EXALOS
The bright light source company

SLED in SD-OCT: Critical Imaging Tools for Eye Surgery and Diagnostics

Kevin Hsu: Director of Business Development,Europe

EPIC Online Technology Meeting: Laser Vision Correction (LASIK, PRK, LASEK, RLE), Eye Surgery and Diagnostics

Outline

- EXALOS Portrait
- What is SLED (Superluminescent Light Emitting Diodes)
- NIR-SLED: Broad Selections
- SLEDs in Spectral-Domain OCT:
  - Implementation and key parameters
- Advancement of Combi-SLEDs for UHR-OCT
- Visible-OCT using discontinuous RGB-SLEDs
- EXALOS Core Competencies

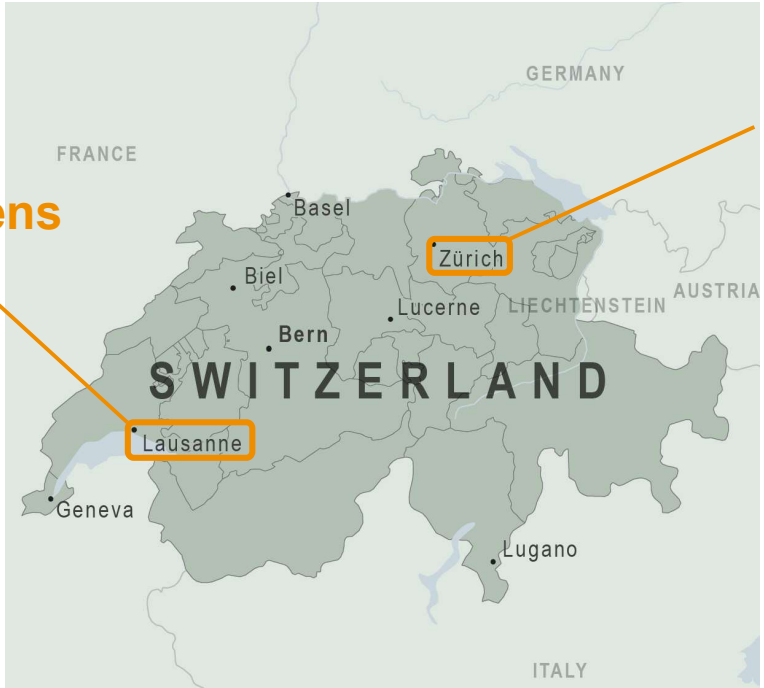
Relevance to this meeting:
OCT in Laser Surgical Machines

EXALOS

EXALOS: Semiconductor-Based Light Source Company

- Founded in 2003.
- Fabless manufacturing of NIR semiconductor devices & in-house RGB source developments
- ISO 9001 certified since 2004
- Worldwide sales in over 20 countries & Over 500 thousand devices in the field
- **#1 leader in SLEDs for Optical Coherent Tomography and optical sensor markets**

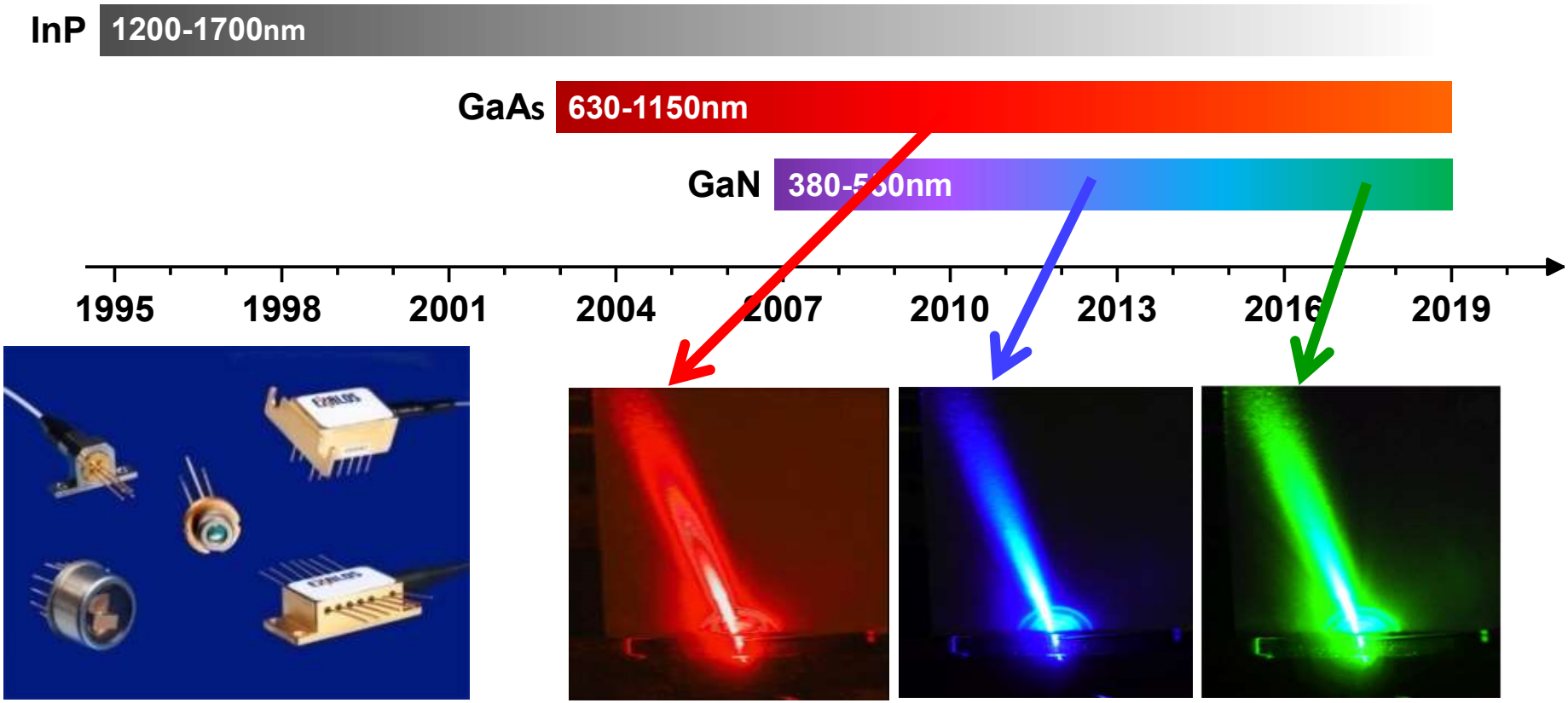
R&D Site Ecublens (Lausanne)
- Development of RGB SLEDs/LDs
- GaN MOCVD growth
- FEOL/BEOL wafer processing development



+ Sales offices in US (East & West coast) and China

HQ Schlieren (Zurich)
- Development of NIR products, integrated modules, electronics, etc.
- Sales
- Management

EXALOS' Products & Material Systems



- 20+ years experience with InP devices
- 15+ years experience with GaAs devices
- 10+ years experience with GaN devices

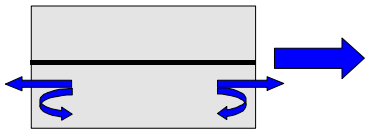
Unique Position in RGB SLEDs & LDs !

What are Superluminescent Diodes?

SLEDs: A Bridge between Laser Diodes (LDs) and LEDs

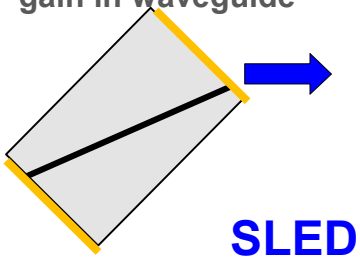
Stimulated Emission (narrowband, directional)	ASE (broadband, directional)	Spontaneous Emission (broadband, not directional)

Laser cavity, gain, feedback



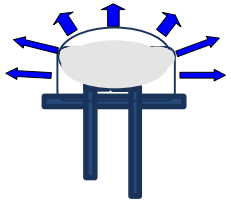
FP LD

Single-pass gain in waveguide

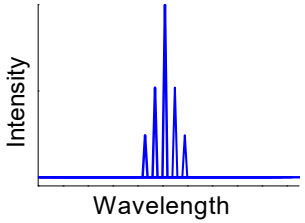


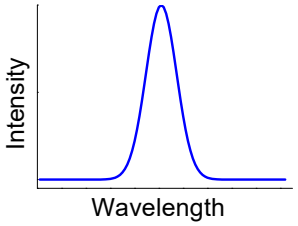
SLED

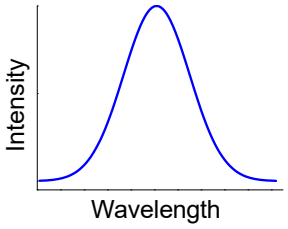
No cavity, No gain No feedback



LED

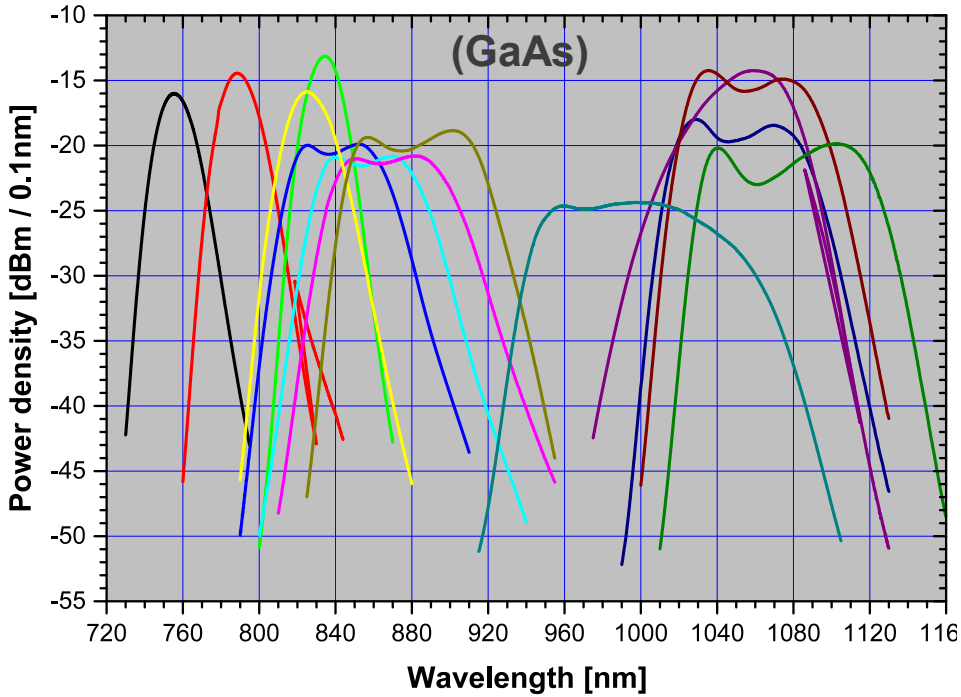




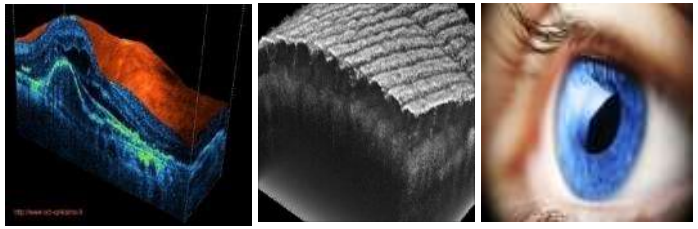


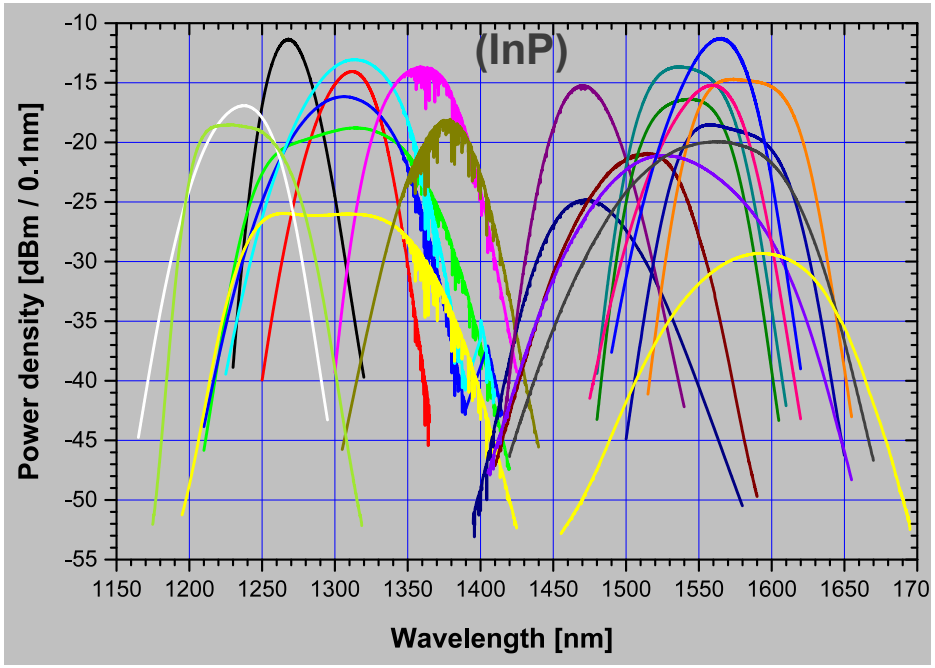
Speckle	✗	✓	✓
Directionality	✓	✓	✗
Polarization	✓	✓	✗

EXALOS NIR-SLEDs: Broad Selections

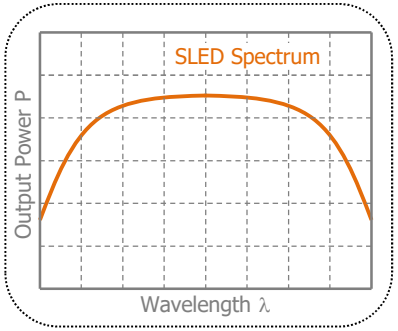


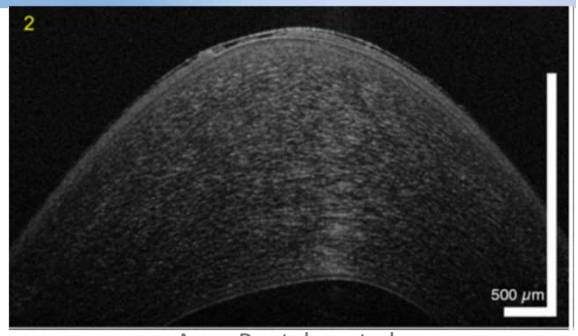
Broad SLED selections for Various OCT applications



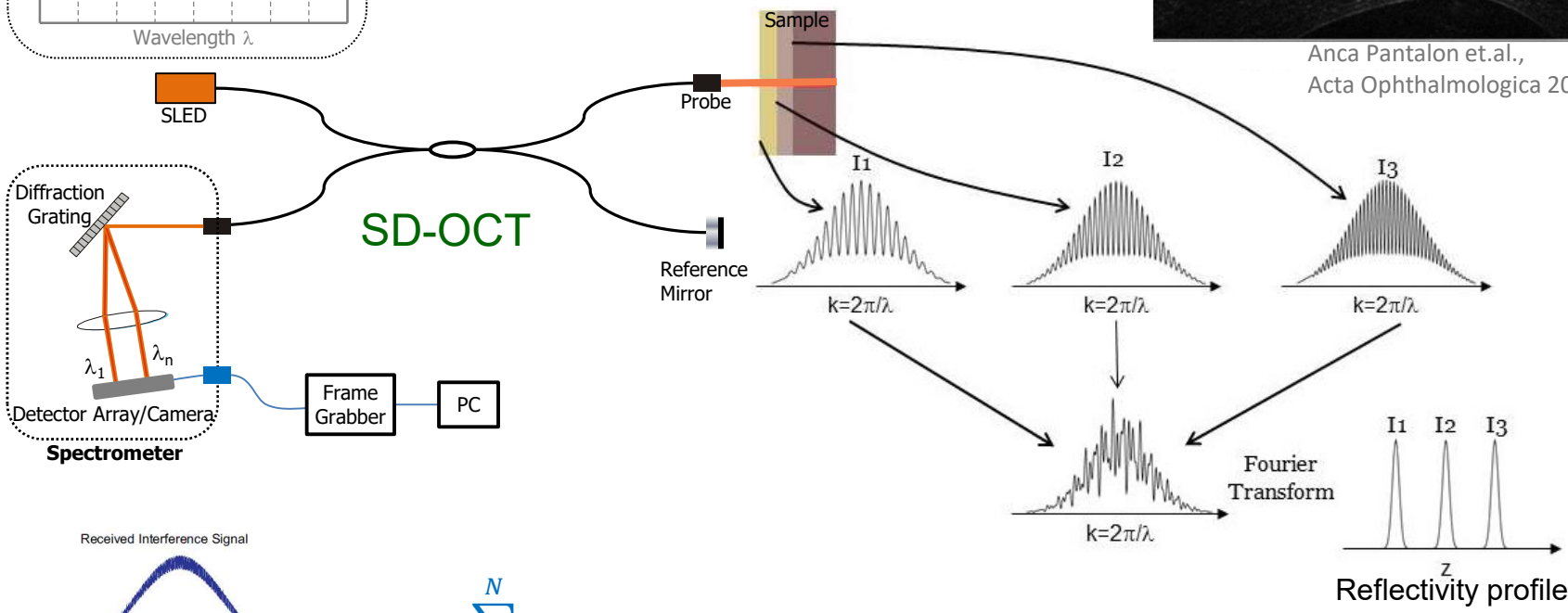


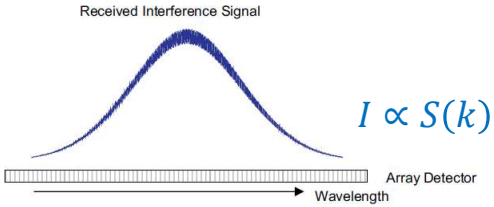
Spectral-Domain OCT Implementation





Anca Pantalon et.al.,
Acta Ophthalmologica 2019

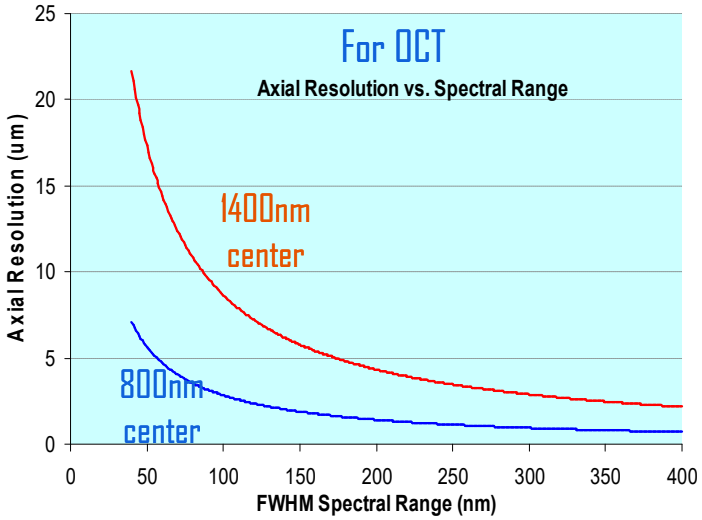




$$I \propto S(k) \sum_{n=1}^{N} \sqrt{R_R R_{Sn}} \cdot \cos[2k(ZR - ZSn]$$

Key Parameters in SD-OCT

- **750nm ~ 900nm:** Cornea & Retinal imaging, low water absorption, sharp contrast from high scattering
- **1060nm +/- 50nm:** Retinal, choroidal layer imaging, whole-eye imaging, low water absorption, low dispersion, lower scattering and higher power limit allowing deeper retinal penetration
- **1310nm +/- 75nm:** Anterior chamber imaging, tissue imaging, lower scattering allowing enhanced imaging contrast at deeper tissue penetration



Spectral Bandwidth ⟷ Axial Resolution

Gaussian spectrum

$$\delta z = \frac{2\ln 2}{\pi}\frac{\lambda_0^2}{\Delta\lambda}$$

Wavelength

Axial resolution

3dB-BW

Spectral Sampling Interval ⟷ Imaging Depth

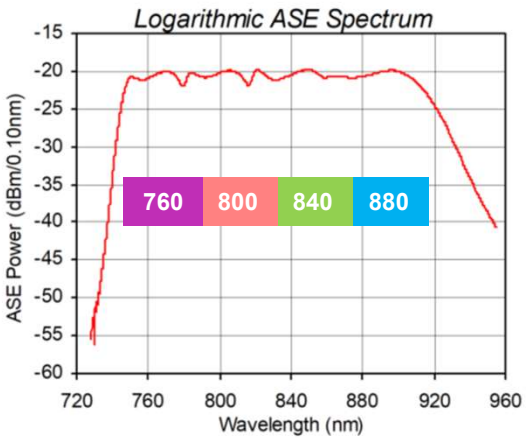
$$\Delta d = \frac{1}{4}\frac{\lambda_0^2}{\delta\lambda}$$

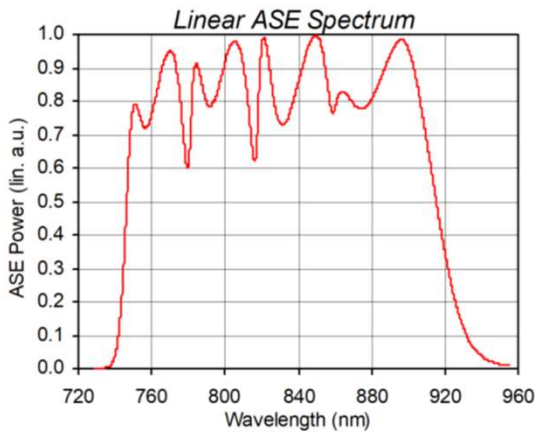
Wavelength

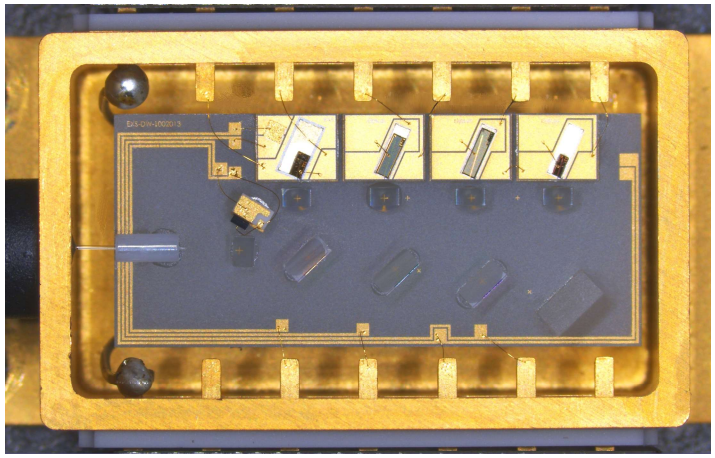
Sampling interval

Non-complex conjugate resolved Imaging depth

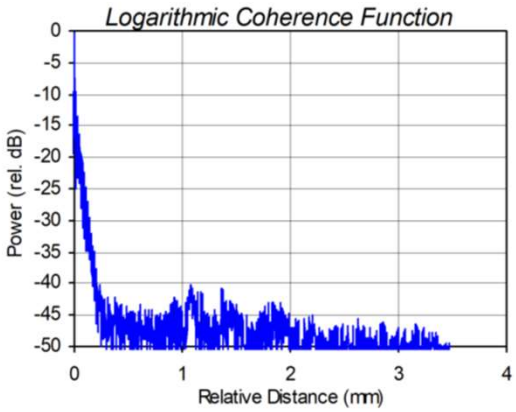
840nm Combi-SLED in 14pin BTF Polarization aligned

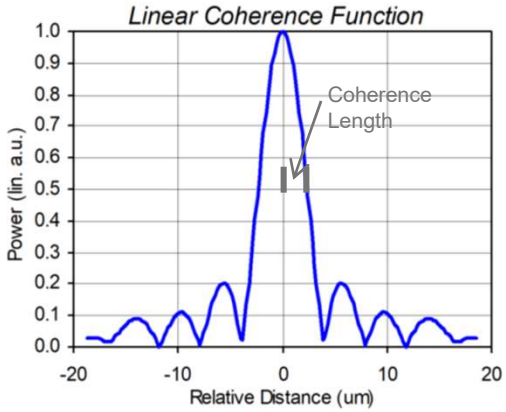


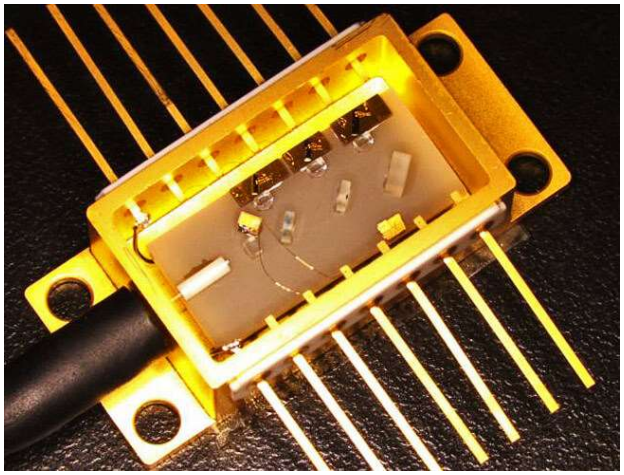




Max Power: 15.44 mW
Center WL: 830.9 nm
3-dB BW: 168.8 nm
10-dB BW: 189.9 nm
Coherence Length (air): 2.4 μm (HWHM of the coherence function)







Advantages of EXALOS NIR Combi-SLEDs

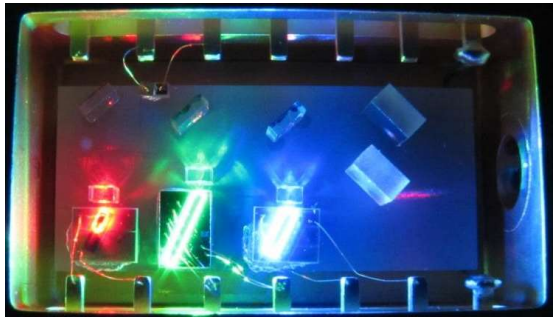
Advantages of EXALOS NIR Combi-SLEDs

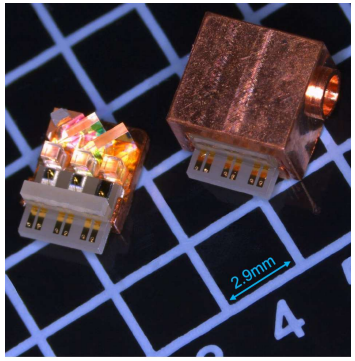
- Compact 14-pin Optical Module
- Ultra-broad optical spectrum
- High output power
- Ultra-low noise (RIN)
- Multiple spectral ranges
- Polarization aligned (compared to combined fiber-pigtailed SLEDs)
- Compact OEM device with drive electronics available

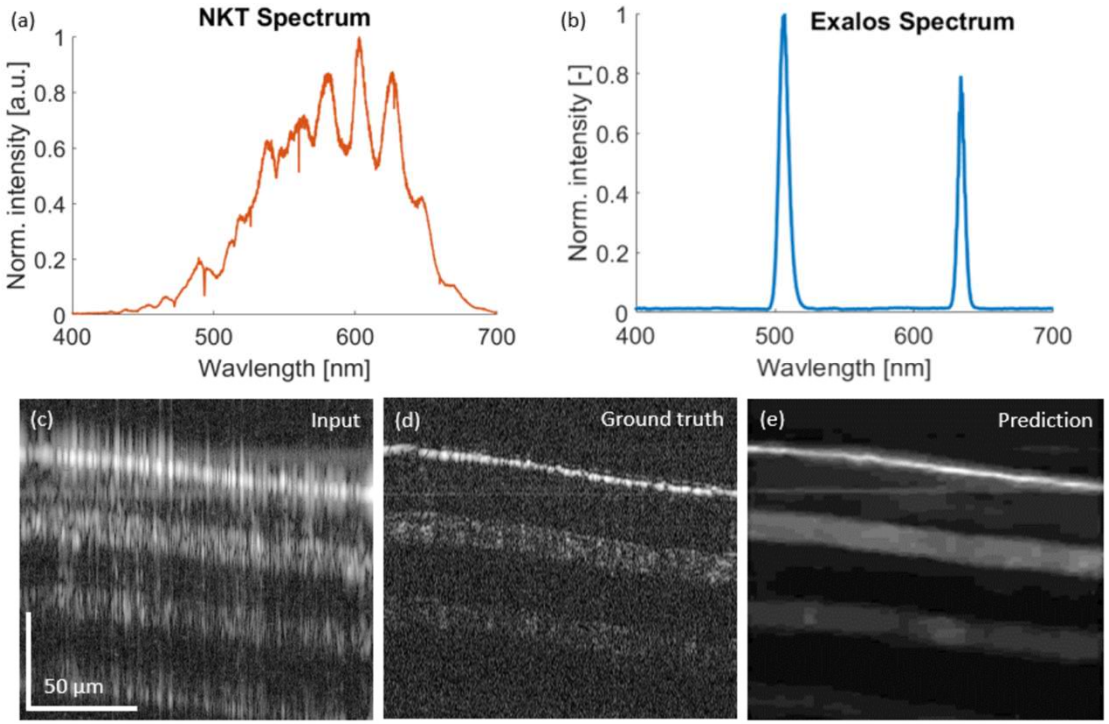
Other BBS such as Ti:Sapph lasers or supercontinuum sources also offer large bandwidths and high output powers. However, these light sources are costly, mostly bulky and have a higher relative intensity noise, thus provide lower SNR compared to SLEDs.

Combi-SLED	Combi-2	Combi-3	Combi-4	Combi-4	Combi-4
3dB BW	100-105 nm	135-140 nm	165-170 nm	170-180 nm	~320 nm
10dB BW	~120 nm	~160 nm	~190 nm	~210 nm	~400 nm
10dB spectral range	810-930 nm	770-930 nm	740-930 nm	1200-1400nm	1250-1650 nm
Coherence length in air	4.3-4.4 µm	3.0-3.1 µm	2.3-2.4 µm	~5.4 µm	
Coherence length in tissue	3.2-3.3 µm	2.2-2.3 µm	1.7-1.8 µm	~4 µm	
Output power (ex-fiber)	8-10 mW	11-13 mW	14-16 mW	18-23 mW	40-50 mW

Reconstruction of Visible-OCT images based on conditional generative adversarial network using discontinuous RGB-SLEDs







These results are a promising first step to reconstruct the depth resolution of OCT images generated by gapped optical spectra and opens the horizon for multiple other applications in the field of OCT using discontinuous light sources.

The imaging results: (using conditional generative adversarial network)
(a) The used spectrum of the NKT source.
(b) The used spectrum of the EXALOS RGB-SLED source (blue not used).
The intensity B-scan images of the scotch tape imaging (c)-(e):
(c) Input data retrieved with the EXALOS RGB source.
(d) The ground truth data acquired with the visible light NKT source.
(e) cGAN predicted data for the input data with the discontinuous light source.

Ref: Antonia Lichtenegger et.al., European Conferences on Biomedical Optics 2021 (ECBO): EW3C.3

Thank You

Bright Light for Everyone

EXALOS provides reliable and high-performance SLEDs for applications in

- Biometry
- Eye Disease Diagnostics
- Image-Guided Ophthalmic Laser Surgery

EXALOS Core Competencies

- Modeling & design of semiconductor devices (SLEDs, SOAs, LDs) from 390-2500 nm
  - Advanced epitaxy design (GaAs, InP, GaN)
  - Complete 3D device modeling
- Free-space optics design
- Micro-optical assembly and packaging
- Low-noise and embedded electronics
- OCT systems and real-time signal processing
- Supply chain management
  - Fabless semiconductor manufacturing model for GaAs & InP
  - In-house Epitaxy and Fabrication of GaN-based devices