equal time separation between the pulses and a phase difference of $\pi$; this pulse train is stable with respect to small fluctuations in soliton positions and phases, about their equilibrium values. To take an example, a GH-limited transatlantic system ($x = 6000$ km, fibre dispersion $D = -3.2$ ps/nm/km) with 20 ps FWHM solitons exhibits mean-square GH noise $\sigma_{\text{GH}} = 1$ unit = 11.4 ps at a 5 GHz pulse rate; at an increased pulse rate of 20 GHz the noise reduces to $\sigma_{\text{GH}} = 2.5 \times 10^{-7}$ ($\approx -16$ dB) due to the large value of $x/L = 60$. This improvement is enough to permit digital PPM with a deviation of $\pm 1$ unit at an error rate of $10^{-7}$, with a potential increase in capacity due to the fold increase in pulse rate.

In order to realise increased capacity, the PPM must be encoded for immunity to the intersoliton dynamical interactions. Let the PPM signal displacements be denoted by $(q(x) \in \mathbb{Z})$; these evolve according to the equation:

$$q(x) = (1/2
\begin{cases} \cos(x/L) \sin(\omega t/2) \Delta f \omega \sin D x \end{cases}$$

(1)

In the absence of the cosine term in Eq. (1), obtained by letting $L \rightarrow \infty$, the displacements would be independent of range $x$, so this term represents the effect of intersoliton interactions, acting on the spectrum $Q(x)$ of the discrete samples $q(x)$ in the manner of a system transfer function $H(x) = \cos(x/L) \sin(\omega t/2)$. This transfer function has zeroes at discrete frequencies, which divide the total bandwidth into a number of bandlimited subbands; Fig. 2 shows an example of this filtering for the case $x/L = 17 \pi/2$. It can be shown, using a theorem by Nyquist, that within each subband the spectrum $Q(x)$ can be shaped to attain zero inter-symbol interference when the subband is sampled at its Nyquist rate, with a subband bit-rate of half its bandwidth. Since this applies to all the contiguous subbands, the capacity of the full band of frequencies in Eq. (1) is half the bandwidth, or $2(\Delta f)^{-1} \text{ b/s}$. This translates to a capacity of 10 Gb s^{-1} for the example quoted above, which is twice the original capacity of 5 Gb s^{-1} using ASK.

clock generation with frame rate = 25 GHz.

The advantages of using fiber loop mirror configuration over the Mach-Zehnder configuration, as in Ref. 1, are that the former is simpler and requires less components to implement. In conclusion, we have proposed a simple scheme to generate optical pulse trains of higher repetition rate using optical loop mirror configuration and it is suitable for future ultrafast (giga/terahertz) optical TDM systems.


CThi8 Fig. 3. (a) TDM demultiplexing with multirate clock; (b) output multirate optical clock pulse train using the same parameters as in Fig. 2 with input pulse separation = 40 ps (frame rate = 25 GHz) in simple loop mirror configuration.

\[
\begin{align*}
\text{train is} & \quad x_m = f_{12} \times x_a \\
& \quad = [8(t - \tau) + 8(t + \tau) \\
& \quad + 28(t)(x_a + D) + 8(t - \tau - \xi) + 8(t + \tau - \xi) \\
& \quad - 28(t - \xi)] / 4.
\end{align*}
\]

where $D_a$ is the pulse broadening functions due to dispersion induced by EDFA and $\xi = (4\Phi/2\pi f_0)$ where $f_0$ is the operating optical frequency. Assume the pulse broadening term $D$ and $D_a$ are negligible and can be reduced to delta functions. By adjusting the phase difference so that $\xi$ equals $2\pi$ and if the pulse width of $x_a$ is smaller than $\tau$, the output rate will be four times higher ($333$ GHz) for $83$ GHz input pulse train as shown in Fig. 2(b).

Note that for continuous pulse train input, the leading and trailing output pulses will add up to give the same power as the others.

Such a device can generate optical pulses of ultrahigh repetition rate (>$200$ GHz), which is extremely hard to achieve from an input pulse train of relatively lower bit rate (<$100$ GHz). It is quite suitable to be used as all-optical clock multipliers for future ultrahigh speed TDM systems. Moreover, it can also be used as CDMA encoder/decoder as in Ref. 1.

In addition, by adjusting the repetition rate of the input pulse train, the output pulse trains will have patterns suitable for multirate TDM demultiplexing (Fig. 3(a)) in which one may need to take more than one consecutive bits in one frame. Figure 3(b) shows the 2 bits/frame.