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PERFORMANCE ENHANCEMENT OF DUAL POLARIZATION COHERENT OPTICAL SYSTEMS WITH AND WITHOUT INLINE DISPERSION COMPENSATION

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ABSTRACT

We study and compare the performance of 112Gb/s Dual polarization coherent optical system for single channel coherent system with different modulation techniques,DP- QPSK(Dual Polarization Quadrature phase shift keying), DP-16QAM(Dual Polarization 16 qadrature amplitude Modulation) using numerical simulations with inline DCF(dispersion compensation fiber) and without inline DCF(but with DSP module for dispersion compensation)using SSMF(standard single mode fiber) for the effect of fiber nonlinearities. Inline dispersion post compensation system was explored to mitigate the impact of transmission impairments. Results obtained shows that the performance of DP-QPSK coherent systems with inline dispersion post compensation is better than the electronic dispersion compensation using DSP module as with DCF they have more tolerance to fiber nonlinearities than those with electronic dispersion compensation but for DP-16QAM coherent system the performance with electronic dispersion compensation is better than with inline dispersion compensation.

KEYWORDS: QPSK, 16QAM, SSMF, coherent system, inline dispersion compensation.

INTRODUCTION

Due to the limitations of transmission bandwidth and continuous growth of network traffic there is a requirement of employing high spectral efficient (SE) transmission systems which reduces the cost per bit as well as increase the total transmission capacity[11],[14] Coherent systems with multilevel modulation formats have the ability to increase the spectral efficiency and decrease the transmission impairments as all the parameters of optical field are accessible after coherent detection[1]. The use of coherent detection has enabled the total electrical field recovery and allows the use of high-precision analog-to-digital converters (ADCs) for signal acquisition and digital signal processing (DSP) for digital coherency. They also have the ability for polarization demultiplexing of dual polarization signals in the electrical domain by high-speed DSP[4] . Initially dispersion compensating fibre was only used to compensate the chromatic dispersion but now compensation is possible in the electronic domain, along with Polarization Mode Dispersion (PMD), which degrade the performance of high speed optical systems systems [2],[3]. With powerful DSP, coherent receivers have the ability to entirely compensate chromatic dispersion in the electrical domain, thus completely eliminating optical dispersion compensation modules (DCMs) in the systems.[6] Multilevel modulation formats such as DP-QPSK and DP-16QAM combined with polarization multiplexing lowers the baud rate of the system and decreases the occupied optical bandwidth.[9] [10] So in optical networks ,the increasing demand of network traffic has been pushing the development of spectrally-efficient coherent systems using multilevel modulation formats with polarization multiplexing.[15] Dual-polarization quadrature phase-shift keying(DP-QPSK) is a phase-modulation system that transmits 2-bit signals which are represented by four phases on two orthogonally polarized light beams respectively. The symbol rate is reduced to one quarter of the system bit rate which allows the use of optical and electrical components with reduced operating bandwidth and increased system immunity to intersymbol interference.[16] Dual-polarization quadrature phase-shift-keying (DP-QPSK) modulation format improved the SE to 2-b/s/Hz [12],[13]. Dual Polarization 16Quadrature amplitude modulation (DP-16QAM) is another modulation format which is extensively used with coherent systems.[5] [7] [8]The polarization multiplexing together with amplitude and phase modulation improves the SE from 2-b/s/Hz (DP-

QPSK) to 4-b/s/Hz (DP-16QAM).The use of dispersion compensating fibers (DCF) has emerged as one of the most practical techniques to compensate for the chromatic dispersion in long-haul optically amplified standard fiber transmission systems.

SYSTEM MODEL

Simulation setup

For simulaton, the optiwave 13.0 simulator has been used . The system model for simulation with and without inline dispersion is shown in the figure1and figure 2 respectively. The simulation of dual polarization coherent systems (DP- QPSK and DP-16QAM) is performed at 112Gb/s. The simulation setup of these systems consists of the transmitter, transmission link , coherent optical receiver, DSP(Digital signal Processing) unit, detection and decoding unit. The transmission link consists of SMF of length 80Km, attenuation 0.2 dB/Km ,dispersion co-efficient 16 ps/nm-km and EDFA amplifier of gain 16dB with noise figure 4dB is used to compensate the effect of attenuation through the fiber. DP-QPSK and DP-16QAM transmitters are used to generate the signal . The transmitter consists of CW (Continuous Wave) laser whose signal is split into two components X and Y components by polarization beam splitter .Each component is passed through MZM(Mach Zehnder Modulator) to generate QPSK signal or 16QAM signal. The signal then passes through the transmission link where it is distorted due to dispersion and nonlinear effects. At the receiver side, the signal is received by the coherent receivers(DP-QPSK and DP-16QAM receivers) . PBS(Polarization Beam splitter) split the received signal .After PBS each polarization of the signal is combined with a LO(local oscillator) in a 90° hybrid. The four signals after the hybrids are detected by four balanced detectors. After coherent reception ,the signals are passed into DSP for processing where the signal is first converted into digital domain.The transversal filter is used to compensate the effect of dispersion. The phase and frequency mismatch between the transmitter and Local Oscillator is compensated by viterbi and viterbi phase estimation algorithm. After DSP unit the signal passes through the Decision circuit and Bit error rate test set to calculate the BER which shows the effect of nonlinearities .In the simulations, the signal of 1024 symbols first propagates in the transmission line. The bit sequence length is sufficient to catch the nonlinear interaction for the system studied here. Table 1 shows the parameters of SMF and DCF.

Table1.Fiber parameters

FIBER	WAVELENGTH (nm)	DISPERSION (ps/nm/km)	DISPERSION SLOPE (ps/nm-km)	ATTENUATION (dB/km)	EFFECTIVE CORE AREA (μm^2)	NONLINEAR REFRACTIVE INDEX (m^2/W)
SMF	1550	16	0.075	0.2	80	26e-21
DCF	1550	-80	0.075	0.5	22	26e-21

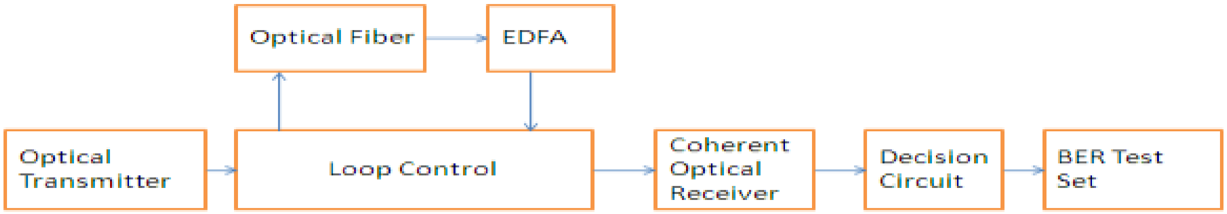


Figure 1 Block diagram of Coherent optical system without DCF

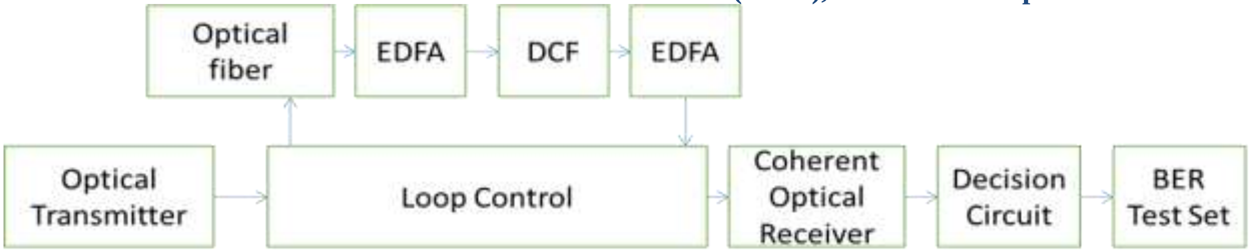
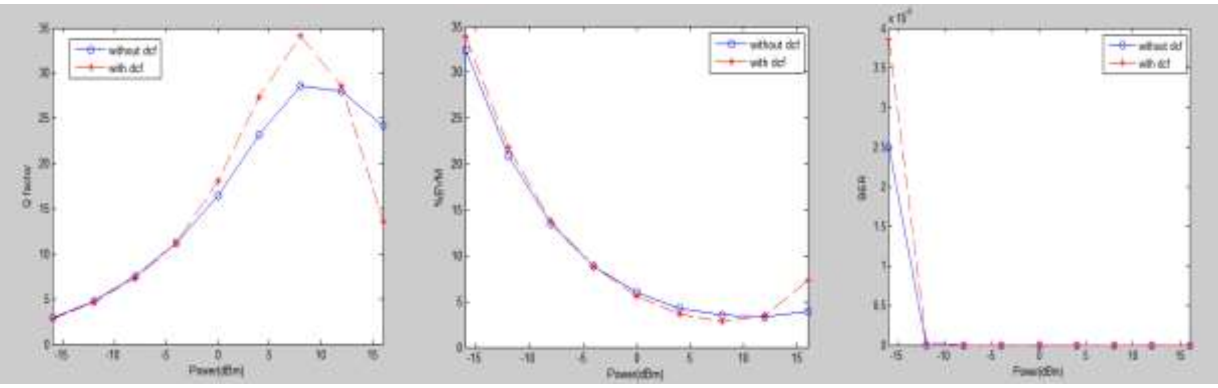


Figure2 Block diagram of coherent system with DCF

RESULTS AND DISCUSSIONS

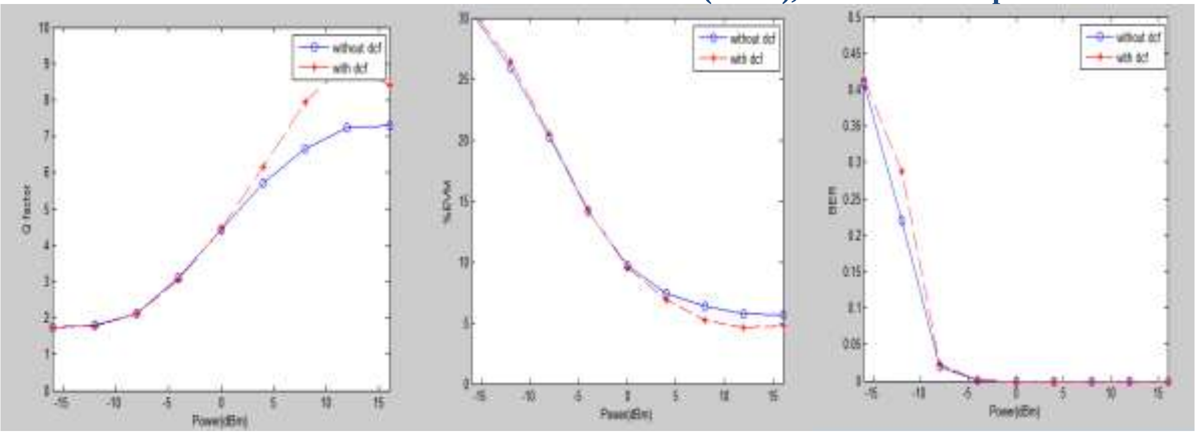
Effect of Input Power

In this paper 112Gb/s DP-QPSK and DP-16QAM single channel coherent systems are analyzed using DSP with and without inline dispersion compensation fiber. The symbol rate for DP-QPSK is 28GB/s and for DP-16QAM is 14Gb/s. The transmission performance of the 112Gb/s RZ-DP-QPSK is given in Fig. 2, which shows the effect of input laser power on BER, %EVM and Q factor after 80 km transmission for the system with and without DCF. The input laser power is varied from -16dbm to 16dBm and output Q factor ,%EVM and BER is calculated according to it. Figure2&3 shows the effect of CW laser power on Q factor ,%EVM and BER on DP-QPSK and DP-16QAM systems with and without inline DCF at a transmission distance of 80km and data rate 112Gb/s. Figure 2 shows that when CW laser power is varied, initially the Q factor increases and reaches at a maximum value and then starts decreasing. The highest value of Q factor in DP-QPSK is obtained at a power of 8dBm with the use of DCF. At the highest value of Q factor the %EVM is also minimum and BER is 0 with the use of DCF. In DP-QPSK ,Q factor is more with DCF as compared without DCF. . BER of DP-QPSK system with DCF is less as compared to with DCF but %EVM is less with DCF from CW laser power from -16dBm to -4 dBm and more with CW laser power 0 to 16dBm.Figure3 shows when CW laser power is varied, initially the Q factor increases and reaches at a maximum value and then starts decreasing. The highest value of Q factor in DP-16QAM is obtained at a power of 12dBm withut the use of DCF. At the highest value of Q factor the %EVM is also minimum and BER is 0 without the use of DCF. BER of DP-16QAM system without DCF is less as compared to with DCF but %EVM is less without DCF from CW laser power from -16dBm to -4 dBm and more from CW laser power 0 to 16dBm.It is clear that using RZ-DP-QPSK, the system with DCF is more tolerant to fiber nonlinearities than that without DCF. When RZ-DP-QPSK is used, the nonlinear tolerance of the system with DCF is significantly increased.



(a) (b) (c)

Figure 2 Variation of (a)Q factor (b) %EVM (c) BER with CW laser power for DP-QPSK system

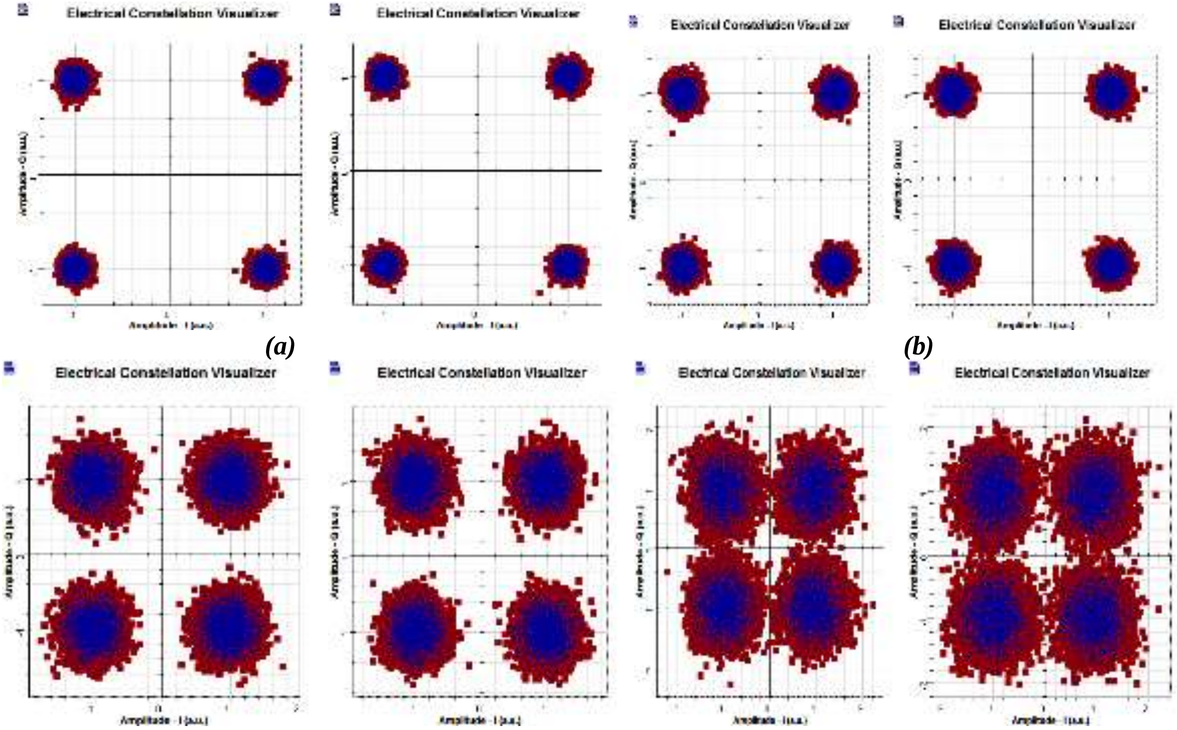


(a) (b) (c)

Figure 3: Variation of (a)Q factor (b) %EVM (c) BER with CW laser power for DP-16QAM system

Effect of distance

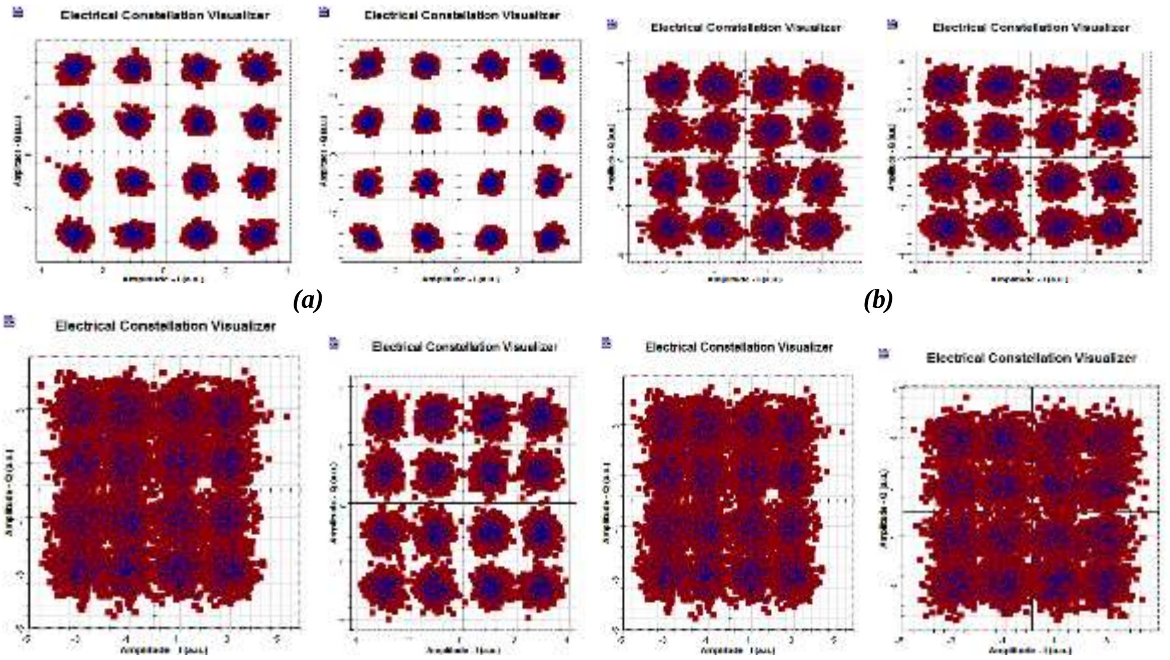
The performance of 112Gb/s coherent optical system is analyzed with and without DCF by varying the length of fiber span. The received signal is assessed for the performance by the Signal Constellation Diagrams , %EVM and BER at the receiver for different fiber spans varying from 40km to 160km. Fig. 4&5 shows the Constellation diagram of DP-QPSK and DP-16QAM after DSP module at the receiver end with DCF and without DCF. The received constellation diagram shows that as the fiber length increases the constellation points gets distorted because the dispersion of optical signal starts dominating, which in turn reduces the overall data rate/channel capacity. In DP-QPSK there is less distortion in constellation points with DCF at different fiber spans than without DCF but in DP-16QAM the distortion is less without DCF than with DCF



(a) *(b)*

(c) *(d)*

Fig4 Constellation diagram of DP-QPSK at link length (a) 60km (b)800km (c) 120km (d) 140km with dcf and without dcf



(a) *(b)*

(c) *(d)*

Fig5 Constellation diagram of DP-16QAM at link length (a) 40km (b)60km (c) 80km (d) 100km with dcf and without dcf

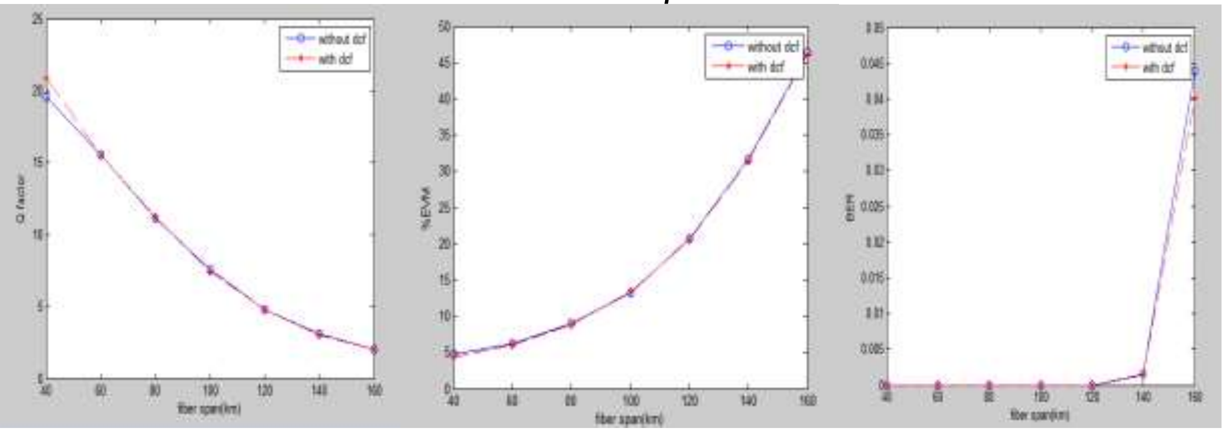


Figure6 Variation of (a)Q factor (b) %EVM (c) BER with length of fiber span for DP-QPSK system

Figure6 shows when length of fiber span is varied, initially the Q factor is maximum, then it decreases with the increase of fiber span length due to the dispersion in the fiber. The highest value of Q factor in DP-QPSK is obtained at a distance of 40km with the use of DCF. At the highest value of Q factor the %EVM is also minimum and BER is 0 with the use of DCF.

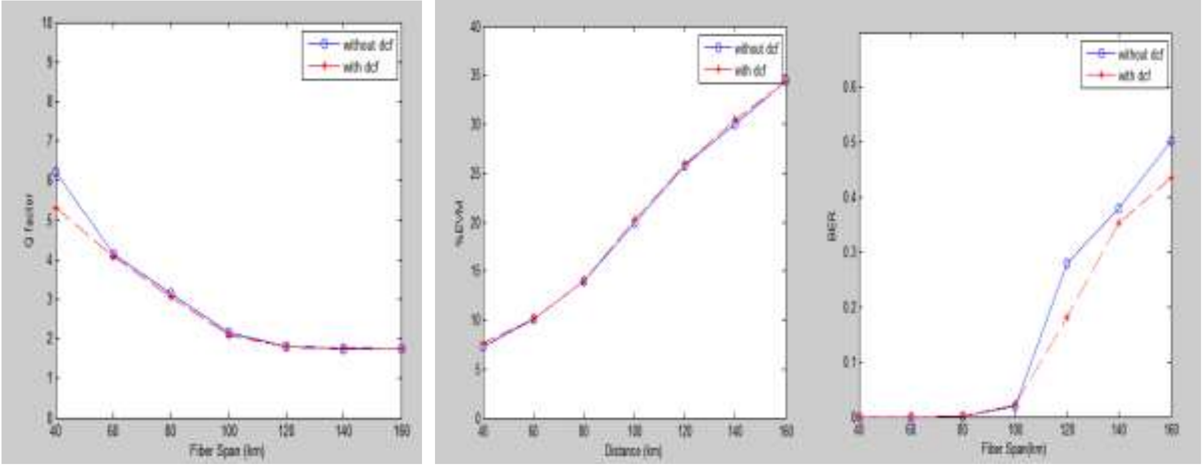


Figure8 Variation of (a)Q factor (b) %EVM (c) BER with length of fiber span for DP-16QAM system

Figure8 shows when length of fiber span is varied, initially the Q factor is maximum, then it decreases with the increase of fiber span length due to the dispersion in the fiber. The highest value of Q factor in DP-16QAM is obtained at a distance of 40km without DCF. At the highest value of Q factor the %EVM is minimum and BER is 0 without DCF.

CONCLUSION

We have studied and compared the performance of the 112-Gb/s DP-QPSK and DP-16QAM Homodyne coherent systems with and without inline DCF in a SSMF transmission which helps to increase data rata and to overcome various nonlinear effects in the fiber. Highest Q factor, minimum BER and minimum %EVM in DP-QPSK and DP-16QAM is obtained with DCF and without DCF respectively The received constellation diagram shows that as the fiber length increases the constellation points gets distorted because the dispersion of optical signal starts dominating, . In DP-QPSK there is less distortion in constellation points with DCF at different fiber spans than without DCF but in DP-16QAM the distortion is less without DCF than with DCF. This shows that in DP-QPSK coherent optical communication systems, post compensation DCF is one of the powerful means to mitigate dispersion, whereby in DP-16QAM dispersion compensation using DSP module can effectively compensate the dispersion .

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