Technische Universität Braunschweig

TPG
THz Photonics Group

Grundlagen der Informationstechnik (HF-Technik/Photonik)

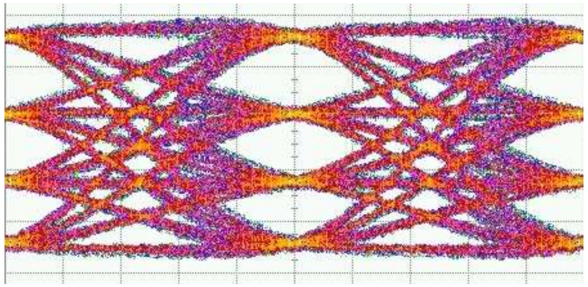
Motivation und Einführung

Thomas Schneider

Einführung

- **THz-Photonics**
  - **Bachelor**
    - **Lineare Optik/Photonik**
      SS
      5 Credits
    - **Optische Nachrichtentechnik**
      WS
      5 Credits
  - **Master**
    - **Nonlinear Photonics**
      WS
      5 Credits
    - **THz-Systemtechnik**
      WS
      5 Credits

Nyquist Silicon Photonics Engine (NyPhE)

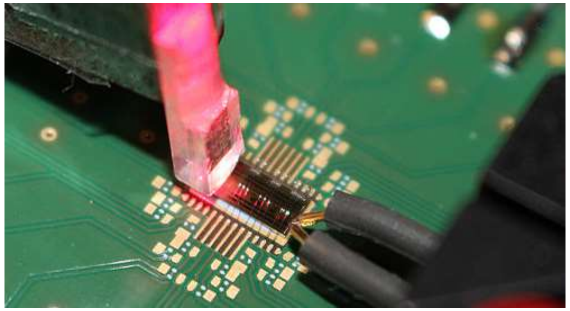


- Kointegragtion von hochkomplexen photonischen und elektronischen Funktionalitäten
- Signalübertragung mit Nyquist-Pulsen
- Integrierte 400 Gbit/s Transceiver für Datenzentren

Silicon-on-Insulator basierte Integrierte Optische Frequenzkämme für Mikrowellen-, THz- und Optische Anwendungen

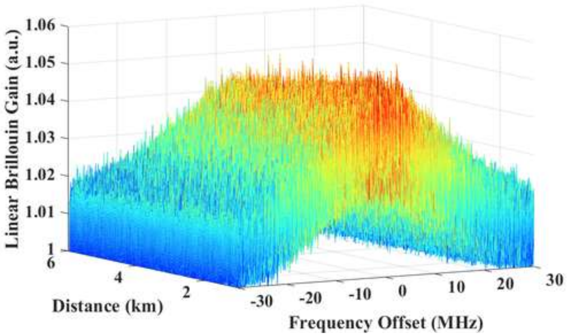
- Mikroresonatorstrukturen
- Integration in Siliziumnitrid und Silizium
- Anwendungen: Spektroskopie, Präzisionsfrequenz-messtechnik und optischen Uhren

PONyDAC (Präziser Optischer Nyquist-Puls-Synthesizer DAC)



- Umwandlung von digitalen in analoge Signale
- Verschachtelung von optischen Nyquist-Pulsen
- Voll integrierter photonischer DAC Chip
- Vielfache Bandbreite heutiger elektronischer Systeme

Künstliche Anpassung der Eigenschaften nichtlinear optischer Effekte für die Verbesserung verteilter Fasersensoren

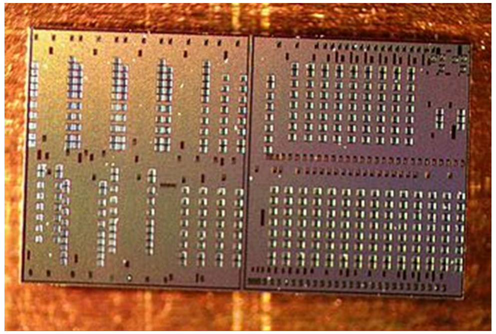


- Messung von Druck und Temperatur auf kilometerlangen Strecken mit sehr geringer örtlicher Auflösung
- Optische Brillouin-Zeitberecihsanalyse

Metrologie für die THz Kommunikation

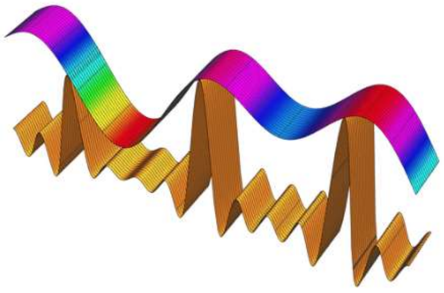
- Sehr schnelle drahtlose Datenkommunikation
- Datenraten größer 100 Gbit/s
- Terahertz-Frequenzbereich oberhalb von 300 GHz
- Metrologie für zukünftige THz-Kommunikationssysteme

Integrated Blocks for Optical Sinc-Shaped Nyquist Pulse Transmission



- Datenübertragung mit maximaler spektraler Effizienz
- Ideale Pulse ohne Interferenzen
- Integration auf Chalcogenid-on-SOI Plattform
- Ultrahohbe Bitraten durch TDM-WDM-Nyquist-Superkanäle

Optische Abtastung ohne optische Pulsquelle



- Grundkonzept der modernen Kommunikation
- Umwandlung von analogen zu digitalen Signalen
- Multiplikation eines Zeitsignales mit Pulsfolge
- vielfach höhere Bandbreite im Vergleich zu herkömmlicher Elektronik möglich

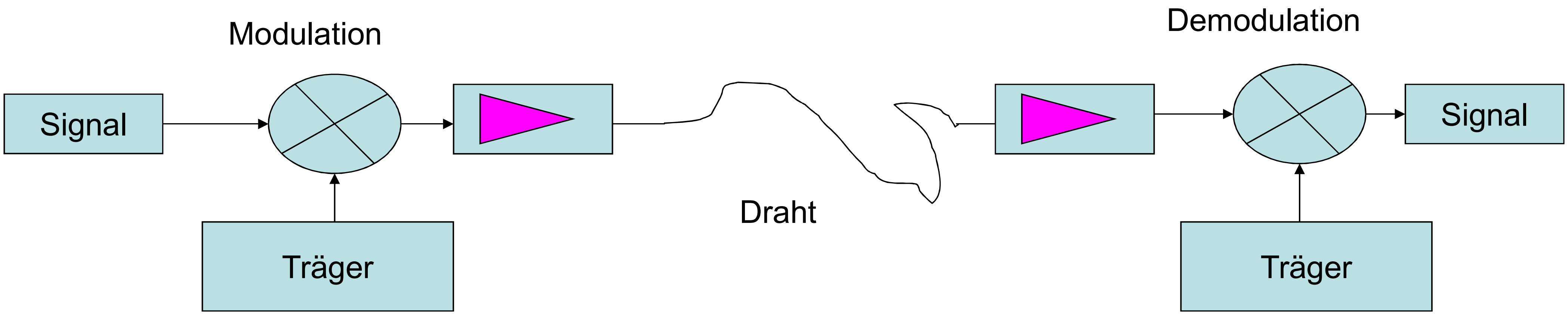
Inhalt

- Motivation und Einführung
- Die elektromagnetische Welle
- Der drahtlose Kanal
- Antennen
- Ausbreitung e/m Wellen
- Berechnung von Funkstrecken
- THz-Kommunikation
- Funksysteme
- Optische Kommunikation
- Silizium Photonik
- Plasmonik

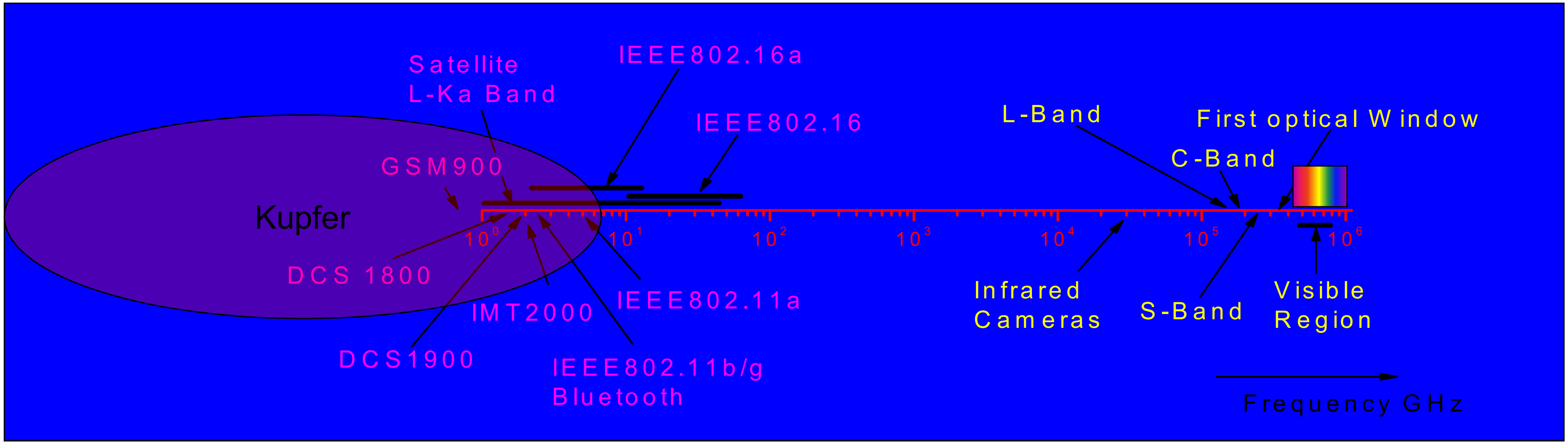
Inhalt

- **Motivation und Einführung**
- Die elektromagnetische Welle
- Der drahtlose Kanal
- Antennen
- Ausbreitung e/m Wellen
- Berechnung von Funkstrecken
- THz-Kommunikation
- Funksysteme
- Optische Kommunikation
- Silizium Photonik
- Plasmonik

Der Träger

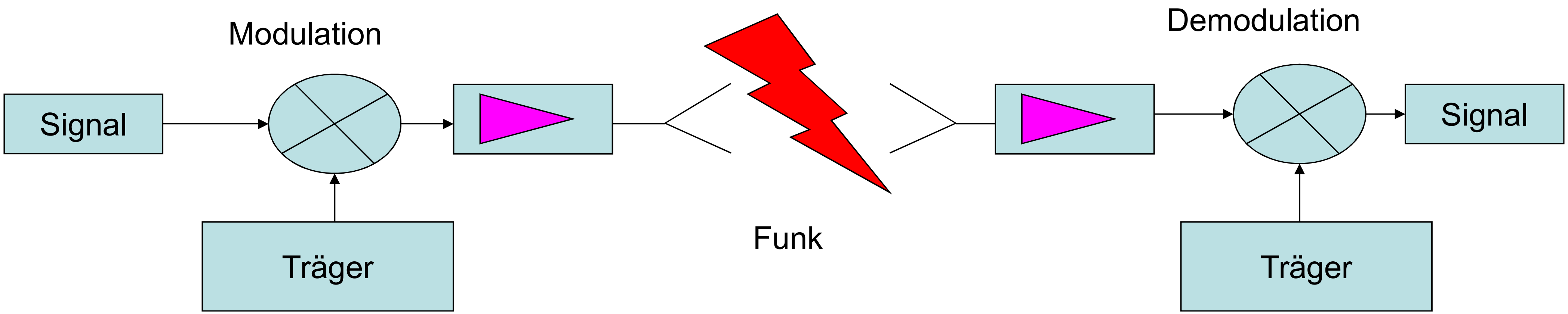


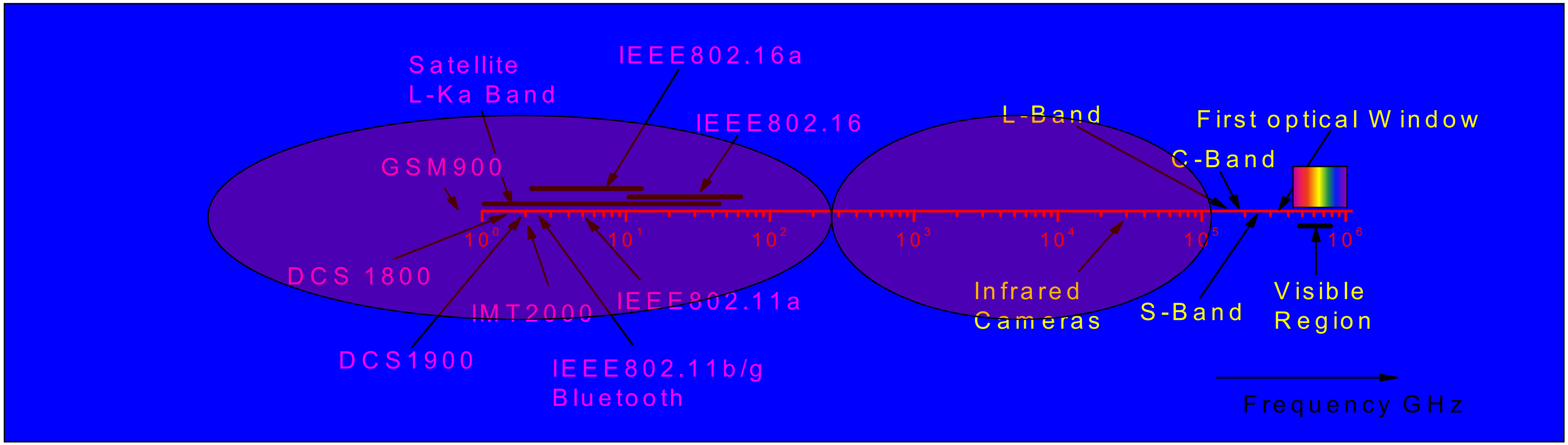
Modulation
Demodulation
Signal
Träger
Draht
Signal
Träger



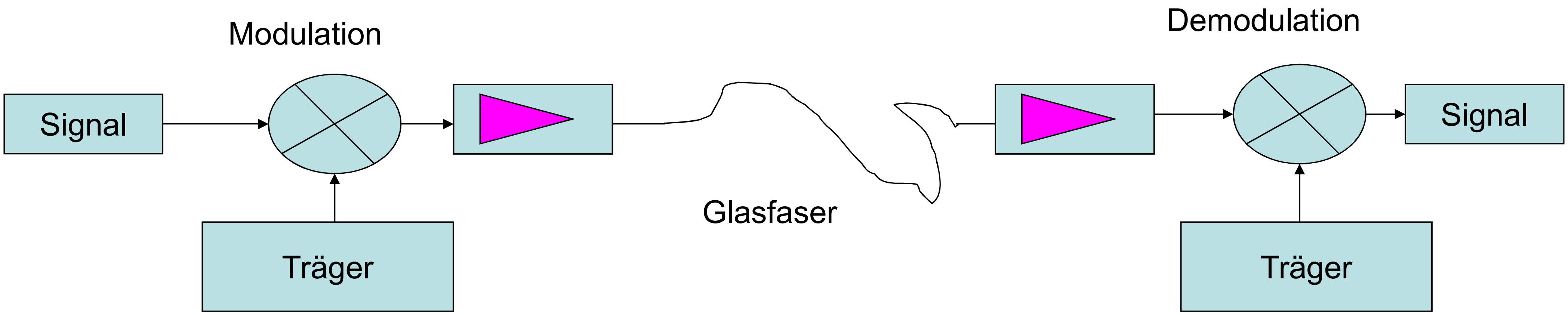
Satellite
L-Ka Band
IEEE802.16a
IEEE802.16
GSM900
Kupfer
DCS 1800
IMT2000
DCS1900
IEEE802.11a
IEEE802.11b/g
Bluetooth
L-Band
First optical Window
C-Band
Infrared
Cameras
S-Band
Visible
Region
Frequency GHz

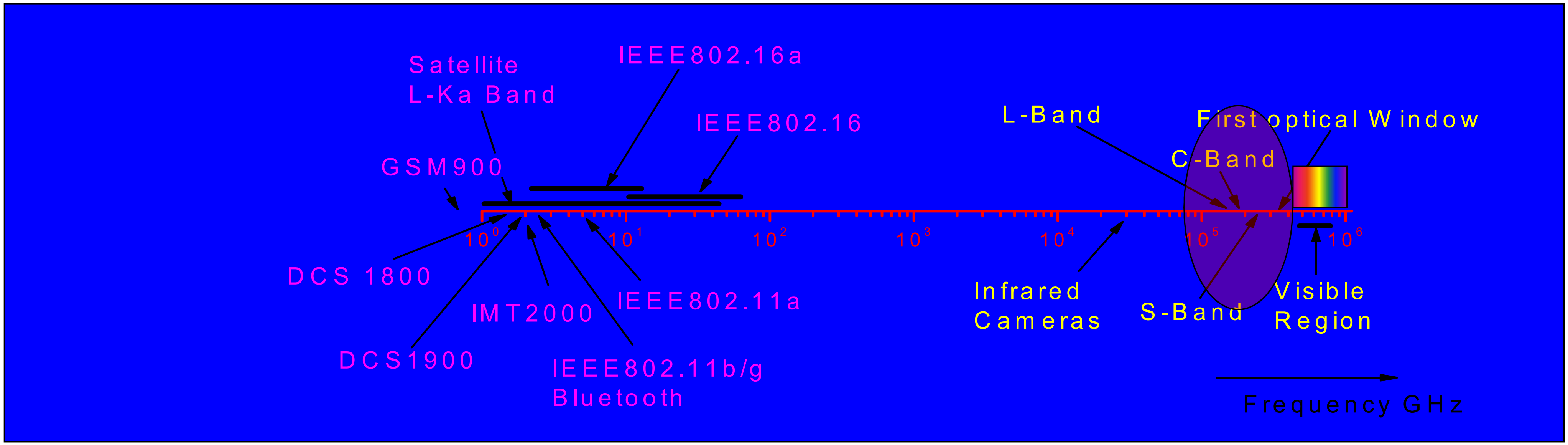
Der Träger


Modulation
Demodulation
Signal
Signal
Träger
Träger
Funk


Satellite
L-Ka Band
IEEE802.16a
IEEE802.16
GSM900
L-Band
First optical Window
C-Band
DCS 1800
IMT2000
IEEE802.11a
DCS1900
IEEE802.11b/g
Bluetooth
Infrared
Cameras
S-Band
Visible
Region
Frequency GHz

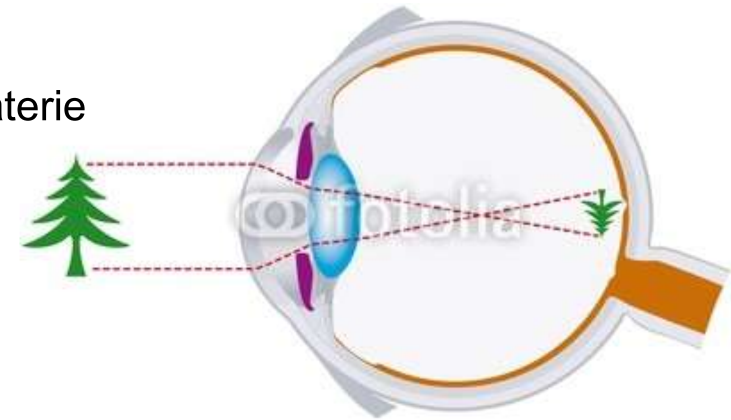
Der Träger


Modulation
Demodulation
Signal
Träger
Glasfaser
Träger
Signal

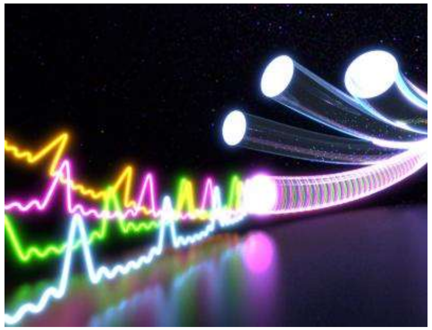

Satellite
L-Ka Band
IEEE802.16a
IEEE802.16
GSM900
L-Band
First optical Window
C-Band
DCS 1800
IMT2000
DCS1900
IEEE802.11a
IEEE802.11b/g
Bluetooth
Infrared
Cameras
S-Band
Visible
Region
Frequency GHz

Einführung

Optik: Aus dem Griechischen „zum Sehen gehörend".
Lehre vom Licht und seinen Wechselwirkungen mit Materie

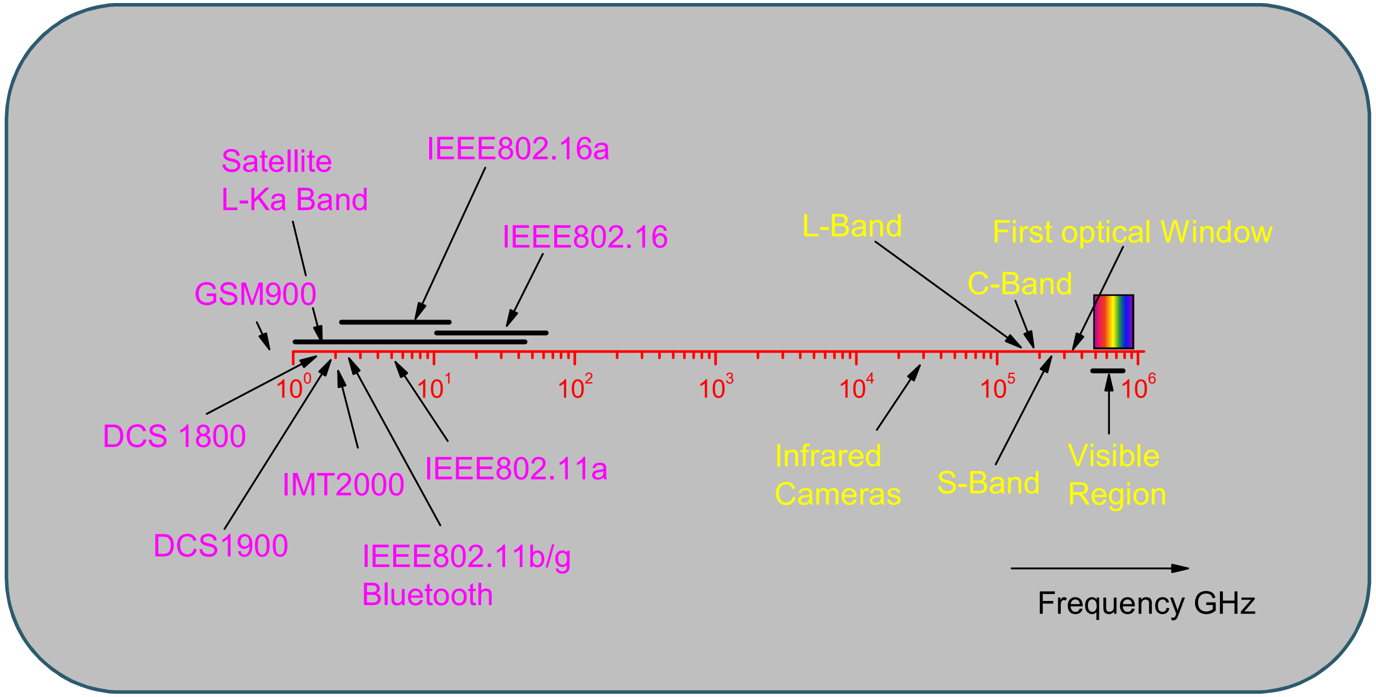


Photonik: Grundlagen und Anwendungen von optischen Verfahren und Technologien auf die Bereiche der Übertragung, Speicherung und Verarbeitung von Information.
Gleichbedeutend mit Optik, allerdings eher auf die Technologien bezogen.
Optik ist eher eine klassische Sicht, während Photonik die Quantensicht mit einbezieht.

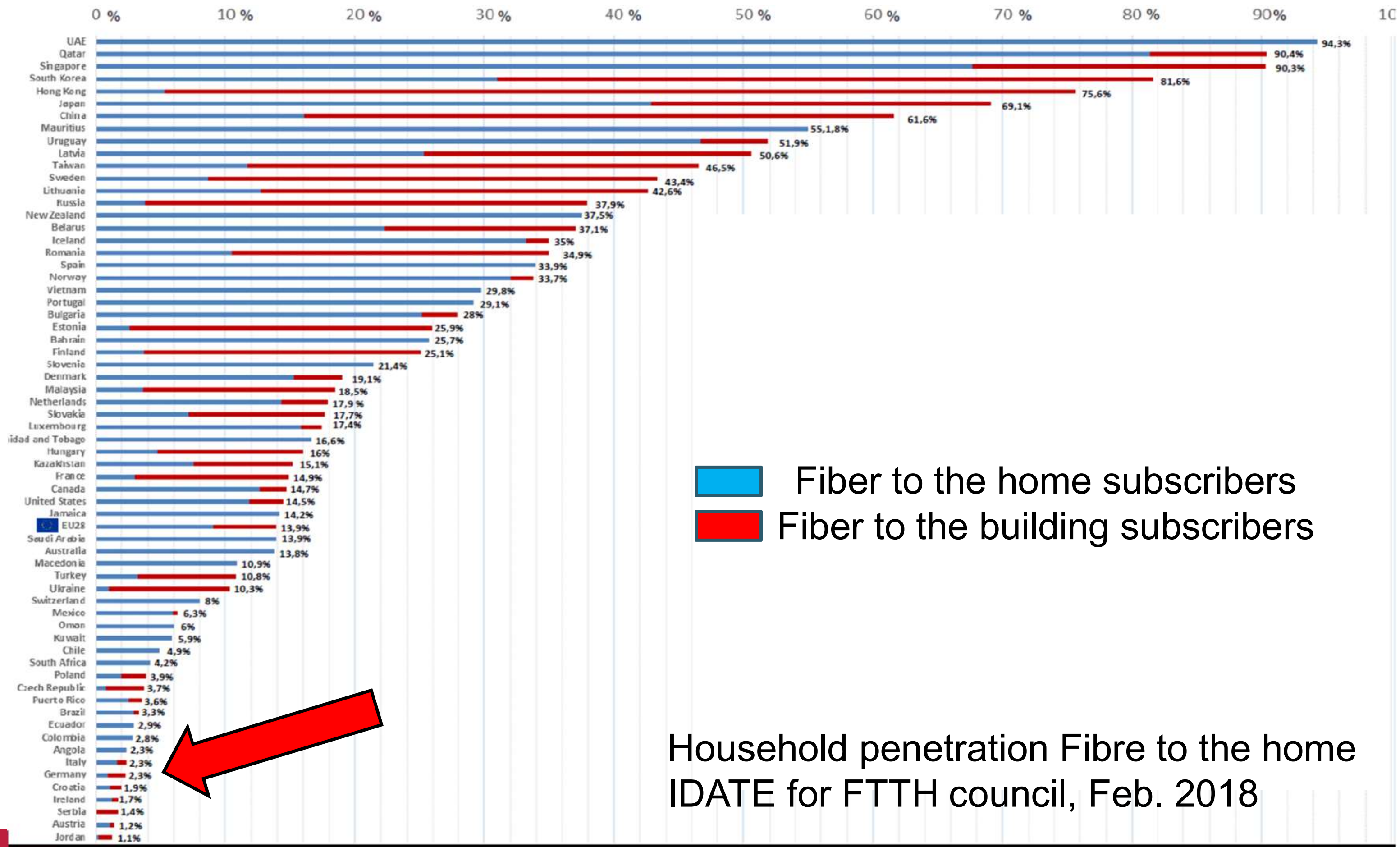


Jamani Caillet, EPFL

Einführung


Satellite
L-Ka Band
IEEE802.16a
IEEE802.16
L-Band
First optical Window
C-Band
GSM900
10^0
10^1
10^2
10^3
10^4
10^5
10^6
DCS 1800
IMT2000
IEEE802.11a
Infrared
Cameras
S-Band
Visible
Region
DCS1900
IEEE802.11b/g
Bluetooth
Frequency GHz

Introduction



Household penetration Fibre to the home
IDATE for FTTH council, Feb. 2018

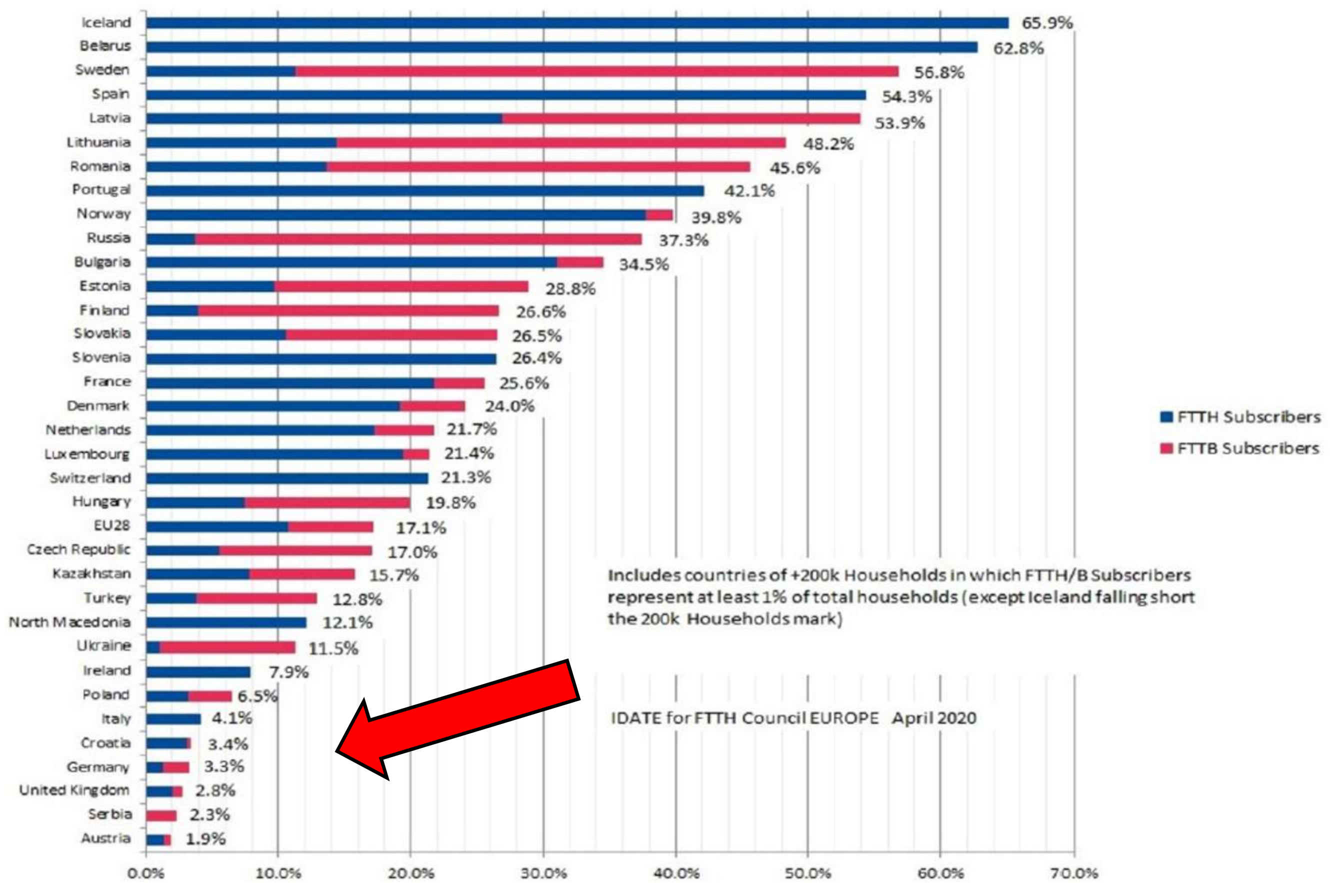
Technische Universität Braunschweig

Terahertz Photonics Group TPG

Einführung

European FTTH/B Ranking

Press release (EMBARGO: 23 April 2020 14.00 CET)



Einführung

This year[4], the country adding the most subscribers is located in Western Europe. France added 1.923.000 new FTTH/B subscriptions and Spain came second adding 1.650.820 new FTTH/B subscribers. **Other countries also experienced an outstanding increase in their number of subscribers** such as Greece (+285%), Ireland (+185%), Switzerland (+176%), Belgium (+111%) and Italy (+45.3%).

[4] Between September 2018 and September 2019

Maximum speed communications I

Nearly two-thirds of the global population will have Internet access by 2023. There will be 5.3 billion total Internet users (66 percent of global population) by 2023, up from 3.9 billion (51 percent of global population) in 2018.

The number of devices connected to IP networks will be more than three times the global population by 2023. There will be 29.3 billion networked devices by 2023, up from 18.4 billion in 2018.

M2M connections will be half of the global connected devices and connections by 2023. The share of Machine-To-Machine (M2M) connections will grow from 33 percent in 2018 to 50 percent by 2023. There will be 14.7 billion M2M connections by 2023.

Within the M2M connections category (which is also referred to as IoT), **connected home applications will have the largest share and connected car will be the fastest growing application type**. Connected home applications will have nearly half or 48 percent of M2M share by 2023 and Connected car applications will grow the fastest at 30 percent CAGR over the forecast period (2018–2023).

Over 70 percent of the global population will have mobile connectivity by 2023. The total number of global mobile subscribers will grow from 5.1 billion (66 percent of population) in 2018 to 5.7 billion (71 percent of population) by 2023.

5G devices and connections will be over 10 percent of global mobile devices and connections by 2023. By 2023, global mobile devices will grow from 8.8 billion in 2018 to 13.1 billion by 2023 – 1.4 billion of those will be 5G capable.

bigger desktop machine needs a fan. A data centre as large as those used by Google needs a high-volume flow of cooling water. And with cutting-edge super-computers, the trick is to keep them from melting. A

of the centre's buildings. Current trends suggest that the next milestone in computing — an exaflop machine performing at 10^{18} flops — would consume hundreds of megawatts of power (equivalent to the output of a small nuclear plant) and turn virtually all of that energy into heat.

processors pump out heat from more than one billion transistors. If a typical desktop machine let its chips simply radiate their heat into a vacuum, its interior would reach several thousand degrees Celsius.

Yet the brain is fantastically efficient compared to electronic comput-ers. It can achieve five or six orders of magnitude more computation for each joule of energy consumed. Michel is convinced that the brain's

This helps the brain to make much more efficient use of space. In a computer, as much as 96% of the machine's volume is used to transport heat, 1% is used for communication (transporting information) and just one-millionth of one per cent is used for transistors and other logic devices. By contrast, the brain uses only 10% of its volume for energy supply and thermal transport, 70% for communication and 20% for com-putation. Moreover, the brain's memory and computational modules are

Nature 492, 174 (2012)

Silicon Photonics

ETH zürich

Behind the Rack – in the Line Card

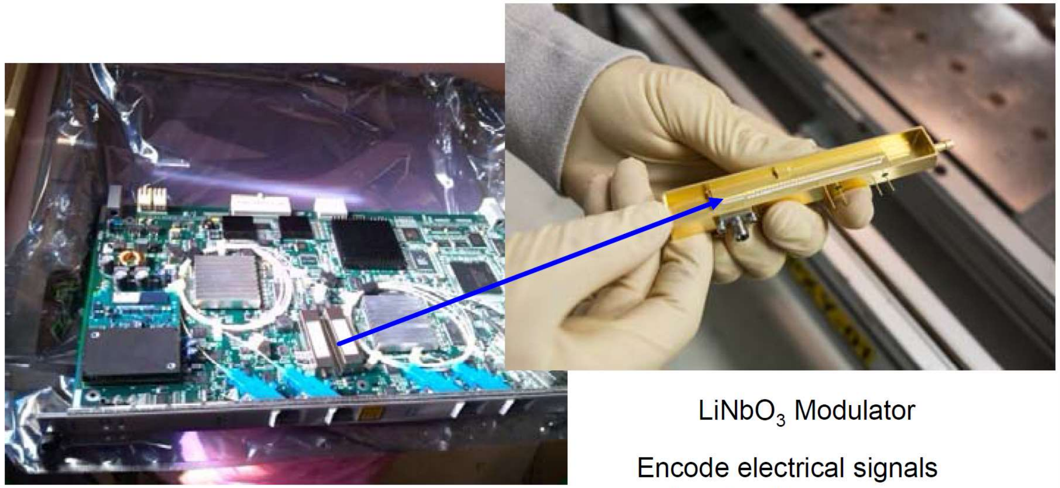
Huawai, 4 port Line Card

Institute of Electromagnetic Fields (IEF) Juerg Leuthold | 12.03.2016 | 4

Silicon Photonics

ETH zürich

Behind the Rack – in the Line Card



Huawai, 4 port Line Card

$LiNbO_3$ Modulator

Encode electrical signals onto optical laser.

Silicon Photonics – Why ?

Silicon is transparent in the infrared spectral range (esp. λ =1.3 - 1.5 μm)

Highly mature **CMOS-process** technology enables processing of optical structures in silicon wafers

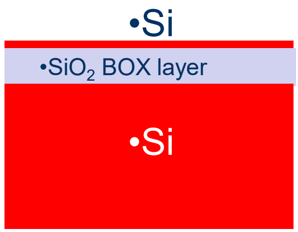
This allows for:

- Small Footprints
- High switching speeds
- Energy efficiency
- High volumes
- Low cost production
- High complexity photonic integrated circuits (PICs)

Possibility of combination of photonic components and electronic circuits on the same chip (**Co-Integration**)

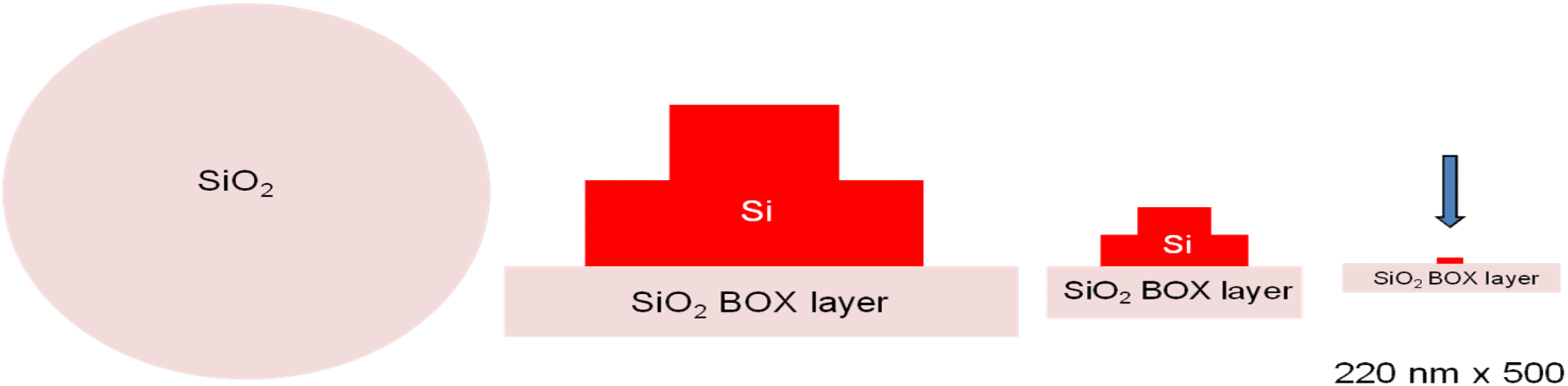
SOI – technology for Photonic Integrated Circuits

- **SOI**
- **substrate**



- **Refractive index of**
- Silicon: n_{Si} = 3.5
- Silicondioxid: n_{SiO2} = 1.45

- **Waveguiding**



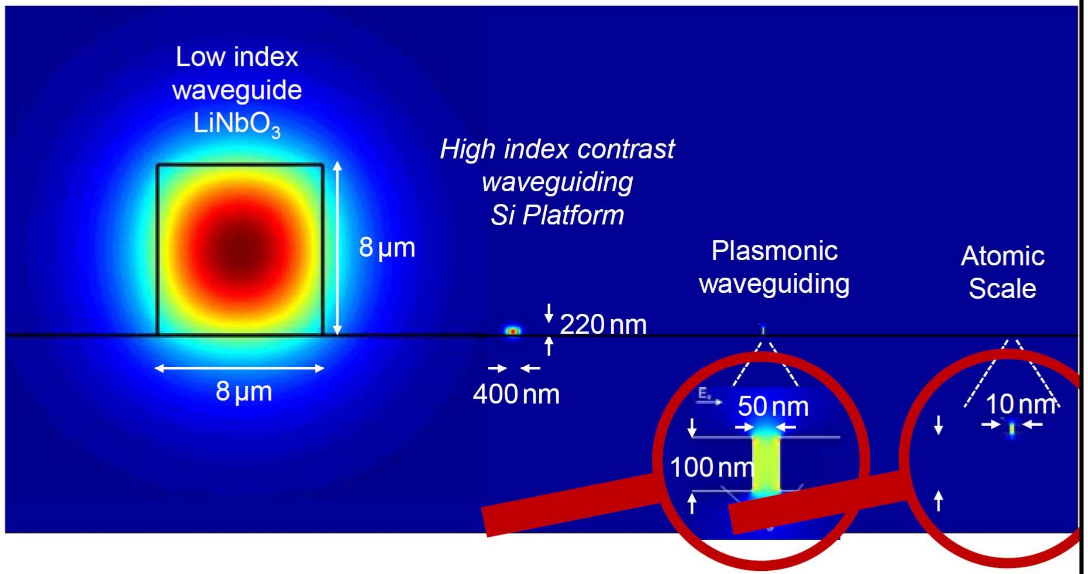
Core of an optical fiber (9 µm)

4 µm SOI rib waveguide

* 1.5 µm SOI rib waveguide

220 nm x 500 nm SOI waveguide (nanowire)

Scaling to Smaller Dimensions



Zusammenfassung

Kommunikationssysteme beruhen auf elektromagnetischen Wellen.

Das Internet und die gesamte moderne Kommunikation nutzen Wellen im (optischen) Bereich für den Transport der Daten.

Für den Zugang zum Internet werden hingegen meist Wellen im Radiofrequenzbereich eingesetzt.

Auch in Datenzentren im Computer und auf dem Chip wird Photonik eingesetzt.

Für die weltweite Kommunikation werden Wellenlängen um 1550 nm (~193 THz) zur Übertragung in Glasfasern benutzt.

Optische Verstärker und die elektronische Signalverarbeitung ermöglichen Datenraten von mehreren Tbit/s in einer einzigen Faser.

Inhalt

- Motivation und Einführung
- **Die elektromagnetische Welle**
- Der drahtlose Kanal
- Antennen
- Ausbreitung e/m Wellen
- Berechnung von Funkstrecken
- THz-Kommunikation
- Funksysteme
- Optische Kommunikation
- Silizium Photonik
- Plasmonik