Optical Clock Recovery and 3R data Regeneration using a Single Electro-Absorption Modulator

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# Acknowledgements

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Electro-absorption modulator structure

- Originally designed for electrically controlled modulation.

- It can be used for optically controlled modulation.

* Courtesy of ‘Japan Aviation Electronics Industry’.
Real Electro-absorption modulator
Strong optical input reduces the electro-absorption
The EAM exhibits a nonlinear transmission

- Probe: 1545 nm
- Pump: 1550 nm
- Pulse width: 3.3 ps
- Repetition rate: 1 GHz
Optical clock recovery
The Transmission is delay dependent

- All-optical timing extraction
Error Signal Generation

Complete information about timing error
Here are the balanced detectors
The measured Error Signal

- Repetition rate 10 GHz.
- $\Delta f = 10$ KHz.
- B.W. = 100 KHz.
Experimental setup for clock recovery
Transient response of the error signal
RF spectrum and timing jitter

r.m.s. jitter = \frac{1}{2\pi f_o n} \sqrt{\frac{P_o \times \Delta f_o}{P_{peak} \times R.B.}}

r.m.s. timing jitter:
- Locked ≤ 120 fs.
- Free running ≤ 60 fs.

fo = 10 GHz., R.B. = 10 KHz., \Delta f = 10 KHz.

locked
free running

50 ps/div, 2mV/div.
160 Gbit/s optical clock recovery

Optical multiplexer
160 Gbit/s Multiplexer
160 Gbit/s auto-correlation

- 2ps FWHM pulse.
- 6.25ps bit-period.
Locking transient response

- 10 μsec acquisition time
Bit-rate flexible optical clock recovery

![Graph showing bit rates vs. jitter](image-url)
Optical 3R Regeneration
Using a Single EAM
• Optical Fiber Transmission Impairments:
  ➢ Attenuation.
  ➢ Timing jitter.
  ➢ Amplitude noise/Distortion

  - **Re-amplification**
  - **Re-timing**
  - **Re-shaping**

  3R regeneration
The Nonlinear transmission of the EAM is appropriate for re-shaping

- 1545 nm.
- $f = 1$ GHz.
Experimental setup for 3R regeneration
Input data is degraded by introducing timing jitter and adding ASE noise

- **2^{31}-1 PRBS.**
- **10 Gbit/s.**
- **OSNR: 18 dB.**
- **Timing jitter:**
  - 500 KHz
  - \sim \text{half pulse width}
The improvement in data after the regenerator

20 ps/div.

20 ps/div.
The bit-error-ratio measurement shows negative power penalty

- $2^{31} - 1$ PRBS.
- 10 Gbit/s.

Power Penalties:
- -4.7 dB.
- +1.7 dB.
Summary

- Optical clock recovery using a single EAM.
- Bit rate flexible up to 160 Gbit/s.
- Small timing jitter $\leq 340$ fs.
- No need for high speed electronics or high-Q tank filters in the clock recovery.
- 3R regeneration using a single EAM.
- 4.7 dB improvement in power penalty with $\leq 230$ fs timing jitter.
Wavelength dependence of the EAM transmission
The bit-error-ratio measurement reveals no power penalty

160 Gbit/s clock recovery.
The Transmission window is adjustable