All-optical serial header processing based on two-pulse correlation

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To investigate the maximum number of channels which could be recovered simultaneously the filter within the cavity was tuned to select another group of four channels for the same cavity length and polarisation. Owing to the different path lengths for different channels within the clock-recovery module, it could be simultaneously locked for a maximum of seven channels. To achieve simultaneous modelocking over a larger number of channels, a phase control section could be incorporated in the clock-recovery module.

Conclusion: Simultaneous multiwavelength clock recovery in a modelocked fibre ring laser configuration has been reported using a novel integrated module. The clock signals were recovered for up to seven wavelengths, although the device can potentially operate over a much wider wavelength range. Although the reported device had a high insertion loss (due to packaging problems), it demonstrates the potential for large-scale monolithic integration for optical processing applications. Improvements in packaging will ensure that the SOA gain compensates for waveguide grating losses and could potentially provide overall device gain, as shown in [8]. In combination with fast SOA nanosecond switching speeds this device has an excellent potential for WDM 3R regeneration and other optical processing functions.

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All-optical serial header processing based on two-pulse correlation

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An all-optical serial header processor is demonstrated using a semiconductor laser amplifier in a loop mirror configuration (SLALOM). The operation of the header processor is discussed and it is experimentally demonstrated with a 10 Gbit/s Manchester encoded (information rate of 5 Gbit/s) packet stream. The operation of the header processor is based on the correlation function of the SLALOM. The header processor can be utilised in devising all-optical packet switches.

Introduction: The need to produce a transparent all-optical packet switch has been well documented [1]. A key component of the all-optical packet switch is an all-optical header processor. In this Letter, an all-optical serial header processing unit (HPU) is demonstrated using a semiconductor optical amplifier (SOA) in an SLALOM configuration.

Two-pulse correlation using a SLALOM configuration is a previously described concept [2, 3]. In this Letter, two-pulse correlation is employed for all-optical header processing. The HPU is required to perform several functions. First, it must provide different outputs for each header. In addition, the HPU must produce correlation pulses only when headers are actually present. Payload data or stray noise in the network should not produce a correlation pulse corresponding to a header. This second aspect is especially crucial in systems where the header and payload are not separated for processing.

The HPU designed here has several advantages. The SLALOM configuration of the HPU in principle allows integration and high-speed functionality [3, 4]. The HPU also simplifies system design since the separation of payload and header is not required. The HPU can also be used with variable sized packets. In addition, the serial nature of the HPU avoids the complication of a serial to parallel conversion needed for parallel header processors [5]. A disadvantage is that a tail section must be included for optimal system performance. However, the tail section is useful in applications where the packet size is variable and packet length information is needed.

In the following Section, the operating principle of the SLALOM based HPU is briefly discussed. We demonstrate the concept experimentally and show that the HPU can discriminate between header and payload and also between individual headers.

Fig. 1 Experimental setup to demonstrate SLALOM based serial all-optical header processor

Traffic from network is coupled into HPU at port 1 and processed output appears at port 2
MZ Mach-Zehnder modulator
PG pattern generator
PC polarisation controller
 τ SLALOM delay line

Operating principle: The HPU is implemented using the structure shown in Fig. 1. The optical packet structure used for this experiment consists of a 4 byte header, a payload section of 80 bytes and a tail section of 4 bytes. An example packet structure is shown in Fig. 2. The header and tail sections are at lower bit rate than the payload. Suppose the packet shown in Fig. 2 enters the HPU at port 1. The header sequence is chosen to utilise the two pulse correlation technique and produce an 8 bit header 'correlation pulse' at port 2. The details of two-pulse correlation using an SLALOM have been presented previously [3]. The high bit-rate packet payload is suppressed because it drives the SOA into saturation. The tail section of the packet is also output as a 'correlation' pulse due

to the SLALOM configuration. The choice of header and tail bit rates are determined by the requirements for the output 'correlation pulse'.

Manchester encoding of the packet payload is used to achieve a crucial criterion of the header processor, the need to differentiate between header and payload. By using a faster bit rate Manchester encoded payload, it is ensured that the header sequence will never be duplicated in the payload. Therefore the payload will never be able to produce the correlation pulses made by header data streams. In addition, the Manchester encoding increases the suppression of the payload by keeping the SOA in saturation when the payload passes through. The saturated SOA can only provide a limited gain to the payload. The tail section is included to ensure that the SOA stays saturated for the entire payload. The disadvantage of Manchester encoding is the loss of effective bit rate in the payload; however, this is offset by benefits such as easier clock recovery in packet switched applications.

Fig. 2 Packet structure for HPU

Header and tail bits are at slower bit rate of 2.5 Gbit/s. Output from packet is shown in lower panel. Header and tail pulses large in amplitude and wide in duration

Fig. 3 8 bit out header correlation pulses for two different packet headers and corresponding headers

Header sequences are hexadecimal representations of bit stream

Experiment: The HPU described above was demonstrated using the setup shown in Fig. 1. A 10 Gbit/s Mach-Zehnder modulator was used to create the packet structure. An average power of -5 dBm was input into the header processing system. The SOA was manufactured by JDS Uniphase and employs a strained bulk active region. The SOA was pumped with 130 mA of current, corresponding to a saturation gain of 9 dB with CW light. The amplifier was offset from the centre of the loop by 1.019 m ($\tau = 4.95$ ns). The frequency of the signal generator was 9.5152 GHz.

The first experiment demonstrates optical header processing using the SLALOM configuration. The input into the HPU is shown schematically in Fig. 2 above the output. The output shows the large suppression between the header/tail and payload sections. The particular header produces a 3.2 ns wide correlation pulse. The tail section, which is common for all packets, corresponds to a 4.7 ns correlation pulse. The suppression ratio between the header and payload sections at the output of the HPU was determined to be 14.95 dB by measuring average power for the

header section and the payload. The experiment shows the ability of the HPU to suppress payload data and therefore avoid the separation of header and payload streams.

The second experiment demonstrates the capability of the HPU to discriminate between different headers. In the left panel of Fig. 3, the correlation pulse corresponding to the packet header (header FF) of Fig. 2 is presented in more detail. The packet header is plotted schematically above the correlation pulse. The correlation pulse has a width of 3.2 ns. Different packet headers produce different header output correlation pulses. In the right panel of Fig. 3 the output pulse for a different header (header E7) is presented. The output for header E7 is two 1.2 ns pulses separated by a gap of 800 ps. The two outputs are easily distinguishable. The overshoot in the second pulse is caused by the injection of a signal into the SOA after a period of no signal. The gain in the SOA partially recovers and delivers more gain than usual for a short period of time. The experiment shows the ability of the HPU to produce different output header correlation pulses for different headers.

Conclusions and discussion: We have shown that an all-optical header processor can be made using an SLALOM structure with a carefully designed packet structure. The HPU discussed in this Letter can differentiate between multiple header patterns. These unique outputs from the HPU can be used to make decisions on packet routing. Our demonstration showed the header processor working with payload data rates of 10 Gbit/s, however we believe that it is also possible to process payload at higher bit rates.

The design of the HPU provides several key advantages over alternate techniques. The serial nature of the HPU removes the additional complexity of the separation of payload and header sections of the packet and does not impose a fixed packet length. In addition, the HPU is a low power device; the amount of input power required can be adjusted by changing the current into the SOA.

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