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Abstract: Under the proper design conditions, an arrayed waveguide grating is capable of producing high repetition rate pulse trains from a lower rate short pulse source. The temporal intensity profile may be equalized to generate a flat-topped pulse train by tailoring the design of the AWG.

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Due to increasing network bandwidth demands, significant research effort has been expended on the development of high repetition rate pulse sources. One attractive methodology is to use lower rate short pulse sources to generate higher repetition rate pulse bursts and/or trains. For example, previous work has been demonstrated in the use of tapped delay lines [1], filtering of supercontinuum [2] with arrayed waveguide gratings (AWG) [3], and spectral slicing [4]. Recently we demonstrated a new scheme utilizing an AWG to generate a high repetition rate burst of short pulses, or in principle a continuous train, at multiple, spatially separated, output wavelengths from a single lower rep rate femtosecond pulse source [5]. A flat-topped output pulse train may be generated by tailoring the design of the AWG.

For the generation of very high repetition rate pulse bursts, the important AWG parameter determining the character of the output is the free spectral range (FSR), which is equal to the inverse of the delay increment per guide ($\Delta\tau$) in the waveguide array:

$$\mathrm{FSR} = \Delta\tau^{-1} = \frac{c}{n_{eff}\ \Delta L} \tag{1}$$

where n_{eff} is the effective index of the waveguide, c is the speed of light in vacuum, and ΔL is the physical path length difference from one guide to the next in the waveguide array section of the AWG. In traditional AWG devices, the FSR is typically required to be large to ensure that a unique output wavelength within the DWDM system is present at each AWG output. For the generation of high repetition rate trains of pulses, we work in the opposite regime, where the optical bandwidth of the source laser, $\Delta\nu$, exceeds the FSR. If the input pulses are bandwidth limited, this means the input pulse width, t_p, is less than the delay increment per guide, $t_p < \Delta\tau$.

In this limit, the output spectrum on a single output guide is multiply peaked, with the spectral peak spacing equal to the FSR. Accordingly, in the time domain, this corresponds to a pulse train with a pulse separation, Δt, equal to the waveguide delay increment, $\Delta t = \mathrm{FSR}^{-1} = \Delta\tau$. The duration of the individual output pulses is the same as the input, while the duration of the envelope of the burst of pulses, T, varies inversely with the AWG passband width, δf. Thus, the waveguide array acts as a series of delay lines, and each pulse in the output train can be identified with propagation through a specific guide in the array. This realization may permit tailored output temporal profiles by engineering the waveguide array loss on a guide-by-guide basis.

For example, Fig. 1 shows intensity cross correlation measurements of two different AWG devices when a modelocked erbium fiber laser producing a 50 MHz train of ~200 fs pulses at 1560 nm is utilized as the source laser. The FSR of both AWG devices is 1 THz corresponding to a delay increment per guide of 1 ps. The left trace of Fig. 1 is from a 100 GHz output channel spacing AWG while the right trace is from a 40 GHz output channel spacing device. Both devices generate an output pulse burst for each input pulse from the source laser. In principle, similar experiments can also be performed using much higher rate (e.g. > 10 GHz) modelocked pulse sources, which may result in continuous or quasi-continuous output pulse trains. The period of the pulses within the burst is 1 ps as expected from the FSR of the devices (equivalently the delay increment per guide within the waveguide array).

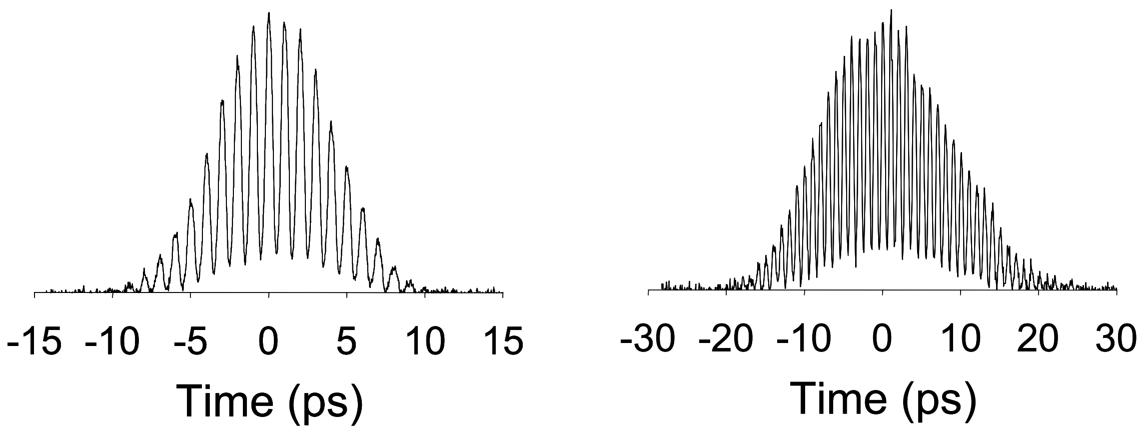

Fig. 1 Intensity cross correlation measurements of the output of 100 GHz output channel spacing (left) and 40 GHz output channel spacing (right) AWG devices both with 1 THz FSR.

The Gaussian envelope of the pulse burst may be considered to be a measure of the relative excitation of the guides within the waveguide array. Using this realization, a flat-topped output temporal intensity profile pulse train should be possible by engineering the loss within the waveguide array of the AWG. Fig. 2 shows measurements of the electric field amplitude [6] of light emerging from different guides within a custom waveguide array fabricated for this purpose. The losses have been adjusted to give close to equal amplitudes over 21 different guides, which should result in generation of nearly flat-topped pulse trains.

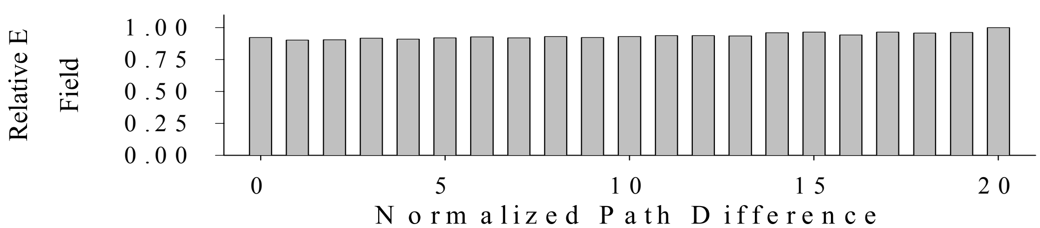

Fig. 2 Measured electric field amplitude in an AWG device designed to have a flat-topped output temporal intensity profile.

Fig. 3 shows power spectra recorded from an AWG with a 500 GHz FSR. The shape of the spectra at each passband resembles a Sinc function which would imply that a rectangular temporal window function is expected at the device output. This power spectra and the measured electric field amplitude imply that the temporal output intensity profile should consist of a flat-topped burst of short pulses.

In summary, high repetition rate pulse bursts have been demonstrated from a specially designed AWG and a single short pulse source laser. The key requirement is that the FSR of the device must be tailored so that multiple filter passbands fit within the input laser bandwidth. The unique properties of this device allow generation of identical, wavelength shifted, very high rate pulse trains for hybrid TDM/WDM communications and photonic signal processing. Initial work has been performed on tailoring the output temporal profile to generate a flat-topped pulse train burst. When applied to a high-repetition rate modelocked source (>10 GHz), these devices could lead to continuous very-high repetition rate output trains (>500 GHz).

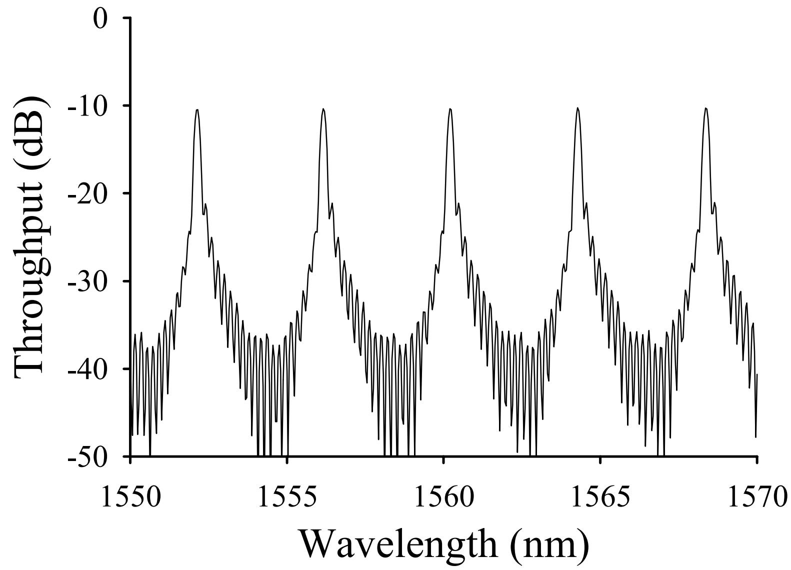

Fig. 3 Measured power spectra from an AWG device with 500 GHz FSR and waveguide losses engineered to generate a flat-topped output temporal intensity profile.

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