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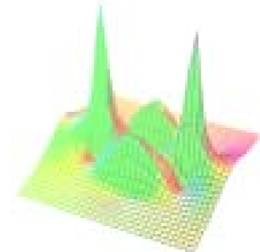
Ultrafast Optical Logics

Univ. Electro-Communications (UEC)

Depart. of Electronic Eng.

Ueno Laboratory, since March 2002

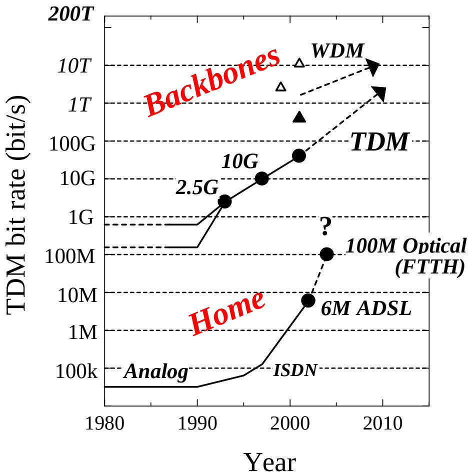


Communication Speed*) has been doubled or trippled every 2-3 years!

Trunk Networks today are driven, and being pushed up by the up-to-date Optoelectronics technology!!

*) the fastest speed in digital TDM communications per fiber, per WDM channel.

In our laboratory at UEC, we are exploring the ultrafast optical logics <u>in the 100 GHz- 1 THz range.</u>



What's Ultrafast Optoelectronics?

Optical Communications Today: Transmitting/Receiving signals with electronic controls
(Optical-Electric conversion is mandatory, everywhere)

Ultrafast Optoelectronics: *Optical signals contol Optical signals, directly (= 'all-optical')*

⇩ *Consequently...*

(A) **Much faster** than the OE-conversion systems

Industry: core components for ***Ultrabroadband communications networks***
(100 GHz- 1 THz transmitters, receivers, node functions, etc.)

Engineering backgrounds:
semiconductor electronics, e-m lightwaves, nonlinear/linear optics

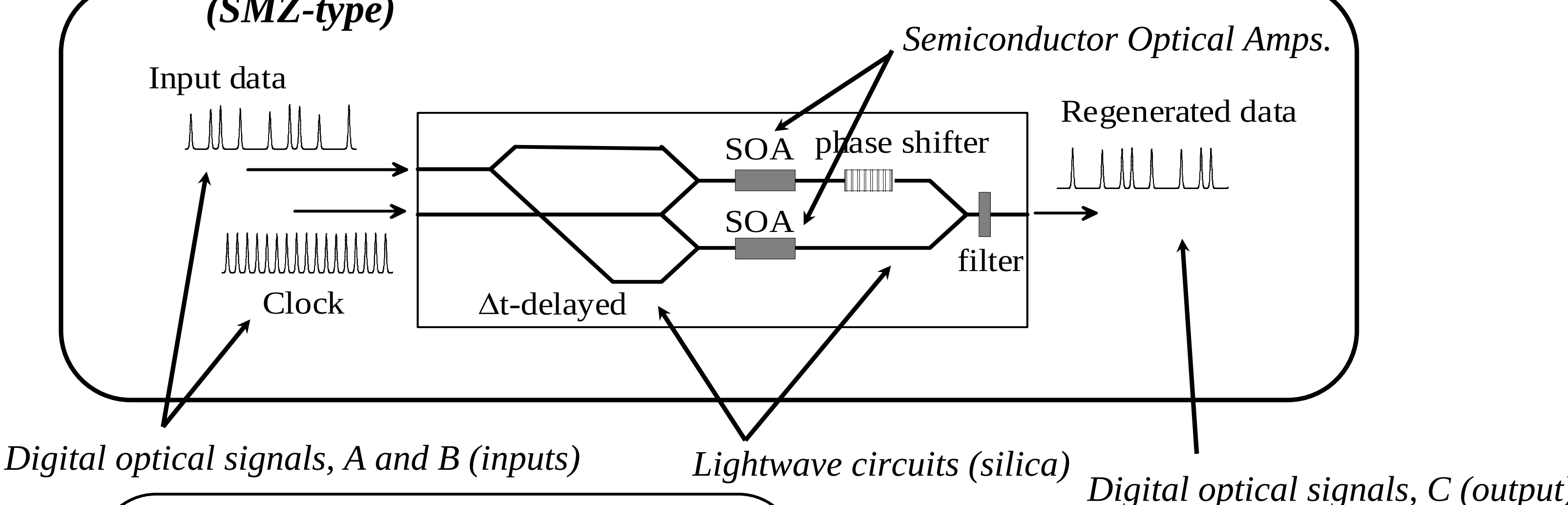
(B) **Direct, straightforward** signal processings, without massive O-E conversions

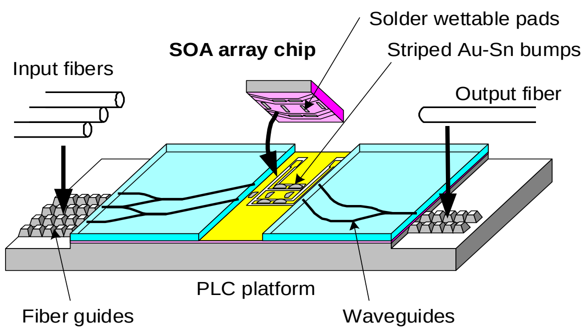
Ultrafast Optical Logic --previous works--

works at NEC, Tsukuba, until Feb. 2002
(supported by Femtosecond Technol. Poject/ FESTA/ NEDO)

Optical logic gate, example (SMZ-type)

K. Tajima, Jpn. J. Appl. Phys. 1993, etc.





Optical Logics results (1)

Y. Ueno et al., IEEE PTL 2001, etc.

Advantages:

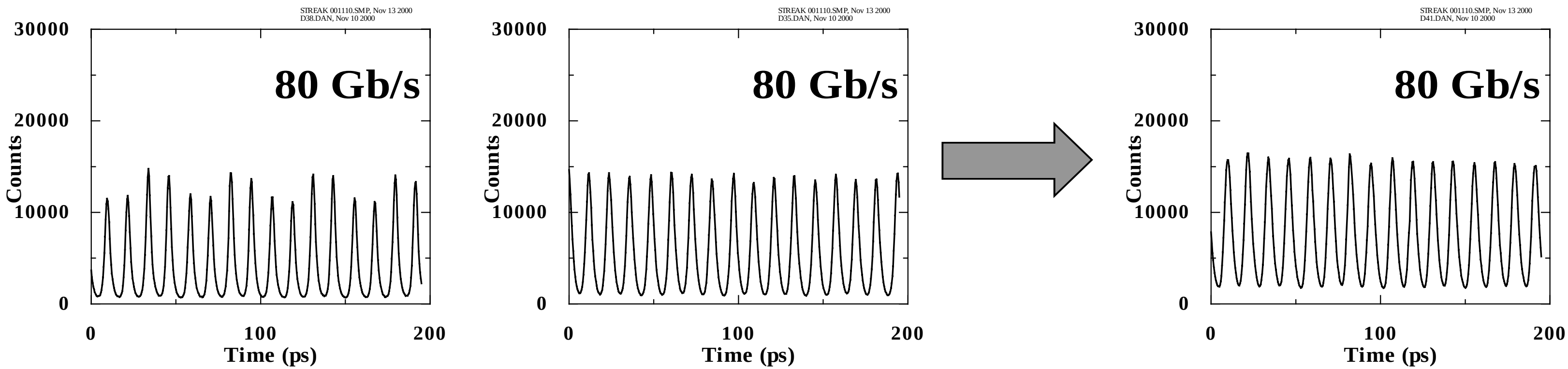
Optical signals canbe Ultrafast (the optical frequency≈200 THz)

All-optical gating canbe Ultrafast (faster than 1 ps)

Power consumptions are relatively small (100-100 fJ/bit)

(Costs: optical-logic's unit size, 100 μm- 1 mm, is larger than that of Si LSI's.)

<u>When digital signal (a) gates the clock signal (b), all-optically, at 80 GHz</u> (≈ AND gate)



(a) Digital input with noise (b) Local clock without noise ***<u>(c) Digital output, whose noise is reduced</u>***

works at NEC, Tsukuba, until Feb. 2002

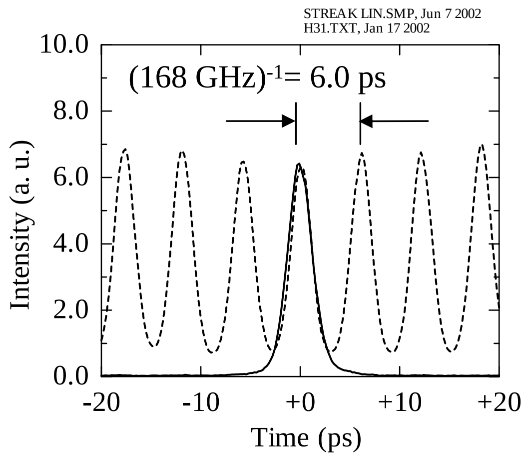
(supported by Femtosecond Technol. Poject/ FESTA/ NEDO)

Optical Logics results (2)

S. Nakamura et al., IEEE PTL 2000
Y. Ueno et al., J. Opt. Soc. Am. 2002

freq. seperation= Δ168 GHz

16:1 Demux for the 160-GHz signals



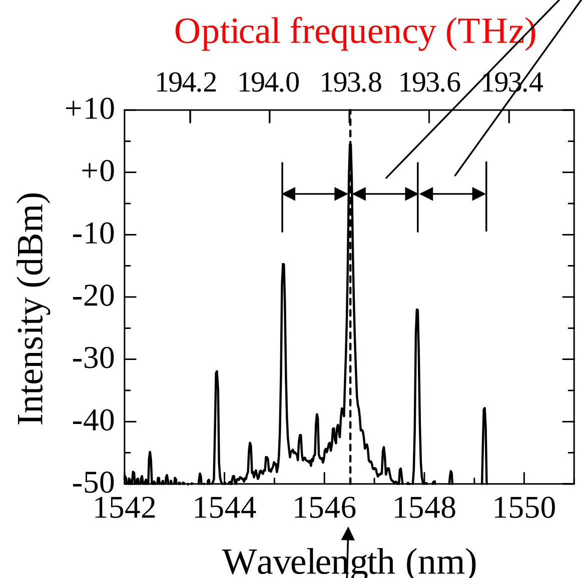
Rise and fall times < **2 ps**

dashed curve: 160-GHz input signal
solid curve: 10-GHz demultiplexed output signal

This response time= 30-to-100 times faster than ***Pentium 4.***

Power consumption is 1-2 Watts (relatively small).

In the optical-frequency domain



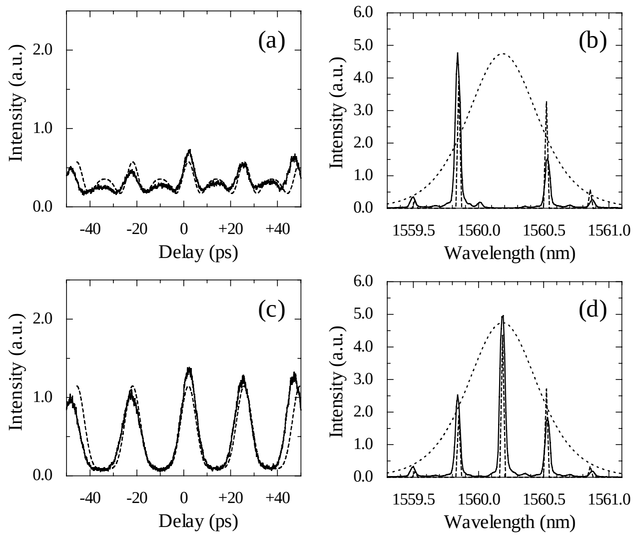
Center wavelength= 1546.5 nm
= 193.80 THz= 193,800 GHz

Fundamental Mechanisms: time vs. frequency domains

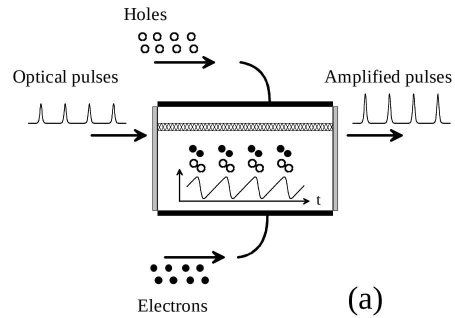
Y. Ueno et al., Opt. Lett. 1998

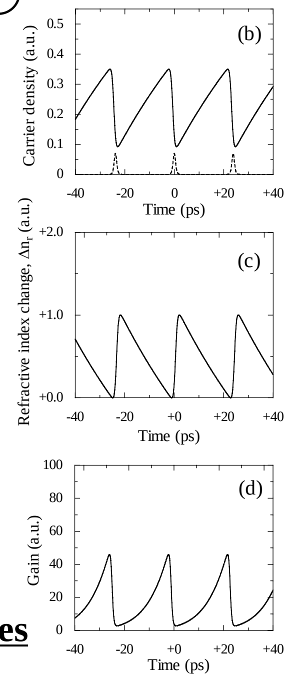
Waveforms | Optical Spectra

Optimized



Optical Amplifier





Modeling at ultrahigh frequencies

Bases of the model:

stimulated-emission-induced carrier recombination and the nonlinear change in refractive index

(a): photon-electron interaction in the SOA

(b): carrier-density oscillation in the SOA

(c): nonlinear change in the effective refractive index

(d): gain modulation

Optimization of the MZI's phase bias (42 GHz, 7 ps)

Measured (solid curves) vs. calculated (dashed curves) data.

(a), (c): output waveforms, (b), (d): optical spectra

(a), (b): biased to $+1.00\pi$, (c), (d): optimized (biased to $+1.10\pi$)

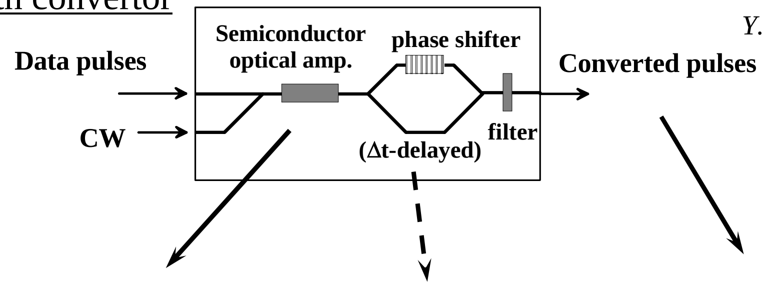
The proposal of this control scheme was based on our successful modeling of the electron-photon dynamics in SOAs at such ultrahigh repetition rates.

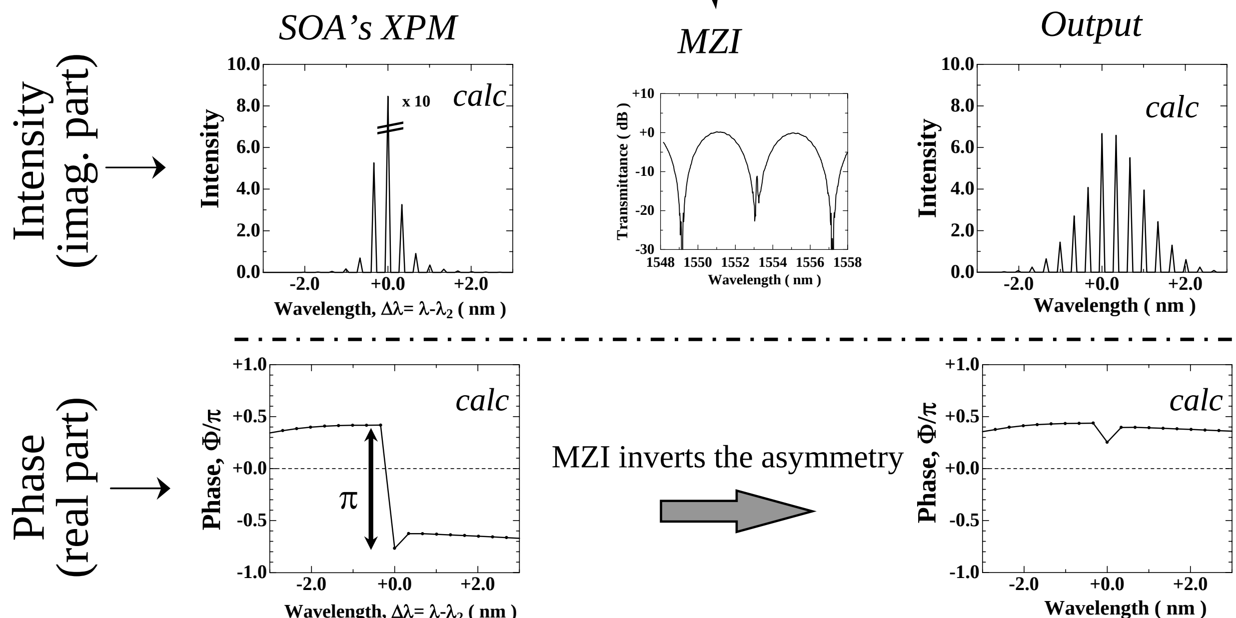
Wavelength-Chirpless output pulses

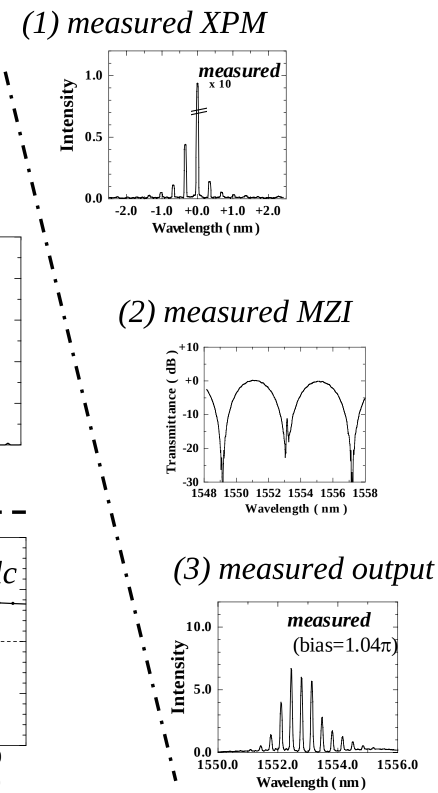
SMZ-DISC wavelength convertor

Y. Ueno et al., Jpn. J. Appl. Phys. 1999

Y. Ueno et al., IEEE PTL 1998







Asymmetric phase profile after SOA
(in contrast to the silica-fiber's nonlinearity)

The spectral phase locks from Red through Blue

Planning, FY 2002

- Ultrafast-and-Ultrabroadband Optical Logic Gatings

Enhancing the fundamental photon-electron mechanisms
that we have built for demux-type gatings (i.e. narrowband),
for more functional logic gatings (mustbe broadband & flat).

For pioneering the 21st-century technology with 'all in the optical domain'
such as wavelength conversion, regeneration, synchronization, and memories.

- Reliable Optical Clock Generation and its Lightwave Controls

Ultrahigh-frequency (10-40 GHz) and ultrashort (1-5 ps) pulse generation
without the mode-locking mechanism (our original scheme).
Potentials: low power consumption, long-term stability, optical integration.

Studying its ring cavity in the three-dimensional domains coherently
(i.e.: time [ps], optical frequency [THz], and electronic frequency [GHz] domains).

1st half of FY 2002: numerical simulation, 2nd half: kicks of experimental works.