Semiconductor Optical Amplifiers for Optical Transmission Applications

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Topics

• Semiconductor Optical Amplifier (SOAs) Design
• Multiquantum well Amplifiers
• QD optical amplifier structure and performance
• Transmission Performance
• Photonic Integrated Circuit using SOAs
Semiconductor Optical Amplifier (SOA) Design
Quantum Dot Formation

Schematic of quantum dot formation. A formation of clusters is observed during epitaxial growth of a semiconductor layer (e.g. InGaAs) on top of another (e.g. GaAs) that has a lattice constant several (3 to 5) percent smaller. The top figure shows the planar substrate. The lower figure shows quantum dots on the higher band gap layer. The dots are covered in a high band gap material for laser or amplifier devices.
Quantum Dot (QD) Amplifier
Ridge guide type
Index Guided QD amplifier
Structure of an InAs/InGaAsP/InP semiconductor optical amplifier
Optical Gain of a QD amplifier

(a) Gain spectrum for Fiber-to-Fiber amplification at 20°C, TM, and 2.0A. The gain peak is around 1490 nm, with a gain spectrum width of approximately 75 nm. The wavelength range is from 1400 to 1600 nm.

(b) Gain and saturation depth at 1563.45 nm, 20°C, and 2.0A. The saturation depth is indicated by Psat = 18.4 dBm.
Wavelength dependence gain, noise figure and saturation output power for a QD-SOA
QD Amplifier Gain Dynamics

- QD amplifier gain recovers fast after depletion by input pulse
  - Layers surrounding the QD serve as reservoir of carriers
  - This results in fast gain recovery
  - Also QD amplifier has high saturation power compared to Quantum well amplifier
QD amplifier show better performance than QW amplifiers

Eye diagrams for 40-Gb/s input signal and signals amplified in QD and QW SOAs. (a) Input. (b) Quantum dot. (c) Quantum well.
Transmission study using in-line SOA

Signal level with distance

BER result initially (A) after 372 km (B)
SOA as a preamplifier in front of Detector

Experimental set up

BER data at 4Gb/s
Transmitter (Tx) and Receiver (Rx) using SOA for WDM Systems

**Tx Configurations with Booster-SOA**

(T1) $\lambda_4$, $\lambda_3$, $\lambda_2$, $\lambda_1$

(Tx) SOAs

AWG

**Rx Configurations with Pre-amp.-SOA**

(R1) $\lambda_8$, $\lambda_7$, $\lambda_6$

PIN G high

SOA

AWG

(R2) PIN G mod. G mod.

SOA

AWG

(R3) APD G mod.

AWG

SOA
Multichannel WDM Sources With Amplifiers
100 Gb/s OOK Transmitter PIC

Photograph of 100 Gb/s (10X10 Gb/s) Transmitter module
Performance of a 100 Gb/s OOK Transmitter PIC

SOA Characteristics of the PIC

Back to Back Eye diagrams for all 10 Channels Using 10 ch. TX and RX PICs
1 Tb/s Transmitter PIC from Infinera Corp. Uses Coherent, polarization multiplexed, QPSK architecture

Each lambda

- TM-I
- TM-Q
- TE-I
- TE-Q

Each PIC
- > 450 Integrated Functions on the PIC
- Tunable DFB, AWG, MZ Mod
- Phase Adj, VOA, MMI, PD

Receiver PIC
Summary

• SOAs have been fabricated which have regular, MQW and QD active region
• QD-SOAs have fast gain and phase recovery

• SOAs are useful for in-line amplification, power boosters for transmitters and pre-amplifiers for detectors

• Photonic integrated circuits (PICs) of transmitters and receivers which uses SOAs have been fabricated for WDM transmission systems

Continuing Research
• All optical logic circuits, e.g. all-optical latches (e.g. Flip-Flops)

• Complex key generator circuits using complex hardware algorithms (multiple PRBS generators and Logic circuits)