Tampere City

- The second largest city, often called “Manchester of Finland”
- > 220,000 inhabitants
- It is likely (according to press release, 2011) that Tampere is the fastest growing urban area.
- Two universities: Tampere University of Technology (Foundation), and the (classical) University of Tampere, totalling 30 000 students

Tampere University of Technology (TUT)

- Established in 1965
- TUT Foundation since 2010
- 10,400 students (2010)
- Collaboration with ≈200 universities around the world
- Funding = 138 M€ in 2010

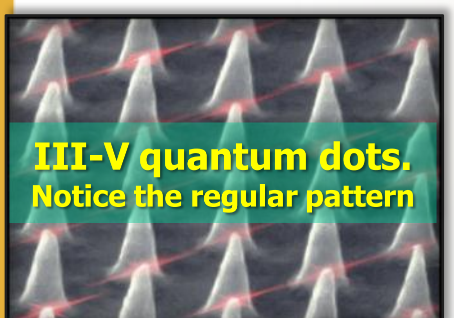
Leading-edge fields of research:

- Nano-photonics, particularly epitaxial growth of III-V's & laser technology
- Signal processing
- Intelligent machines

Plus: Centres of Excellence in Research appointed by the Academy of Finland: *Signal Processing Algorithm Research Group (SPAG)* together with *Generic Intelligent Machines Research* (GIM) of Helsinki University of Technology

Nano-technology research

Optoelectronics Research Centre - ORC



Semiconductor technology

- molecular beam epitaxy (MBE) of III-V semiconductors (5 commercial MBE’s)
- ultra-fast and high power lasers
- Solar cells, one is on board an ESA’s satellite (Equator-S)

Surface science

- nano-structured metals and semiconductors
- surface-environmental interactions
- functionalized surfaces (for catalysis & corrosion)

Nano-photonics

- Nano-imprint lithography (or NIL)
- plasmonics

NANOTECHNOLOGY

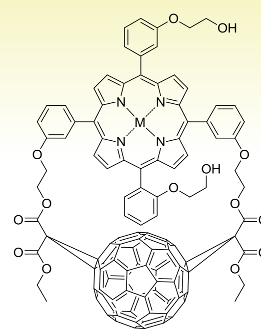
Nanochemistry for functional materials

Laboratory of Chemistry at Department of Chemistry and Bio-engineering

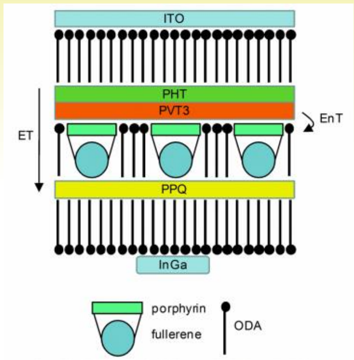
Organized molecular structures

- Mono molecular organic films
- Alternating organic molecular layers
- Self-assembled molecular structures
- Metal and semiconductor nano-particles
- Functionalized nano-particles

Synthesis

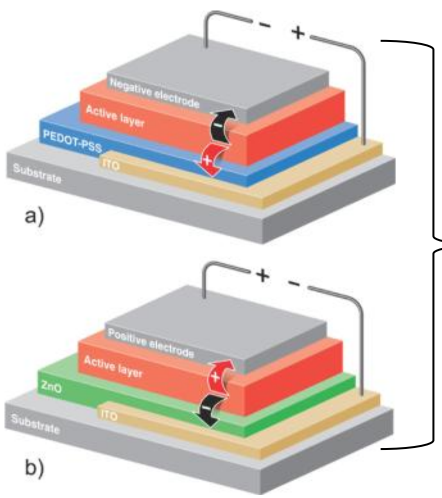


Fabrication of thin-films

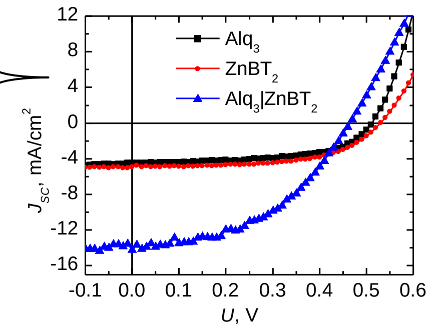


Phenomena studied in molecular structures

- Photo-physics of excited state
- Energy transfer
- Photo-induced electron transfer
- Photo-induced vectorial charge transfer
- Charge transport in organic structures
- Function of all organic solar cells



Organic Solar Cells prepared in open air, functioning with the efficiency of **6.7 %**



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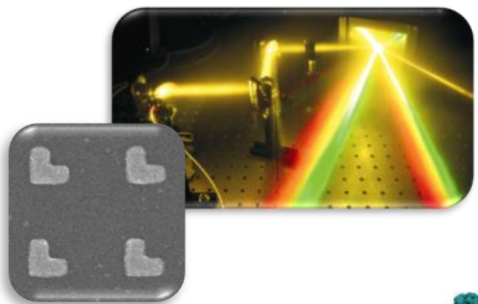
Nano-technology Research

TUT Department of Physics

Aerosol physics

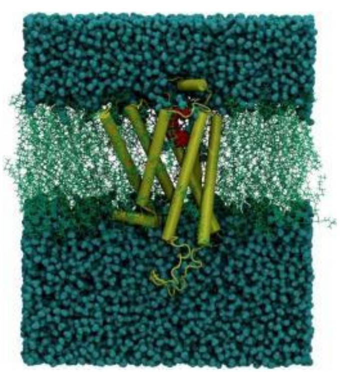
- Nanoparticle and nanopowder generation up to 1 g/min
- Functional nanocoatings in large scale
- Aerosol measurement, detection, instrumentation, 1 nm to 10 µm
- Traceable aerosol particle number concentration standard (5-1000 nm)

Optics: non-linear nano-photonics



- Supercontinuum and broadband sources
- Electromagnetic localization
- Nonlinear metamaterials
- Microscopy of nano-objects

Computational physics



- Unlocking ways of how lipids modulate membrane protein function
- Development of drugs for treatment of cardiovascular diseases
- Polymer coatings for optimizing optical and mechanical properties of solid materials
- Functionalization of nanocellulose

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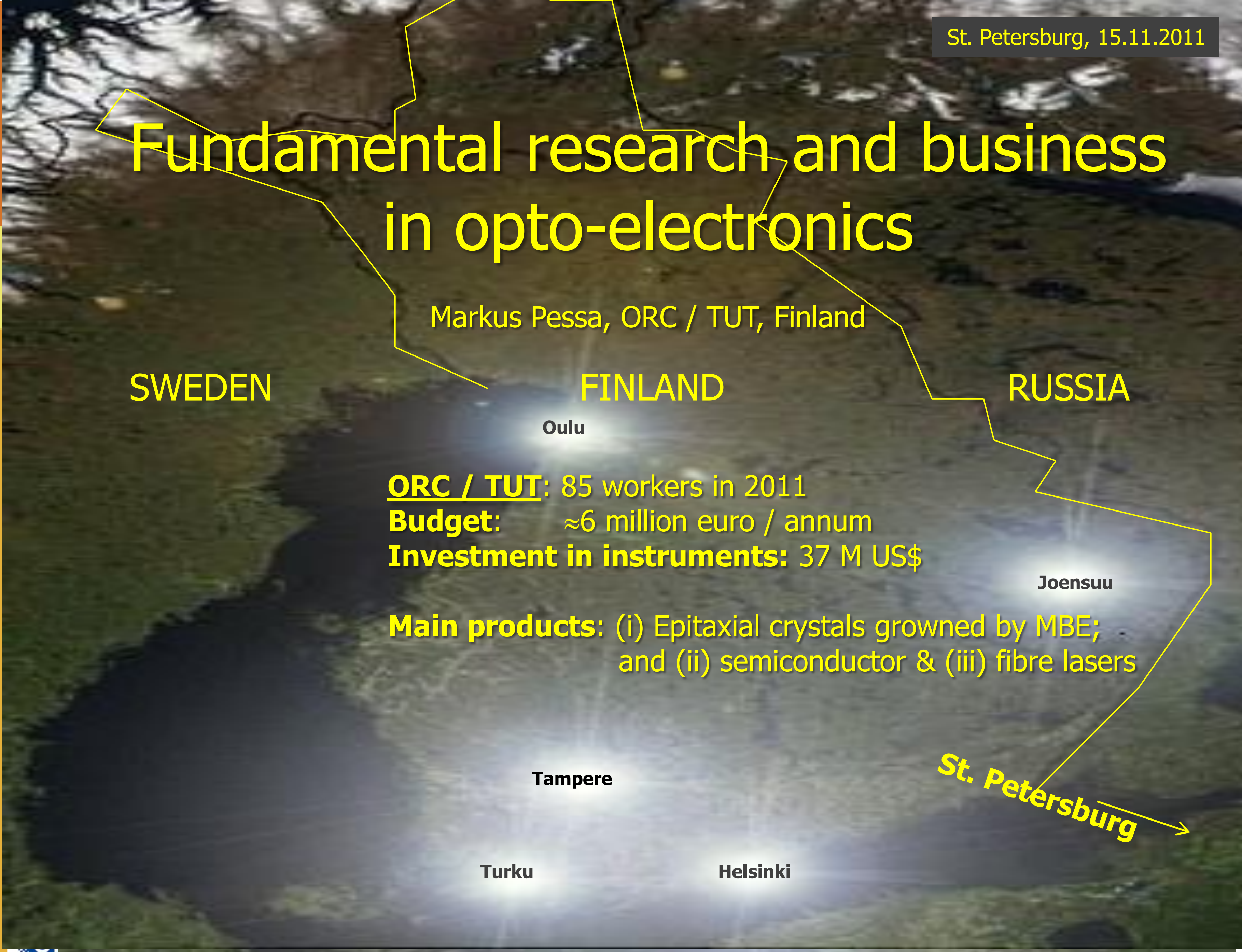
Fundamental research and business in opto-electronics

Markus Pessa, ORC / TUT, Finland



ORC / TUT: 85 workers in 2011
Budget: ≈6 million euro / annum
Investment in instruments: 37 M US$

Main products: (i) Epitaxial crystals growned by MBE; and (ii) semiconductor & (iii) fibre lasers

My “recommendations”

Many scientists are afforded excellent opportunities to exploit results of their fundamental studies

But too often people forget that

”A random walk of discovery” is likely to be an inefficient process from the point of view of industry

Therefore, you should strive for scientific advances, assisted by knowing where you are headed. This procedure, difficult as it may be, helps build a bridge between **academia and industry**

Photonics companies in Finland are largely created as spin-offs from ORC / TUT

A million-dollar question is how to establish a company which would utilize your scientific observations commercially

I'll show you how we did

St. Petersburg, 15.11.2011

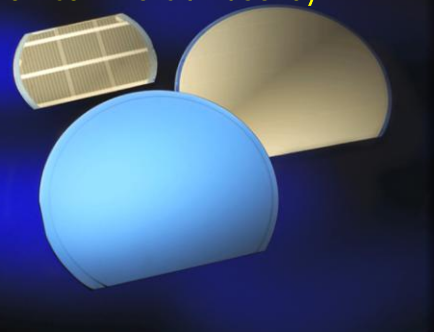
COHERENT
Coherent Finland Oy

Coherent Finland

Owned by Coherent Inc., Santa Clara, since 2002.

Products:
Epitaxial wafers by MBE and semiconductor lasers

Epitaxial III-V semiconductor wafers by Coherent Finland for commercial use by MBE



FAP – Coherent turn-key diode system for industrial applications; 100 < P < 1 kW

VECSELs (Semiconductor Disk Lasers), $\lambda \approx 976$ nm

Coherent Finland moved to Santa Clara, California, in 2010 and sold all these buildings to Corelase (2010). So, Corelase moved in (2011)

St. Petersburg, 15.11.2011

CORELASE Oy, founded in 2003

Owned by Rofin-Sinar Inc. since 2007.

These buildings were bought by Corelase 2010

Products:
Fiber lasers and systems

X-lase has pulse energy = 6μJ; pulse width = 10-30 ps; λ = 1064 nm

For micro material processing

O-lase *cw* fiber laser. Power ≈ 1 kW; λ = 1080 ± 5 nm, $M^2 < 1.7$; 20-μm fiber core; 12 pumps at λ = 976 nm

For welding, cutting and drilling

St. Petersburg, 15.11.2011

Modulight

MODULIGHT. Founded in 2000
Products: Semiconductor lasers for various purposes

Security/Defense	Medical	Industrial	Communications
			
Pointing and illumination	Photodynamic therapy and vein surgery	Illumination, projection, and laser scanning	Digital communications
Range-finding and targeting	Hair removal and therapeutic treatments	Cutting, marking, welding, and optical pumping	Analog communications
Sensing and monitoring	Diagnostics, illumination and materials processing	Spectroscopy and printing	Test and Measurement

TOOLBOX: Custom lasers, Electronics, Optics, Breadboards, 3D robotics

Ready2Lase

Modulight Application Development & Integration Platform

EpiCrystals Oy, founded in 2003

Main Product will be pico-projector

EPICRYSTALS

EpiCrystals will provide full-colour pico-projector modules where strong IR is converted into visible: 450 < λ < 650 nm by frequency-doubling

Patented **DeCIBEL**® laser platform

US patent granted

7 supporting applications pending

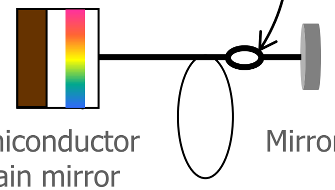
Expected time of announcing a commercial pico-projector is 2015: a new mobile phone application

RefleKron Oy

Founded in 2004. Key products: SESAMs and partnership in fiber laser companies

PRODUCTS (presently)

2000- 2004: Basic research of a **SESAM**; this is a technology for ultra-fast laser pulses



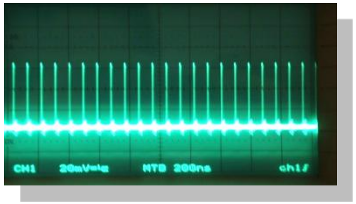
2005: Partnership with a fiber laser developer, Fianium Ltd., UK

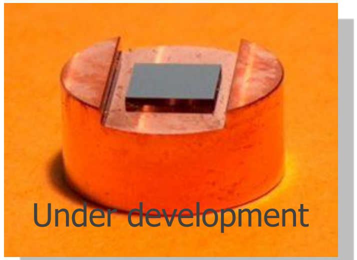
A broad spectral band, spectral width over 1 μm. **A super-continuum light** source

DEVELOPMENT (presently)

2008 -: New SESAMs for solid-state lasers and mid-IR

Ultra-fast pulse train: from <**100 fs to 10 ps**



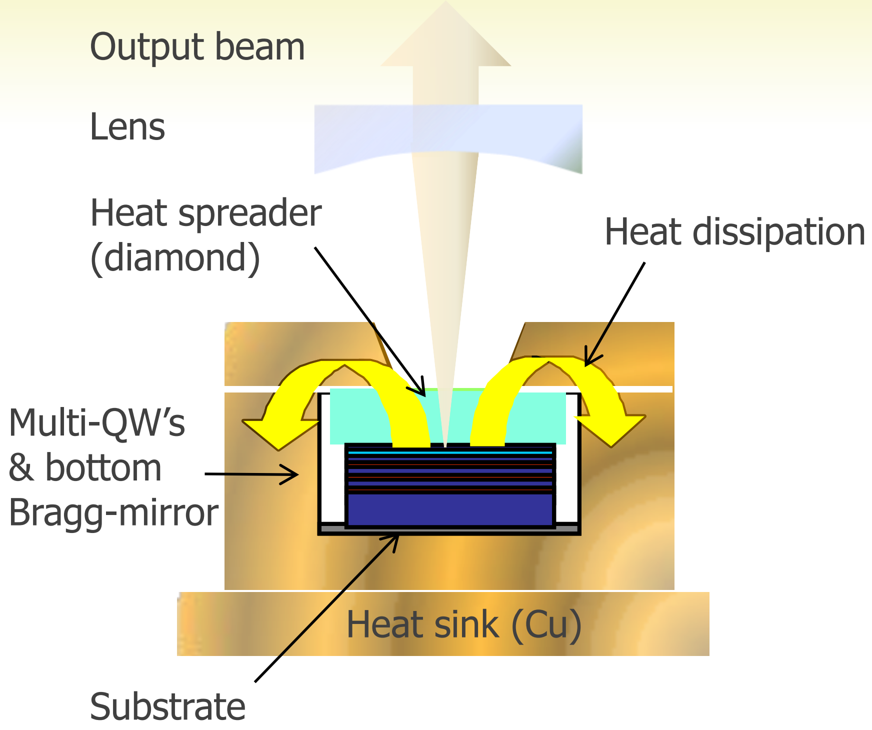


New potential business

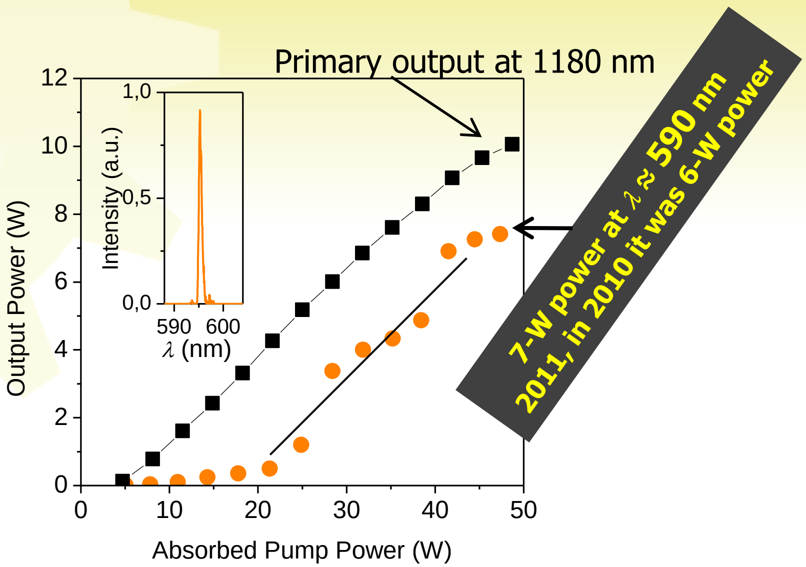
- Optically pumped surface-emitting lasers
- Surface gratings for DFB semiconductor lasers
- GaAs-based multi-junction solar cells

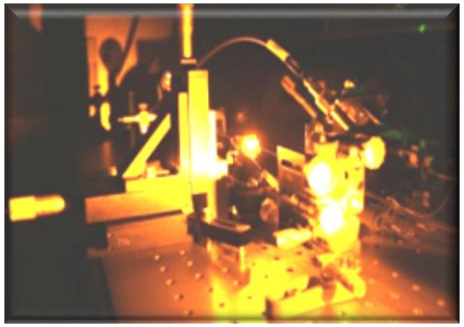
Optically pumped disk laser operating at $\lambda > 1\ \mu m$

Vertical external cavity surface emitting laser, VECSEL

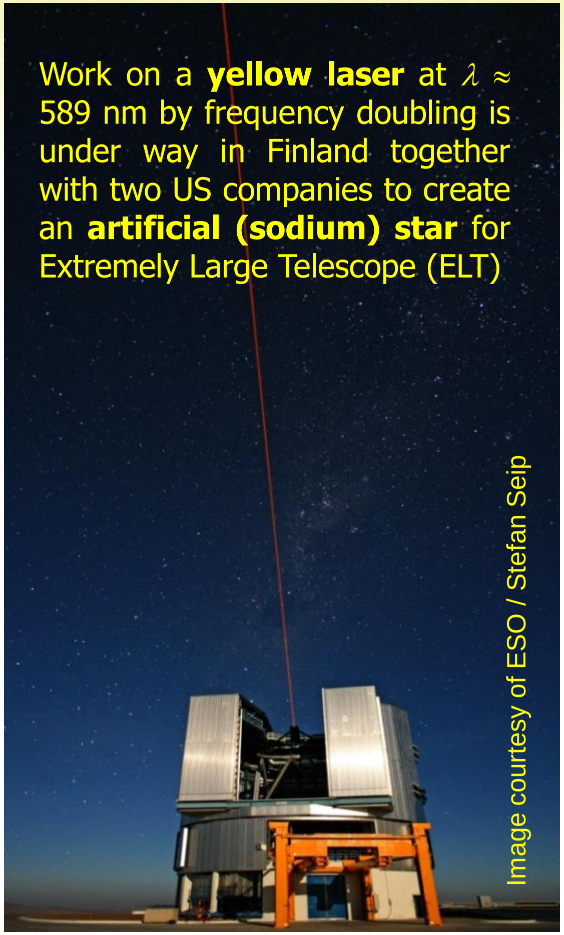


Optically pumped disk laser at yellow wavelength by frequency doubling. One application: ELT





Work on a **yellow laser** at $\lambda \approx$ 589 nm by frequency doubling is under way in Finland together with two US companies to create an **artificial (sodium) star** for Extremely Large Telescope (ELT)



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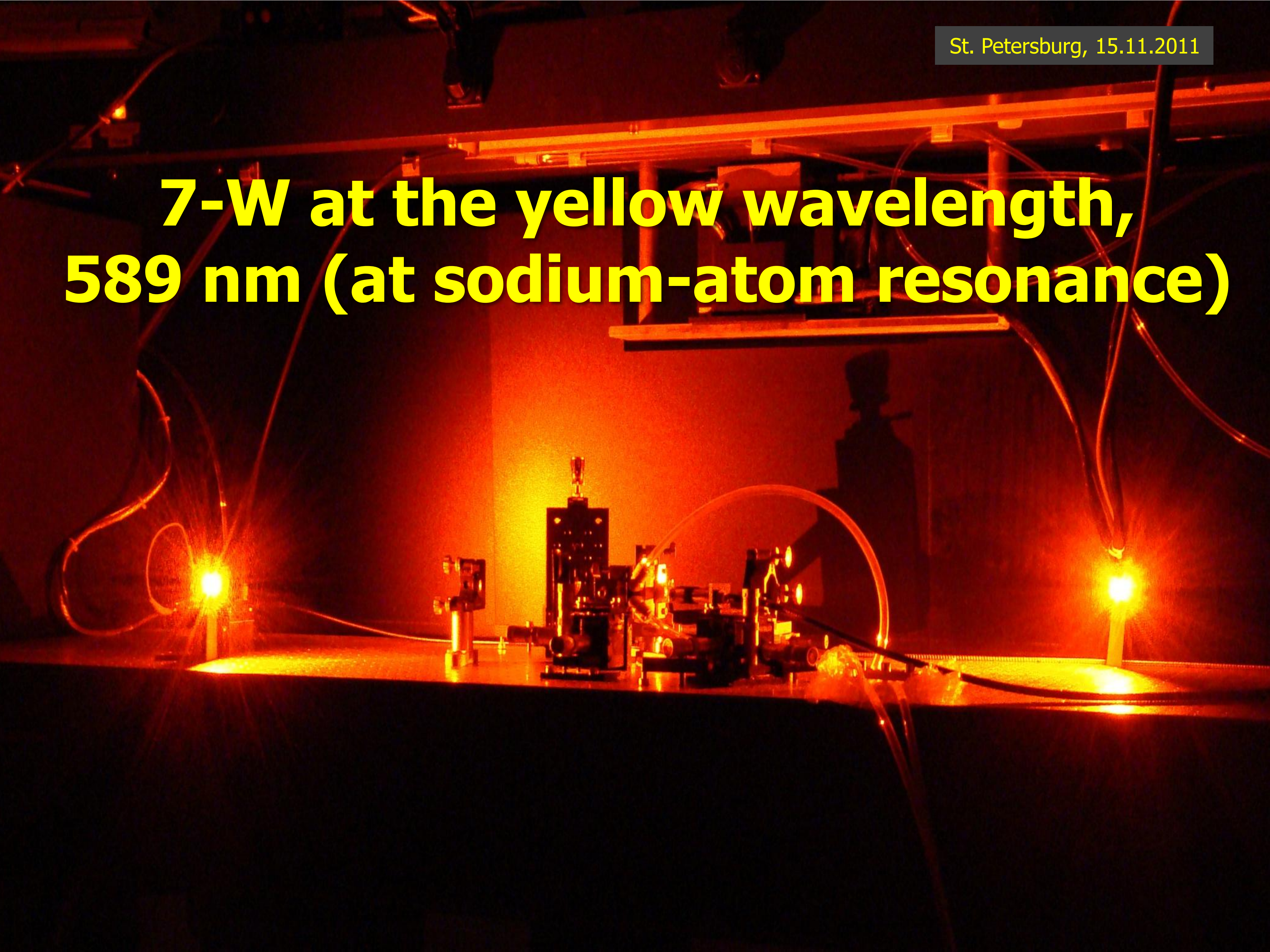

St. Petersburg, 15.11.2011
7-W at the yellow wavelength,
589 nm (at sodium-atom resonance)

New potential applications for business

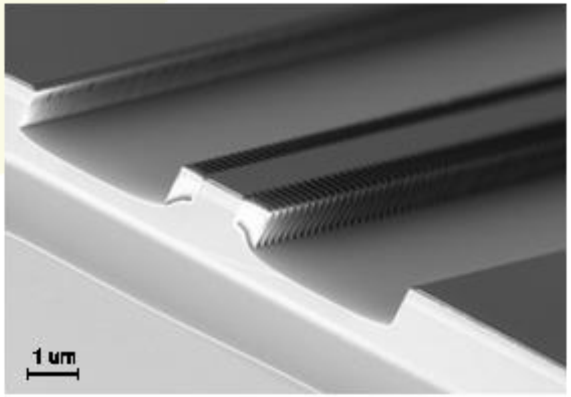
- Optically pumped surface-emitting lasers
- Surface gratings for DFB semiconductor lasers
- GaAs-based multi-junction solar cells

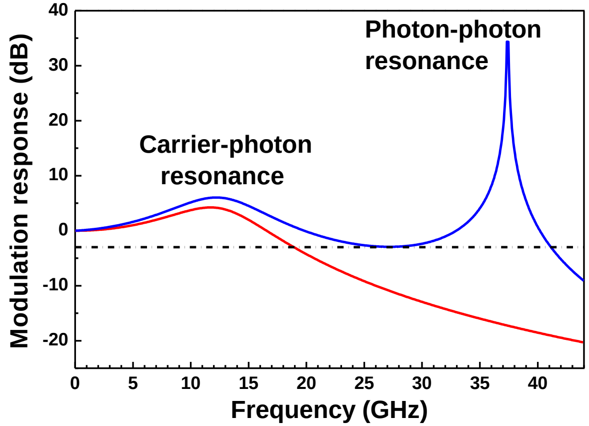
Application of nano-imprint lithography:

1.55 µm DFB laser for high-speed telecomm

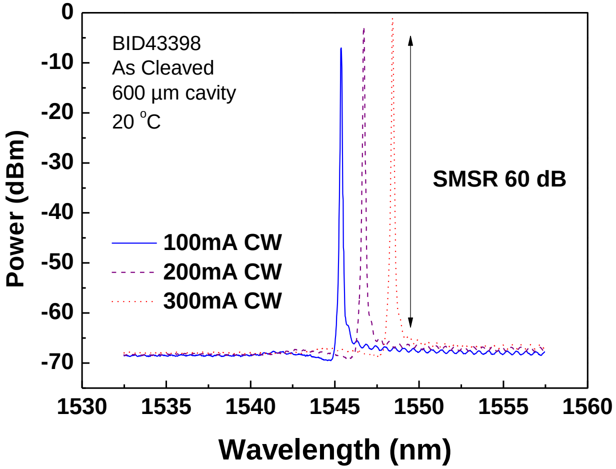
Edge-emitting laser diodes with NIL-based surface gratings

for high modulation bandwidth, ≈ 40 GHz (*theoretical*), at the photon - photon resonance; experimentally we have got a carrier – photon peak at 20 GHz, 2011





The emission peak is well locked !



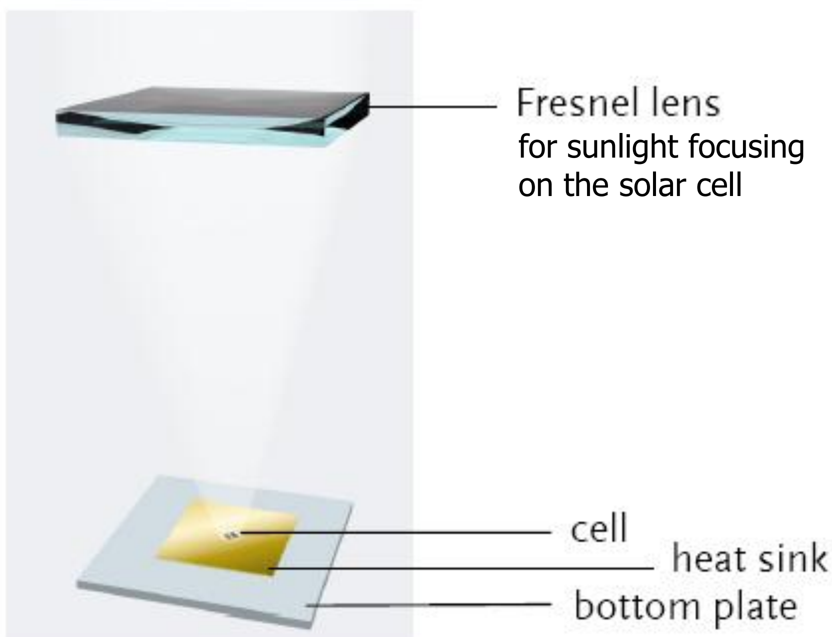
An European development project: SEVENTH FRAMEWORK PROGRAMME + DELIGHT

ORC Optoelectronics Research Centre
Tampere University of Technology

New potential applications for business

- Optically pumped surface-emitting lasers
- Surface gratings for DFB semiconductor lasers
- → GaAs-based multi-junction solar cells

Another dilute nitride application :
Solar cells for concentrated photo-voltaics



THEORY:

38% - 1 sun

47 % - 500 suns

40 % - 1 sun

52 % - 500 suns

3 junction	4 junction
First junction GaInP absorbs light E > 1.85 eV	First junction GaInP absorbs light E > 1.85 eV
second junction GaAs absorbs light 1.85eV > E > 1.4eV	second junction GaAs absorbs light 1.85eV > E > 1.4eV
third junction GaInNAs absorbs light 1.4eV > E > 1eV	third junction GaInNAs absorbs light 1.4eV > E > 1eV
GaAs or Ge substrate	fourth junction Ge absorbs light 1eV > E > 0.67eV
	Ge substrate

future generation

Theoretically, it is possible to obtain a 70-% efficiency with very many junctions. The highest efficiency obtained experimentally in US is 41.1 % for a 4-junction-cell under 1000 -sun illumination

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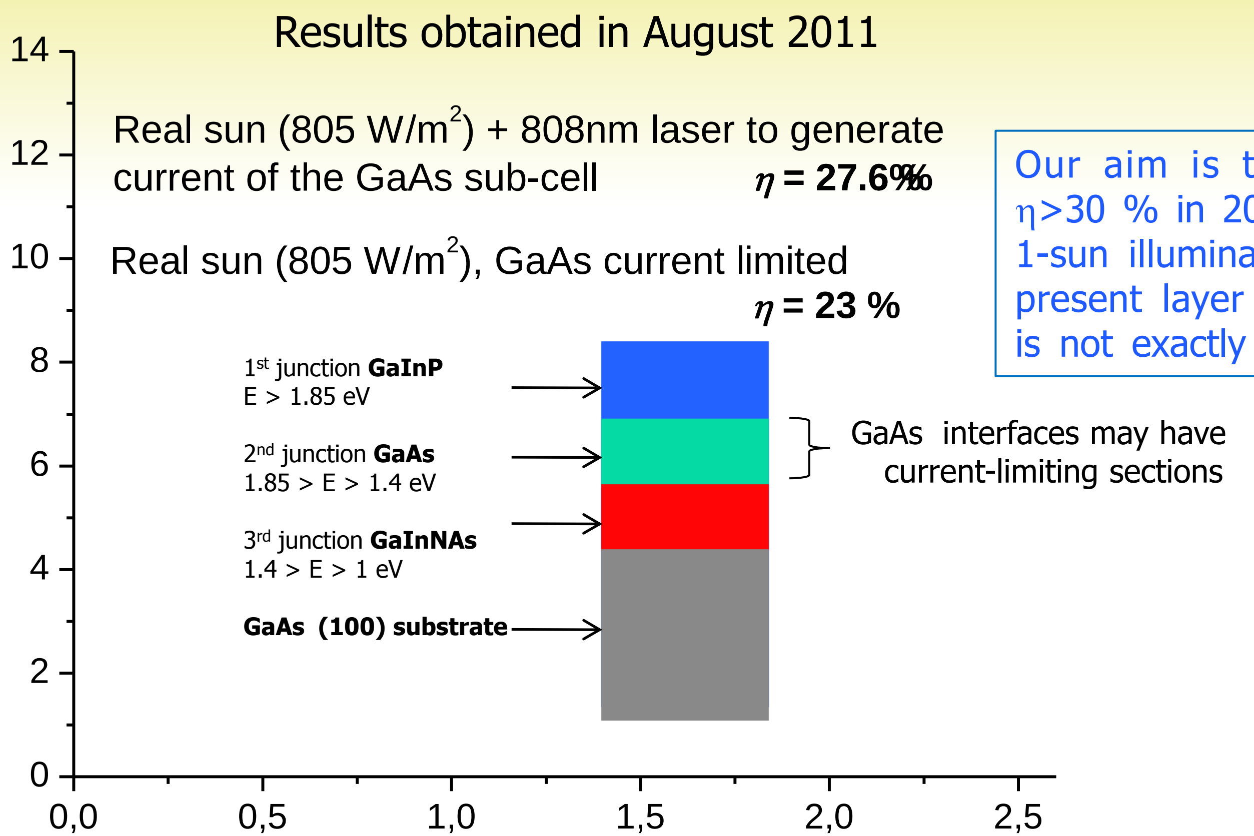
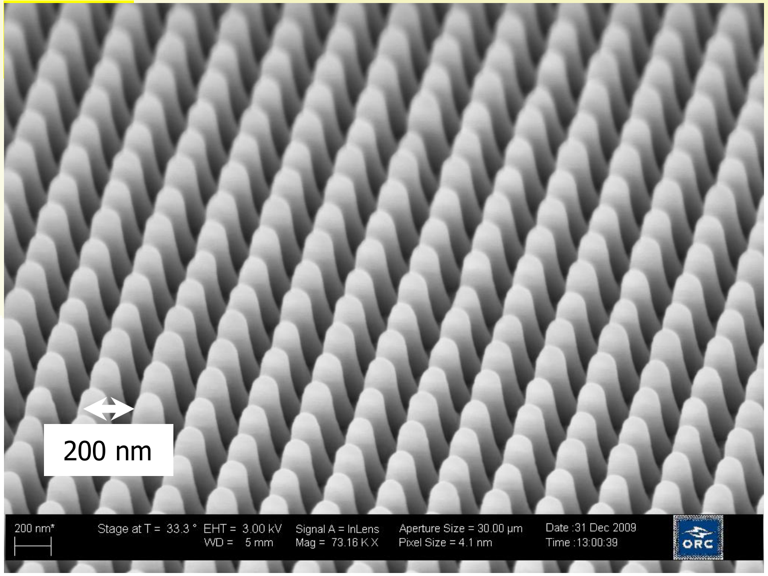
MBE-grown dilute nitride (InGaNAs) 3J-solar cells. Results under 1-sun light (in open air)



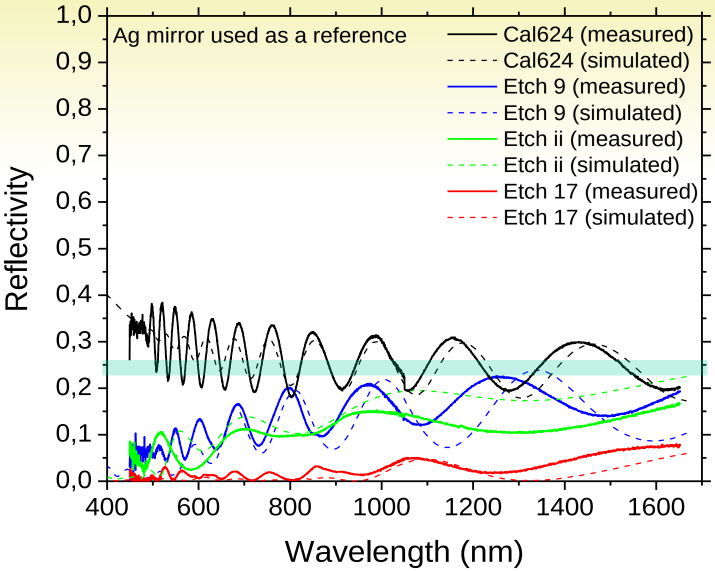
Our aim is to obtain $\eta > 30$ % in 2011 under 1-sun illumination. The present layer structure is not exactly complete

Broadband anti-reflection coatings with nano-structures

Published in *Solar Energy Materials & Solar Cells, Vol. 94, 2010, pp. 1845-1848*



Antireflection **moth-eye** nano-structure at sub-wavelengths, etched on an AlInP top layer for a broad spectral-band absorption by the underneath layers, and for wide light incident angles. Back reflection: 2.5 % (theoretically 1.6 %)



Average back-reflection at 450 - 1650 nm Because NIL is a low-cost method, this structure is suitable for use in large-area devices (e.g., solar cells)

NIL = Nano-imprint Lithography


St. Petersburg, 15.10.2011