All-Optical Wavelength Conversion for NRZ-OOK Signal based on Four-Wave Mixing in a Silicon Waveguide

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Introduction

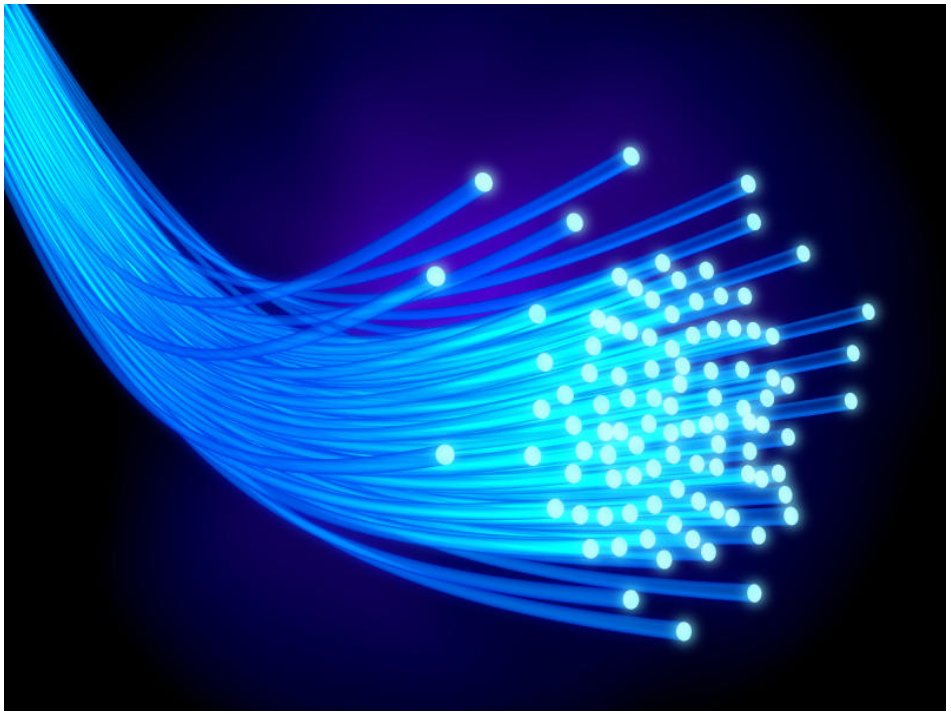
Fibre optical communications

Advantages

- High bandwidth
- Low loss

but

- All-optical systems not fully developed
- Cannot transfer high power



On-off keying (OOK)

- No light is `0`, light is `1`.
- Simplest modulation format
- NRZ-OOK vs RZ-OOK

Wavelength conversion

- To convert a beam to another wavelength preserving the signal.
- Allows wavelength division multiplexing
- Some components need specific input wavelengths

Introduction

Four-wave mixing (FWM)

- Nonlinear effect: depends on $\vec{\mathbf{P}} = \varepsilon_0 \chi_e \vec{\mathbf{E}} + \vec{\mathbf{P}}^{\mathrm{NL}}$
- Parametric (instantaneous) process
- Two photons (ω_1, ω_2) in, two photons (ω_3, ω_4) out

Energy and momentum conservation

$$\omega_1 + \omega_2 = \omega_3 + \omega_4 \quad \text{frequency matching}$$
$$\vec{\mathbf{k}}_1 + \vec{\mathbf{k}}_2 = \vec{\mathbf{k}}_3 + \vec{\mathbf{k}}_4 \quad \text{phase matching}$$

$$\left(\|\vec{\mathbf{k}}\| = \frac{n(\omega)\omega}{c} \right)$$

When $\omega_1 = \omega_2$: Degenerate FWM ($\omega_i = 2\omega_p - \omega_s$)

Introduction

Components

- Passive
  - Attenuators
  - Isolators (ISO)
  - Optical couplers
  - Polarization controllers (PC)
  - Wavelength division multiplexers (WDM)
  - Modulators
    - ★ Mach-Zehnder modulator (MZM) (amplitude modulator)
- Active
  - Tunable lasers (TL)
  - Amplifiers
    - ★ Erbium doped fibre amplifier (EDFA)

Preparatory experiments

Generally educational

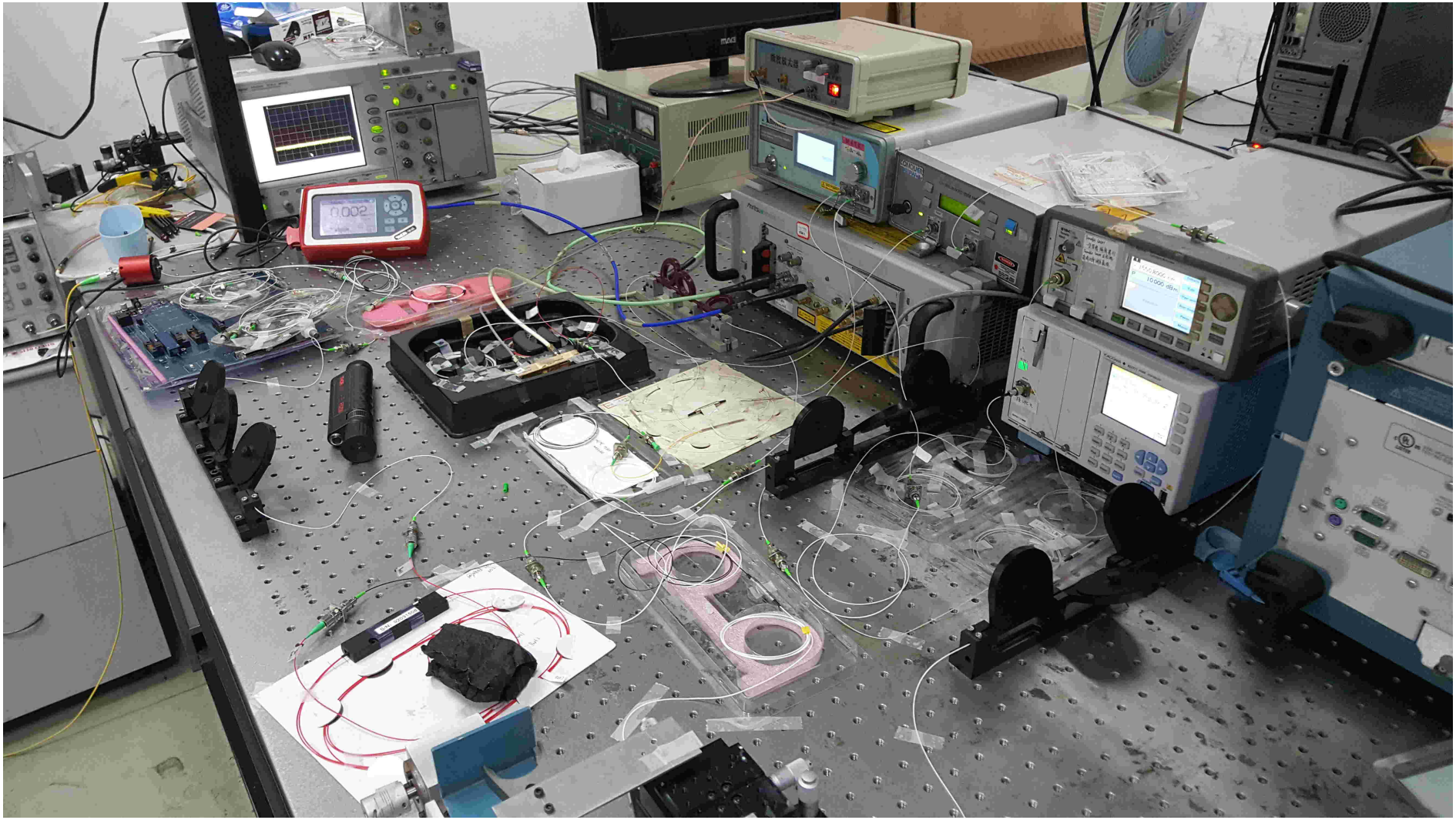
1. Fibre fusion splicing
2. Properties of passive components
3. Construction of a fibre laser
4. Properties of an optical amplifier

Directly preparatory

1. Continuous wave wavelength conversion (in fibre)
2. Modulation of an OOK signal

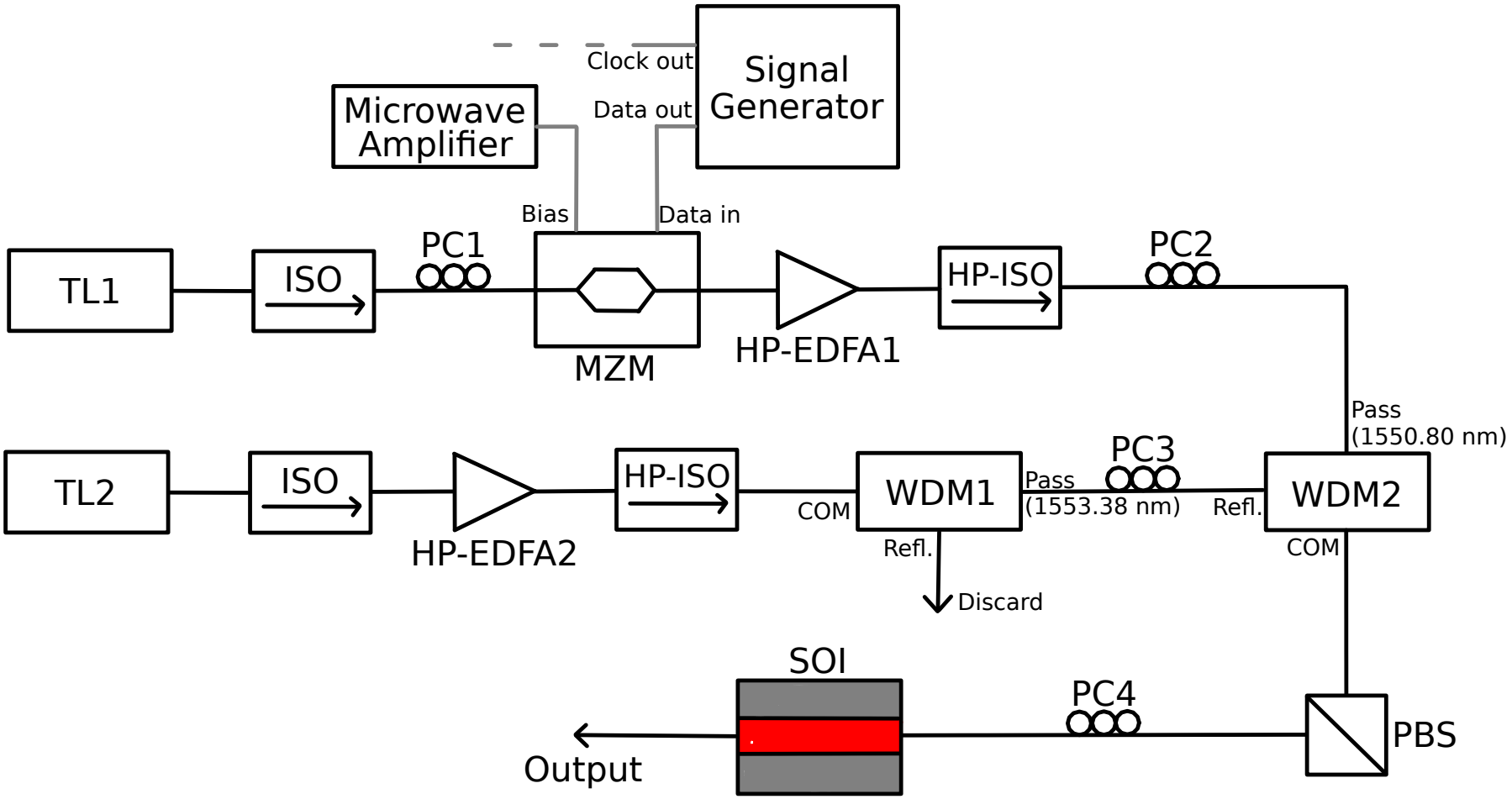
Main experiment

Setup



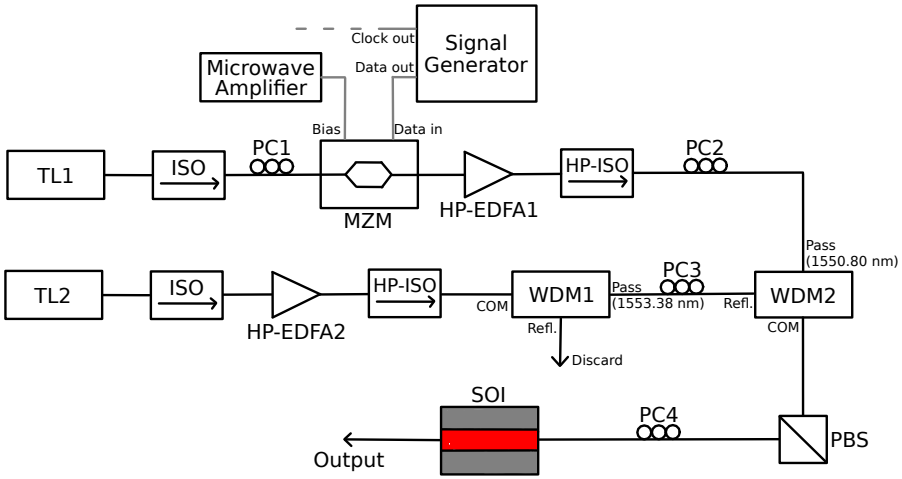
Main experiment

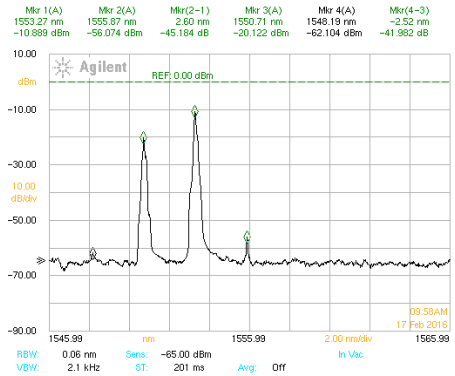
Setup



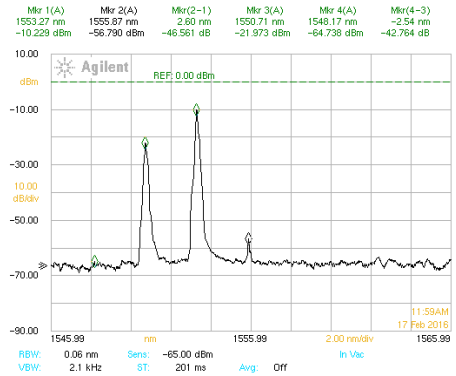
Main experiment

Measurements (optical spectrum analyser)

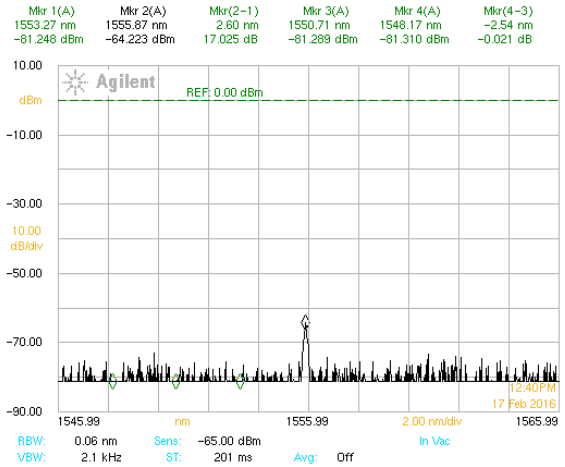




(a) Continuous



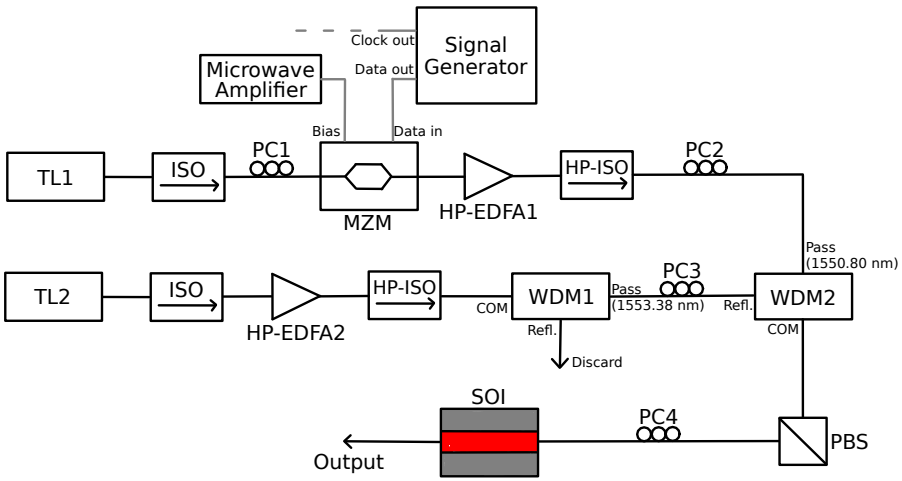
(b) OOK signal



(c) Filtered OOK signal

Main experiment

Measurements (power levels)



(dBm)	CW	OOK
Signal after PBS	17.84	15.7
Pump after PBS	25.1	26.16
Combined after SOI	23.3	23.71

Converted signal: $-20\,\mathrm{dBm} = 10\,\mu\mathrm{W}$

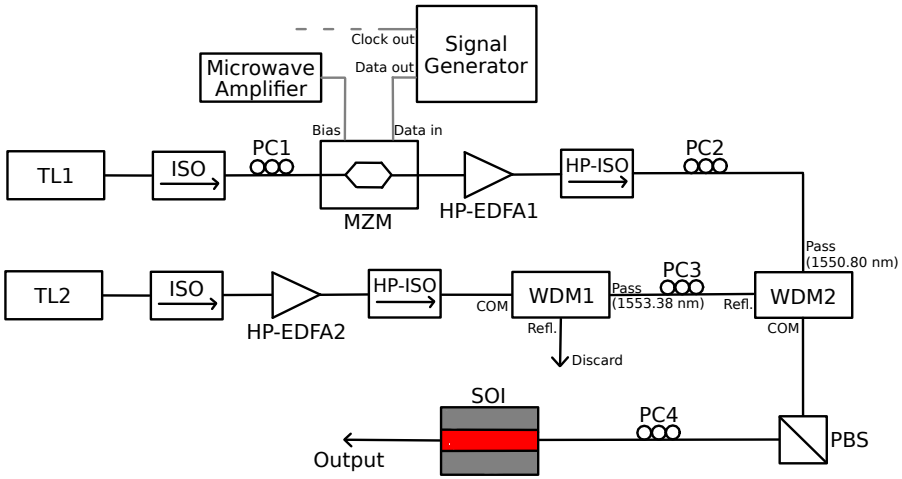
$$P_{\mathrm{dBm}} = 10 \log_{10}\left(\frac{P}{1\,\mathrm{mW}}\right)$$

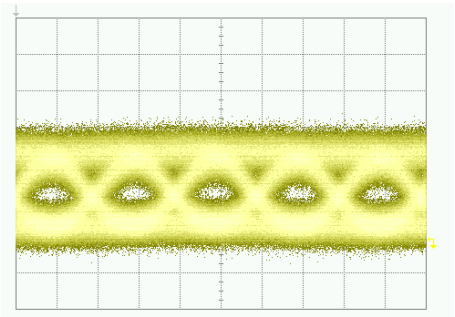
0 dBm
1 mW

30 dBm
1 W

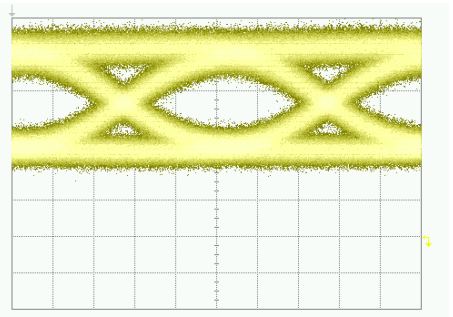
Main experiment

Measurements (oscilloscope)

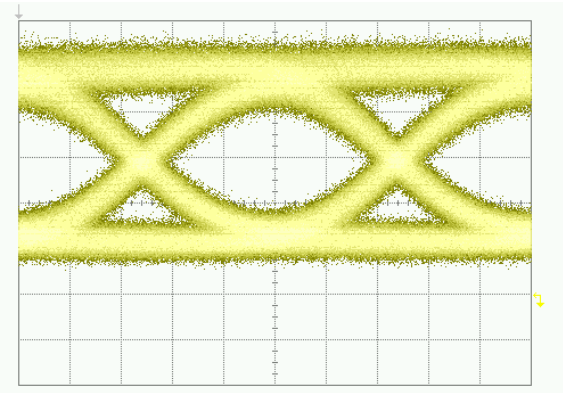




(a) Before EDFA



(b) After EDFA



(c) After WDM2

None available for the converted signal!

Thank you!

Image sources

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