All-Optical Clock Recovery using Stimulated Brillouin Scattering

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Outline

• Various clock recovery techniques
• Stimulated Brillouin optical clock recovery
• Experimental results to date
• Concluding remarks
Transparent optical networks will require optical switches for:

- Synchronization between traffic and switches.
- Demultiplexing time channels in OTDM systems.

**Why All-Optical Clock Recovery?**

Nonlinear Optical Loop Mirror

Soliton Dragging Logic Gate

Clock in

Data

Data with control

Data

Clock

Timing window
Methods of Optical Clock Recovery

- Opto-electronic phase locked loops
- Mode-locked lasers
- Self-pulsations in laser diodes
- Optical tank circuits
  - Fabry-Perot filters and resonators
  - Stimulated Brillouin scattering (SBS)
Opto-Electronic Clock Recovery

Input Data (optical) → TW-LDA → BPF → PD

Δf

Optical clock → Mixer → Phase comp

f₀/n + Δf (optical)

f₀/n

f₀/n

Rate dependent component
Optical Clock Recovery-Fiber Mode
Locked Ring Laser

Data in

Phase or amplitude modulator

Rate dependent component

BPF

Isolator

Fiber line stretcher

EDFA

Filter

Clock out
Optical Clock Recovery using Self-Pulsating Diode Laser

- The self-pulsation frequency of the amplifier locks to the input bit rate
- Bit-rate dependent
Optical Recovery using Mode-locked Multi-segment Semiconductor Laser
Optical Tank Circuits

Data Filter Clock

Rate and wavelength dependent component

FSR

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Stimulated Brillouin Scattering

The pump creates a forward propagating acoustic grating. The pump scatters off this grating with a downward Doppler shift.
**Brillouin Optical Clock Recovery**

Data signal in

Clock signal out

- Downshifts data by phonon frequency ($f_{\text{seed}}$)
- Stokes wave provides amplification

$\text{Isolator}$

$10.9\,\text{GHz}$

$80$

$20$

$\text{Mod}$

$\text{Fiber}$

$f_{\text{data}}$

$f_{\text{clock}}$

$f_{\text{data}}$

$f_{\text{stokes}}$
Advantages of Brillouin Clock Recovery

• Bit-rate insensitive
• Clock output is stable through long periods of zeros (170 at 10 GB/s)
• Wavelength independent
Experimental Results

Data in

Output clock

1.2 ps relative jitter

Data signal in

Clock signal out

Pump

Stokes

20 km DSF fiber

20.8000 Hz

120.0 m/div  39.7 nV

120.0 m/div  39.7 nV

80

10.9GHz

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Jitter vs. Signal Power

Data signal in

80

20 km DSF fiber

Pump

Stokes

10.9GHz

20

Clock signal out

Jitter (ps)

Power (dBm)
Jitter vs. Number of Zeros

Diagram showing a system with pump and Stokes, 20 km DSF fiber, and clock signal output. The graph plots Jitter (ps) against Number of zeros.
Conclusions

• An all-optical Brillouin Clock has been demonstrated
• Compatible with all-optical networks
  o Bit-rate independent
  o Wavelength independent
  o Not limited by electronic speeds