808nm – high power diode lasers for long term stable pump modules

G. Erbert, K. Häusler, W. Pittroff, G. Tränkle FBH

T. Schwander Tesat Spacecom
Outline

- FBH
- Design, technology and properties of single emitters
- Performance of CW laser bars
- QCW pump sources for BepiColombo
- First results for QCW pump sources with higher power and repetition rate (ATLID)
- Summary and outlook
Facts & Figures

- **Shareholders**
  - State of Berlin / Federal Republic of Germany

- **Founded in**
  - 1992

- **Member / Partner of**
  - Forschungsverbund Berlin e.V.
  - Leibniz Association
  - Technische Universität Berlin
  - Humboldt-Universität zu Berlin

- **Staff**
  - 160 (including 75 scientists & PhD students)

- **Budget / Turnover**
  - 14 M€ (including 5 M€ project revenues)
Mission of FBH

Applied research and development of microwave & optoelectronic devices, circuits and modules:

Innovations with Microwaves & Light

Market-driven & customer-oriented

- Close cooperation with partners in research and industry serving customers needs
- Part of value chain
- Demonstrators, pilot & small scale production
- Stringent quality management, DIN EN ISO 9001:2000
Research Topics

- Microwave components
- Power diode lasers
- UV emitters
- III/V-technologies

Programs

- Research and Development on microwave & optoelectronic devices, circuits, modules
- Transfer programs
  - Spin-offs and start-ups
  - SMEs
  - Global players
- Services
value chain
808nm diode lasers - basic technology of FBH

- **design:**
  - GaAsP – QW,
  - AlGaAs LOC structure (x ≈ y+0.3)
  - low vertical divergence

- **chip-technology**
  - MOVPE multi wafer reactor
  - process line (full wafer 3“)
  - passivation after cleaving
  - coating by dielectric layers using IBS

- **mounting**
  - AuSn soldering of chips
  - use of expansion matched submounts
  - Au wire bonding

![Diagram showing vertical farfield distribution](image)
808nm diode lasers of FBH – basic data

typical data of 100µm stripe emitters

- Threshold current density
  \( \approx 250 \text{A/cm}^2 \)

- Slope efficiency
  \( > 1.2 \text{W/A} \)

- Temperature stability
  \( > 120 \text{K} \)

- COD level (500µs, 50Hz)
  \( > 10 \text{W/100µm} \)

- TM polarisation

![Graph showing optical power and current relationship for diode lasers.](attachment:image.png)
808nm diode lasers of FBH – basic reliability

- **Lifetime test at high facet load**
  - Mounting on C-Mount \( R_{th} \approx 10 \text{K}/\text{W} \)

- **Excellent stability**
  - 40mW / \( \mu \text{m} \) stripe width

- **failures at 50mW / \( \mu \text{m} \) stripe caused by internal defects

- **QCW – bar performance** determined by mounting issues and homogeneity!
  - Stability of chip material against optical load
    - > 50 000h @ 2% duty cycle
  - small chips

![Graph showing current vs. time for different power outputs and temperatures](image)
CW – laser diode benches for space suited 808nm pumping modules

- **Projects**
  - LCTSX
  - ALADIN
  - GIFTS
  - LTP
  - QSL

- **Chip design**
  - minbar (chip size <5mm)
  - low fill factor

- **Space qualified mounting process**
  - expansion matched materials
  - AuSn – solder
  - high precision, robust FAC fixing
  - external spectral stabilization
Reliability of space suited CW- laser diode benches

- Long term test ⇒ reliability > 0.99  4 years at P = 1W  (≤10mW/μm)
- Tested mounting scheme
  - temperature cycling
  - mechanical issues
808nm – QCW pump sources for Bepi Colombo

Requirements

- 700 W usable power (fibre coupled)
- 200µs pulse width, ≤10Hz rep. rate
- Long term stability
  - 300 Mio shots
  - about 10 year storage
- $T_{op} = (22 \pm 10) \, ^\circ C$
- Environmental conditions (-45°C ... 65°C)
- small size and low weight
808nm – QCW pump sources for Bepi Colombo: chip - design

- design for 70W power / bar (derated power level)
- GaAsP QW
- LOC -structure
- small chip size
  - facet load 20mW/µm
  - 4.5 mm emitting aperture (half of standard bar!)
  - 1.5 mm resonator length
  - 35 emitter, filling factor 70%
- conversion efficiency of chip ≈ 60%
- wavelength (807 ± 2)nm
808nm – QCW pump sources for Bepi Colombo: mounting issues

- no dense vertical stacks
- Single devices 
on 10x10mm² footprint
- Expansion matched materials
- AuSn soldering  
  (chip, n-contact plate)
- Wire bonding
- Approved FAC fixing
808nm – QCW pump sources for Bepi Colombo: L-U-I curves

- \( I_{th} \approx 15 \, \text{A} \)
- \( I_{op} \approx 70 \, \text{A} @ 70\,\text{W} \)
- Slope \( \eta_d \geq 1.25\,\text{W/A} \)
- conversion efficiency \( \eta_c \approx 50\% @ 70 \, \text{W} \)
- Series resistance \( R_s \approx 9 \, \text{m\Omega} \)
- COD level \( P_{\text{max}} > 250\,\text{W} \) ! ( > 80mW/\( \mu \text{m} \))
808nm – QCW pump sources for Bepi Colombo: spectral peak 806nm
- spectral width (95% power) < 4nm
- additional modulation by FAC
- wavelength shift determined by temperature

Bar 09a12 from F0694-4
λ@ 70W = 805.8nm;
λ@100W = 806.5nm;
λ@150W = 808.7nm;
t = 22°C

Intensity vs. Wavelength (nm)
808nm – QCW pump sources for Bepi Colombo: beam profile

- Fast axis with collimation: \( \theta_\perp < 5\text{mrad (}>95\% \text{ power)} \)
- Slow axis: \( \theta_\parallel < 120\text{mrad (>95\% power)} \)
Preliminary life test for bars Bepi Colombo

- **Purpose**
  - demonstration of feasibility
  - determination of screening parameters

- **Conditions**
  - 10 devices (348 emitters) (selected by L-I curve + 300h burn in at 100A / 10Hz)
  - constant current $I_{op} = 142A$ ($P > 150$ W)
  - 20 Hz
  - 1300 h $\approx 93.6$ Mshots
### Results of life test

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I&lt;sub&gt;th&lt;/sub&gt; /A</td>
<td>13.6</td>
<td>14.7</td>
<td>13.9</td>
<td>13.0</td>
<td>14.6</td>
<td>14.0</td>
<td>13.6</td>
<td>13.2</td>
<td>14.0</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>13.7</td>
<td>14.8</td>
<td>15.1</td>
<td>13.2</td>
<td>15.1</td>
<td>14.6</td>
<td>15.6</td>
<td>13.8</td>
<td>13.7</td>
<td>14.2</td>
</tr>
<tr>
<td>I&lt;sub&gt;op&lt;/sub&gt; (100W) /A</td>
<td>92</td>
<td>94</td>
<td>92</td>
<td>92</td>
<td>93</td>
<td>94</td>
<td>94</td>
<td>92</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>92</td>
<td>100</td>
<td>92</td>
<td>104</td>
<td>92</td>
<td>100</td>
<td>100</td>
<td>105</td>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td>Δλ /nm</td>
<td>0</td>
<td>0.5</td>
<td>0.1</td>
<td>-1.3</td>
<td>0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.7</td>
<td>1.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Emitter failure</td>
<td>0</td>
<td>1*</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>1*</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- no bar failed  (EOL – current limit  I<sub>op</sub> < 110A @100W)
- Long term stable spectral behaviour  Δλ < 1nm
- Reliability > 0.999 per bar for  P<sub>op</sub> = 70W, 3.15x10<sup>8</sup> shots (10Hz, 1 year)
  - calculation based on random single emitter failures,
  - acceleration by power (P/P<sub>op</sub>)<sup>2.3</sup>
  (2.3 standard value of 808nm devices)
808nm - QCW – pump sources for higher average power (ATLAS)

- Requirements
  - 808nm
  - space qualification issues similar to Bepi Colombo
  - output power $\geq 100W$ per bar
  - repetition rate $\approx 100Hz$
  - reliability 10 Gshot

$\Rightarrow$
- improved chip design for slightly higher peak power
- Improved mounting scheme designed for 10x-higher average power
808nm - QCW – pump sources for higher average power (ATLAS) first results I

100W power / bar

- GaAsP QW
- improved layer - structure
- chip size
  - facet load 30mW/µm
  - 4.5 mm emitting aperture
  - 1.5 mm resonator length
  - 35 emitter, filling factor 70%
- conversion efficiency of chip ≈ 65%
- wavelength (807 ± 2)nm
808nm - QCW – pump sources for higher average power (ATLAS) first results II

- spectral peak at 804.5nm
- enabling $\lambda$ - tuning by CW bias current
- spectral width < 4nm (95% power)
- wavelength shift determined by temperature
Summary – 808nm QCW pump lasers

- **electro – optical performance**
  - $I_{op} < 100A @ 100W \ (\approx 70A @ 70W)$
  - $P_{cud} > 3 \times P_{op}(70W)$
  - $\lambda \approx (805...806)\text{nm}$, $\Delta \lambda (95\%) \leq 5\text{nm} \ @ P_{op}$
  - far field $\Theta_\perp < 5\text{mrad}$, $\Theta_\parallel \approx 120\text{mrad} \ @ 95\%$
  - $U_{op} \approx 2.4 \text{ V} \ @ 100A$

- **mounting scheme**
  - proved design for 10Hz
  - thermal cycling between – 45°C and 65°C

- **reliability** $> 0.999 \ (70W, \ 1 \text{ year}, \ 10\text{Hz})$ expected
outlook

- To do - short range
  - screening procedure
  - verification of reliability
  - extended life time tests (acceleration!?)
  - reducing series resistance

- Improvement opportunities chip - longer range
  - optimised design (pumping scheme)
  - wavelength stabilisation by internal gratings (DFB /DBR)