



## Technology Transfer at UC-Santa Barbara [for successful start-ups]



Larry A. Coldren  
ECE & Materials, UC-Santa Barbara



Technology &  
Industry Alliances

## Start-Ups: Some Context

UC Santa Barbara

- University technology is early stage (embryonic, even)
  - A lot of risk in developing products
- Established companies prefer relatively “de-risked” opportunities
  - Challenging to find interested established companies if technology needs significant investment
- Startups, formed specifically to further develop one key technology, can fill that gap very effectively – or continue to expand into a mature, long-term company

*And while they are doing it....*

- Create jobs
- Attract funding to region
- And if they are lucky...  
become the next Google??





- 1989: Digital Instruments (atomic force microscope), acquired by Veeco Instruments (now Bruker Instruments)
  - Digital Instruments' spin-off, Asylum Research, formed in 1999
- 1989: \*Computer Motion, Inc (robotic surgery) , acquired by Intuitive Surgical
- 1990: Uniax (organic LEDs), acquired by DuPont
- 1992: Optical Concepts (VCSELs), acquired by W.L. Gore
- 1994: \*Software.Com/Openwave (Internet messaging) → Sonos
- 1995: Terabit Technologies (InGaAs/Si APDs), acquired by Ciena
- 1996: \*Indigo Systems (IR imaging)
- 1996: Nitres (GaN LED lighting), acquired by Cree
- 1998: Agility (widely-tunable lasers), acquired by JDS Uniphase
- 1998: Expertcity/Citrix Online
- 2000: \*Calient Networks (photonic switching), acquired by Suzhou Chunxing Prec. Mech.
- 2003: Aeries Photonics (VCSELs, SBIRs, IR imaging, etc.), acquired by FLIR
- 2008: Aurion (InGaAsP/SOI—Int. Silicon Photonics), acquired by Juniper Networks
- 2008: \*Freedom Photonics (1300nm tunables, SBIRs, etc.)



All of these companies maintain a footprint in Santa Barbara.  
 Many of these have early entrepreneurs who are still actively building second- and third-generation start-up companies from technology developed at UCSB.

\*Not a direct spin out of UCSB technology

## Entrepreneurial Engineering at UCSB

+ 230 companies started from campus

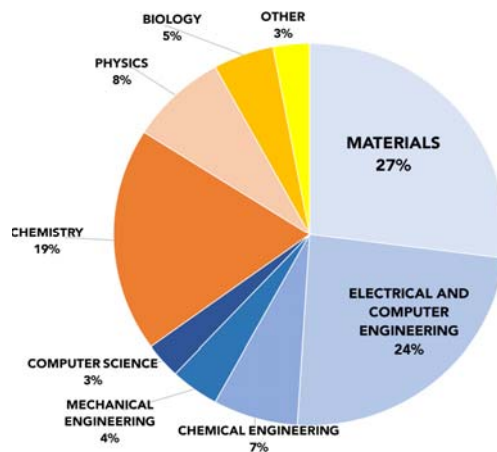
Average of 14 companies formed every year



UC SANTA BARBARA  
College of Engineering



- According to recent research, UCSB tech start-ups raised \$53M in 2017 and \$124M in 2018 (to-date) from angels and VCs.
- Recent Successful Startup Exits:
  - August, 2016: Aurrion – Acquired by Juniper Systems (\$165M)
  - July, 2016: ShadowMaps – Acquired by Uber
  - October, 2016: CytomX IPO (currently trading at approx. \$23)
  - February, 2014: Inogen IPO (currently trading at approx. \$247)
  - December, 2014: Eucalyptus – Acquired by Hewlett Packard
  - December, 2012: Asylum Research – Acquired by Oxford Instruments (\$80M)
  - August, 2012 Sirigen – Acquired by Becton Dickinson (\$90M)



### Invention Portfolio 90 New in FY18

- 664 Active Inventions
- 474 Active US Patents\*
- \*Inventions can be subject to more than one patent*
- 261 Active Foreign Patents

### License Agreements

#### 37 New in FY18

- 134 Active

**65% of New Invention Portfolio Involves CoE**

Typical Situation (small funding levels):

- **Industry request (Existing large company)**
  - Royalty-free license to all inventions generated in project
- **University position**
  - Depending upon funding level, provide right of first refusal to obtain a non-exclusive, royalty-bearing license
  - Filing and maintenance costs to be born by licensee and fair and reasonable royalties to be negotiated, based upon value of invention
  - Preferential exclusive licenses may also be negotiated at fair and reasonable terms; if not desired, non-exclusive licenses to other parties may be negotiated with up-front fees required

For larger funding levels (where all project costs are covered):

- **More favorable pre-negotiated IP terms can be obtained**

- **Move useful advances into the private sector**
  - Why not just publish and let existing companies select what they want?
    - Professional pride may inhibit process in companies
    - Start-up costs in companies compete with existing priorities
    - Inventors (from universities) more driven to make ideas succeed
    - Start-ups more willing to license IP, because they need protection
    - Start-ups may be best avenue to mature IP with Angel, VC or government funding. Then, companies can decide what to select (acquire) after start-up proves feasibility (or not)
- **Fulfills a primary role of a University**
  - Technology developed benefits society
  - Rewards faculty and student entrepreneurs (attracts/retains/supplies quality)
  - Provides resources to enable further teaching and research
    - (Indirectly→ SBIRs, gifts, etc.; supports university facility costs. A modest percentage of patent royalties are returned to departments)

- Keep a good lab notebook (regardless)
- Educate yourself in Entrepreneurism (TMP @ UCSB)
- When your viable idea for a high-demand product occurs:
  - Submit all University developed IP to University IP office (TIA)
  - Develop plan to create product: who are customers; how to market; what team is required; what resources are needed; timeline; how costly; how to finance
  - Find separate space/facility to work and develop new company IP
  - Look into finance options—SBIRs; Angel investors, friends and family, VCs
  - License University IP if desirable
  - Manage costs: e.g., outsource expensive fabrication costs
  - Select quality team members, and only those needed

## Entrepreneurism:

### UCSB Technology Management Program



New Venture Competition:  
*TMP's flagship entrepreneurial program*



**Established 2001**

*Campus-wide, year-long*

*Transformative Educational Experience*

*Strong Network of Mentors and Advisors*

*Track Record of Successful Startups*

### TMP Academic Programs:

- **Technology Management Certificate** (for current undergraduate students)
- **Graduate Program in Management Practice Certificate** (for current graduate students)
- **Master of Technology Management** (professional masters degree)
- **PhD in Technology Management**



## Student Entrepreneur Success Stories



**inogen**

- Winner 2001 NVC
- 2014 IPO
- Market value \$2.5 B



**apeel sciences**

- Winner 2012 NVC
- \$70M+ capital raised



**TrackR**

- Winner 2009 NVC
- \$63M capital raised
- Revenue \$50M-\$100M

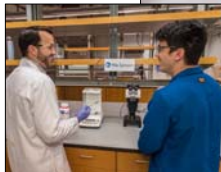


**Sirigen**

- Winner 2003 NVC
- Acquired by BD, 2012

Find separate space/facility:

## CNSI Technology Incubator – Laboratory Resource for Startups



- Mission – Bring scientific and technological innovation into the **economy** and society
  - 900 sq. ft. of wet-lab / dry-lab space set aside for Incubator
  - Collaboration with UCSB I&E Ecosystem
- Eligibility
  - Active corporate licensees of UCSB intellectual property
  - Companies founded by UCSB faculty, staff, or students
  - Local pre-production community start-ups

Current residents

Milo Sensors **bioProtonics** **MENTIUM** **FLUENCY** **NexuS** **NEXT**  
 (Incubator prize, Summer 2018) **LAAMI** **apeel sciences**  
 Therapeutic Devices **Photonics**

Former members

Outsource expensive fabrication/testing:

## UCSB Shared Facilities

Nanotech Labs



MRL Labs



47 Facilities  
304 Instruments

*Part of what makes UCSB - and Santa Barbara in general - a good place to start a company*

## Nanotech Facility Overview

# UCSB

- ~12,000 sq. ft. of cleanroom space (class 1000, 100)
- Full set of nanofabrication tools for thin film patterning, deposition, etching, integration, modification, characterization, metrology
- ~\$50M of fabrication equipment (replacement cost)
- Operates as a highly accessible user facility
- Highly skilled staff for supporting process development, tool training, maintenance
- ~ \$6M/yr in yearly recharges. ~\$4M/yr from industrial use (\$3.5M small company)
- No State subsidy for the facility. Runs on recharges only.

Main corridor for access to 7 Bays/6 Chases



Bay 3  
Class 1,000 - Deposition



Bay 6  
Class 100 - Lithography



[www.nanotech.ucsb.edu](http://www.nanotech.ucsb.edu)

The convergence of research and innovation.

- **Lithography**– Steppers (i-line(2) and DUV), EBL, Contact, Nanoimprint
- **Etching** – ICP(3), CAIBE, RIE(3), SiDRIE, vaporHF, XeF<sub>2</sub>, CMP



ASML-DUV-248nm  
Only 3 at Universities  
Sub-200nm Full Wafers  
Si-Photonics  
Quantum Computing



JEOL 6300 EBL  
Sub-10nm Patterning  
<5nm Stitching errors  
Full Wafers  
THz electronics  
Advanced Photonics



Panasonic ICP Etcher/Asher  
Dielectrics, Metals, Semiconductors  
Workhorse systems – often >18 Hrs/day  
nm-scale control - reproducible

The convergence of research and innovation.

### Map of Institutions Served 2006-2018



- **Regional (CA) Reach**
  - ◆ 185 in state external industrial institutions (and 18 Academic)
  - ◆ Includes: Google, HP, Apple, Raytheon, Lockheed Martin, Cree, JDSU, Juniper Networks, Bruker, HRL, Teledyne, Northrop Grumman, Intel, KLA-Tencor, JPL, Tyco, Dupont, FLIR, Myriads of small and start-up companies
  - ◆ 46 SB/Goleta Area
- **National Reach**
  - ◆ 58 out-of-state External Industrial Institutions out of state
  - ◆ 41 External Academic Institutions out of state

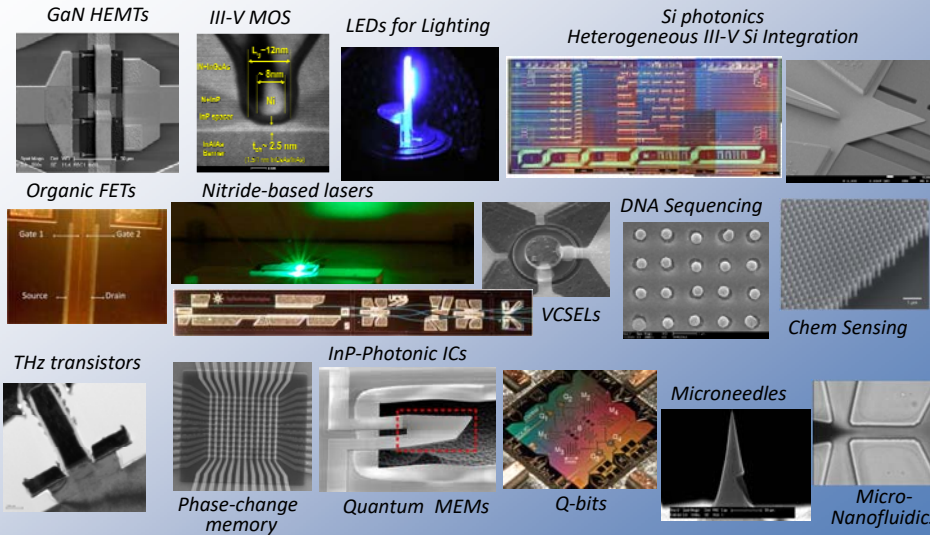


The convergence of research and innovation.

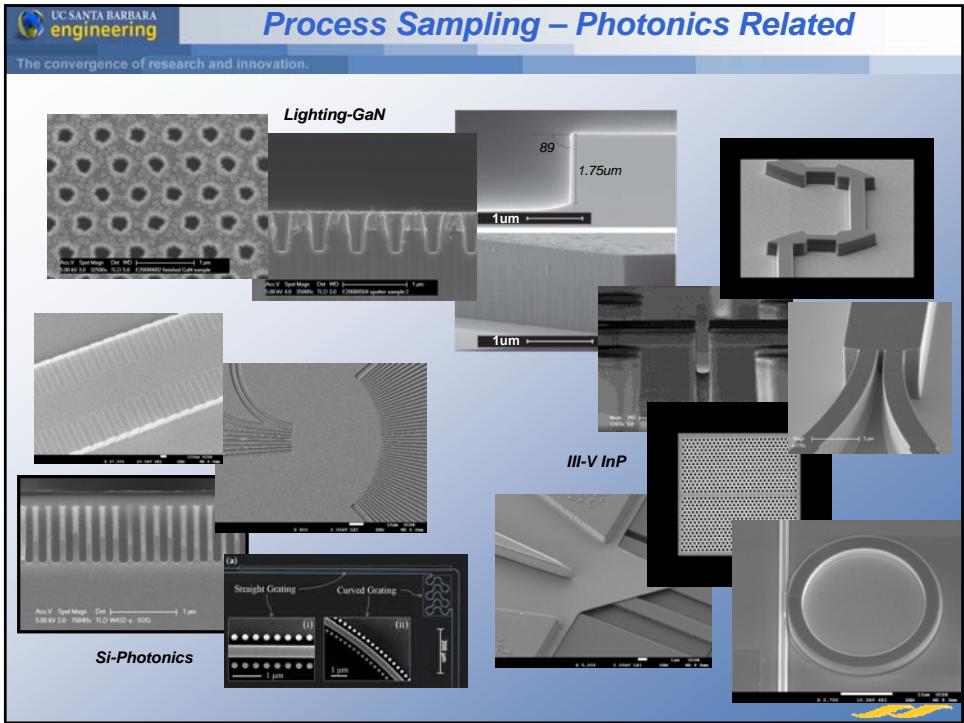
<p>Fluency Lighting Nexus Photonics Ultra-low Loss Technologies 3DCD Applied Materials Bruker Metrology Continental Advanced Lidar Solutions, Inc Coming Technology Center Cree Facebook Technologies, LLC FLIR Commercial Systems FLIR EOC Garmin International, Inc. General Atomics Google Inc. HP Labs Hughes Research Laboratories Infineon Juniper Networks KLA-Tencor Inc Lam Research Corporation Lockheed Martin, Missiles &amp; Fire Control Raytheon Vision Systems Space Exploration Technology Corp. SRI International Technicolor HES Teledyne Scientific &amp; Imaging The Aerospace Corporation Toyon Research Corporation 3D-Sensir Inc (Acqubit) AdTech Photonics Advanced Modular Systems</p>	<p>Advanced Nanostructures AdvR Aeonian Semiconductor Technology AlSthesis Products, Inc. Angstrom Science Apic Corporation Applied Nano Applied Nanostructures, Inc Aptitude Medical Systems Inc Astrileux Corporation Asylum Research Atollo Engineering, LLC Ayar Labs Calient Networks CBrite Christian Gutleben Complete Genomics Inc. Crossbar Inc. Crystalline Mirror Solutions LLC Crystalline Mirrors (Vixar) Drinksavvy Inc. Duet Microelectronics ELR Systems LLC Freedom Photonics, LLC Genapsys Inc GenXComm Inc Ideal Power Inc Innovative Micro Technology InnovativeIII-V.Solutions Laser Components DG Inc Laxense, Inc. Laxmi Therapeutic Devices Magic Leap</p>	<p>Milo Sensors Inc. Momentum Optics, LLC Nano Precision Medical Numerical Design, Inc. Omniome, Inc. Owl Biomedical Inc. Parthian Energy Pendar Technologies PiMEMS Inc. Praevium Research Promerus LLC QmagIQ RLC Solutions Rodman Scientific Royole Corporation Sensor Creations SensorMatrix Sientra Inc Silicon Designs, Inc. Solar Junction Corporation Solution Deposition Systems Soraa Laser Diode, Inc Soraa, Inc. Spectradyne LLC SurForce Corporation TelAztec Terry Therapeutics Transphorm Tribogenics Ultima Genomics VoxtelNano Westar Automation LLC Xerial Sciences Zephyr Photonics</p>
--	--	--

The convergence of research and innovation.

### Electronics, Photonics, MEMs, Microfluidics, Materials, Physics



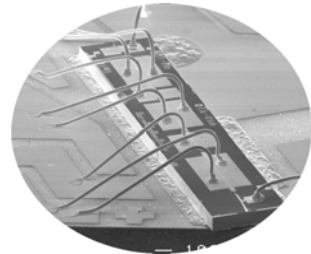
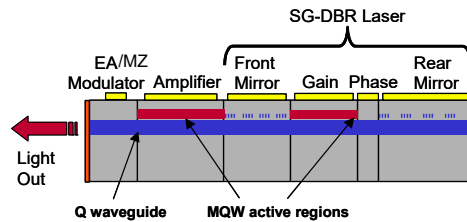
Solid-State Lighting, Photovoltaics, Thermoelectrics, Oxide Electronics



**Example 1:**

**Agility Communications** (Acq. JDSU 2005 → Lumentum)

- Formed 1998 by Coldren students + Coldren; based on fundamental 1988 UCSB patent filing
- Widely-tunable (full C-band) sampled-grating-DBR lasers with integrated SOAs and modulators; use of off-set quantum-wells for active-passive



**Advantages:**

- smaller space
- lower cost
- lower power consumption
- high reliability



# Agility's Unique Platform—2001-2005

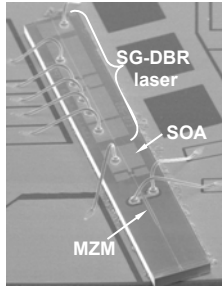
## Integration Replaces Discretes



Laser Source



LN Modulator



Optical Amplifier



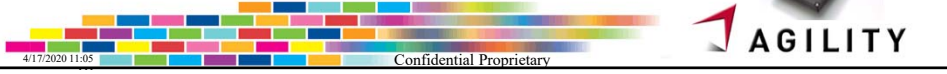
VOA

**Higher Reliability, Smaller Size, and Lower Cost:**

- Significant Part Count Reduction for DWDM
- Eliminates Multiple Packaging
- Single Chip Reliability
- Only Tunable Integration Platform in the Market

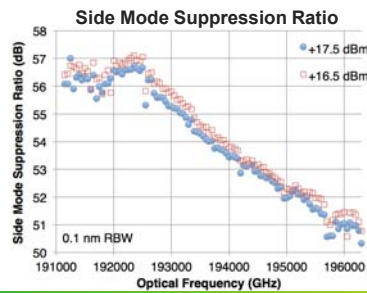
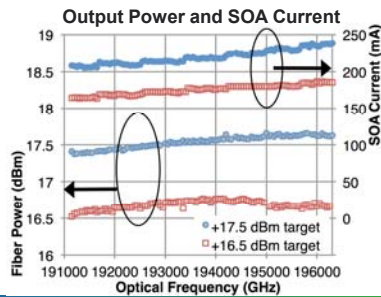
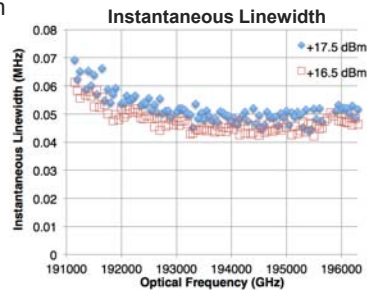
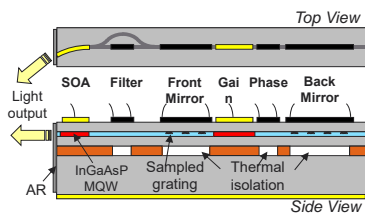
**Tunable Tx/Rx Transponder with all control electronics primary product —2002→**

**Integrated MZM after 2004**

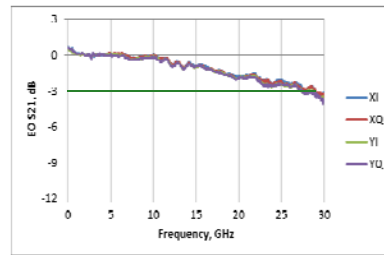
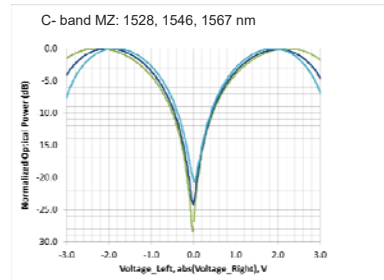
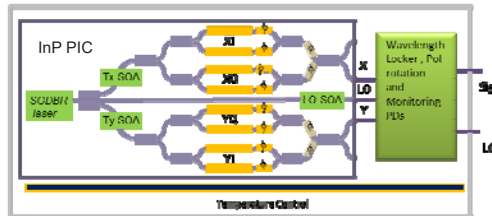


## Narrow linewidth thermally-tuned SGDBR Laser—2015

- 70kHz linewidth and 50dB SMSR at +17dBm fiber power over 41nm range in C-band



## C-band Tunable Integrated Coherent Transmitter PIC

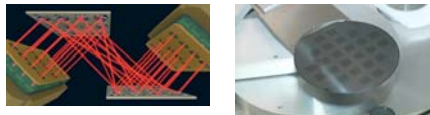
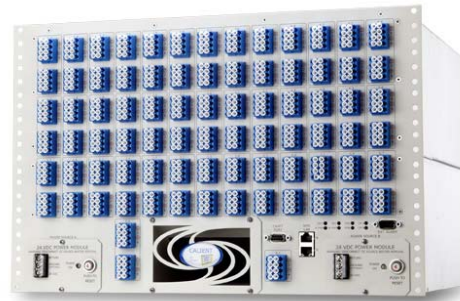


- Narrow Linewidth Sampled-Grating DBR laser
- Two quadrature Mach-Zehnder modulators
- High power LO output
- 3 SOAs
  - Independent power control for LO and each Tx polarization
  - VOAs
- InP PIC technology is employed for 32 Gbaud 100 and 200 Gb/s coherent pluggable modules

### Example 2:

## CALIENT's S-Series Optical Circuit Switch (OCS)

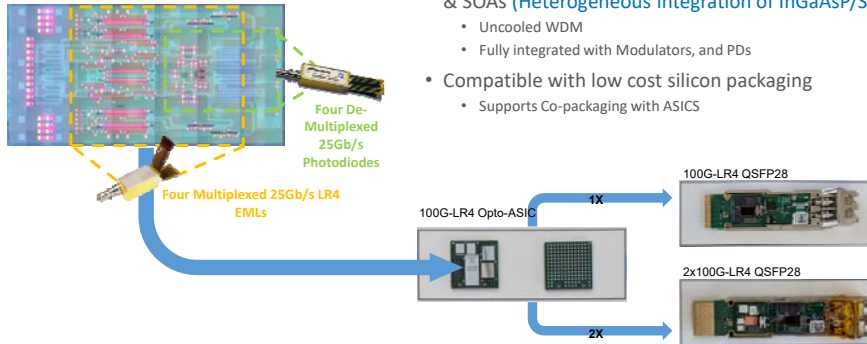
- **Up to 320 User Ports – 640 Single Mode Fiber Terminations**
  - 320x320, 160x160 options
- **10, 40, 100 Gbit/s per port and beyond**
- **25ms typical setup time (<50ms Max)**
- **Less than 30ns latency**
- **Ultra low power (<45w), small size (7RU)**
- **TL1, SNMP, OpenFlow, REST APIs**
- **Less than 3.0 dB Insertion Loss**



Founded by Bowers, et al, 2000  
Acquired 2017, Suzhou Chunxing Prec. Mech.

### Example 3:

## Aurion - Fully integrated Silicon Photonics



- Founded by Alexander Fang and John Bowers out of UCSB in 2008
- Acquired by Juniper Networks – 2016
- The Only Silicon Photonics Platform with WDM Lasers & SOAs (Heterogeneous integration of InGaAsP/SOI)
  - Uncooled WDM
  - Fully integrated with Modulators, and PDs
- Compatible with low cost silicon packaging
  - Supports Co-packaging with ASICs

## Aurion - Photonic Integrated Circuits (PICs)

- Leveraging the economies of scale pioneered by the silicon industry

- Photonic Integrated Circuit (PIC) fabrication leverages silicon design, process, test, package, and foundry infrastructure for complete photonic systems
- **Impact:** Fundamental and permanent improvements in cost per bit-per-second

- Uncooled WDM technology

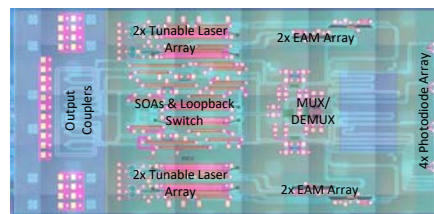
- No TEC required to operate over temperature
- Integrated micro heaters keep wavelength sensitive components tuned to the wavelength grid
- **Impact:** Higher capacities for networking interfaces

- Packaged like an ASIC

- Packaged along side other ASICs on the same substrate
- **Impact:** Greater flexibility in how bandwidth carried on light is processed inside the electronic portions of networking systems.

- ASIC like Reliability

- Single-chip, solid state devices vs discrete components
- **Impact:** Photonics that scale with the system



#### PIC stats

- 100Gb/s LR4 compliant
- Area = 34 mm<sup>2</sup>
- 67 photonic components interconnected with waveguides
- Many components contain subcomponents (laser = 8)



Examples 4 & 5:

## GaN Start-ups from UCSB

- **Case Study 1: 1996—2000 Nitres (LED)**
  - Prof. Mishra & DenBaars start Nitres Inc.-GaN LED and FET company in U.S.-Acquired by CREE Inc.
  - LED lightbulbs commercialized
- **Case Study 2: 2013→ SLD Laser**
  - Prof. Nakamura, Speck, DenBaars, et al spin-out GaN laser leader SLD Laser (from Soraa formed in 2008).
  - LaserLight commercialized
- **Case Study 3-Transphorm**
  - Prof. Mishra spins-out power switching company
  - GaN based Power supplies commercialized



**SSLEEC** Solid State Lighting and Energy Electronics Center  
UNIVERSITY OF CALIFORNIA, SANTA BARBARA



## Cree, Inc. to Acquire Nitres, Inc., a Leader in Nitride Semiconductor Device Development; Company to Launch Solid State Lighting Subsidiary

Apr 11, 2000, 01:00 ET from [Cree, Inc.](#)

DURHAM, N.C., April 11 /PRNewswire/ -- Cree, Inc. (Nasdaq: Cree), the world leader in the development and manufacture of semiconductor materials and electronic devices made from silicon carbide (SiC), today announced it has signed a definitive agreement to acquire privately held Nitres, Inc., a leader in research and development of nitride-based semiconductor devices. Under the terms of the agreement, Cree will acquire all of the outstanding and vested shares of Nitres stock in exchange for approximately 1.5 million shares

Nitres founded in 1996 by DenBaars and Mishra



**SSLEEC** Solid State Lighting and Energy Electronics Center  
UNIVERSITY OF CALIFORNIA, SANTA BARBARA





# SLDLASER

## LASERLIGHT: THE NEXT GEN SSL SOURCE

- Low Luminance
- Droop/Auger
- Safe

- High Luminance
- >10k brighter vs LED
- >20X power per chip
- Not Safe

- High Luminance
- 100X brighter vs LED
- 500lm from 300um
- Safe

- Incoherent emission provides safety & regulatory acceptance versus direct LD **(Sora continues in the first two boxes)**



SSLEEC Solid State Lighting and Energy Electronics Center  
UNIVERSITY OF CALIFORNIA, SANTA BARBARA



# SLDLASER



**“Laser diodes are lighting’s future.”**

Nobel Laureate Physics & SLD Laser Co-Founder  
Shuji Nakamura



SSLEEC Solid State Lighting and Energy Electronics Center  
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

