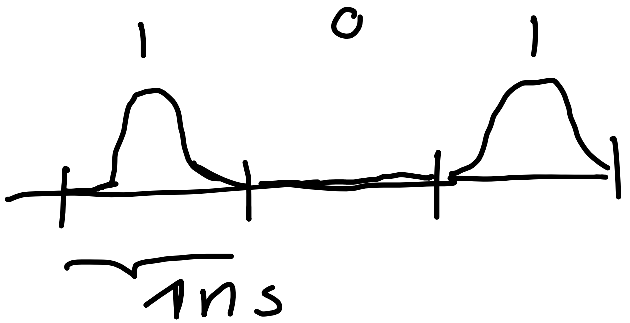
GVD-INDUCED LIMITATIONS – DISPERSION MANAGEMENT

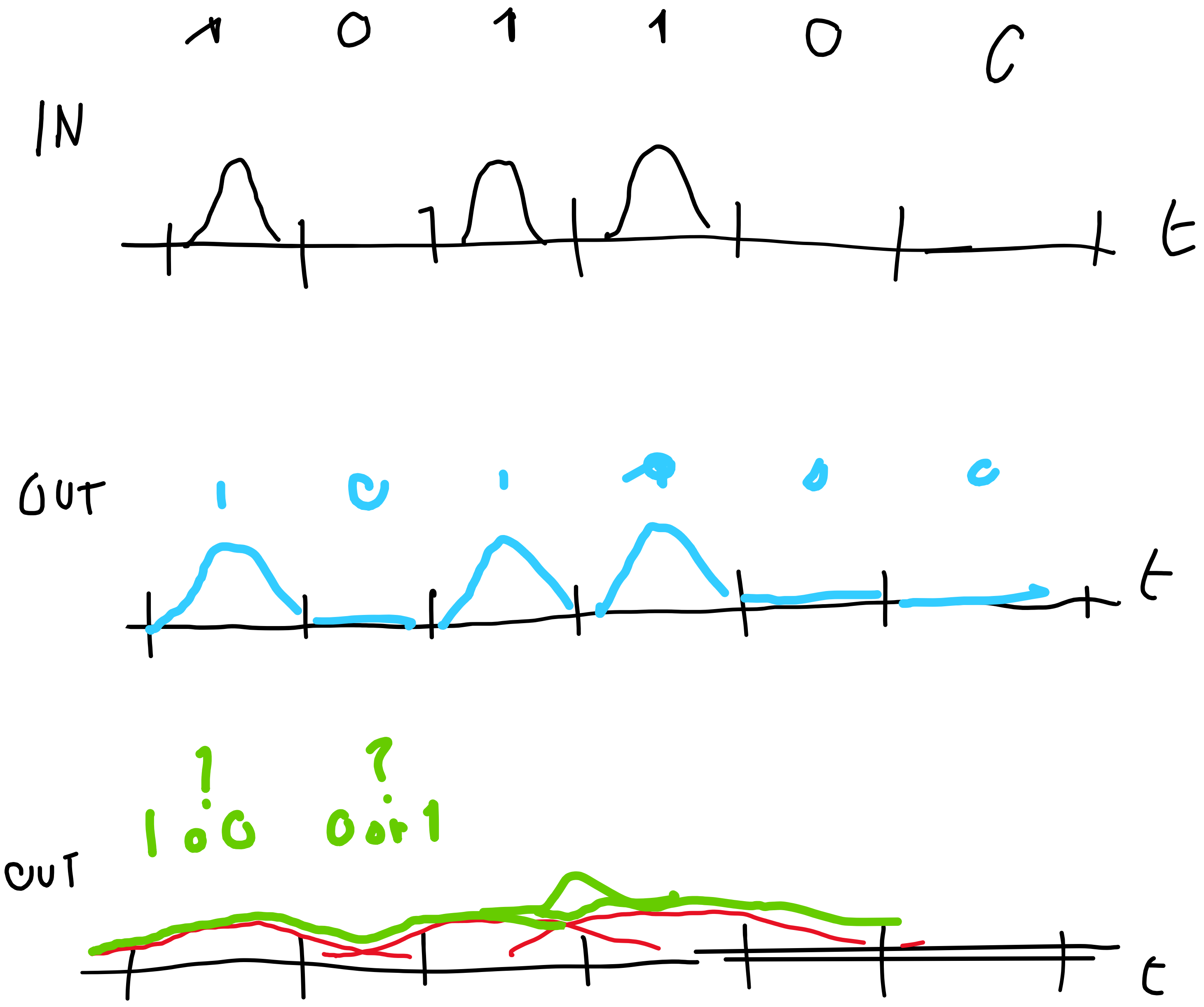
In a fiber optic communication system, information is transmitted over a fiber using a coded sequence of optical pulses whose width is determined by the bit rate B of the system.

$B = 1\,\text{Gbps} \quad \longleftrightarrow$



Dispersion-induced broadening of pulses is undesirable as it interferes with the detection process and leads to errors if the pulse spreads outside its allocated bit slot (i.e. $T_B = 1/B$).

The dispersion problem becomes quite serious when optical amplifiers are used to compensate for fiber losses because L can exceed thousands of kilometers for long-haul systems



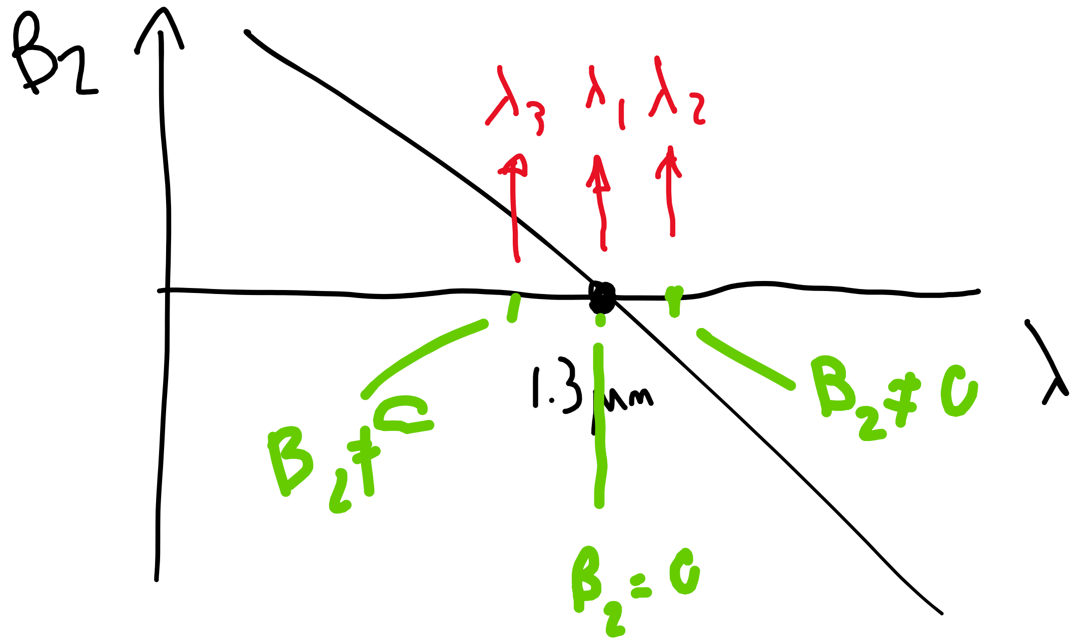
small dispersion
no errors

significant dispersion
possible errors

WE consider numerical simulation about interference.

DISPERSION COMPENSATION

Even though at the zero-dispersion wavelength is most desirable from the standpoint of pulse broadening, other consideration may preclude such a design. For example, at most one channel can be located at zero-dispersion wavelenght in a WDM system.



Moreover, strong four-wave mixing (~~a~~ nonlinear distortion effect) occurring when β_2 is zero or relatively low forces WDM systems to operate away from the zero-dispersion wavelenght so that

each channel of the WM has a finite value of β_2.
Of course, GVD-induced pulse broadening then becomes of serious concern.

The technique of dispersion management provides a solution. It consists of combining fibers with different characteristics such that the average GVD of the entire link is quite low.
In practice, a periodic dispersion map is used.
When the average GVD is zero, dispersion is compensated.

Such a dispersion-compensation technique takes advantage of the linear nature of Eq. (1).

The basic idea can be understood from Eq. (5).

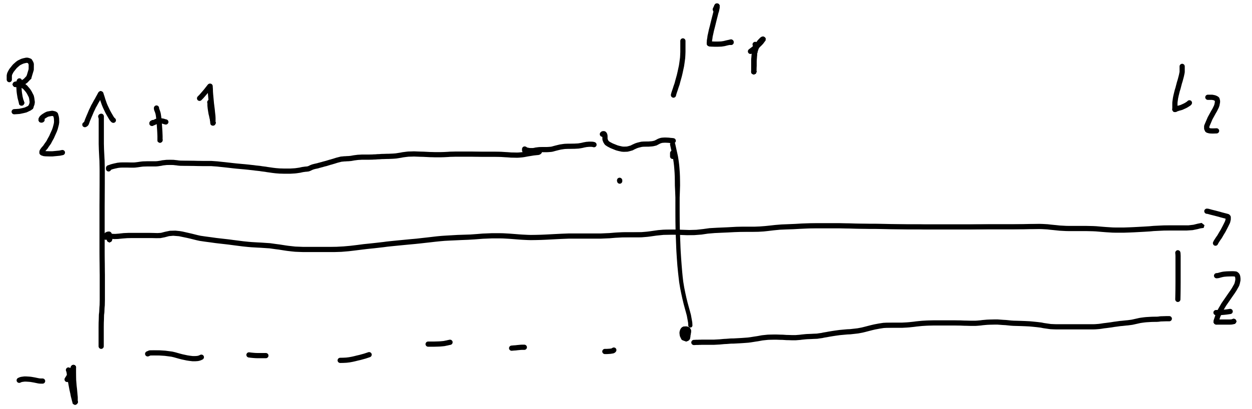
For a dispersion map consisting of two fiber segments, Eq. (5) becomes

$$F(L_m, t) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} \hat{F}(0,\omega)\exp\left(\frac{i}{2}\omega^2\left(\beta_{21}L_1 + \beta_{22}L_2\right) - i\omega t\right)d\omega$$

where $L_m = L_1 + L_2$ is the dispersion-map period, and β_{2j} is the GVD parameter of the fiber segment of length L_j ($j = 1, 2$). By using also the definition $D = -2\pi c/\lambda^2 \, \beta_{2j}$ The condition of dispersion compensation can be written as:

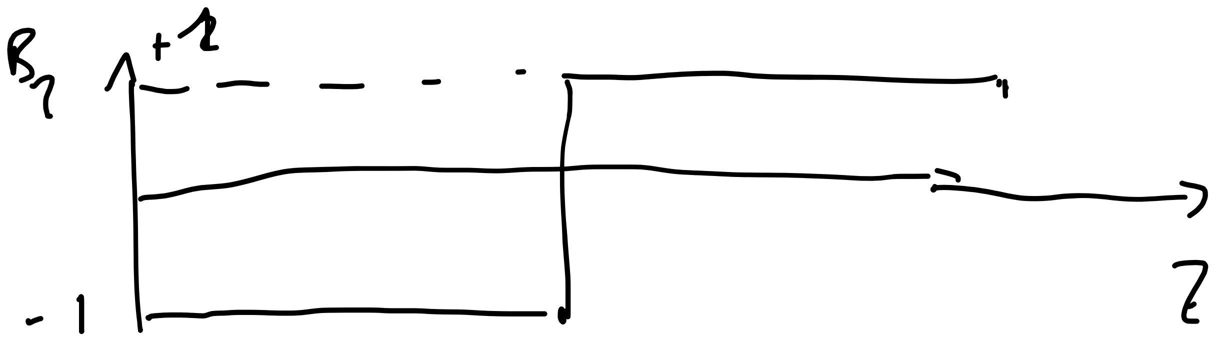
$$D_1 L_1 + D_2 L_2 = 0$$

As $A(L_m, t) = A(0,t)$ when this condition is satisfied, the pulse recovers its initial width after each map period, even if pulse can change significantly within each period. The condition can be satisfied in several different ways. The simple one: if two segments are of equal lengths ($L_1 = L_2$), the two fibers should have $D_1 = -D_2$.



$L_1 = L_2$

The same happens with opposite situation



We prove this compensation numerically. →

However a large quantity of standard fiber is already installed in existing systems.
Because this fiber (SMF) has anomalous GVD at 1.5 μm with $D \simeq 16$ ps/km nm, its dispersion

can be compensated by using a relatively short segment of dispersion-compensating fiber (DCF) designe to ha values of $D = -160\ ps/km\,nm$

$$L_1 D_1 + L_2 D_2 = 0$$

$$D_2 = -10\, D_1$$

leads to

$$L_2 = \frac{1}{10} L_1$$

$L_1 = 50\,Km$, $D_1 = +16\ ps/km\,nm$

$L_2 = 5\,Km$, $D_2 = -160\,ps/km\,nm$

Average GVD is zero, but the local GVD is very high. This property make the Four-wave-mixing effect negligible.