Ferdinand-Braun-Institut
für Höchstfrequenztechnik

Reliable high-power red-emitting laser diodes

Bernd Sumpf

Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH)
Gustav-Kirchhoff-Str. 4
12489 Berlin

...translating ideas into innovation

Outline

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4. Tapered Lasers
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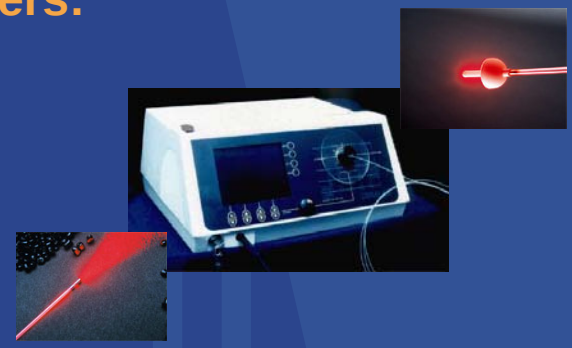
Introduction

Application of high-power red-emitting diode lasers:

- Light sources for the photodynamic therapy
  - e.g. λ = 652 nm: Foscan® - biolitec Pharma
  - Moderate lifetime of about 1000 h



- Laser display applications
  - High Brightness
  - Lifetime up to 10000 h

- Pumping of fs – solid-state lasers (Cr:LiSAF/Cr:LiCAF)

State of the art

- **100 µm stripe width broad area lasers (BRIGHT):**
  - P_{max} (15°C) = 3.1 W, Conversion efficiency η_C = 0.39
  - Reliable operation at 800 mW over 5000 h [1]

- **10 mm laser bars, 20 x 60 µm:**
  - P_{max} (15°C) = 12 W, Conversion efficiency η_C = 0.3 [2]
  - Reliable operation at 7 W over 900 h [3]

- **5 mm (10 x 100 µm) and 6 mm (12 x 60 µm) laser bars (BRIGHT):**
  - P_{max} (15°C) = 12 W, Conversion efficiency η_C = 0.29 [1]
  - Reliable operation at 5 W over 5000 h [1]

- **Tapered lasers - P_{max} (15°C) = 900 mW [4]**

1. B. Sumpf *et al.*, 20th ISLC 2006
2. J.S. Osinski *et al. Electronics Letters* 34, 2336-2337 (1998)
3. D. Imanishi *et al.*, 19th ISLC 2004
4. N. Linder et al., CLEO 2004; CMJ1

Introduction

650 nm laser structure challenging:

- Low barrier height for electrons and holes
  - High temperature sensitivity ($T_0 \approx 60$ K)
  - Relatively small internal efficiencies ($\eta_i \approx 0.8$)
  - Large transparency current density ($j_{TR} \approx 300$ kA/cm^2)
- Quaternary AlGaInP waveguide layers necessary
  - Reduced crystal quality
  - Reduced facet stability
  - Large series resistance

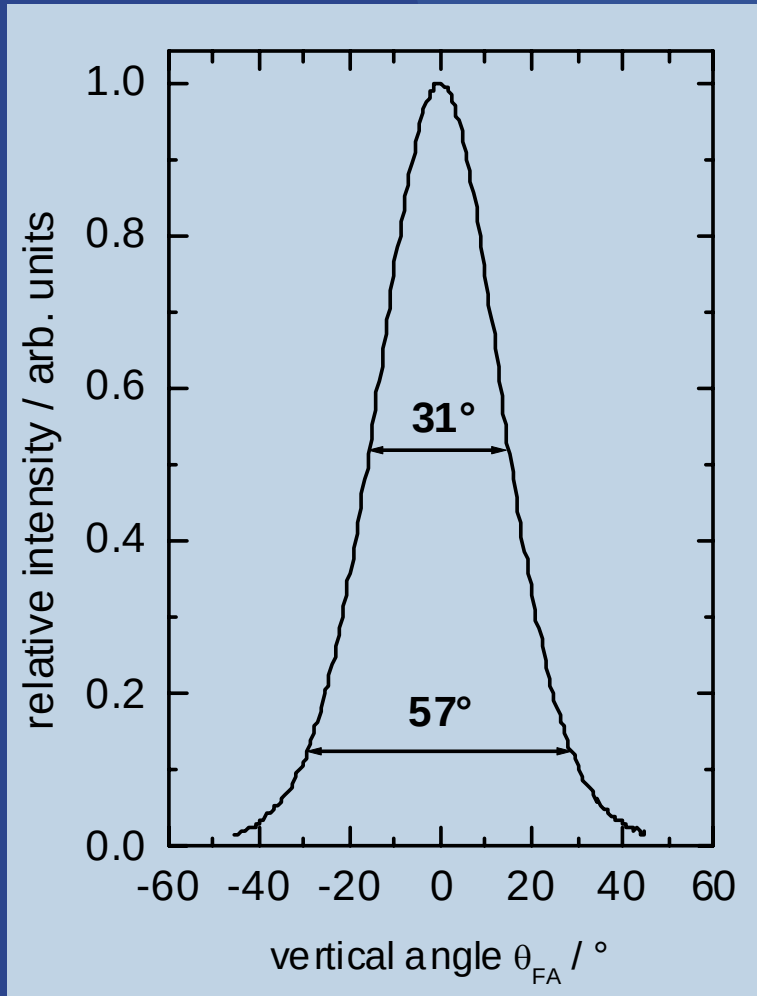
650 nm laser structure

- **Improved layer design**
- **Vertical far field:**

  Θ_{FA} = 31° (FWHM); 57° ($1/e^2$)

- **Material data:**

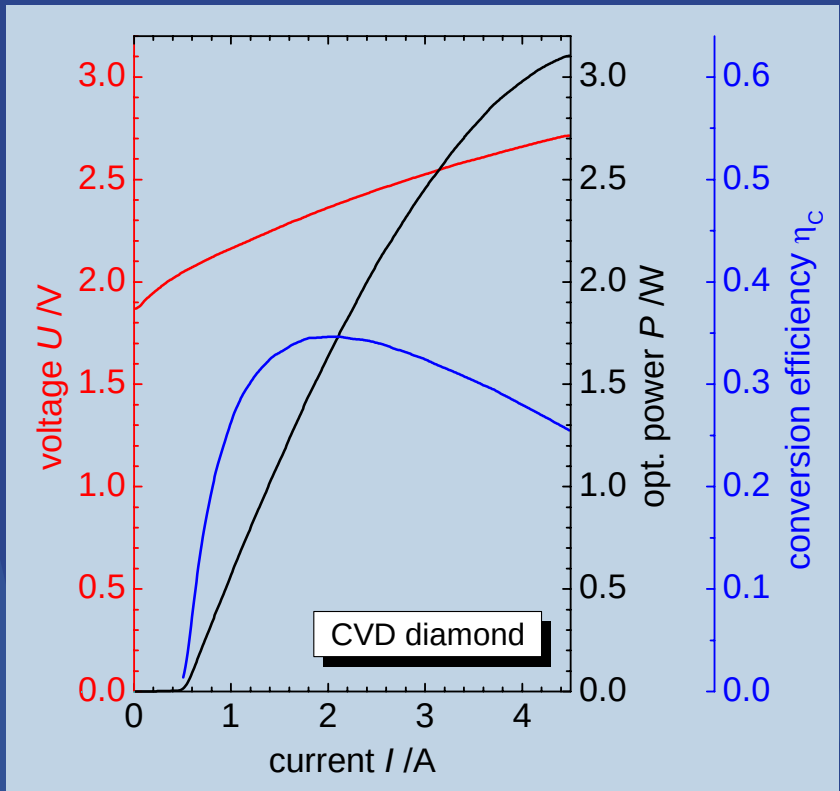
internal efficiency	$\eta_i \approx 0.85$
internal losses SQW	$\alpha_i \approx 1\ cm^{-1}$
characteristic temp.	$T_0 \approx 60\ K$

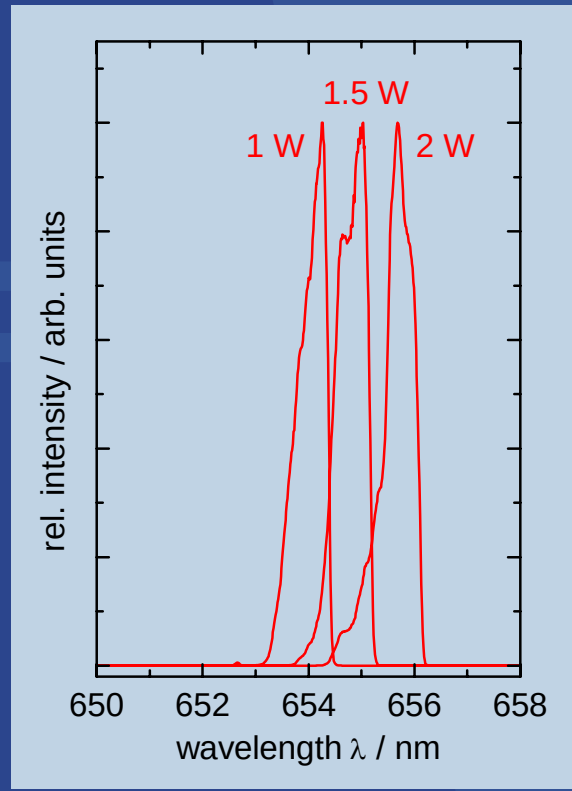


650 nm broad area lasers

100 µm x 1.5 mm; SQW; T = 15°C: I_{th} = 530 mA S = 1.0 W/A

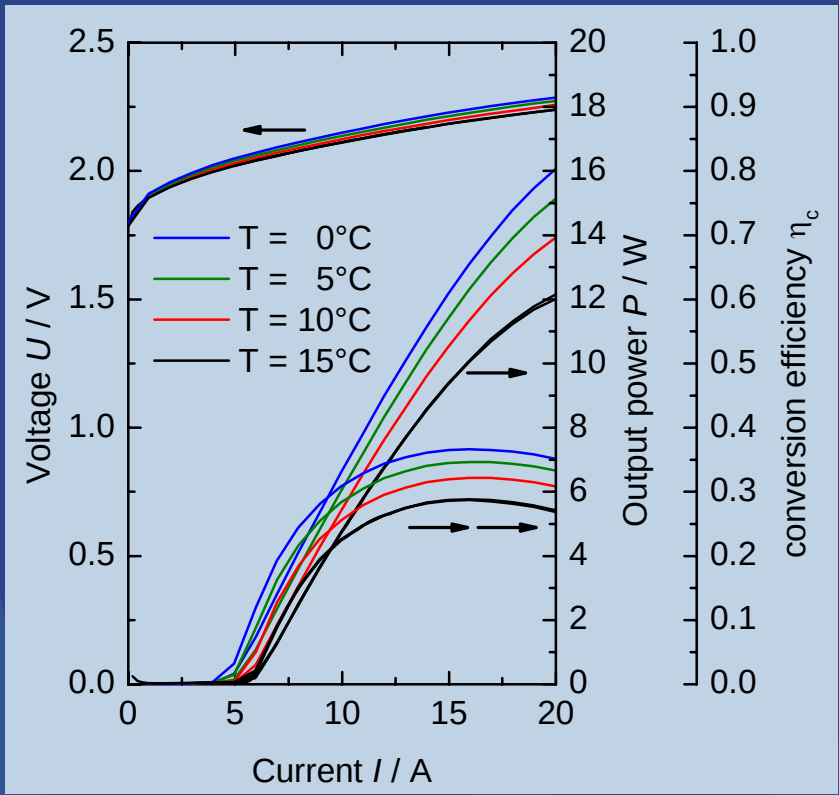
CVD diamond submounts P (4.5 A) = 3.1 W R_{th} = 5.5 K/W

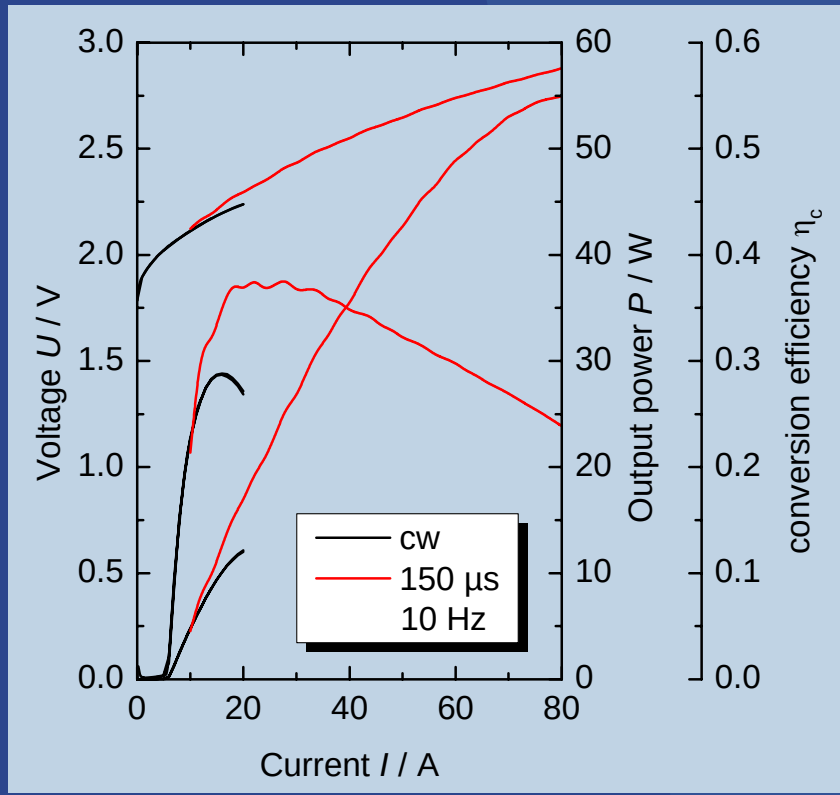




650 nm laser diode bars

SQW; 5 mm wide; 10 x 100 µm x 1500 µm; R_f = 4%; $0°C \leq T \leq 15°C$





- **CW-output power 12.1 W at 15°C and 16 W at 0°C; η_C = 0.29 (15°C) … 0.39 (0°C)**
- **QCW-output power 55 W at 15°C (150 µs, 10 Hz)**

650 nm broad area lasers and bars – aging test

5 mm wide bars – 10 x 100 µm at 7 W

one failure at 7700 h, one no failure

MTTF ≈ 18000 h

6 mm wide bars – 12 x 60 µm at 5 W

5(6) no failure

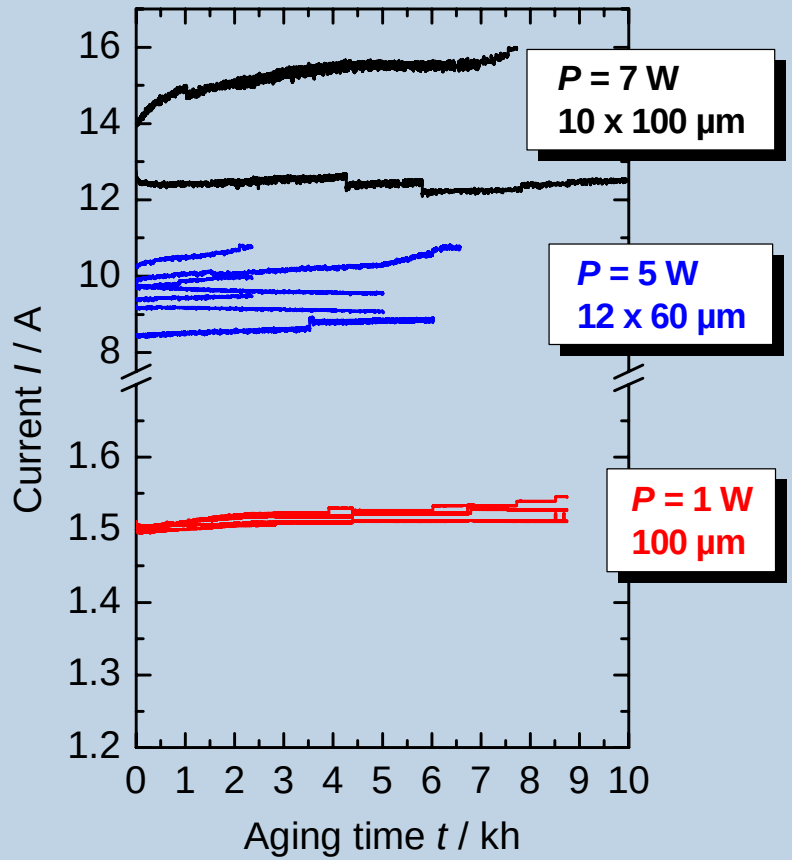
MTTF ≈ 30000 h

100 µm stripe width BA lasers at 1 W

Diamond heat spreader

5(5) – t ≥ 8750 h; MTTF ≥ 44000 h

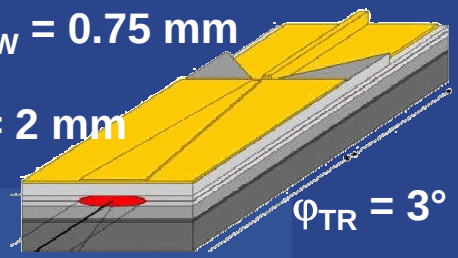
- Lifetime sufficient for medical applications
- Material reliability suitable for display application



650 nm tapered lasers

L_{RW} = 0.75 mm

L = 2 mm



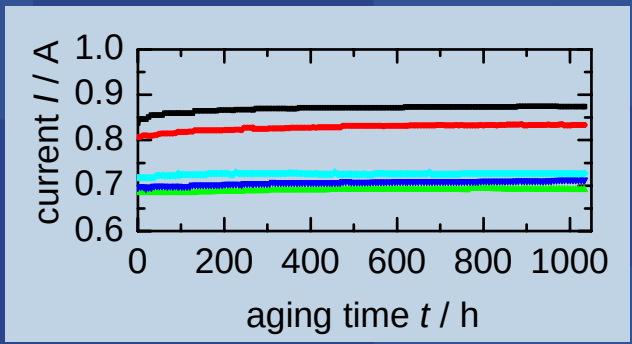
SQW; T = 15°C: I_{th} = 420 mA, S = 0.7 W/A

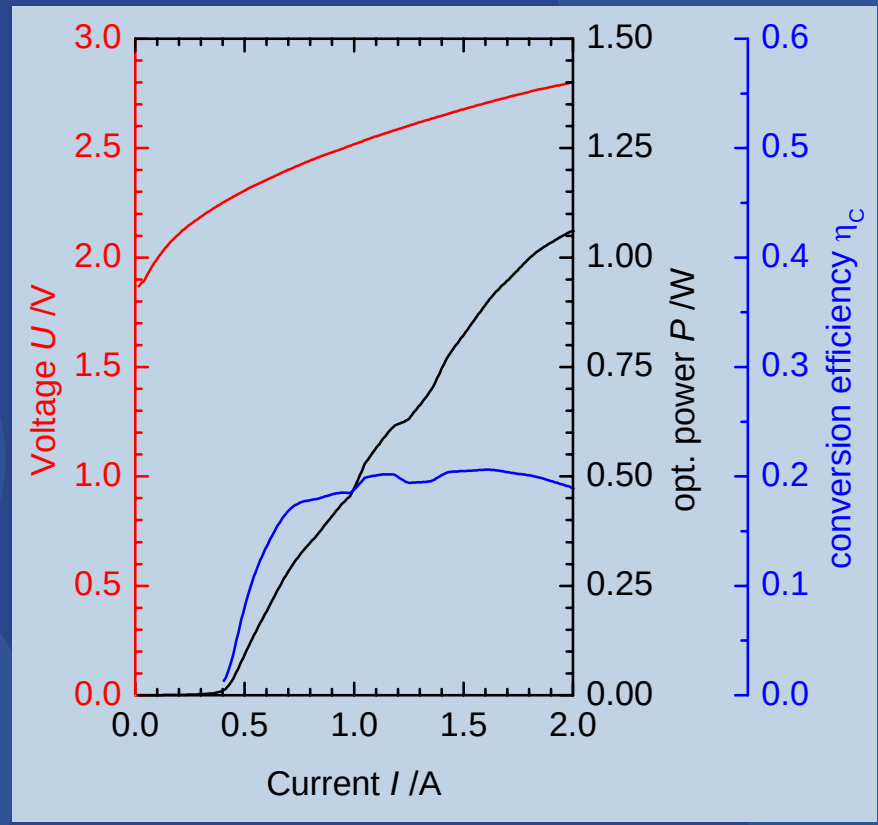
CVD diamond submount; $\eta_{C\text{-}max}$ = 0.2, P (2 A) = 1.1 W

Nearly diffraction limited beam quality

- P = 250 mW
- 87% of the output power from a beam waist of 7.5 µm

Reliable operation at 250 mW, 1000 h





Summary

- Device parameters and reliability sufficient for the application for PDT applications.
- QCW output power suitable for the pumping of fs-Cr:LiSAF lasers.
- Material quality sufficient for laser display applications
- Broad area lasers, bars, and tapered lasers are available.

Acknowledgments

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