Outline

— Introduction - Towards Tbs with Plasmonics
— Plasmonic Modulators – the POH Toolbox
— Applications in Optical Communications
— Summary
+34 million t CO2 equivalent
+15...40 %

Internet Usage due to COVID-19\[2]\n
Equipment power consumption\[4]\n
"Elephant in the room"

Global Data Center Traffic per year\[1\]
15 000 000 000 000 GB

Global Data Center Energy Consumption 2030\[3\]
3...15 %

Key Issue – Electrical ↔ Optical

Today’s EO modulators:
- Too slow
- Poor integration
- Too energy-consuming
Breaking The Bottleneck!

Plasmonic Modulators
- Small
- Fast
- Energy Efficient

Cross Section
Human Hair
Towards Tbs

- High symbol rates of >100 GBd
- Compact integration and parallelism
- Low power consumption
Plasmonic Modulators –
the POH toolbox
Plasmonic-Organic Hybrid Modulator

**Plasmonic Phase Modulator**

- The basic building block
- Surface plasmon polariton propagates along slot waveguide filled with nonlinear material
- Voltage drop across nonlinear material
  → Phase shift (Pockels effect)
Plasmonic Organic Hybrid Modulator

**Plasmonic Phase Modulator**

- Strong field confinement and good overlap of optical and driving field → High efficiency

- Metals of waveguide act as their own electrode → Small RC-constant → High speed

The POH Toolbox

Mach-Zehnder Interferometer

Phase Modulators
The POH Toolbox

Mach-Zehnder Modulator (MZM)

Phase Modulators
The POH Toolbox

Mach-Zehnder Modulator (MZM)

IQ-MZM

What About the Challenges?

- Plasmonic MIM waveguide losses: 0.5 dB/µm
- Small length → on-chip losses: 8 dB\[^{[1]}\]
- Different design:
  - Rings\[^{[2]}\]: 2.5 dB
  - Race track\[^{[3]}\]: <5dB
- Trade-off between losses and drive voltage → Dual-drive scheme

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\[^{[3]}\] A. Messner, et al., in ECOC’20, Tu1B-6(2020).
Let’s apply the **POH MZM** to Optical Communications
Dual-Drive POH MZM

- No travelling wave electrodes
  - Apply differential voltage drop over each phase shifter
    - 2x voltage drop

- No 50 Ω termination
  - Lumped capacitance
    - 2x voltage drop

222 GBd Demonstration

- 222 GBd NRZ data modulation
- Transmission over 120m
- No EO bandwidth limitation

Monolithic Integration

Summary

— Introduction - Towards Tbs with Plasmonics

— Plasmonic Modulators – the POH Toolbox
  — Phase modulator is basic building block
  — From MZM to IQ modulator

— Applications in Optical Communications
  — High speed (222 GBd)
  — Simple modulation format \(\rightarrow\) reduce power hungry DSP
  — Compact integration with platform of your choice