IVA- JSPS Seminar The Future is Light



The Blue Laser and its Application in Modern Technologies

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21st Century – the Century of the Photon

Photonics – the physical science of light

Mastering of the photon relies on *scientific progress and innovation* in: optics, material science, electrical engineering, nanotechnology, physics, chemistry and biology

Where is Photonics important?

Information and Communication ٠ Technologies (ICT)



Life Science and healthcare

Manufacturing & quality control •



Lighting, displays and solar energy ٠







Security, metrology ٠ and sensors





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Photonics is everywhere!

Photonics is a Key Enabling Technology for Europe

as acknowledged by the European Commision in 2009

••• PHOTONICS²¹

Photonics - A Key Enabling Technology of Europe

One of the most important industries for the future with substanitial leverage effect on our economy, workforce and welfare



Lasers

• What ?

A 50⁺ old light bulb

- How ?
- •Why should they be blue ? Where ?



Basic Laser



 R_{n}

 E_0



Atoms in a matrix

Energy diagram for a laser stimulated emission

 E_2

 E_1

LASER Action

May 17, 1960: Ted Maiman's ruby laser



Laser History

- 60-ties laser invented and most effects discovered
- 70-ties a solution looking for a problem ...
- 80-ties problems discovered!
- 90-ties commercial success!!
- 00-ties everybodies toy!!!

Gas lasers -

Diode lasers Diode Pumped Solid-state lasers Fiber lasers

The first blue laser Ar-ion laser 0.1 % efficient ...





Laser revenues and 2018 forecast





The diode laser

the smallest and most frequently used laser



Nobel prize 2000 Zhores I. Alferov A.F. loffe Physico-Technical Institute, St. Petersburg The diode laser and the optical fiber are the backbone of telecommunication







First blue diode laser 1996 - based on GaN

The Diode-Pumped Solid-State Laser

Converts a poor diode laser beam to a high quality laser beam

- spatially, spectrally and temporally engineered



Diode pumped solid-state laser – the green pointer



Pumping solid-state lasers with blue diodes



Energy level scheme for Pr³⁺ in YLF

Blue pumped Pr:YLF lasers





Nobel Laureate Shuji Nakamura with Nichia Blue diode lasers





What are lasers really good for?

(In the early days you were still allowed to smoke in your lab...)

Everything...





Blue laser based lighting – laser headlights



Blue lasers excite a yellow phosphorus. It emits intense white light that shines backward onto a reflector forming the white light beam.





Optical Storage relies on Laser Diodes

- diffraction limits the spot size



DVD (red laser diode)





Blue laser (Blu-Ray/HD DVD)



1 ##25.0 kV 200E4 2605/99 DUR F05

Blue light generated with AlGaAs diode laser



IEEE Photon. Technol. Lett., 1, 316, 1989

Photonics for data storage and data centres



5D data storage with ultrafast nanostructuring in quartz: unlimited lifetime 700 MB



5 GB



50 GB



360 TB

Data centres are extremely energy hungry and some projections indicate a 20% share of the electricity consumption for the ICT sector

Photonic Integrated Circuits (PICs) might be a solution



Under water communication

Water has a minimum absorption in the blue



Blue Laser Diode Enables Underwater Communication at 12.4 Gbps





Full HD 1080p

·

Blue laser writing of masks and displays



126ft

Laser printers and Graphics





... micro-projectors, head-up displays, laserTV



Imaging and displays – large laser projectors





Manufacturing

3D printing or additive manufacturing



Biophotonics

"Development and application of optical techniques, particularly imaging, to the study of biological molecules, cells and tissue"

Biophotonics where blue lasers are used:

- Medical diagnosis together with imaging and sensors
- Surgery and medical treatment
- Testing of drug and food quality
- Agriculture



A huge potential for photonic technologies

Health care spendings will increase substantially (>20% of GDP by 2050)

Focus is changed from treating to keeping people healthy

Societal evolution is asking for new technologies!

Shift to a new healthcare model:

- Preventive
- Predictive
- Personalized
- Participatory



Imaging and Sensors

- Fluorescence Spectroscopy
- Visualization
- In-vitro and in-vivo

Multispectral imaging

three-dimensional dataset with two spatial dimensions and spectrum



tissue physiology, morphology, and composition for diagnosis

Dental fluorescence imaging





- Photodynamic therapy
- Skin treatment (acne) and tattoo removal
- Cornea surface reshaping

Anti-microbial photodynamic therapy with Riboflavin (B_2) 447nm laser applied with Riboflavin as photosensitizer.

Phototherapy of oral cancer

Blue laser and Riboflavin as a new treatment for Malaria

Retinal photocoagulation using blue-green laser - 488/514 nm





Keratoconus treatment





Advanced Light Microscopy – Nanoscopy

STimulated Emission Depletion microscopy

- A laser is exciting a fluorescently marked sample
- The outer parts of the fluorescent spot is quenched
- Only emission from the central spot is recorded



http://zeisscampus.magnet.fsu.edu/articles/su perresolution/introduction.html Difference between confocal and super resolution view of a human cell. Credit: Dr. Dr. Kandasamy Biomedical Microscopy Core University of Georgia.

Biotechnology and Pharmaceutics

Lab on a chip – chip based tests for lab and doctor's office Fluorescently labeled antibodies bindes to antigenes on the sample surface (virus or bacteria) systematic and fast analysis of substance reactivity

















Flow cytometer Fluorescence-activated cell sorting (FACS)

ROYAL INSTITUTE OF TECHNOLOGY

- Cell counting through biomarker detection
 - Analysis cells flowing in a stream
 - Multiparameter analysis (phys, chem characteristics)
 - Up to thousands of particles per second
 - Diagnosis eg. blood cancer and others
 - FACS: extending the analysis for sorting cells



Becton-Dickinson fluorescence activated cell sorter

Advantages of FACS

Precision. Sensitivity. Single cell analysis. Sampling statistics. High-throughput.



Disadvantages of FACS

Bulky and costly (200.000 USD). Requirement of highly trained operators. Relatively large volume of sample required (100ul)











Multifunctional Optical Fibers

Multi-functional optical fibers - a platform for study of cells

Searching, collecting and counting μ m-size particles



Scil



OF TECHNOLOGY

High performance micro-flow cytometer based on optical fibers





High throughput (2500/s), precision and sensitivity Small, compact and inexpensive. Possible for point-of-care applications





Optogenetics

How optogenetics works

protein from algae Take the gene for this protein... Stimulate neurons with light and express light-sensitive ion channels - measure the effect This protein is an ion channel that opens in response to blue light So now you can cause neurons to fire just by flashing blue light! urtesy of MIT McGov

Optogenetics was chosen the "Method of the Year" 2010



With the right combination of neurons, you can activate an entire brain circuit to control specific behaviors (like movement)





LIDAR (Light detection and ranging)

Drone implementation of inelastic hyperspectral lidar for vegetation structure profiling

LIDAR Before...



now drown based



20

60

Diode fibre fabrics

Diode fibres for fabric-based optical communications *Nature Aug. 2018*

Summary and outlook

- Blue lasers have applications everywhere
- Photonics is a key for societal development in the 21st century

www.laserphysics.kth.se

don't worry be happy

That's all folks!