

The logo for oclaro, featuring the word "oclaro" in a bold, white, lowercase sans-serif font. The letters are set against a dark blue background that has a subtle gradient and a bright light flare effect in the upper right corner. A small "TM" trademark symbol is located at the bottom right of the word.

oclaro™

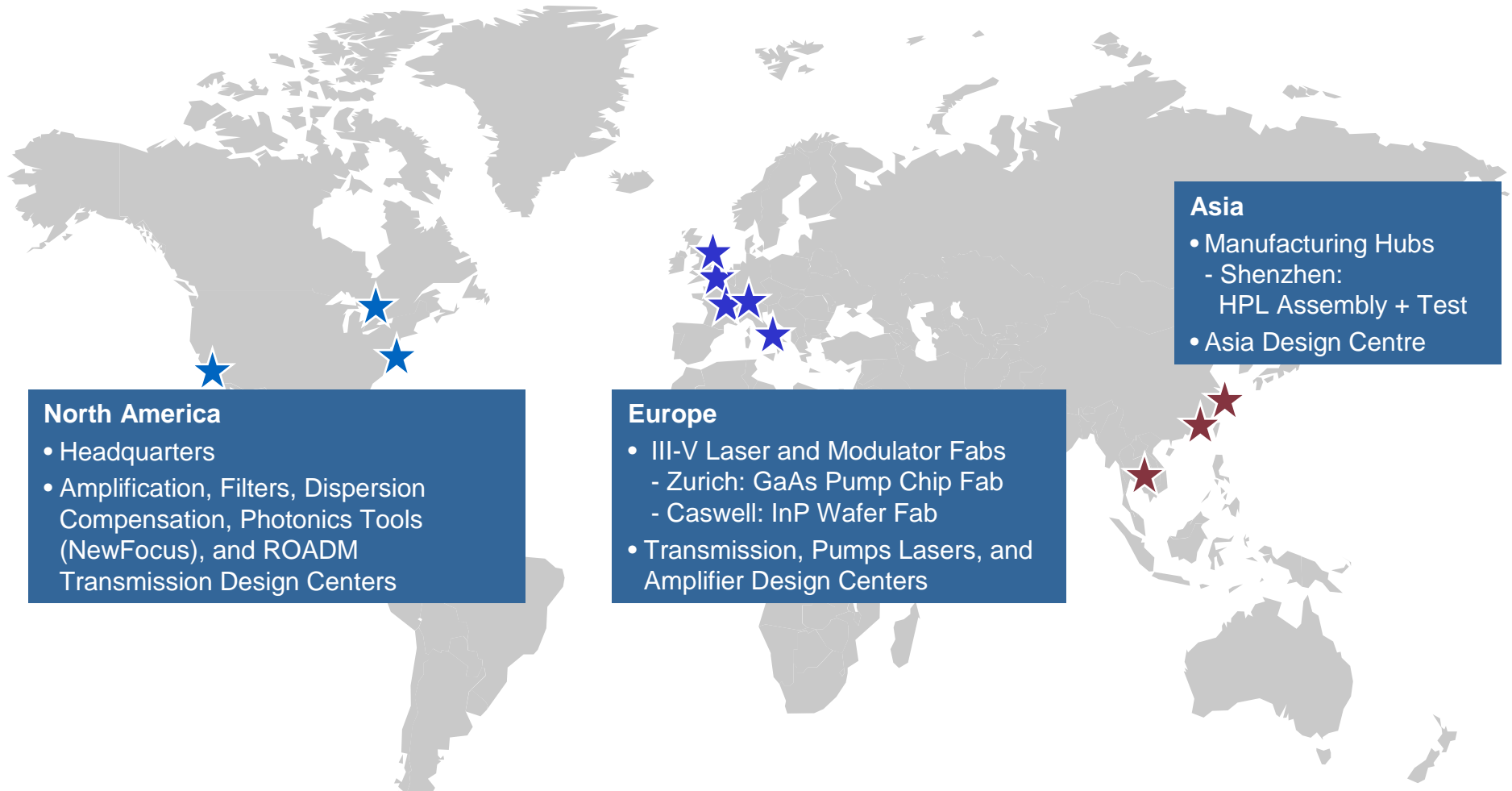
Pump Laser: MicroSwiss Erfolgsgeschichte

Norbert Lichtenstein, July 2009



- Founded in 1988, Headquarter in San Jose, CA
- Public, NASDAQ traded company
- Approx. 3000 employees
- Acquisitions-Mergers:
 - Marconi and Nortel optical components in 2002
 - Cierra Photonics and Ignis Optics in 2003
 - New Focus and Onetta in 2004
 - Avalon in 2006
 - Bookham rebranded as Oclaro on April 27, 2009, following its successful merger with Avanex Corporation
- Products & solutions for telecom and industrial&defense photonics
 - Telecommunications Optical Components
 - Advanced Photonics Solutions
 - High Power Laser Diodes, VCSELS, & Optomechanical Systems (NewFocus)

Global Presence and Flexible 24/7 Company



Cost Optimized and Global Engineering Teams
Flexible and De-Risked Manufacturing Infrastructure
Fabs for Leading Chip-level Innovation

Advanced Optical Solutions for green applications

- High Power Laser Diodes for Industrial applications: Environmental-friendly manufacturing
- Low power / polarized VCSEL: Energy consumption in battery driven PC pointing devices
- RGB display & projection: Resource saving (printing)

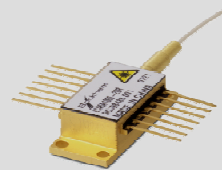
Expansion of Portfolio

- Announced to acquire Spectra Physics High Power Laser Diode Business in exchange to New Focus
- Expected to form largest merchant supplier of high power laser diodes

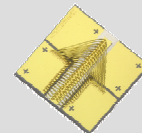
High Power Lasers & VCSELs



High Power Laser Diode Bars



Single Mode Single Emitters



Multi Mode Single Emitters



VCSELs

Photonics Tools and Filters



Lasers & Accessories



Optomechanics



Optoelectronics



OEM Solutions



Filters

Bookham Switzerland AG

Binzstrasse 17
8005 Zurich
Switzerland

Employees: 170
Size: 116,585 sqft

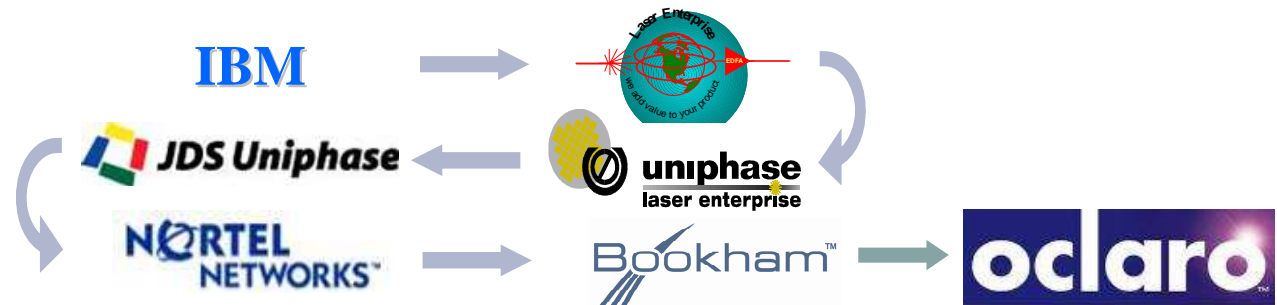


Key Products

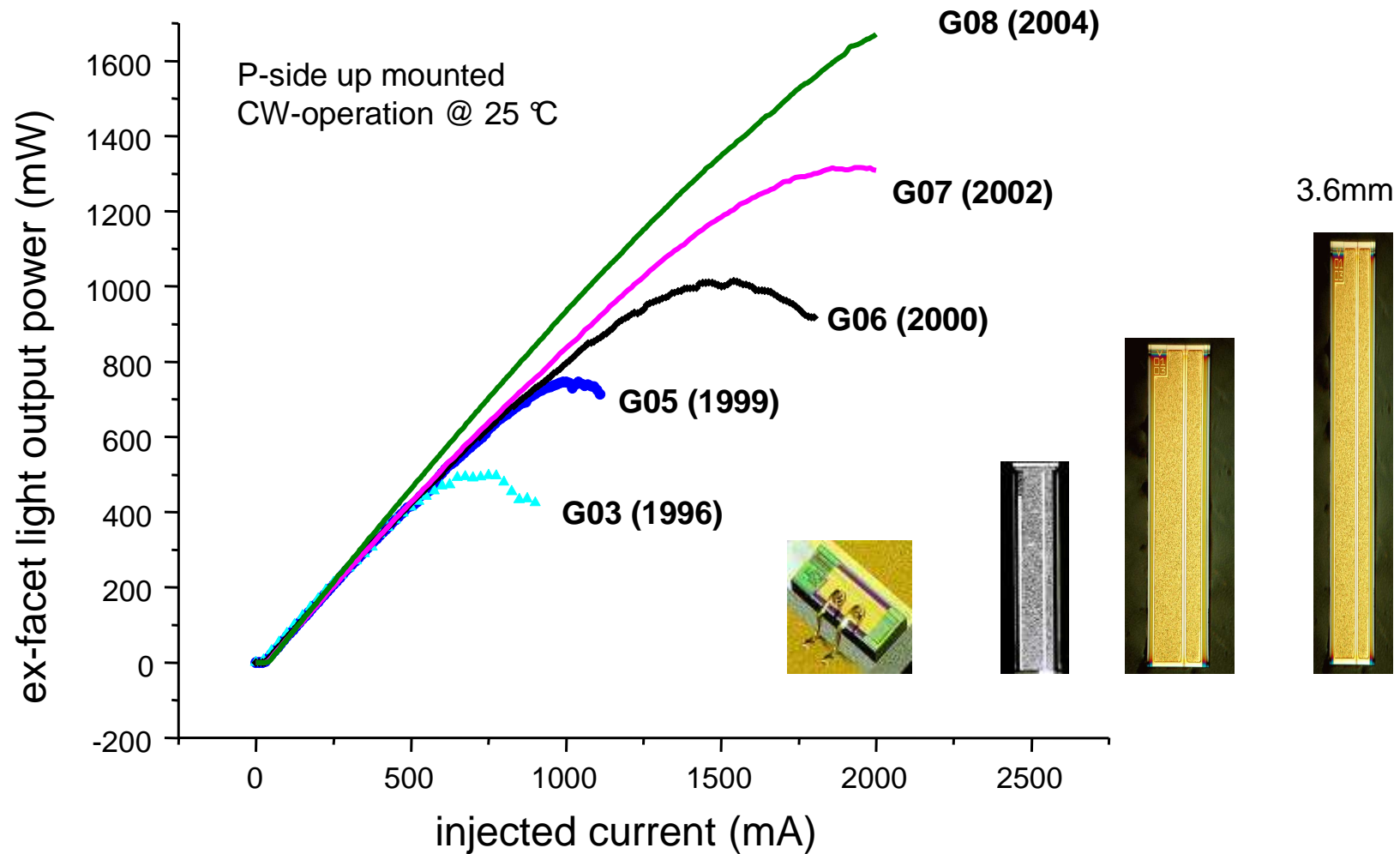
- High power 790 -1070nm multimode laser diode bars and single emitters
- 980 nm single mode pump laser diodes
- VCSELs

History

- *Beginning:* breakthrough in the reliability of 980nm pump laser diodes at IBM Zurich in 1987 using E2 facet passivation technology
- *Today:* Development and high volume manufacturing of high power laser diodes with highest brightness and reliability
- *Owners:*

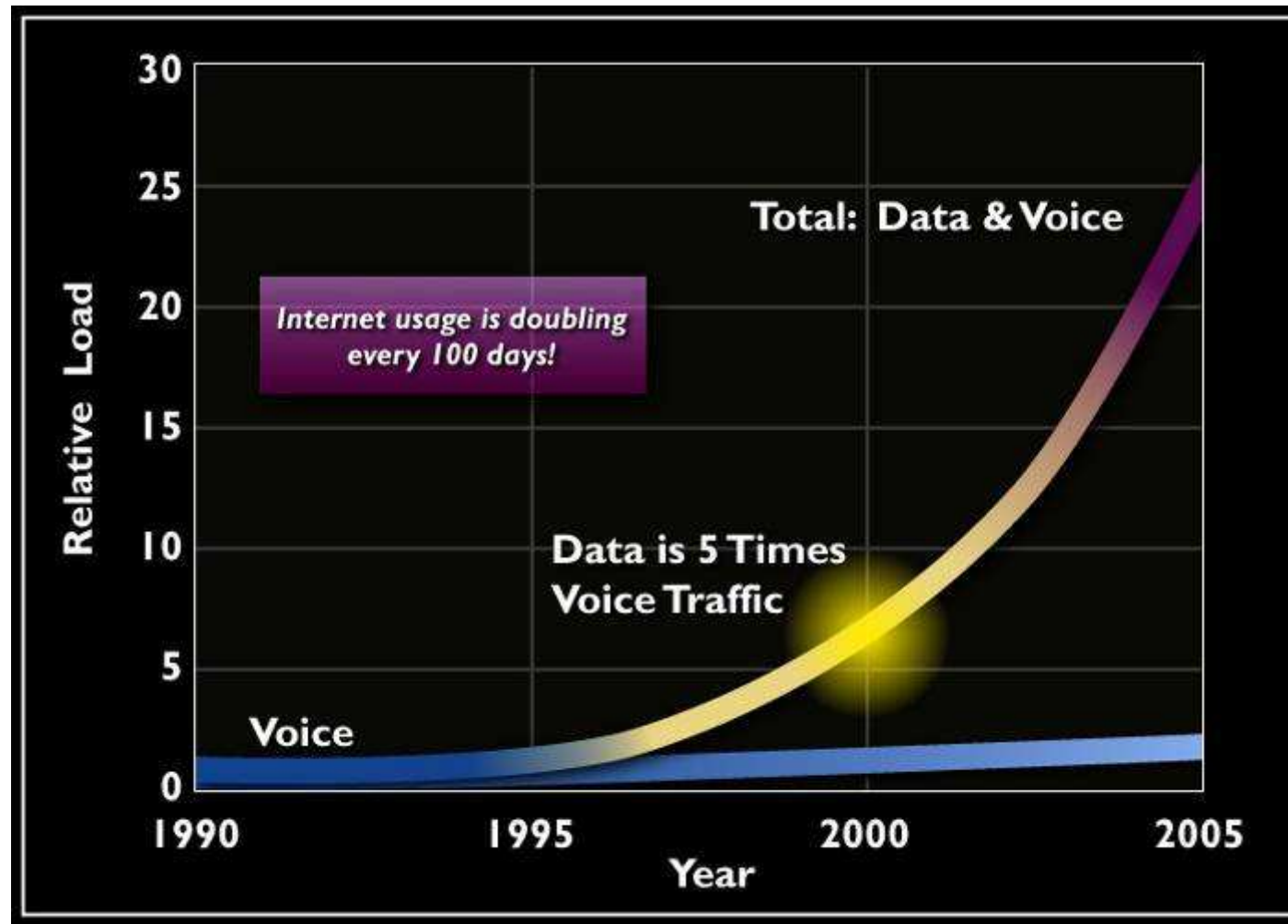


980 Chip Development / Telecom



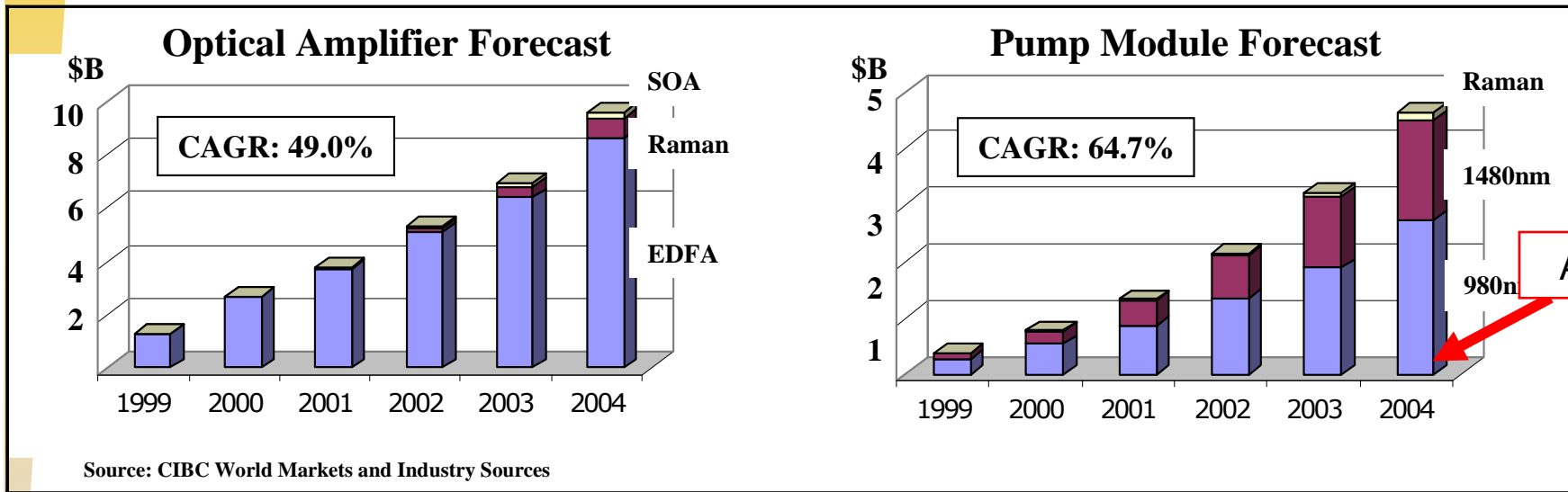
10 Years ago

Market Drivers



Market

As seen in 1999



- Technology leadership requires investment
 - Difficult in downturn... as well as in boom times
- Funding MicroSwiss PE48:
 - Funding of technology development
 - „Entwicklung der Prozess- und Montagetechnologie für Hochleistungs-Halbleiterdioden“
- Targeting alternative products & markets
 - Diode MM Pumps for Fiber laser & amplifier
 - Diode Bar Pumps for solid state laser pumping
 - Assembly process for efficient heat removal

- **Markets that we address**

- Materials Processing



Medical / Analytical



- Printing and Graphics Art

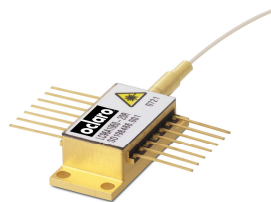
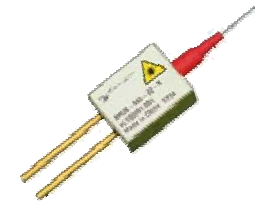
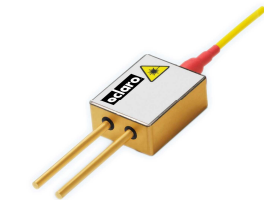
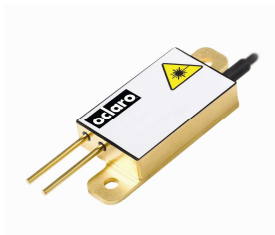


Defense / Homeland Security



- **Laser diode technology to enable**

- Fiber Lasers
- Solid State Lasers (Rod&Disk)
- Direct Diode Applications
- Frequency Conversion



- 25W out of a 105 μ m fiber 0.15NA
 - Multiple single emitters inside
 - Prototypes with 40W and more
- 10W out of a 105 μ m fiber 0.15NA at 9xxnm
 - 14W out of 200 μ m fiber at 940nm
- 2W at 793nm out of a 105 μ m fiber
 - For Thulium pumping
- Up to 750mW telecom grade single-mode pumps
- 1W peak power wavelength stabilized seed
 - 1064nm and 1030nm wavelengths
- 80-100mW 1.5 μ m DFB seed

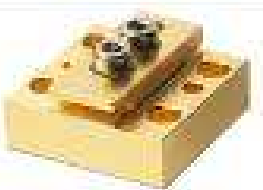
Most complete portfolio of active components for your Fiber Lasers



- 150W - 200W Bar on Microchannel Cooler
 - Highest commercially available power
 - Wall plug efficiency up to 68%
 - 5 wavelengths available



- 80W VHB Bar on Microchannel Cooler
 - 3.2mm Aperture
 - 5 wavelengths available



- 80-100W Bar on passive Cooler
 - Fill Factor 20%- 30%
 - 4 wavelengths available



- Polarization & wavelength combiners
 - Wavelength combiner non-polarizing
 - High transmission

Widest portfolio of components to build your Direct Diode System



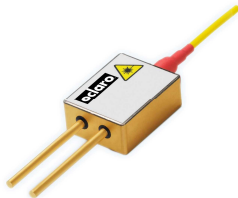
- Linear arrays at 808nm
 - 4 and 6 bar arrays readily available
 - Up to 12bars custom solutions



- 100W 50%FF Bar on Microchannel Cooler
 - 79x, 808nm
 - Highest commercially available power



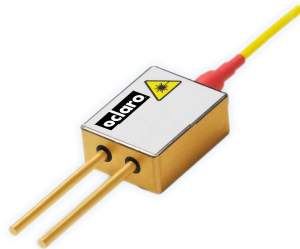
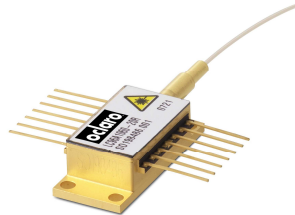
- 60W 30%FF Bar on Passive Cooler
 - Fill Factor 20%- 30%
 - 793, 808nm



- Multimode Single Emitters 808nm
 - 4W/7W Chip on Submount, C-Mount
 - 3W/6W out of a 105 μ m / 200 μ m fiber



- Multi-emitter 808nm Modules
 - 3W/6W out of a 105 μ m / 200 μ m fiber
 - Prototypes with 30W from a 200 μ m fiber



Analytical and medical

- 250mW 976nm CW SHG Pump for frequency conversion
- 1W pulsed 1064/1030nm Narrow Band FBG pumps
- 2W single emitters and 30W bars at 1470/15xxnm

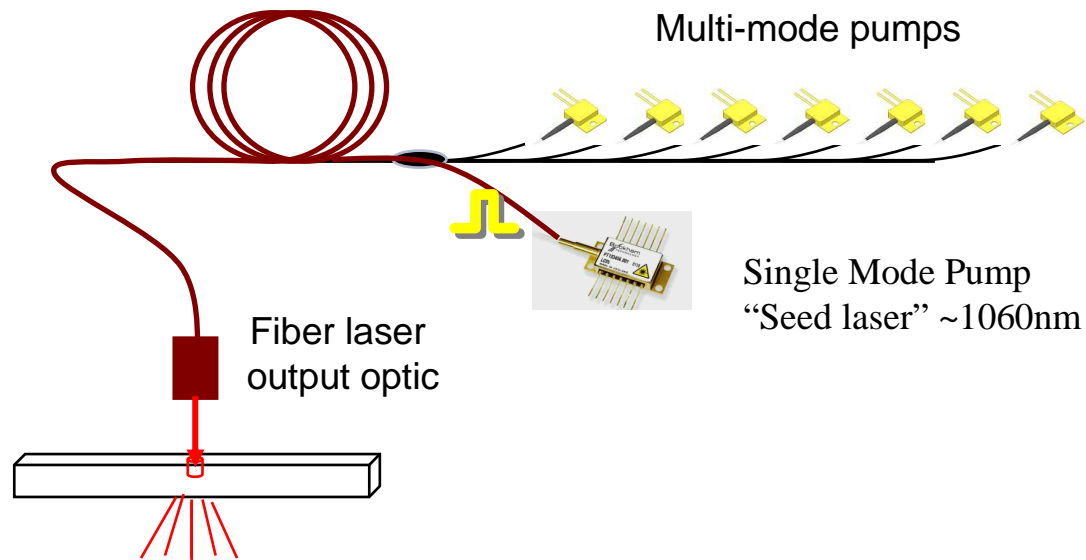
Defense and homeland security

- 14/15xx nm multimode single emitters and bars
- Up to 100mW 1.5 μ m DFB Lasers

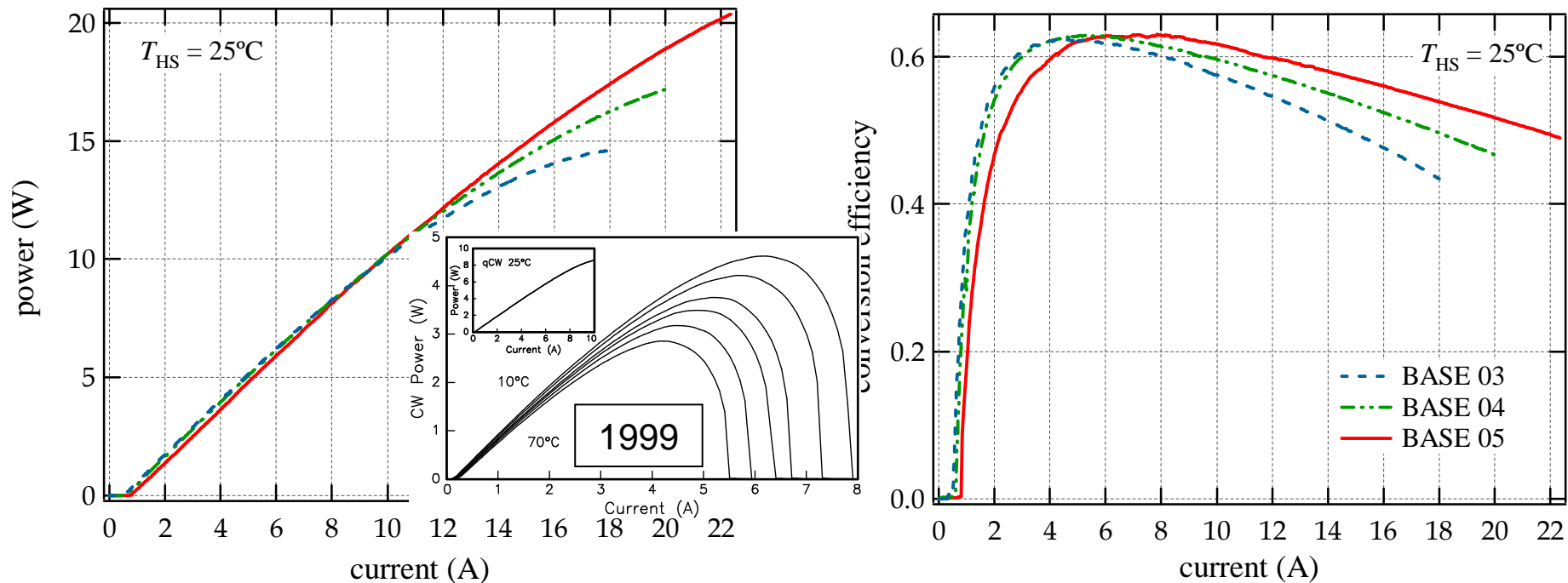
Graphics Art and Printing

- 2W 830nm 40 μ m fiber / 3W 940nm 50 μ m fiber MM Single Emitters
- 808nm Single and MM Lasers

Fiber Amplifier: 1060 Seed & MM Pump



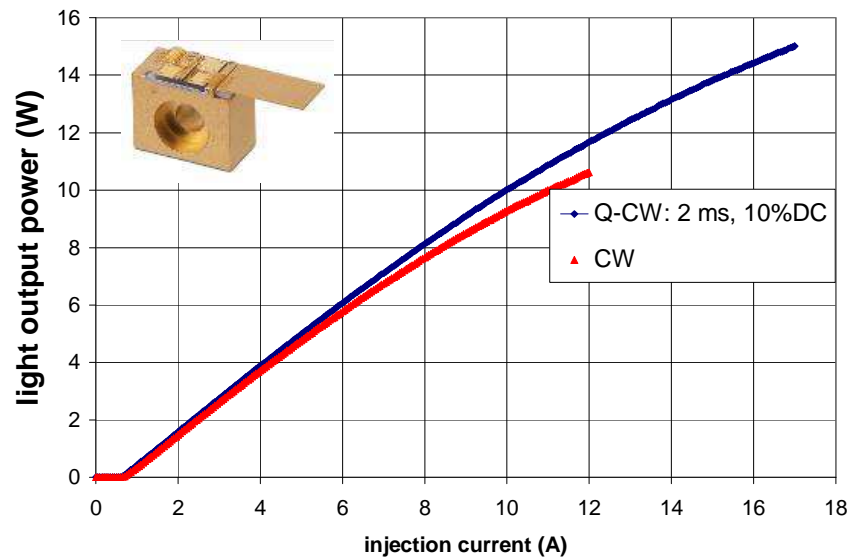
- Many 'fiber lasers' are based on a master laser diode and a fiber amplifier
 - Lower cost
 - More freedom to define spectrum
 - Ease of modulation



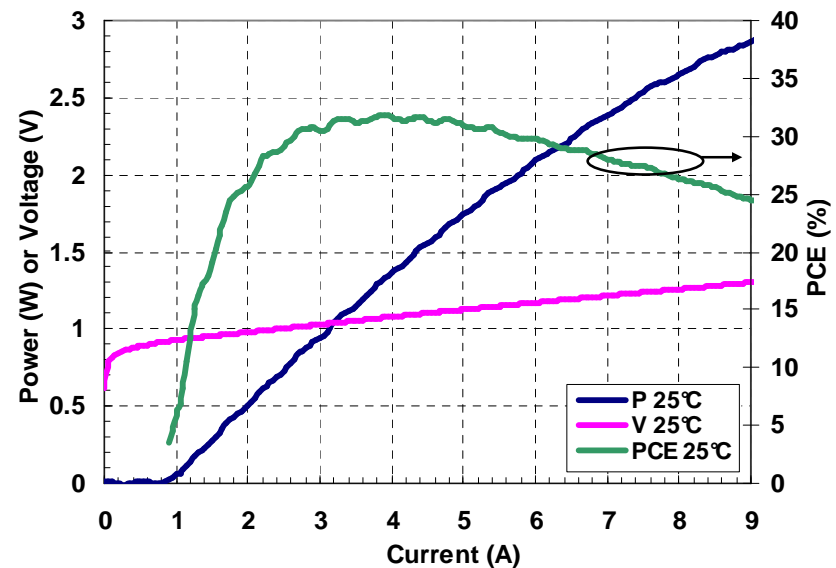
- Continuous improvement of maximum power and conversion efficiency at Pmax
- BASE 05:
 - ex-facet power of 20 W at $I_{op} = 22 \text{ A}$, $T_{hs} = 25^{\circ}\text{C}$
 - $WPE_{max} = 63\%$, $WPE_{20W} = 50\%$



Roadmap

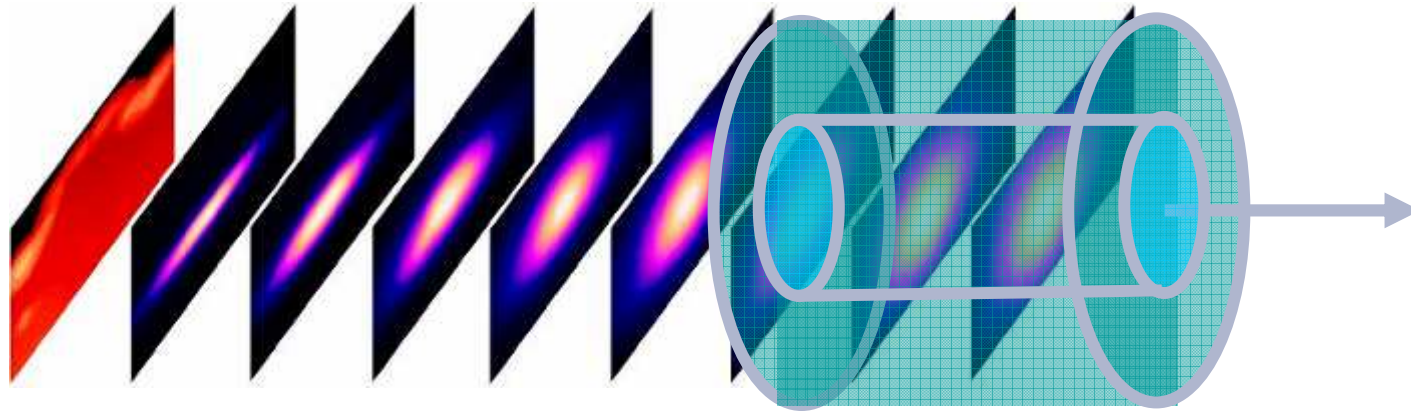


7xx/8xx nm



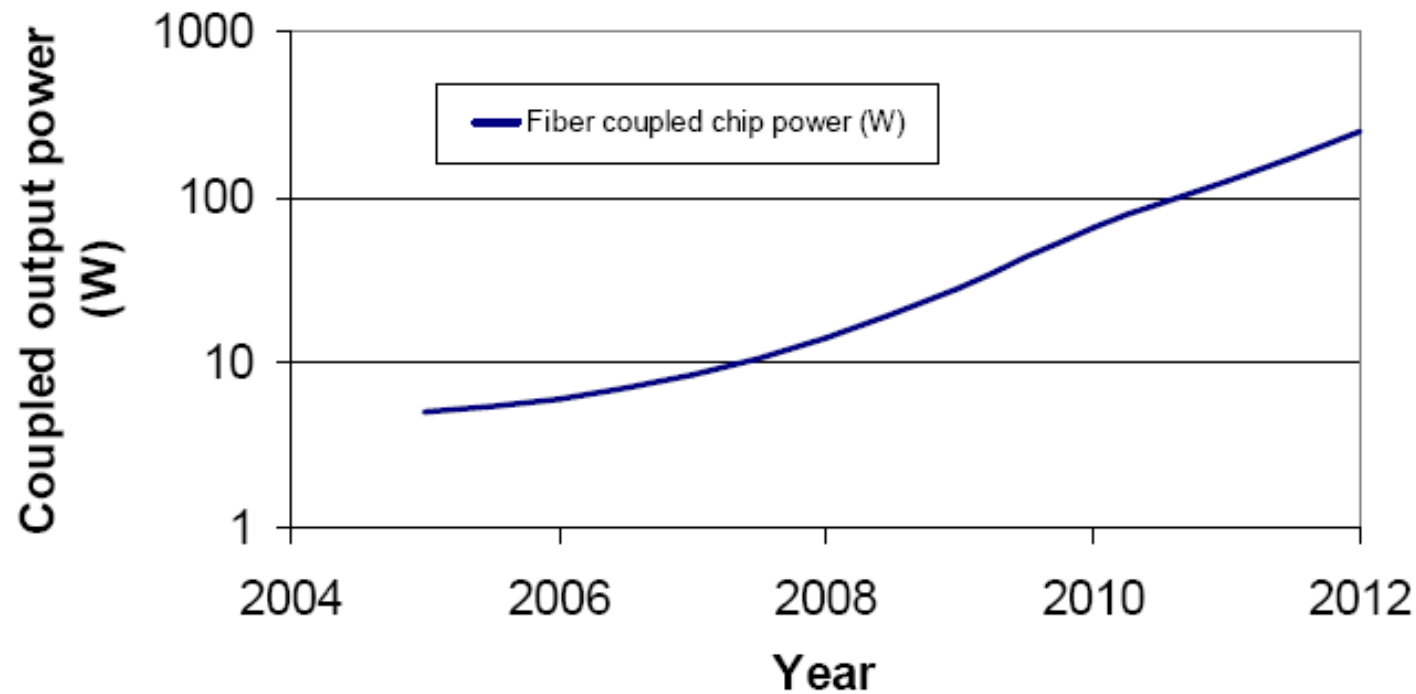
14xx/15xxnm

- Scalability in wavelength range 780-1100nm and 1.3-1.6um
 - 808nm: >10W CW with high optical robustness
 - 1500nm: >2.5W with good temperature stability
- Direct diode or Thulium fiber laser
 - Eye-safe material processing



- Constant Radiance: *it's not possible to increase radiance by combining radiation of several uncorrelated but otherwise identical sources*
- Consequences:
 - Engineering to maximize efficiency from electrode to work piece: Brightness, coupling efficiency, wallplug efficiency and cost
 - Maximise fiber coupled power prior to fiber combining

Expected FC Power from 105um Fiber



- Brightness increase in fiber by multiplexing
 - Geometrical (multiple emitter): >10x
 - Polarization multiplexing: 2x
 - (Dense) wavelength multiplexing: >2x

10W 105um MM Uncooled Module



- **Module**

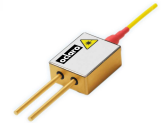
- Improved chip with 90um stripe
- Hermetic 2-pin TO-258 package
- 0.15NA or 0.22NA 105um fiber
- Floating anode/cathode

- **Electro-Optical**

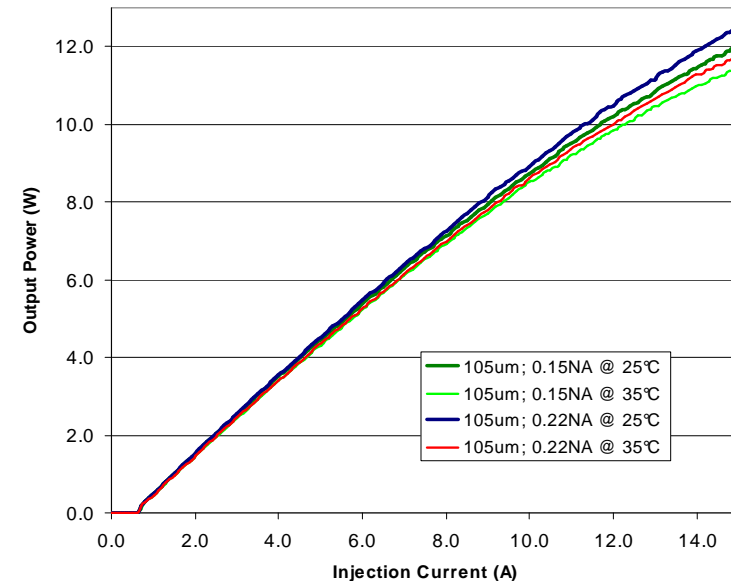
- Power: 10W @ <12A
- Wavelength: 915, 940, 960, 975nm
- Slope Eff.: 1W/A
- Wallplug Eff: 48%
- Op. Temp: 15 to 60°C

- **Reliability**

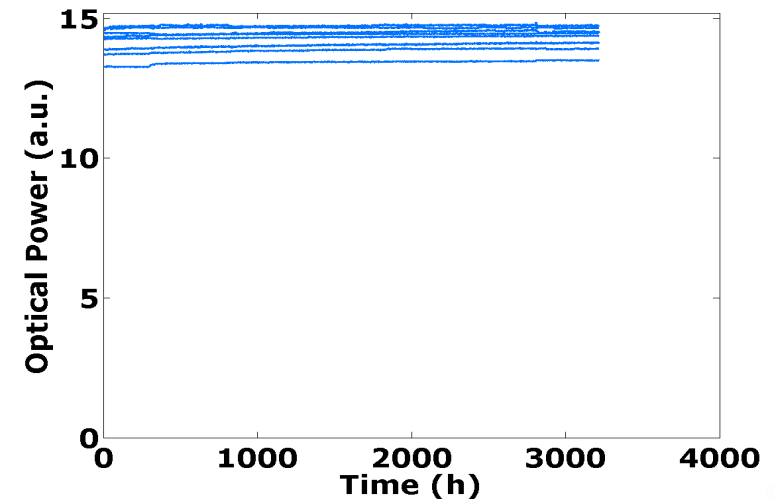
- More than 3000h chip and module lifetest data available
 - Failure Rate: <5kFIT



P-I -V Curves of 0.22/0.15NA



Chip Lifetest Curves at 15A, 15C:



25W 105 μ m Multi-Emitter MM Module



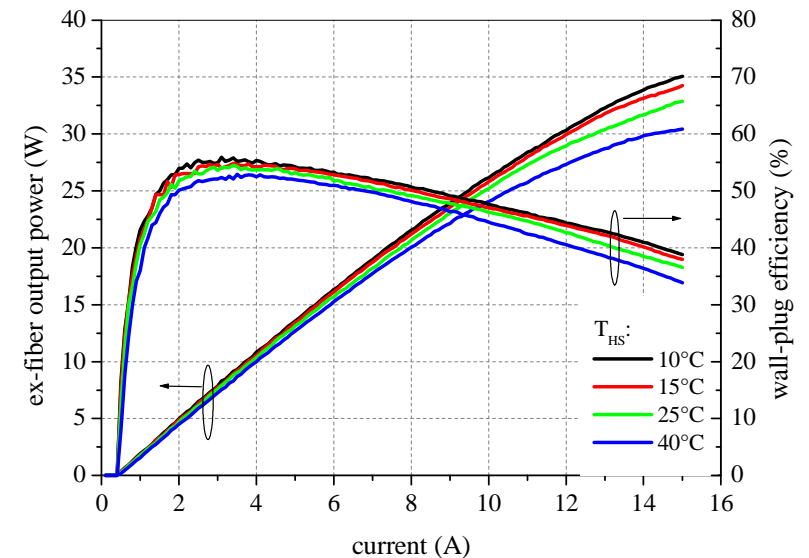
• Module

- 3 single emitters inside
- 2-pin package
- 0.15NA or 0.22NA in 105 μ m fiber
- Floating anode/cathode
- Hermetically sealed
- Additional functionality:
1060nm blocking filter included

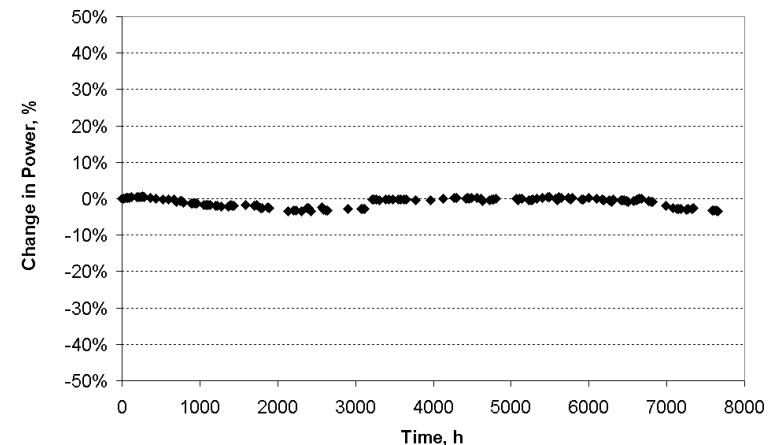
• Electro-Optical

- Power: 25W
- Current: 11A
- Wavelengths: 915, 940, 960, 975nm
- 1064 isolation: >35dB

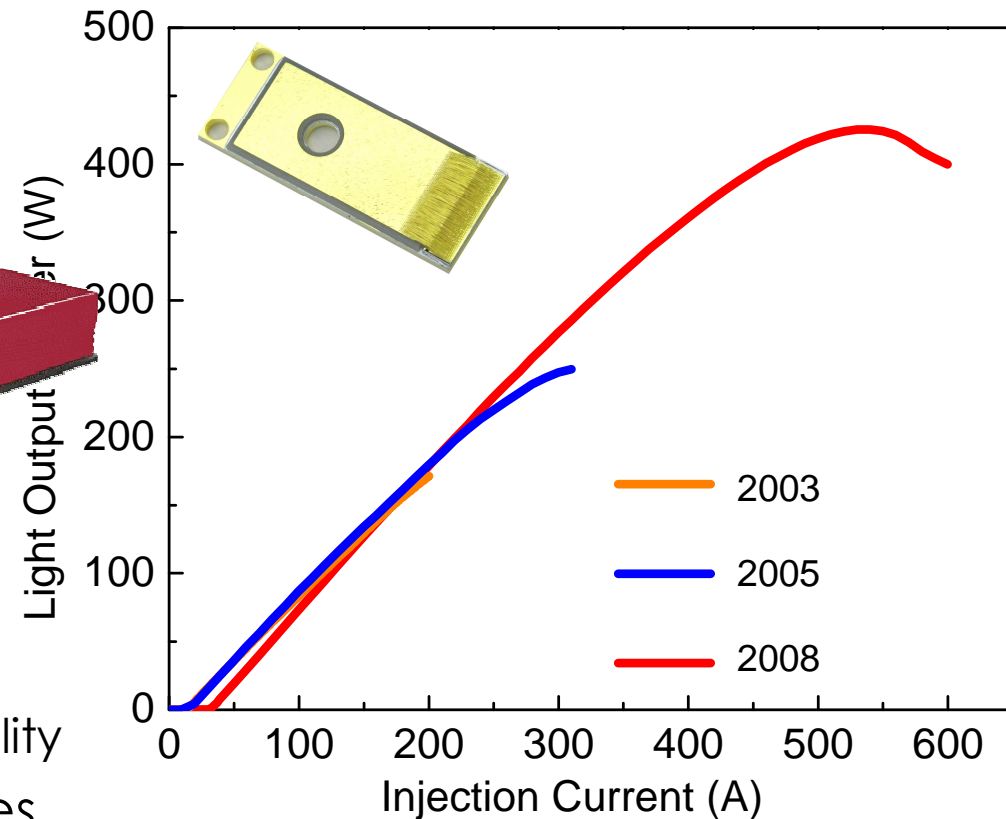
P-I -V Curves of 0.15NA 3-Emitter Module:



Module Lifetest, 25C:



High Power Laser Bars

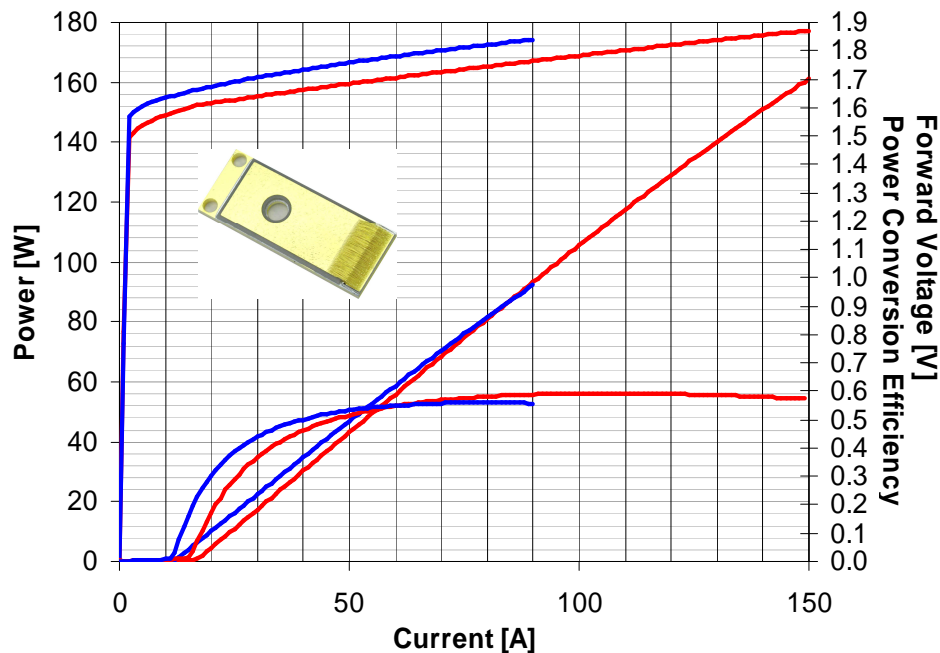


- Industry Leader
 - Power, Brightness, Reliability
- Enabling new technologies
 - Direct Diode Systems:
4kW @ 30mm mrad (600um 0.1 NA)

Next Gen (G3) 808 nm Bars

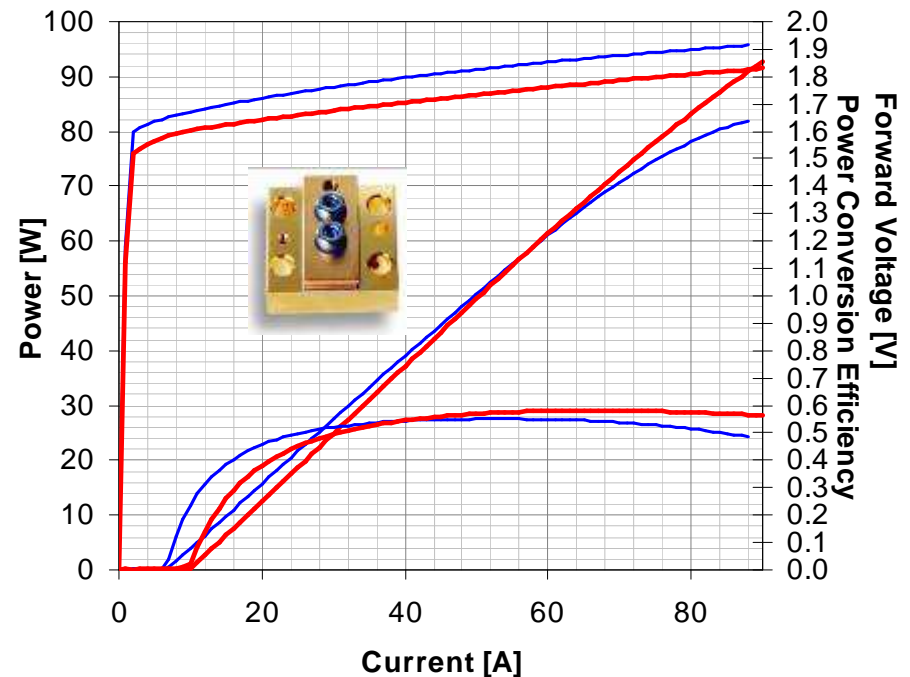


BAC60C-808-02: 50% FF, 1.2 mm cavity
Next generation 50% FF bar: 1.8 mm cavity



- High Fill-Factor Design (50%)
 - 59% PCE at 110W, 58% at 140W
 - 160W power for 150A drive current

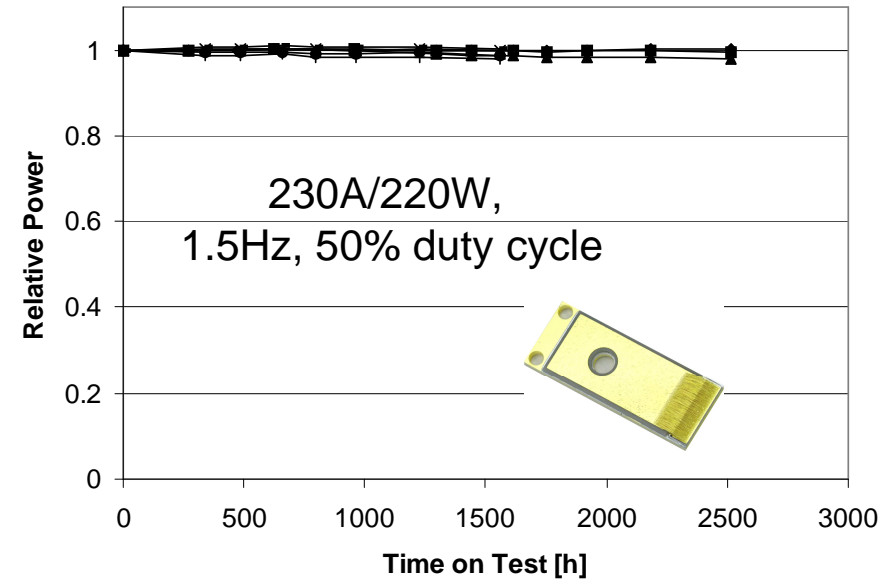
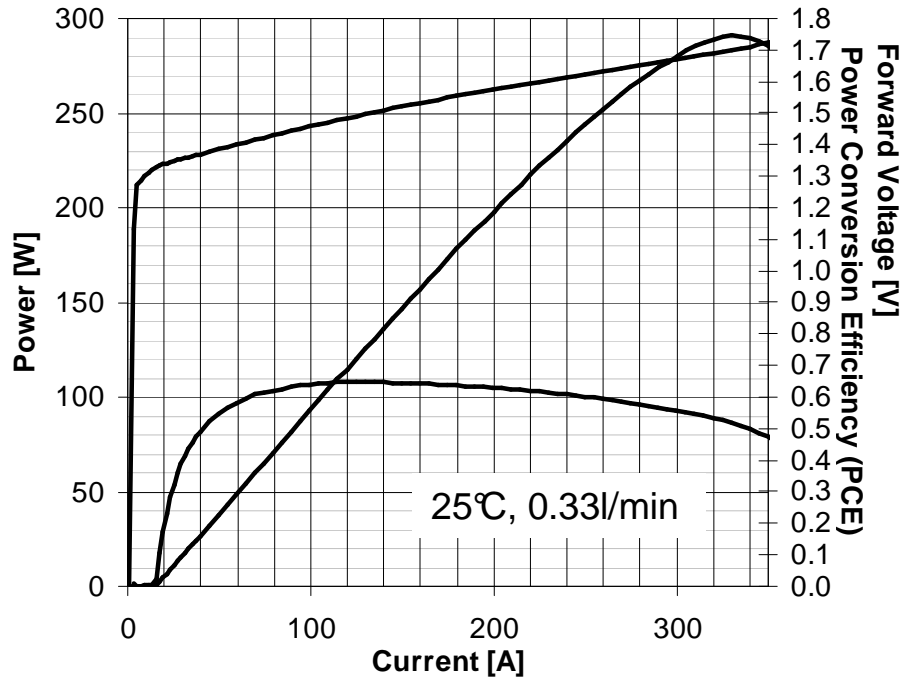
BPC40C-808-01: 30% FF, 1.2 mm cavity
Next generation 30% FF bar: 1.8 mm cavity



- Low Fill-Factor Design (30%)
 - 59% PCE at 80W, 56% for 91W
 - 91W power for 90A drive current

Industry leading efficiency, power and reliability

9xx Optimized Conversion Efficiency



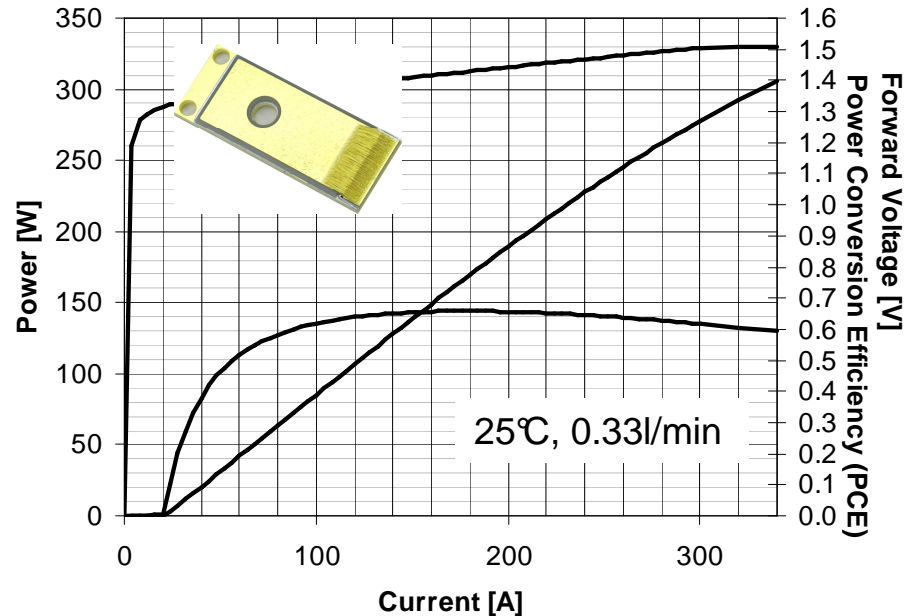
- Optimized conversion efficiency
 - 2.4mm cavity length
 - **68% PCE** for 120W output power
 - 280W peak power, limited by roll-over
- Reliability test at 230A/220W
 - Hard pulsed test condition (0-230A)
 - Degradation rates <1% per 1000h

	PCE	Light	Heat
Laser Diode	68%	120W	56W
Bulb Lamp	5%	120W	2280W

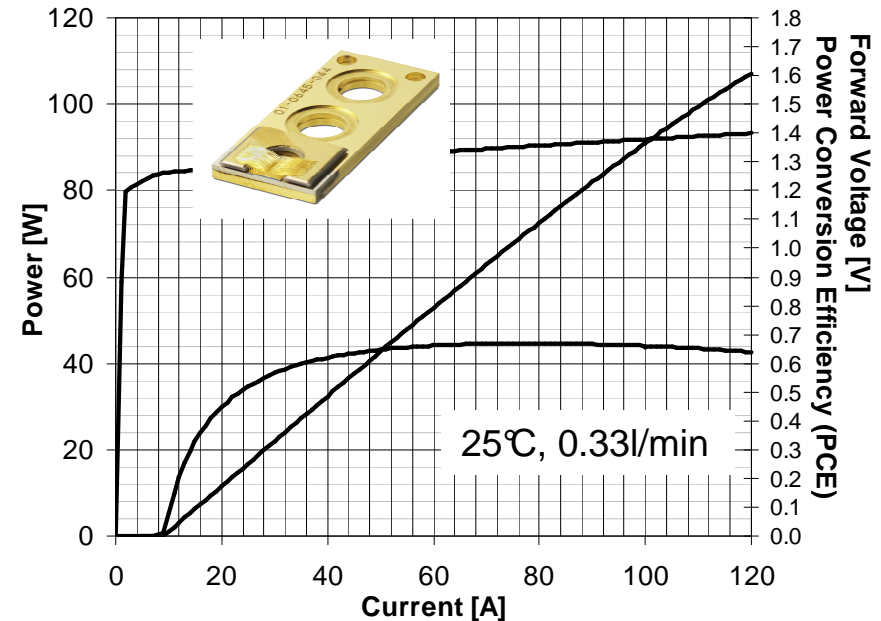
9xx Power Scaling



10 mm wide 980nm 200W bar



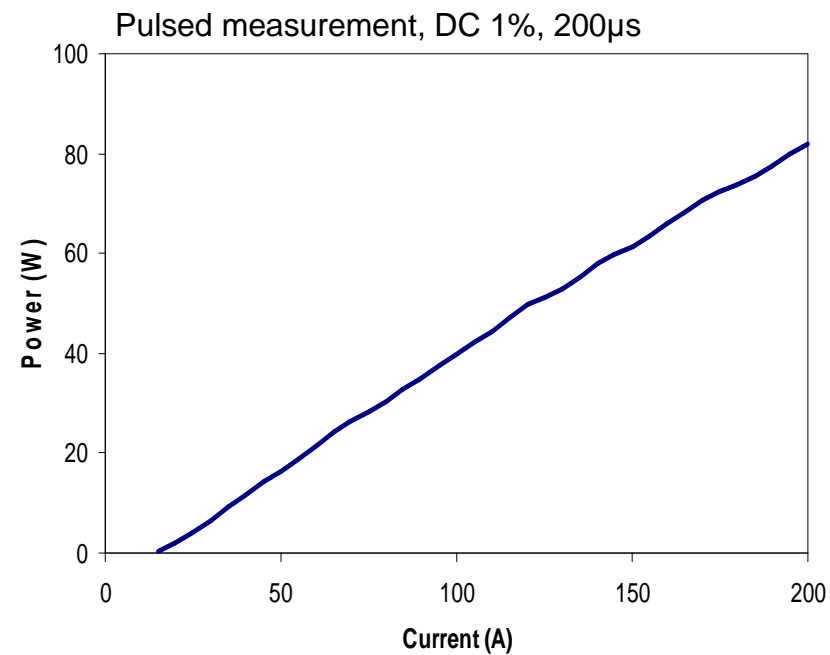
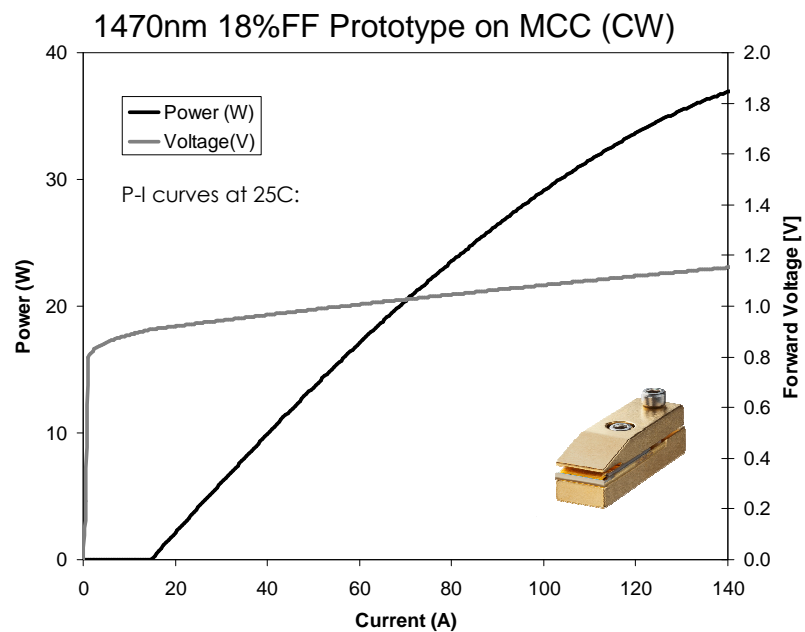
3.2 mm wide 1020nm VHB bar



- Design for maximum power
 - 66% at 200W
 - 60% at 300W
 - Low smile: <2um
- => **First 200W commercial product**

- Reduced aperture for high brightness
 - PCE: 66% at 80W
- Peak output power 120W
 - Low smile: <1um
- => **equivalent of 300W full size bar**
- => **Wavelength extension (1020, 1060) enabling further power scaling in WL multiplexed Direct-Diode Systems**

14/15xxnm 30W BAC Prototype



976nm Narrow Band SHG Pump



- **Mechanical**

- Cooled Butterfly package
- Polarization maintaining fiber
- Narrow band FBG

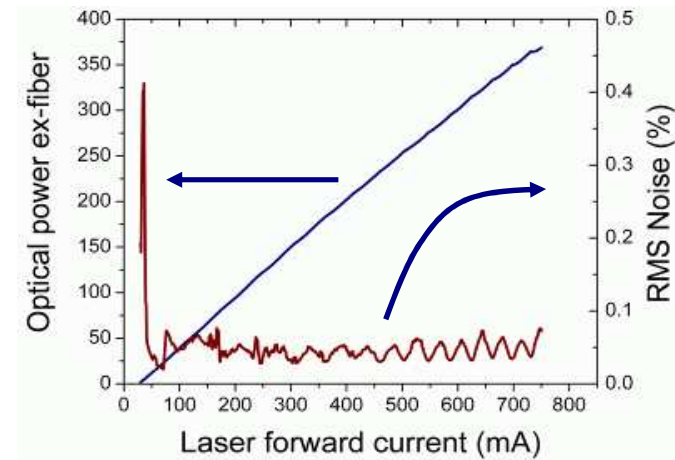
- **Application**

- Second Harmonic Generation (SHG) Pump (e.g. blue lasers)

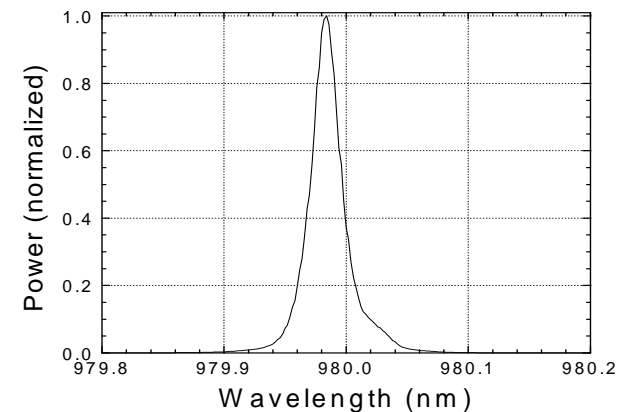
- **Performance**

- Power: typ. 300mW
- Wavelength: 976nm
- Bandwidth: <100 pm
- Noise: <0.25% RMS (100-250mW)

P-I and noise curves of SHG pump:



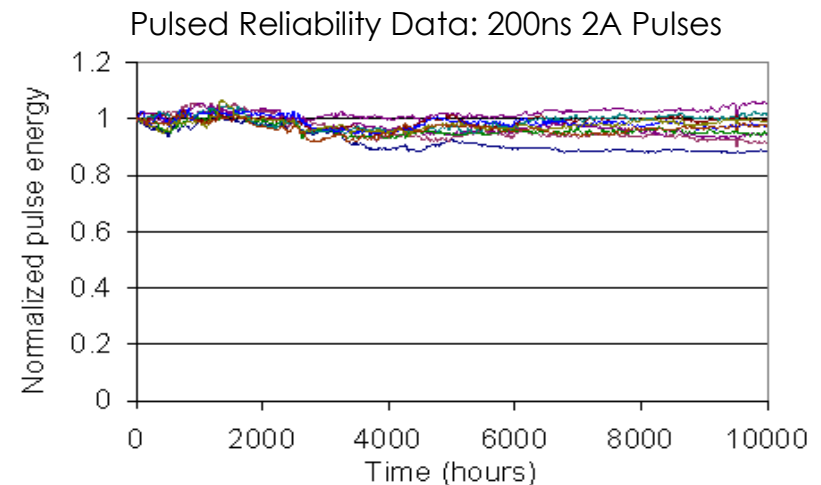
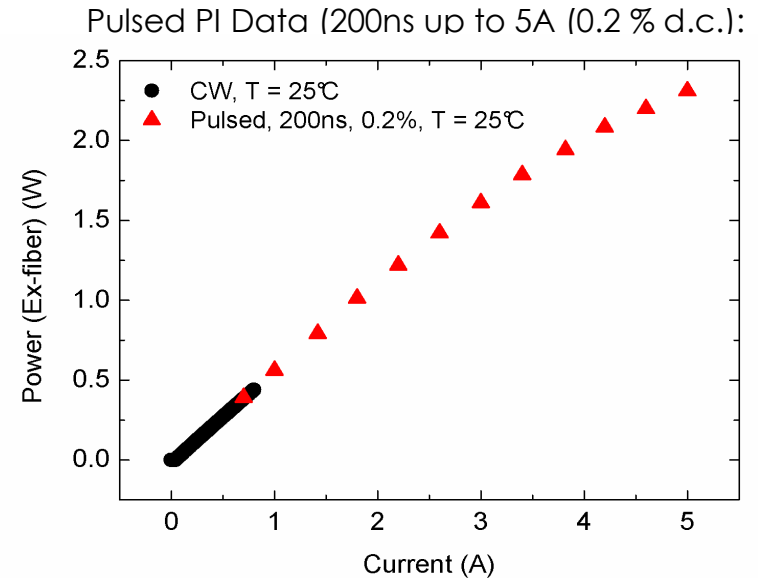
Spectrum of SHG Pump



1060nm / 1070nm Module without FBG



- **Mechanical**
 - Cooled Butterfly package
 - Polarization maintaining fiber
- **Application**
 - 10xxnm Module for Pulsed Fiber Laser Applications
- **Electro-Optical**
 - CW Power: 400mW
 - CW Current: <750mA
 - Wavelength: 1060nm or 1070nm
 - Efficiency: >55%
- **Reliability**
 - Qualified for industrial applications
 - Pulsed data:
 - up to 5A 200ns PI
 - 10000hrs lifetest up to 2A 200ns and 4000hrs up to 3.5A 200ns available



1064nm Module with Broadband FBG



NEW

• Device

- Cooled butterfly package
- Polarization maintaining fiber
- Short distance broadband FBG (<20cm FBG to lens distance)

• Application

- Pulsed Fiber Laser Applications

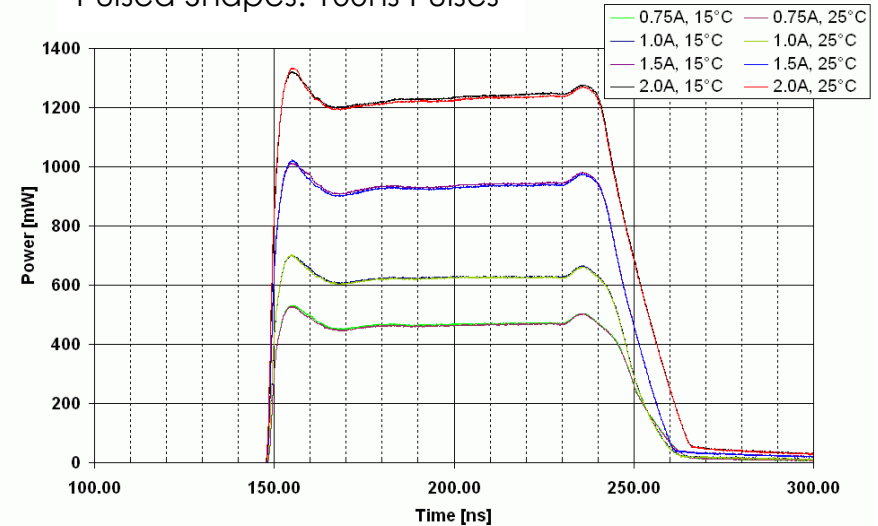
• Target Pulse Performance

- Peak Power: 1W @ <2A
- Pulse: 5-100ns; <500kHz
- Wavelength: 1064nm
- Spectral Width: 0.9nm (<2nm) (pulsed)

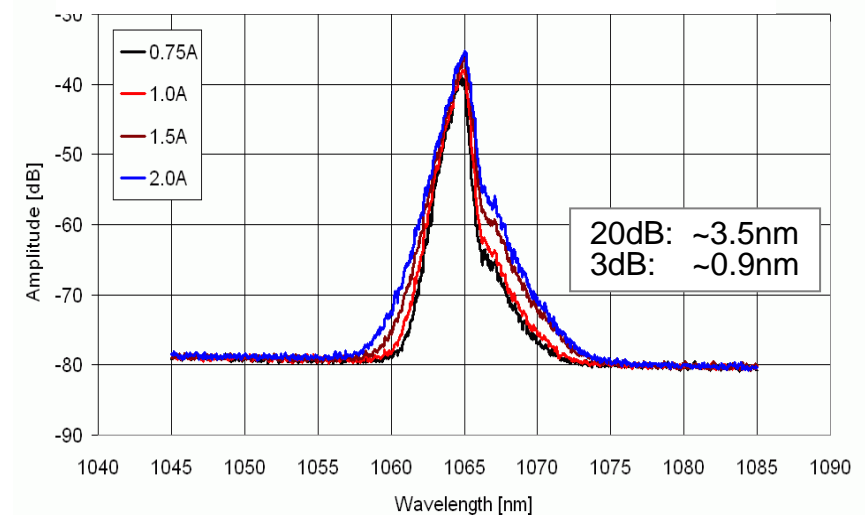
• Reliability

- Qualified for Industrial Applications

Pulsed Shapes: 100ns Pulses



Pulsed Spectrum: 100ns Pulses, 25°C



10xx nm Module with Narrow Band FBG



NEW

- **Device**

- Cooled butterfly package with PM fiber
- Short distance narrow band FBG (<20cm FBG to lens distance)

- **Application**

- Pulsed Frequency Conversion Applications

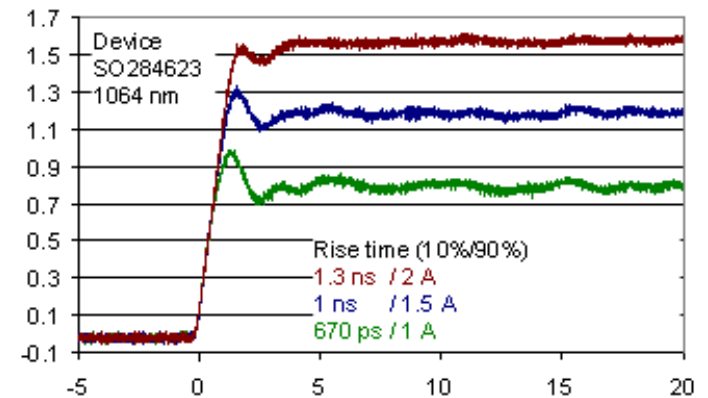
- **Pulse Performance**

- Peak Power: 1W @ <2A at 1064nm
0.75W @ <1.5A at 1030nm
- Pulse: 5-100ns; <500kHz
- Rise-time: <2ns
- Wavelength: 1030 or 1064nm
- Spectral Width: <0.3nm (pulsed)

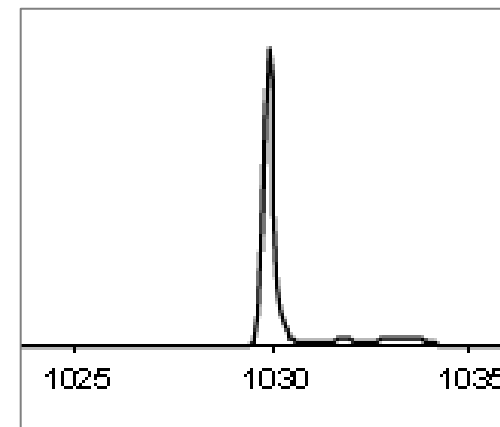
- **Reliability**

- Qualified for Industrial Applications

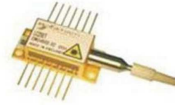
Pulse performance of 1064 NB FBG



Typical CW Spectrum of 1030nm Module with narrow band FBG



1.5 μ m DFB Module



NEW

- **Device**

- Cooled Butterfly package
- ITU grid wavelengths
- 80-100mW output power

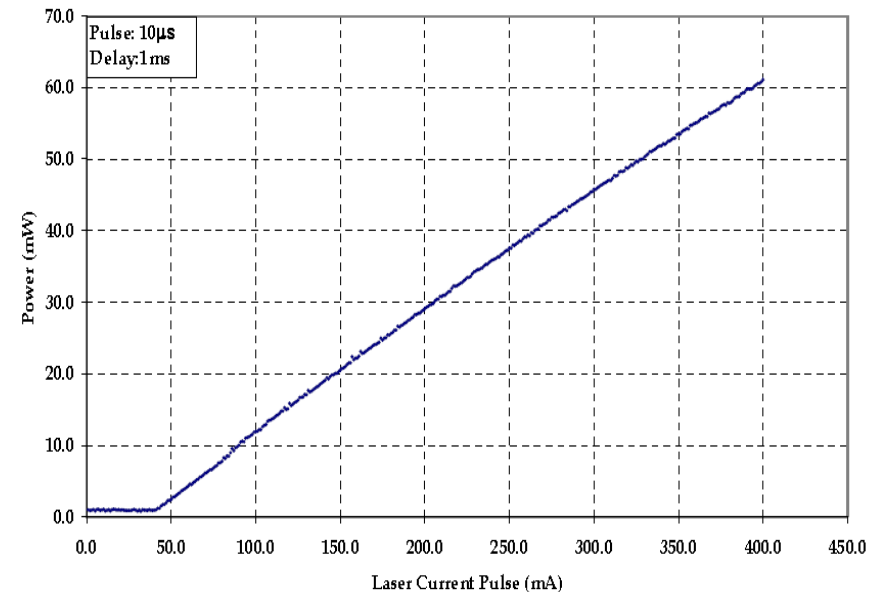
- **Application**

- Seed Laser Module for Eye Safe Pulsed Fiber Laser Applications

- **Electro-Optical**

- CW Power: 80-100mW
- Wavelength: 1529 - 1605nm
- Linewidth: 0.3MHz
- RIN: <-150dB/Hz
- Isolation: >25dB

Pulsed PI Data of 1.5 μ m DFB Laser (10 μ s)



- High power laser diodes represent highly efficient light sources
- New and environmentally friendly applications enabled
- Roadmap for brightness $>100\text{W}$ from 105um fiber
- Success story for technology funding

oclaro™

norbert.lichtenstein@oclaro.com