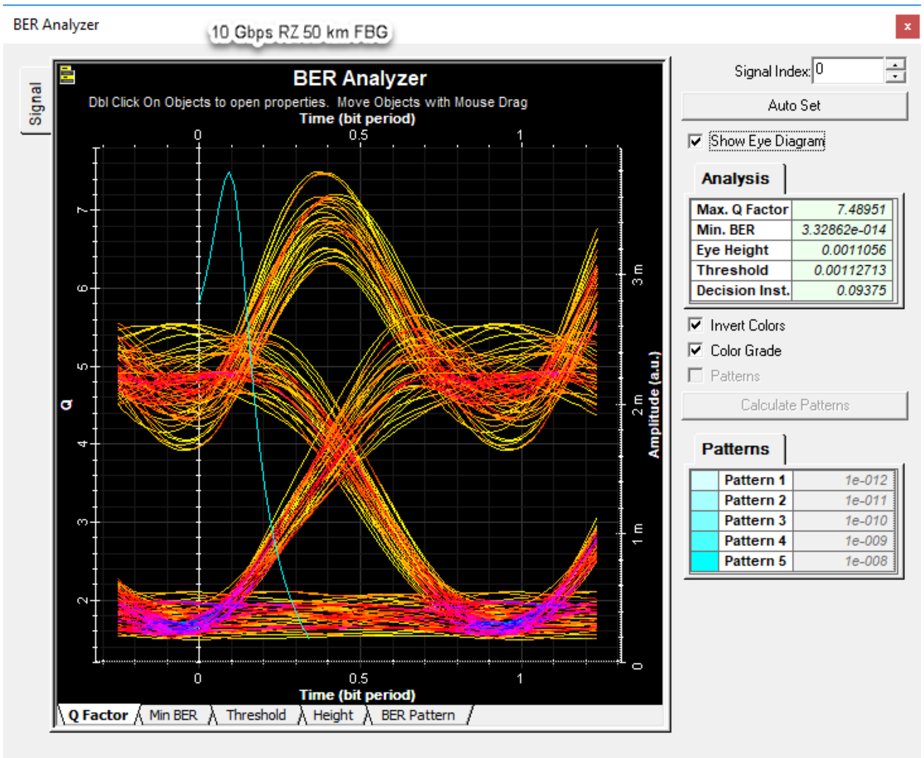
73. 10 Gbps RZ 30 km FBG



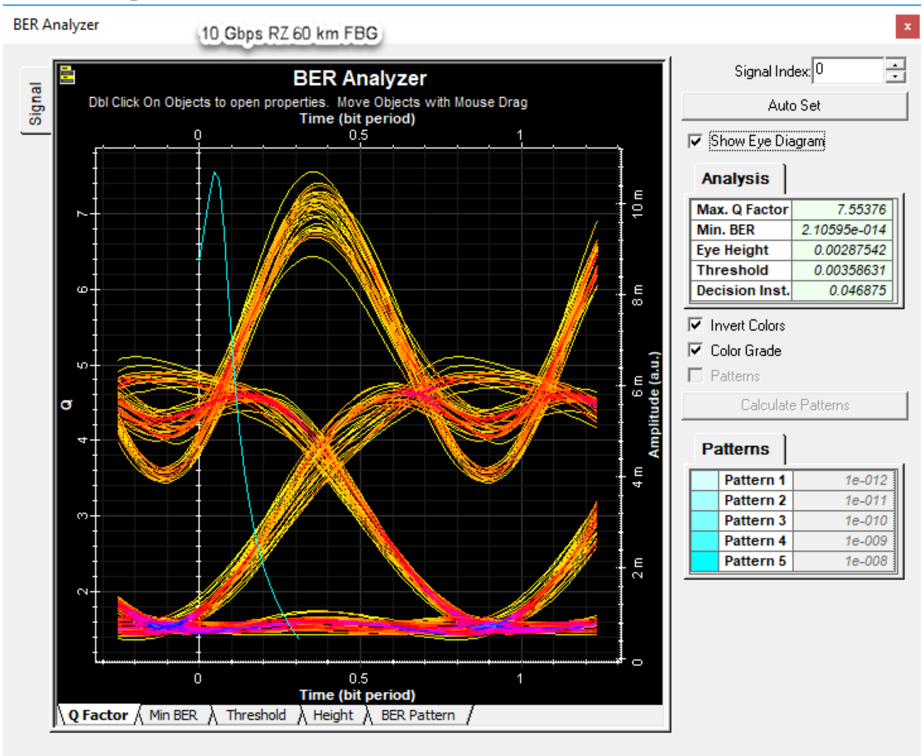
74. 10 Gbps RZ 40 km FBG



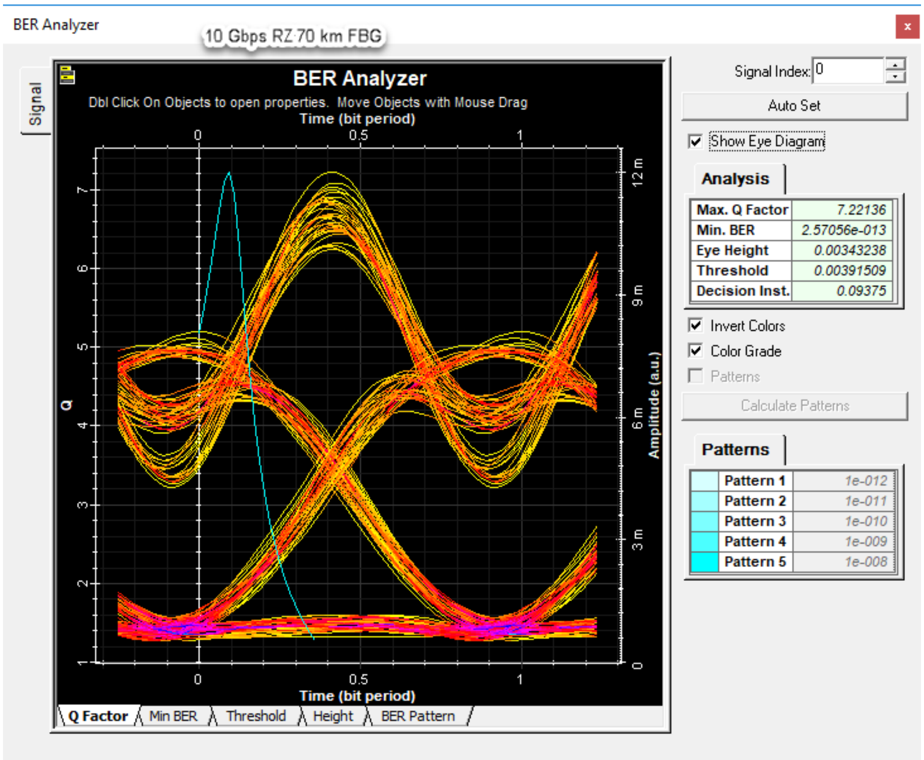
75. 10 Gbps RZ 50 km FBG



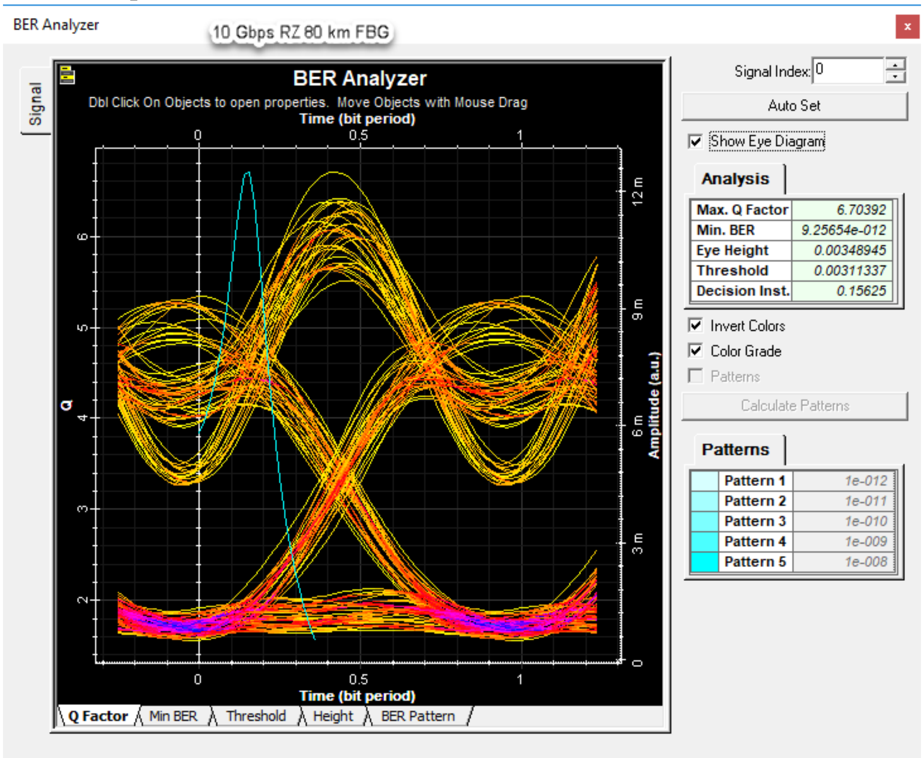
76. 10 Gbps RZ 60 km FBG



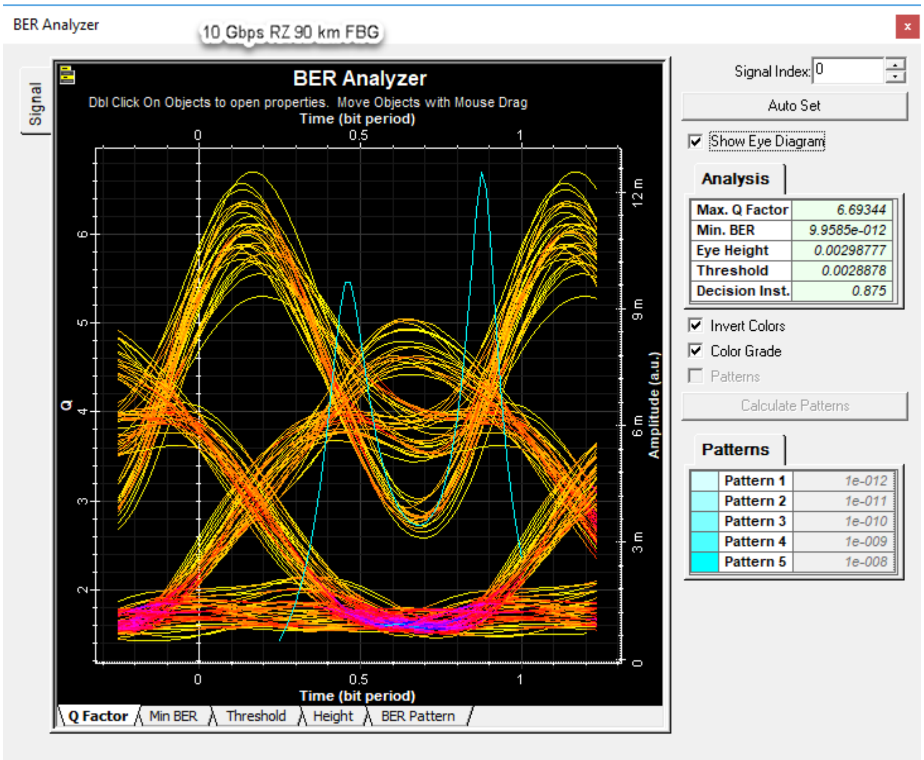
77. 10 Gbps RZ 70 km FBG



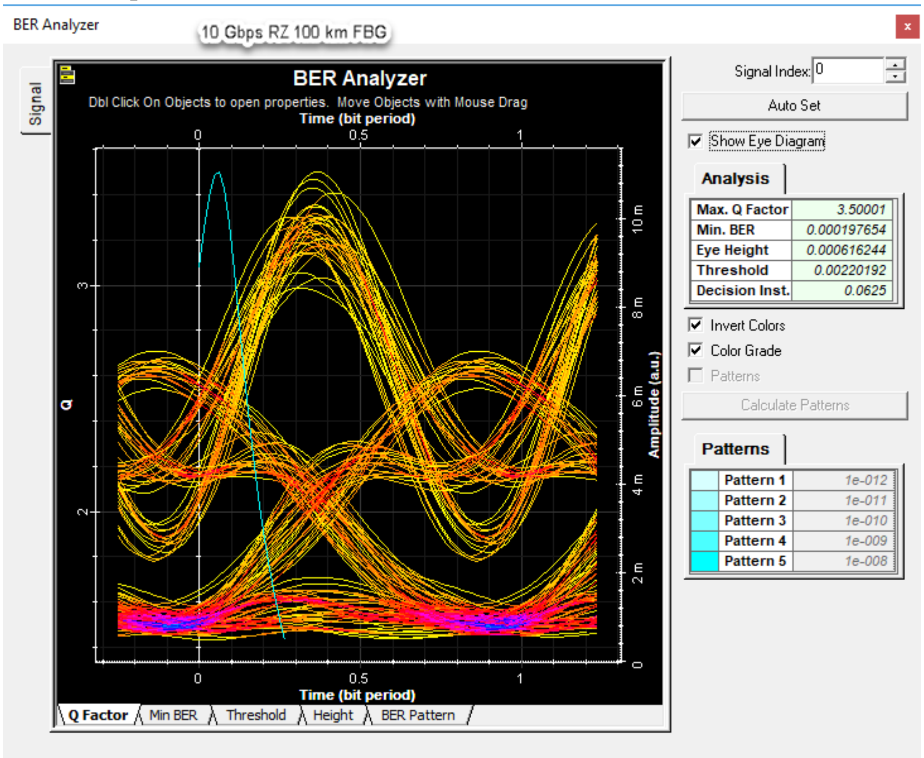
78. 10 Gbps RZ 80 km FBG



79. 10 Gbps RZ 90 km FBG



80. 10 Gbps RZ 100 km FBG



Lampiran 2 *DataSheet*

1. *bit rate*

SONET/SDH Signal Hierarchy

Synchronous Transport Signal Level n = STS-n = $n \times 51.84$ Mbps
STM=Synchronous Transport Module, OC=Opical Carrier level

ANSI Designation	Optical Signal	CCITT Designation	Data Rate (Mbps)	Payload Rate (Mbps)
STS-1	OC-1		51.84	50.112
STS-3	OC-3	STM-1	155.52	150.336
STS-9	OC-9	STM-3	466.56	451.008
STS-12	OC-12	STM-4	622.08	601.344
STS-18	OC-18	STM-6	933.12	902.016
STS-24	OC-24	STM-8	1244.16	1202.688
STS-36	OC-36	STM-12	1866.24	1804.032
STS-48	OC-48	STM-16	2488.32	2405.376
STS-96	OC-96	STM-32	4976.64	4810.176
STS-192	OC-192	STM-64	9953.28	9620.928

The Ohio State University — Raj Jain

2. Wavelength

Figure 8-17 *Wavelength-division multiplexing*

Table 8-3 ITU GRID

Center Wavelength – nm (vacuum)	Optical Frequency (THz)
1530.33	195.9
1531.12	195.8
1531.90	195.7
1532.68	195.6
1533.47	195.5
1534.25	195.4
1535.04	195.3
1535.82	195.2
1536.61	195.1
1537.40	195.0
1538.19	194.9
1538.98	194.8
1539.77	194.7
1540.56	194.6
1541.35	194.5
1542.14	194.4
1542.94	194.3
1543.73	194.2
1544.53	194.1
1545.32	194.0
1546.12	193.9
1546.92	193.8
1547.72	193.7
1548.51	193.6
1549.32	193.5
1550.12	193.4
1550.92	193.3
1551.72	193.2
1552.52	193.1
1553.33	193.0
1554.13	192.9
1554.93	192.8
1555.75	192.7
1556.55	192.6
1557.36	192.5
1588.17	192.4
1558.98	192.3
1559.79	192.2
1560.61	192.1
1561.42	192.0
1562.23	191.9
1563.05	191.8
1563.86	191.7

3. Photodetector APD

FIBER OPTIC TELECOMMUNICATION

The most commonly used photodetectors are the PIN and avalanche photodiodes (APD). The material composition of the device determines the wavelength sensitivity. In general, silicon devices are used for detection in the visible portion of the spectrum; InGaAs crystal are used in the near-infrared portion of the spectrum between 1000 nm and 1700 nm, and germanium PIN and APDs are used between 800 nm and 1500 nm. Table 8-5 gives some typical photodetector characteristics:

Table 8-5 Typical Photodetector Characteristics

Photodetector	Wavelength (nm)	Responsivity (A/W)	Dark Current (nA)	Rise Time (ns)
Silicon PN	550–850	0.4–0.7	1–5	5–10
Silicon PIN	850–950	0.6–0.8	10	0.070
InGaAs PIN	1310–1550	0.85	0.5–1.0	0.005–5
InGaAs APD	1310–1550	0.80	30	0.100
Germanium	1000–1500	0.70	1000	12

Some of the more important detector parameters listed below are defined and described in Module 1-6, *Optical Detectors and Human Vision.*

Responsivity—the ratio of the electrical power to the detector's output optical power

Quantum efficiency—the ratio of the number of electrons generated by the detector to the number of photons incident on the detector

Quantum efficiency = (Number of electrons)/Photon

Dark current—the amount of current generated by the detector with no light applied. Dark current increases about 10% for each temperature increase of 1°C and is much more prominent in Ge and InGaAs at longer wavelengths than in silicon at shorter wavelengths.

Noise floor—minimum detectable power that a detector can handle. The noise floor is related to the dark current since the dark current will set the lower limit.

Noise floor = Noise (A)/Responsivity (A/W)

Response time—the time required for the detector to respond to an optical input. The response time is related to the bandwidth of the detector by

$$BW = 0.35/t_r$$

where t_r is the rise time of the device. The rise time is the time required for the detector to rise to a value equal to 63.2% of its final steady-state reading.

Noise equivalent power (NEP)—at a given modulation frequency, wavelength, and noise bandwidth, the incident radiant power that produces a signal-to-noise ratio of *one* at the output of the detector (Source: Electronic Industry Association—EIA)

4. RF *Frequency*

Frequency bands

The radio spectrum of frequencies is divided into bands with conventional names designated by the International Telecommunications Union (ITU):

Frequency	Wavelength	Designation	Abbreviation[6]	IEEE bands[7]
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF	-
30–300 Hz	10^4–10^3 km	Super low frequency	SLF	-
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF	-
3–30 kHz	100–10 km	Very low frequency	VLF	-
30–300 kHz	10–1 km	Low frequency	LF	-
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF	-
3–30 MHz	100–10 m	High frequency	HF	HF
30–300 MHz	10–1 m	Very high frequency	VHF	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF	UHF, L, S
3–30 GHz	10–1 cm	Super high frequency	SHF	S, C, X, Ku, K, Ka
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF	Ka, V, W, mm
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF	-

Frequencies of 1 GHz and above are conventionally called microwave,[8] while frequencies of 300 GHz and above are designated millimeter wave. More detailed band designations are given by the standard IEEE letter- band frequency designations[7] and the EU/NATO frequency designations.[9]

5. Power Laser

Performance Specifications: Typical Product Configurations (more options available)

PD-LD Part No.[1]	Wavelength (nm) Min. Typ. Max.	Min. Fiber Coupled Power (mW)	Threshold Current (mA) Typ. Max.	Operating Current (mA) Typ. Max.	Monitor PD Current (mA) Min. Typ.
Continuous Wavelength InGaAsP Lasers @ 25C					
PL13U001100B-R-I-01	1290 **1310** 1330	1 mW	6 20	18 40	InGaAs 0.1 0.8
PL13N0.51FAA-0-I-01	1290 **1310** 1330	0.5mW FC/APC	6 20	18 40	InGaAs 0.1 0.8
PL13U0011SAA-0-I-01	1295 **1310** 1325	1 mW SC/APC	6 20	18 40	InGaAs 0.1 0.8
PL15M0011FAA-0-I-01	1530 **1550** 1570	1mW FC/APC	10 30	30 60	InGaAs 0.1 -
PL15N0.51FAC-R-I-01	1530 **1550** 1570	0.5 mW FC/APC	10 30	30 60	InGaAs 0.1 0.8

Parameter	Condition	Min	Typ	Max	Unit
Optical Isolation	Temp.= +25°C	30	45	—	dB
	Temp.=-40~+85°C	20	—	—	

6. 5G *Frequency*

5G expected to use a wide range of frequency bands

The ability to use a range of frequency bands and access technologies to deliver the particular requirements of a specific use case or service, will be a key characteristic of 5G networks.[60] This is likely to require the use of frequency bands other than those currently dedicated to mobile broadband use, and the flexible use of unlicensed spectrum or sharing of underutilised spectrum to provide extra capacity when required.

5G networks are expected to require a wide range of frequencies both below and above 6 GHz, although the exact frequencies are yet to be identified. A number of industry groups, academics and governments around the world have begun to explore the possibility of using higher frequencies for mobile broadband communications.

The ACMA and Australian industry representatives recently attended the International Telecommunication Union (ITU) Radiocommunication Sector 2015 World Radiocommunication Conference (WRC–15). The WRC–15 made a number of decisions that will influence how the issue of additional spectrum for mobile broadband will be considered around the world, and in Australia.

[58] ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015, pages 33–34.
[59] ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015 and ACMA, *Five-year spectrum outlook 2015–19:* The ACMA's spectrum demand analysis and strategic direction for the next five years, August 2015, page 38.
[60] Huawei, 5G: A Technology Vision, January 2014, page 6.

Under WRC–15 Agenda item 1.1 additional spectrum allocations for mobile services on a primary basis and additional identifications for International Mobile Telecommunications (IMT) were made in a number of bands. The main outcome of this agenda item was the significant international harmonisation of the frequency ranges 1 427–1 518 MHz and 3 400– 3 600 MHz for IMT.