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für Höchstfrequenztechnik

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SPACECOM

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

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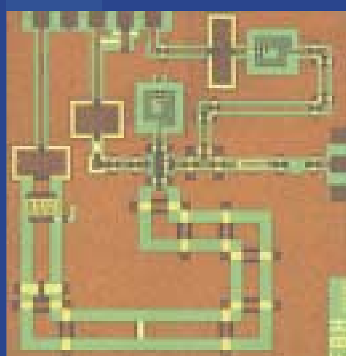
...translating ideas into innovation

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:

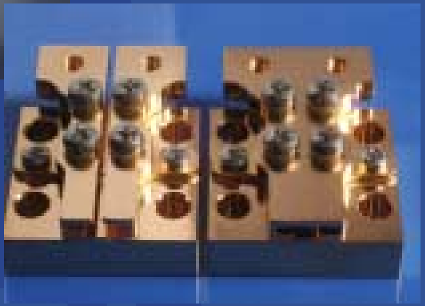
Innovations with Microwaves & Light

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

GLC Certified ISO 9001

Research Topics

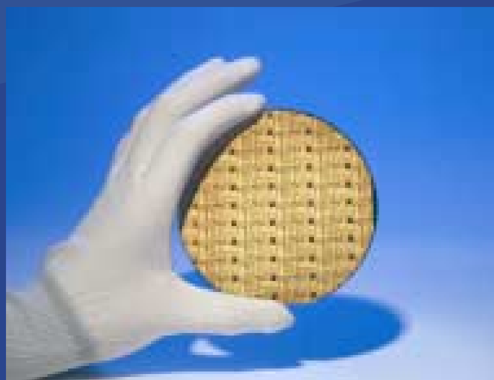


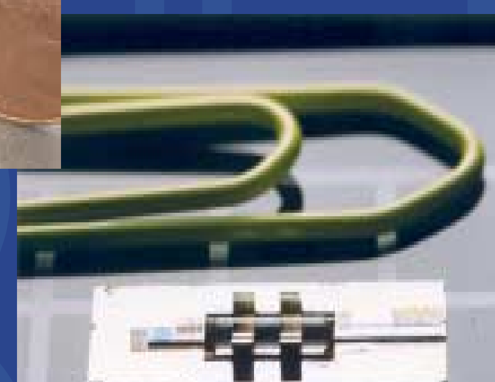
- Microwave components
- Power diode lasers
- UV emitters
- III/V-technologies

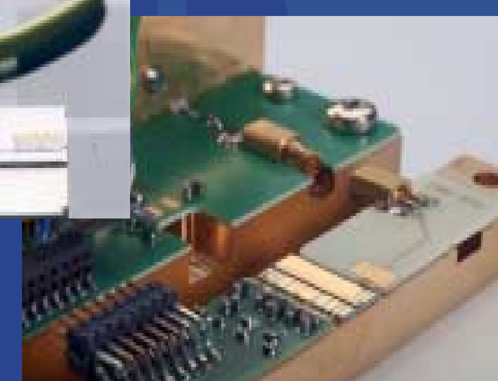
Programs

- Research and Development
  on microwave & optoelectronic devices, circuits, modules
- Transfer programs
  - Spin-offs and start-ups
  - SMEs
  - Global players
- Services

value chain

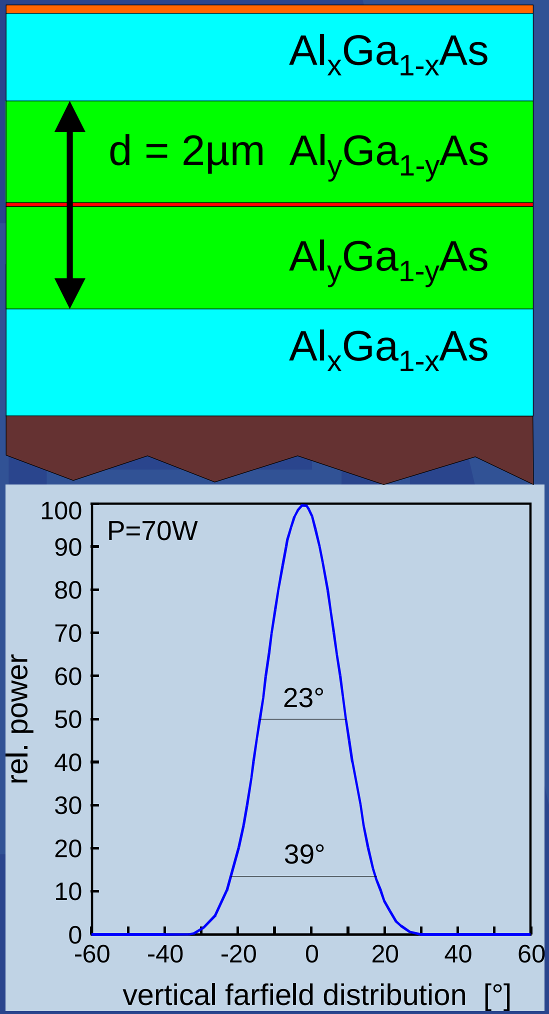






808nm diode lasers - basic technology of FBH

- **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



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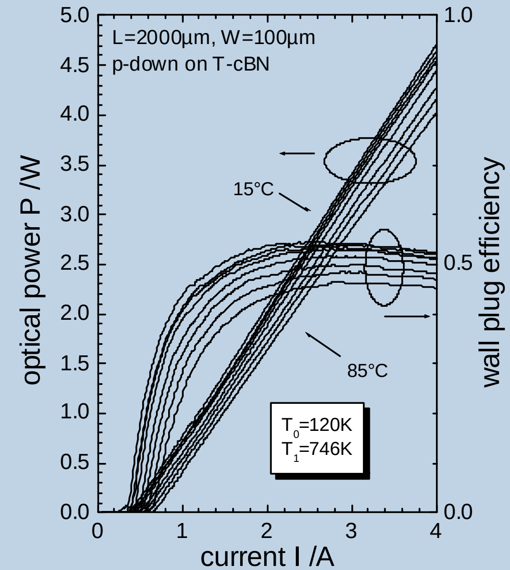
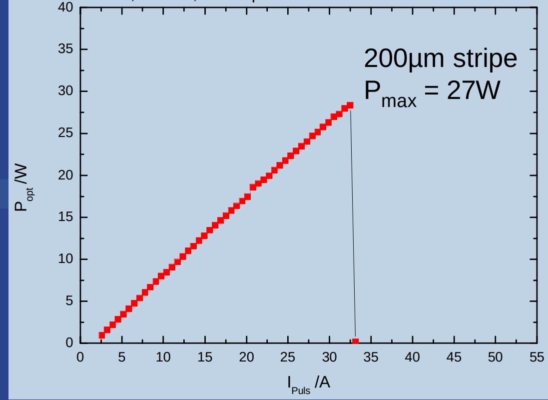
808nm diode lasers of FBH – basic data

typical data of 100µm stripe emitters

- **Threshold current density**
  ≈ 250A/cm²
- **Slope efficiency**
  > 1.2W/A
- **Temperature stability**
  > 120K
- **COD level (500µs, 50Hz)**
  > 10W/100µm
- **TM polarisation**

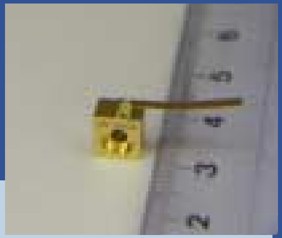


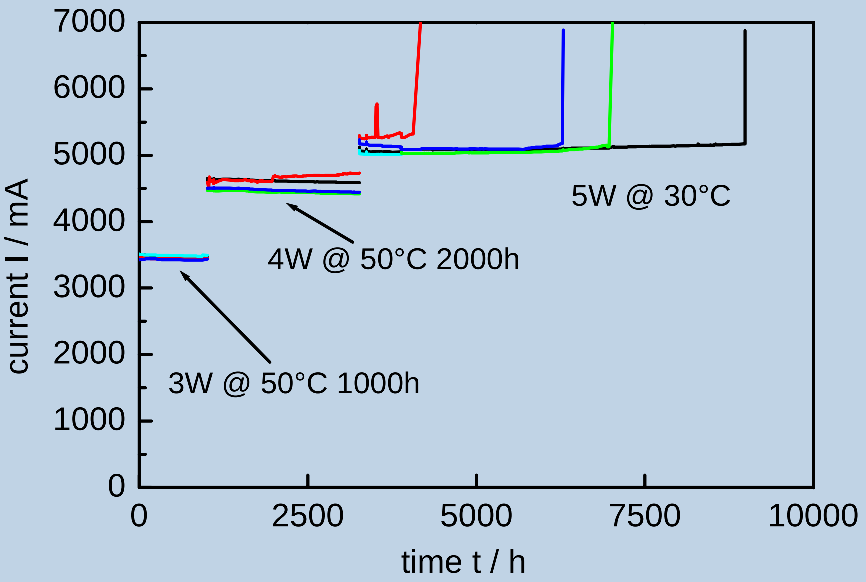
080713 aus C0179-3 (2252,2304)
t=25°C, f=50Hz, w=500µs



808nm diode lasers of FBH – basic reliability

- Lifetime test at high facet load
  - Mounting on C-Mount (R_{th}≈10K/W)
- Excellent stability
  40mW / µm stripe width
- failures at 50mW / µm 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





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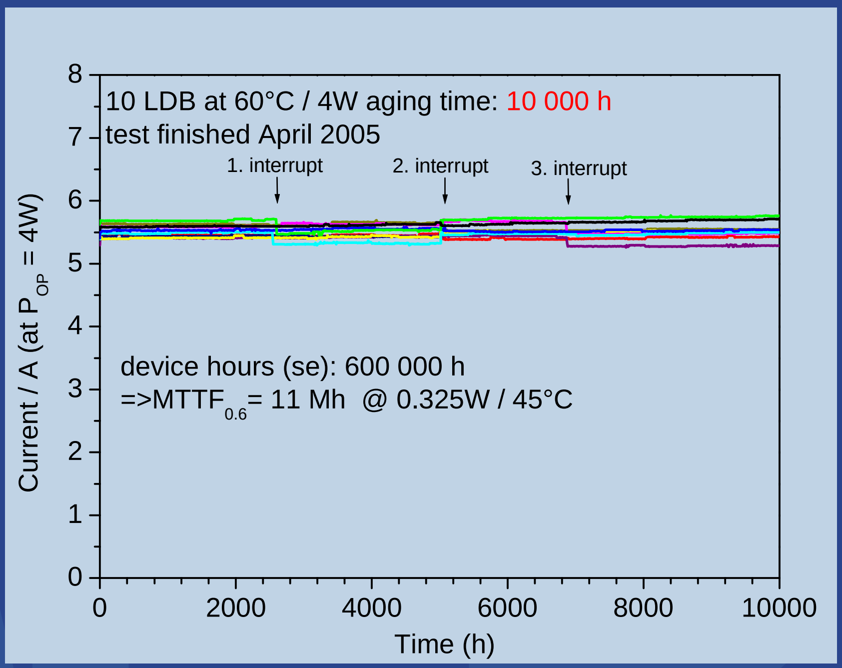
CW – laser diode benches for space suited 808nm pumping modules

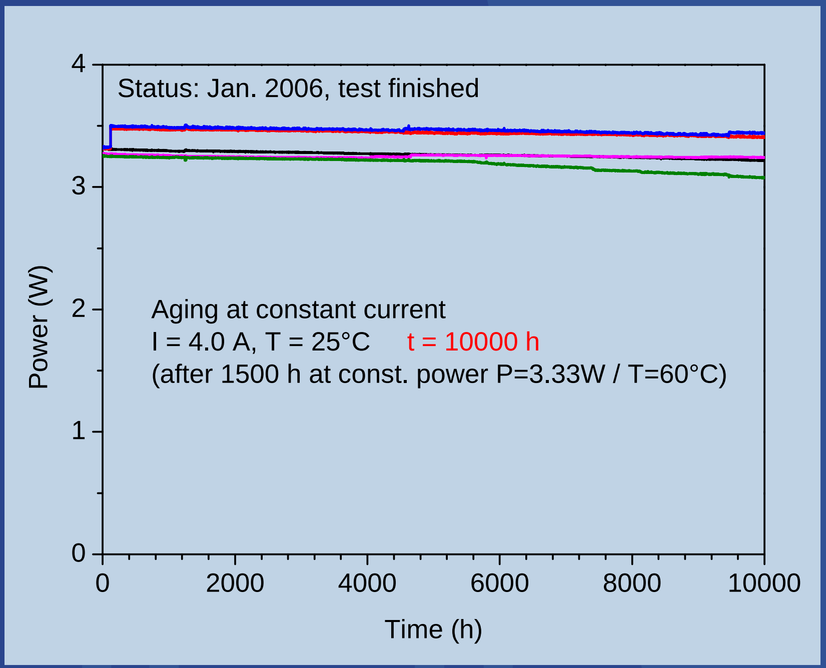
- **Projects**
  - LCTSX
  - ALADIN
  - GIFTS
  - LTP
  - QSL
- **Chip design**
  - minibar (chip size <5mm)
  - low fill factor
- **Space qualified mounting process**
  - expansion matched materials
  - AuSn – solder
  - high precision, robust FAC fixing
  - external spectral stabilization

Reliability of space suited CW- laser diode benches

4W, 10 000h, 60°C LCTSX



4A, 10 000h, 25°C ALADIN



- **Long term test ⇒ reliability > 0.99 4 years at P = 1W (≤10mW/µm)**
- **Tested mounting scheme**
  - temperature cycling
  - mechanical issues

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808nm – QCW pump sources for Bepi Colombo

Requirements

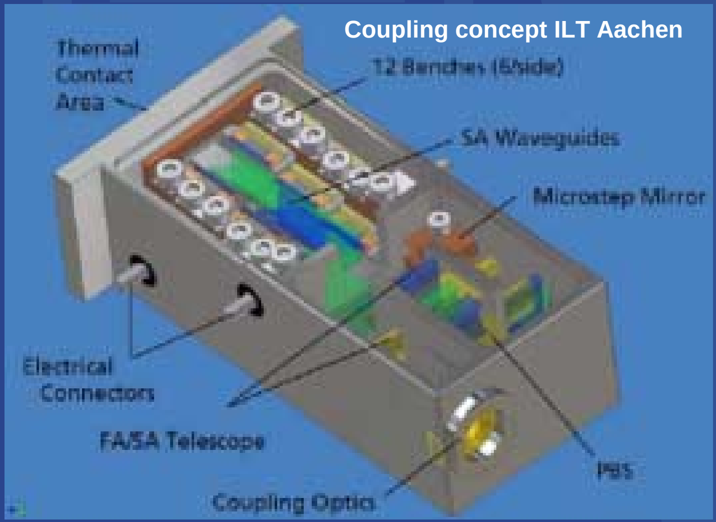
- 700 W usable power (fibre coupled)
- 200µs pulse width, ≤10Hz rep. rate
- Long term stability
  - 300 Mio shots
  - about 10 year storage
- $T_{op} = (22 \pm 10)$ °C
- Environmental conditions (- 45°C … 65°C)
- small size and low weight

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



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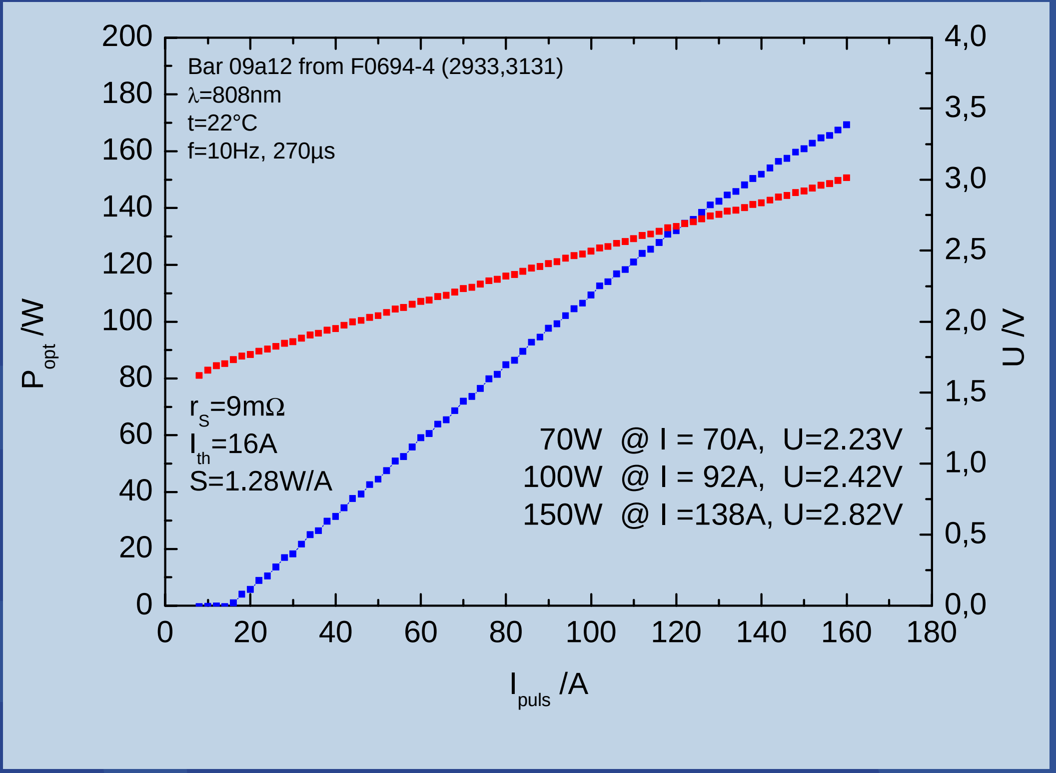
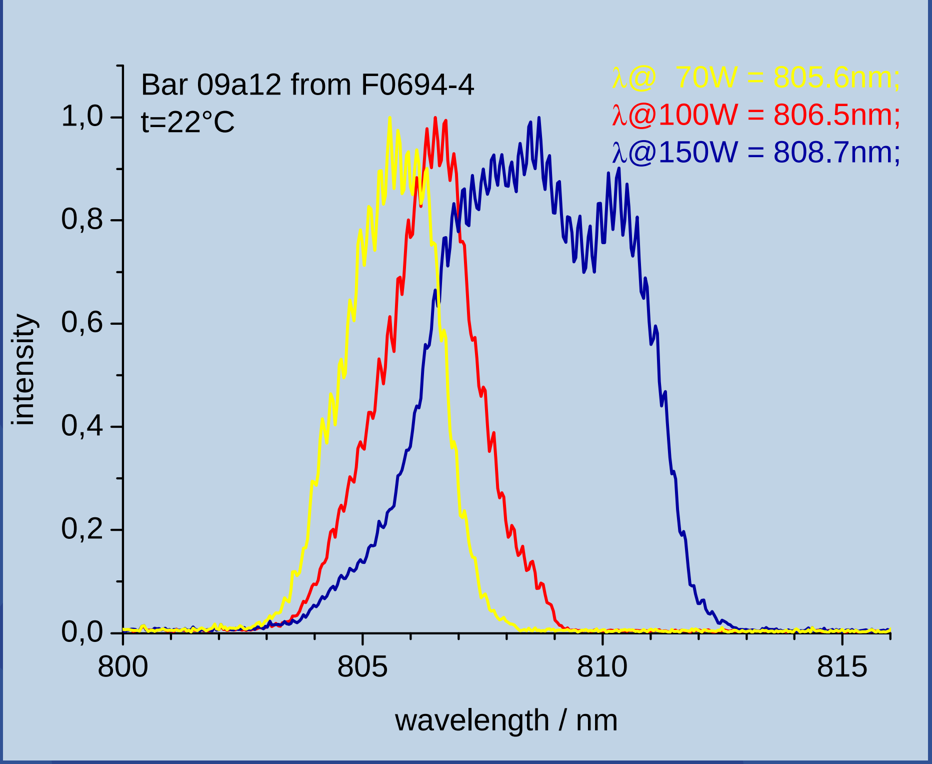
808nm – QCW pump sources for Bepi Colombo : L-U-I curves

- $I_{th} \approx$ 15 A
- $I_{op} \approx$ 70 A @ 70W
- Slope $\eta_d \geq$ 1.25W/A
- conversion efficiency
  $\eta_c \approx$ 50% @ 70 W
- Series resistance
  $R_s \approx$ 9 mΩ
- COD level P_{max} > 250W !
  (> 80mW/µm)

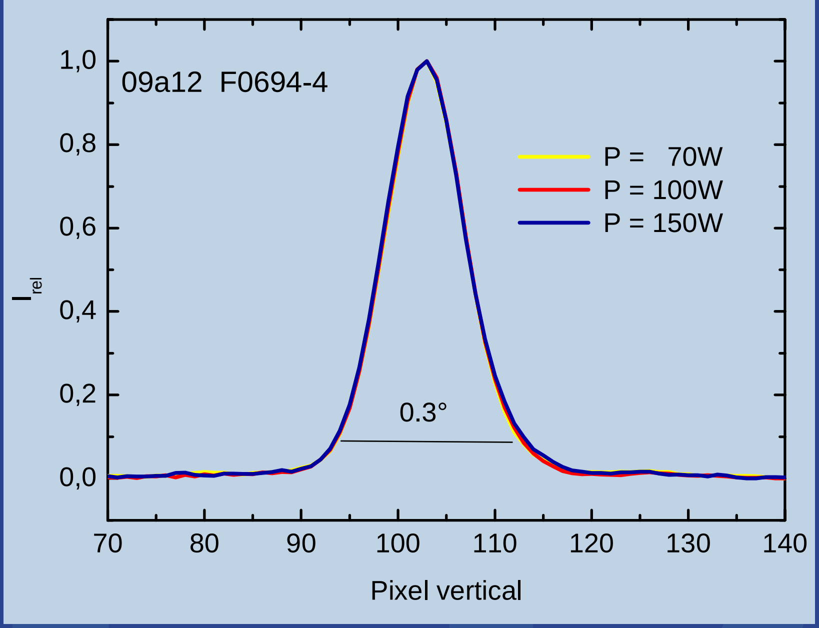


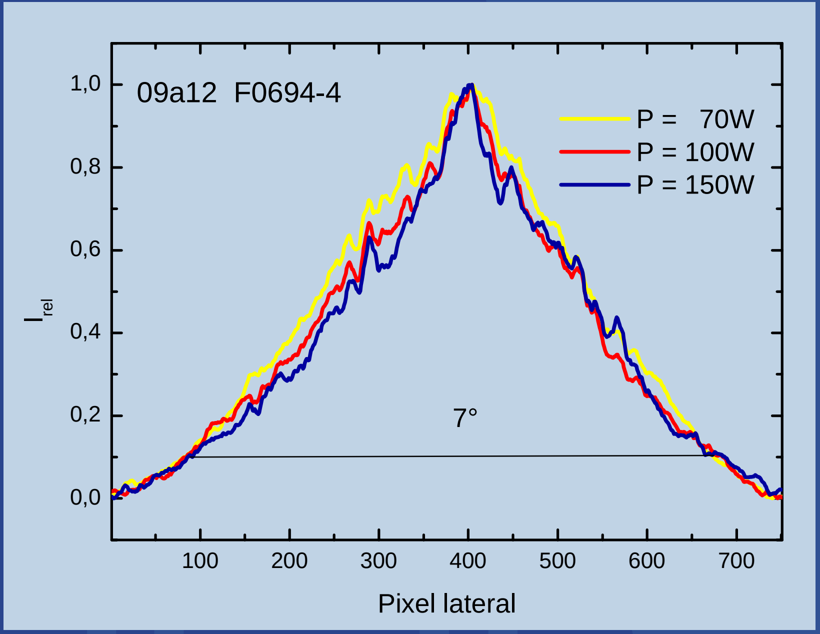
808nm – QCW pump sources for Bepi Colombo : spectral

- spectral peak 806nm
- spectral width (95% power) < 4nm
- additional modulation by FAC
- wavelength shift determined by temperature



808nm – QCW pump sources for Bepi Colombo : beam profile

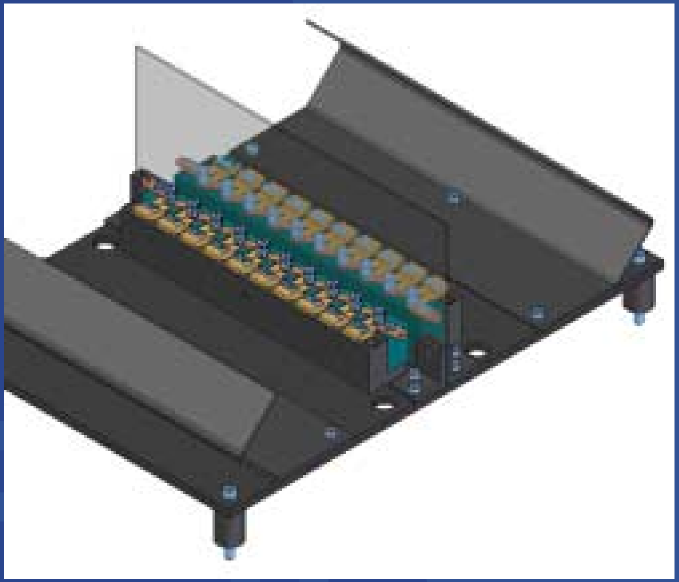




- **Fast axis with collimation** **$\theta_{\perp}$ < 5mrad (>95% power)**
- **slow axis** **$\theta_{||}$ < 120mrad (>95% power)**

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 ≈ 93.6 Mshots

Results of life test

Parameter	1	2	3	4	5	6	7	8	9	10
I_{th} /A	13.6 13.7	14.7 14.8	13.9 15.1	13.0 13.2	14.6 15.1	14.0 14.6	13.6 15.6	13.2 13.8	14.0 13.7	13.9 14.2
I_{op} (100W) /A	92 92	94 100	92 92	92 104	93 92	94 100	94 100	92 105	92 96	92 94
$\Delta\lambda$ /nm	0	0.5	0.1	-1.3	0	0.2	0.2	0.7	1.1	0.1
Emitter failure	0	1*	0	7	0	2	1*	6	0	0

- no bar failed (EOL – current limit I_{op} < 110A @100W)
- Long term stable spectral behaviour $\Delta\lambda$ < 1nm
- Reliability > 0.999 per bar for P_{op} = 70W , 3.15×10^{8} shots (10Hz, 1 year)
  - calculation based on random single emitter failures,
  - acceleration by power $(P/Pop)^{2.3}$
    (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

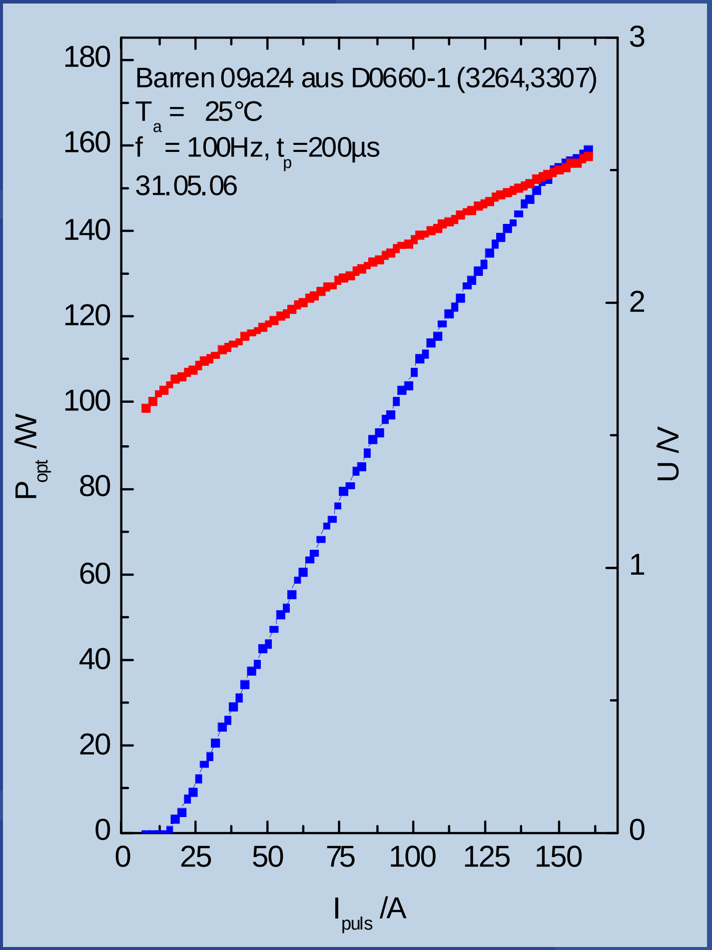
$\Rightarrow$

- **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**



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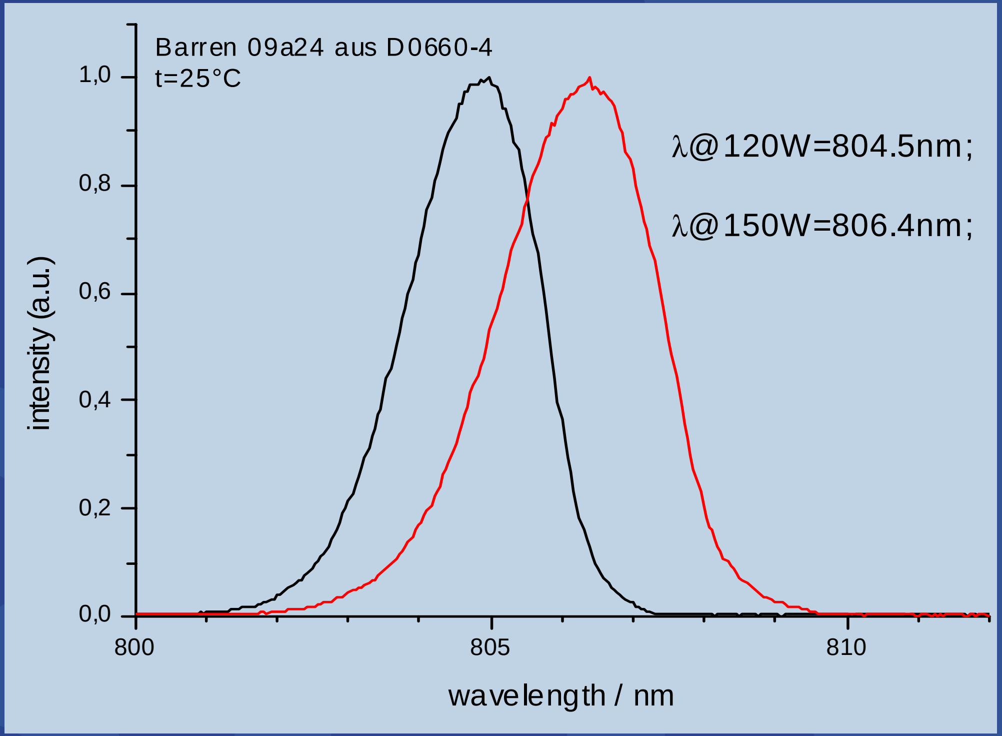
808nm - QCW – pump sources for higher average power (ATLAS) first results II

- spectral peak at 804.5nm
- enabling λ - 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 (≈ 70A @ 70W)
  - P_{cod} > 3x P_{op}(70W)
  - $\lambda \approx$ (805...806)nm, $\Delta\lambda$ (95%) ≤ 5nm @ P_{op}
  - far field $\Theta_{\perp}$ < 5mrad, $\Theta_{\parallel}$ ≈ 120mrad @ 95%
  - U_{op} ≈ 2.4 V at 100A
- mounting scheme
  - proved design for 10Hz
  - thermal cycling between – 45°C and 65°C
- reliability > 0.999 (70W, 1 year, 10Hz) 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)