



High-power, high-brightness Al-free active region tapered lasers at 915 nm

**N. Michel, I. Hassiaoui, M. Lecomte, O. Parillaud,
M. Calligaro, M. Krakowski**

**Alcatel-Thales III-V Lab, Route Départementale 128
91767 Palaiseau, France**

Acknowledgements: the support of the European Commission through the IST project n°511-722, WWW.BRIGHT.EU

Acknowledgements: Y.Robert, M. Carbonnelle, C. Dernazeratian and L. Teisseire for excellent technical assistance





High-power, high-brightness Al-free active region tapered lasers at 915 nm

Introduction

Brightness

Laser structure

Index-guided tapered lasers (IG1)

Clarinet lasers

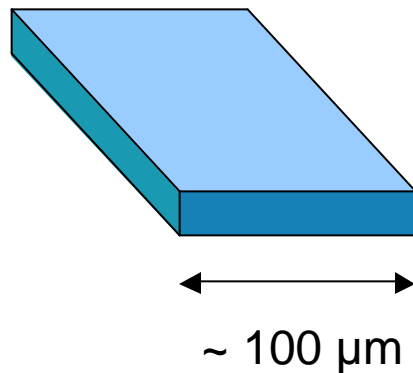
Conclusions





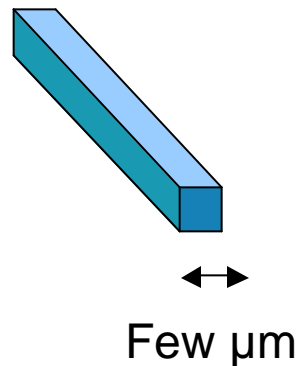
- Targeted Applications:**
- Pumping of solid-state lasers
 - Pumping of Er or Er/Yb lasers and double cladding amplifiers: 975 nm and 915 nm

Broad area laser



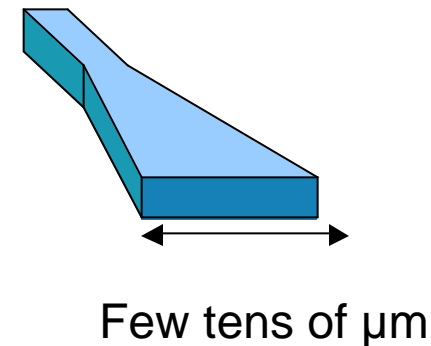
- High Power
- Highly multimode

Ridge



- Low Power
- Single mode
- High beam quality

Tapered laser



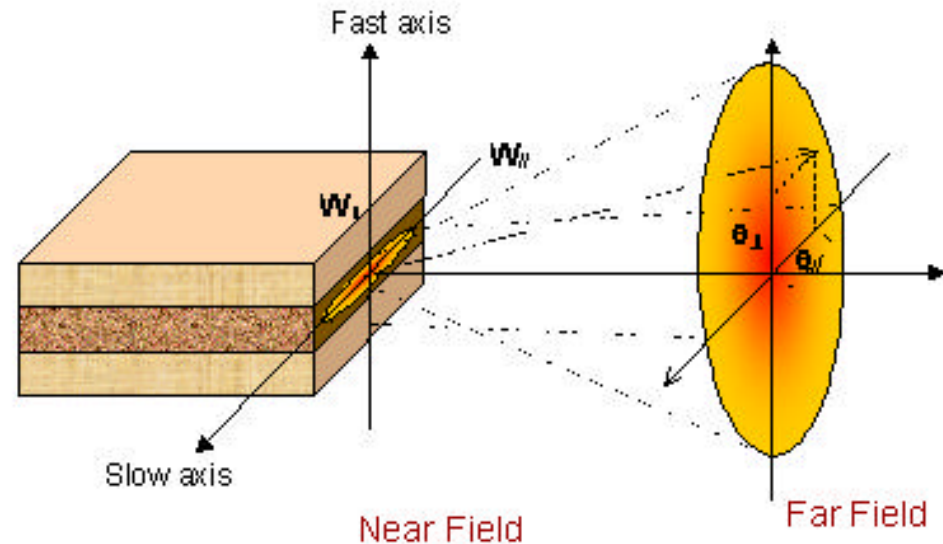
- High Power
- Single mode
- High beam quality

Case of a single emitter

$$\text{Brightness } B = \frac{P(W)}{S(\text{cm}^2) \cdot \Omega(\text{srd})}$$

$$= \frac{P}{I^2 M_{//}^2 M_{\perp}^2}$$

Beam propagation factor



$$M_{\perp}^2 = \frac{P}{4I} w_{1/e^2}^{\perp} q_{1/e^2}^{\perp}$$



Fast axis : diffraction limited beam ($M_{\perp}^2 \sim 1$)

$$M_{//}^2 = \frac{P}{4I} w_{1/e^2}^{//} q_{1/e^2}^{//}$$

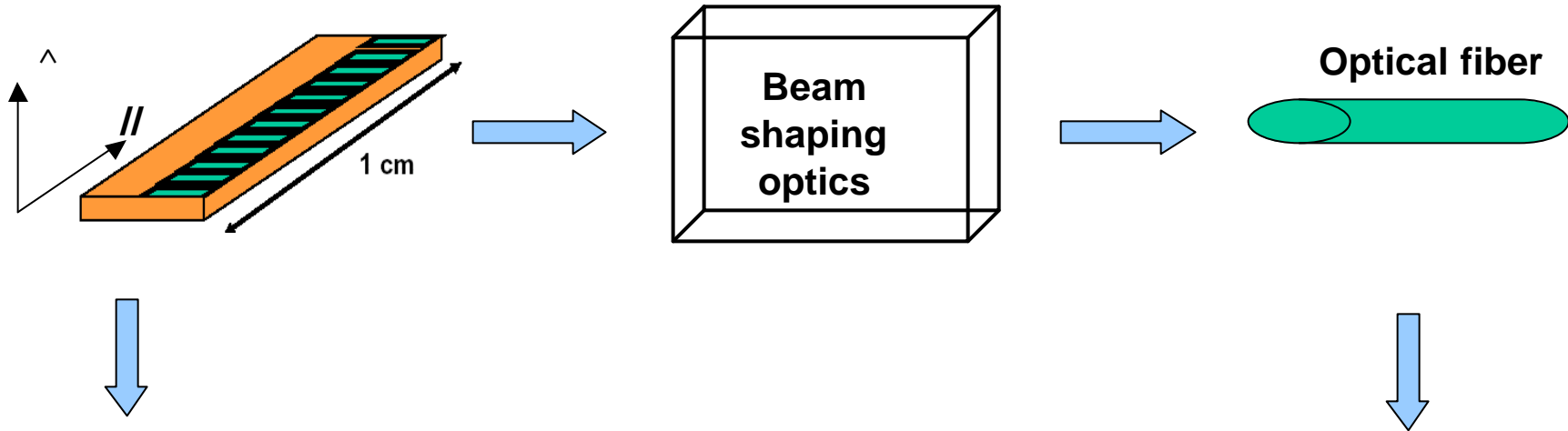


Slow axis : $1 < M_{//}^2 < 20$

High P and Low $M_{//}^2$
 High B



Case of a bars

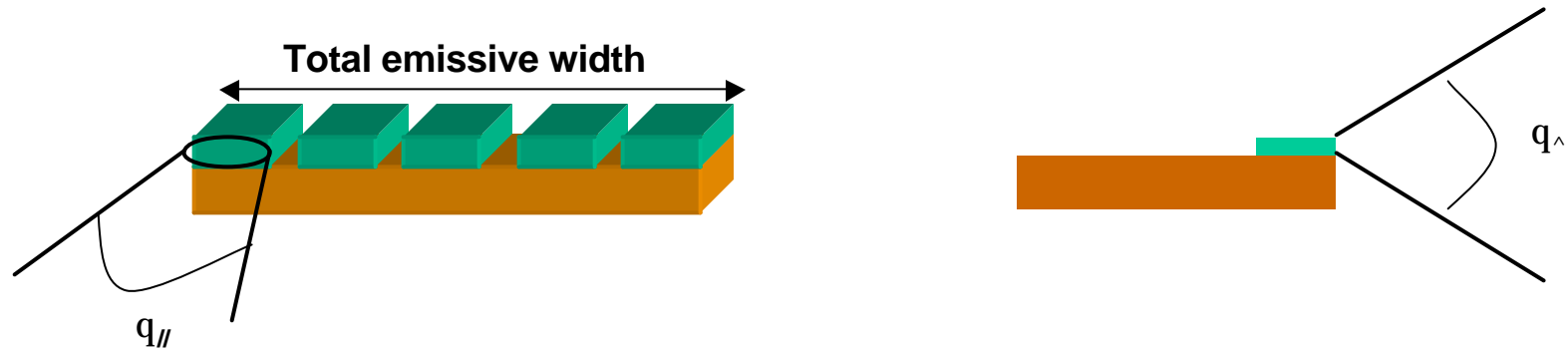


$$BPP_{bar} = \sqrt{BPP_{\perp} \times BPP_{\parallel}} \leq \frac{1}{\sqrt{2}} BPP_{fiber} = \frac{1}{\sqrt{2}} f_{fiber} \times 2NA_{fiber}$$

Condition for efficient coupling



Case of a bars

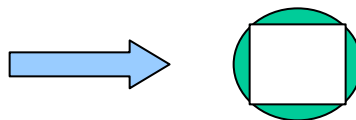


$$BPP_{\perp} = w_{\perp} \times q_{\perp} \quad \leftarrow \text{diffraction limited beam}$$

$$BPP_{//} = \text{Total emissive width} \times q_{//} \quad \leftarrow \text{we need a low } q_{//}$$

Beam shaping optics

 N intermediary beams



$$BPP'_{\perp} = BPP_{\perp} \times N$$

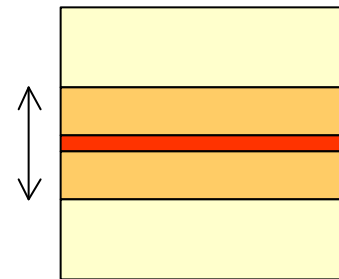
$$BPP'_{//} = BPP_{//} / N$$

High P and Low $q_{//}$
 P High B

Internal parameters

$a_i = 0.5 \text{ cm}^{-1}$
 $h_i = 86\%$
 $J_0 = 86 \text{ A/cm}^2$
 $GG_0 = 15 \text{ cm}^{-1}$

Large Optical Cavity (LOC)

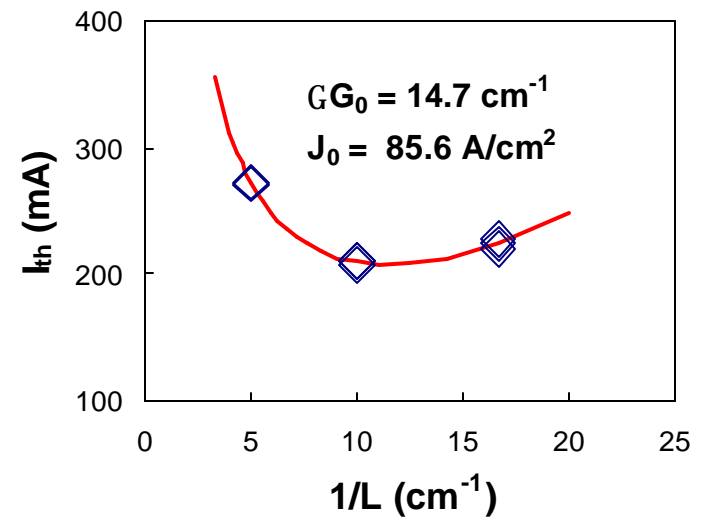
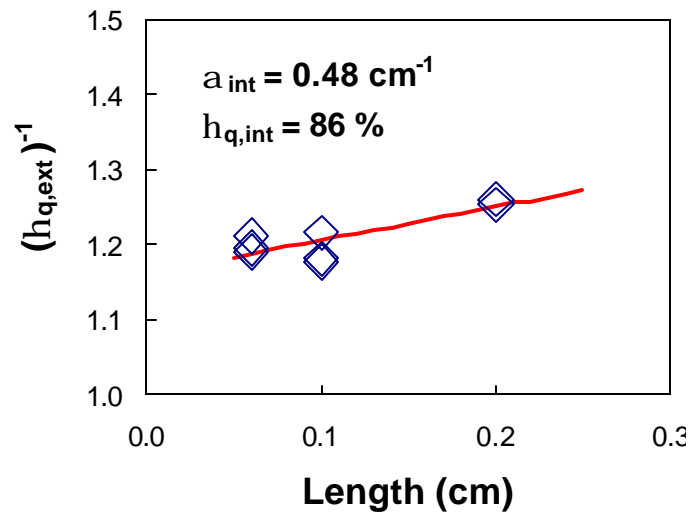


AlGaInP
GaInP
GaInAs 1QW
GaInP
AlGaInP

Characteristic temperatures

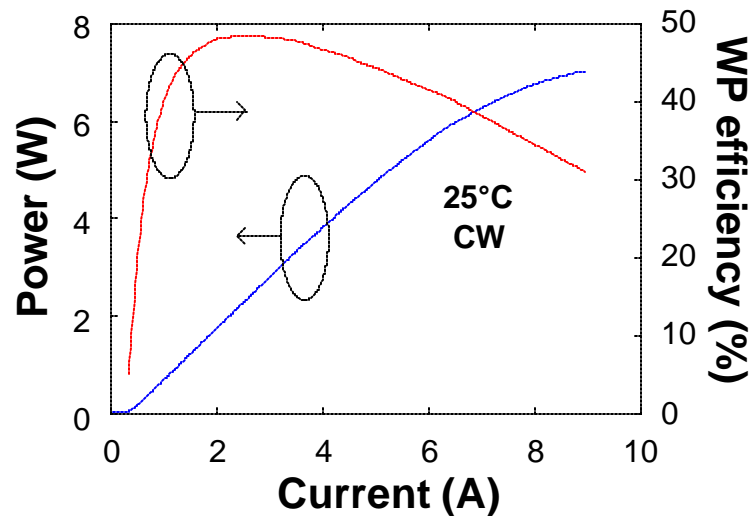
$T_0 = 179 \text{ K}$
 $T_1 = 572 \text{ K}$

On 2 mm as-cleaved BA laser (CW)

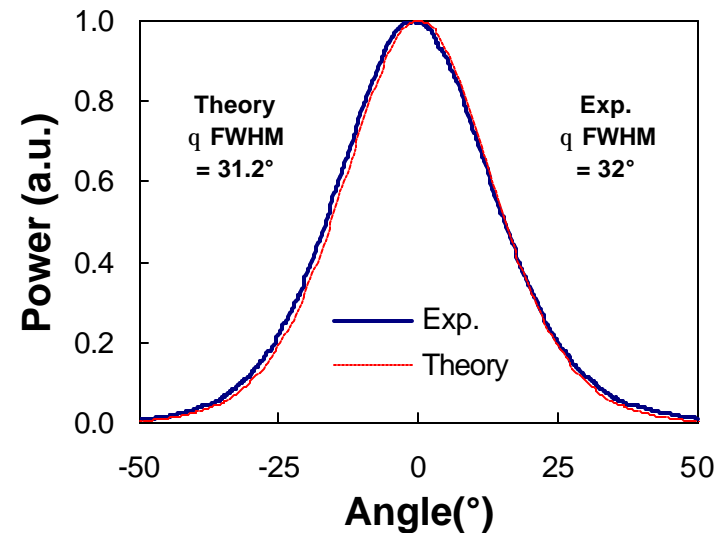




Power characteristics

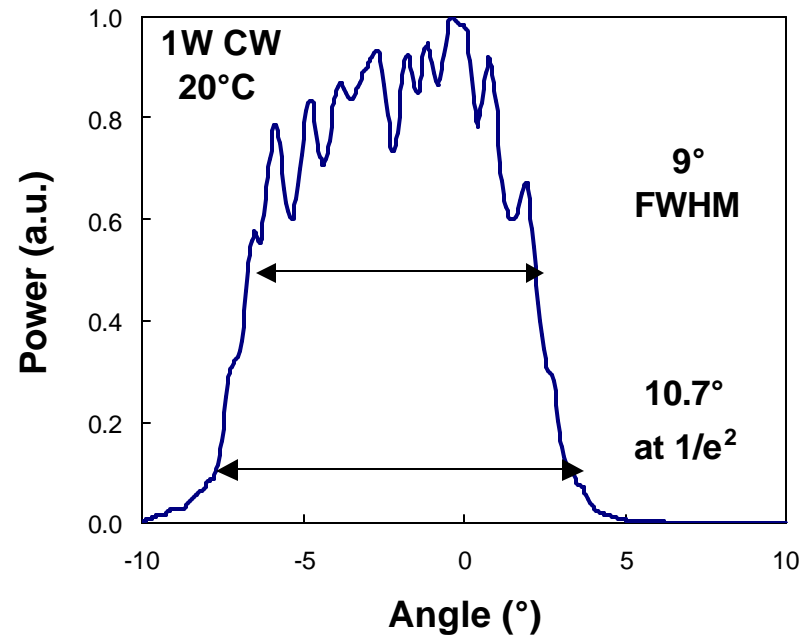


Far-field profile (fast axis)



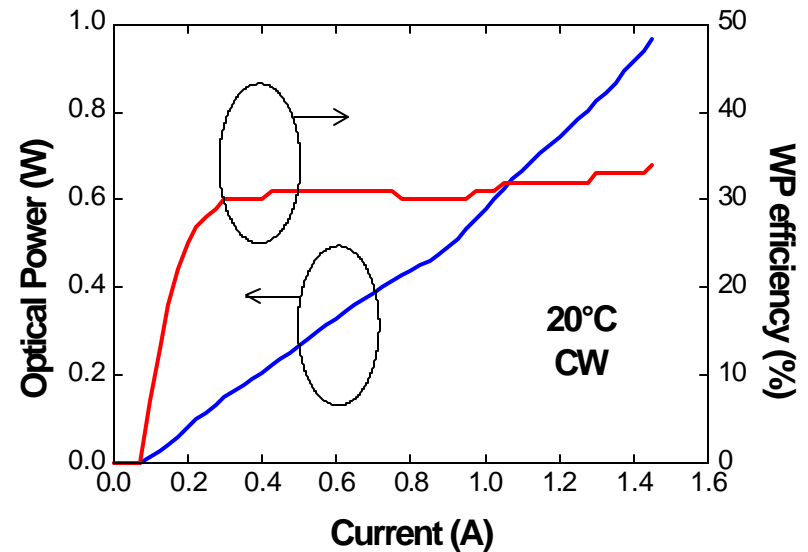
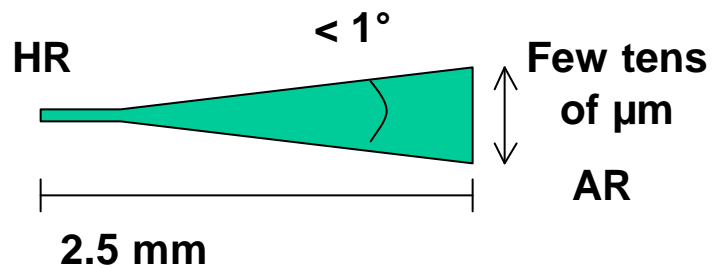
AR/HR
2 mm x100 μ m
 $I_{th} = 411$ mA
 $h_d = 1.05$ W/A
 $P_{max} = 7$ W
 $\theta_{\wedge} = 32^\circ$ FWHM

Far-field profile (slow axis)



$M^2 = 15.3$ at 1/e²
 $M^2_{SS} = 17.1$
 $B = 7.8$ MW/cm²/sr

Power characteristics (CW)

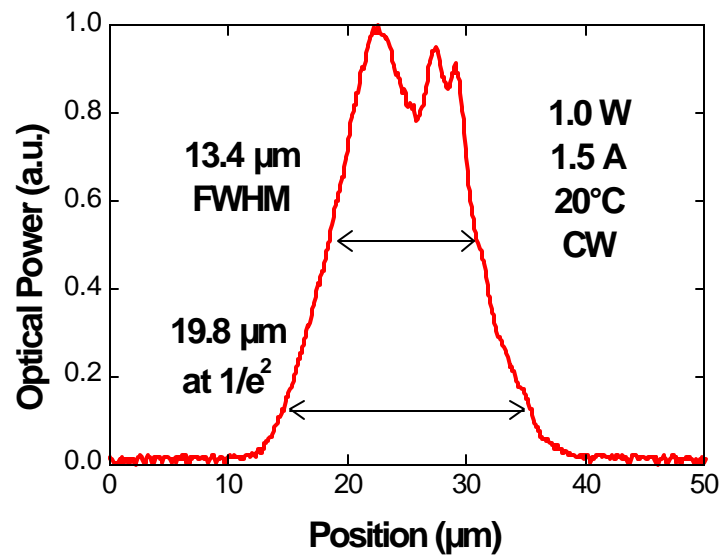


Temp. (°C)	I_{th} (mA)	h_d (W/A)	R_s (W)	T_0 (°C)	P_{opt} (mW)	Current (mA)	Lambda (nm)
20	89	0.75	0.48	179	1000	1500	918.7

Near max. power

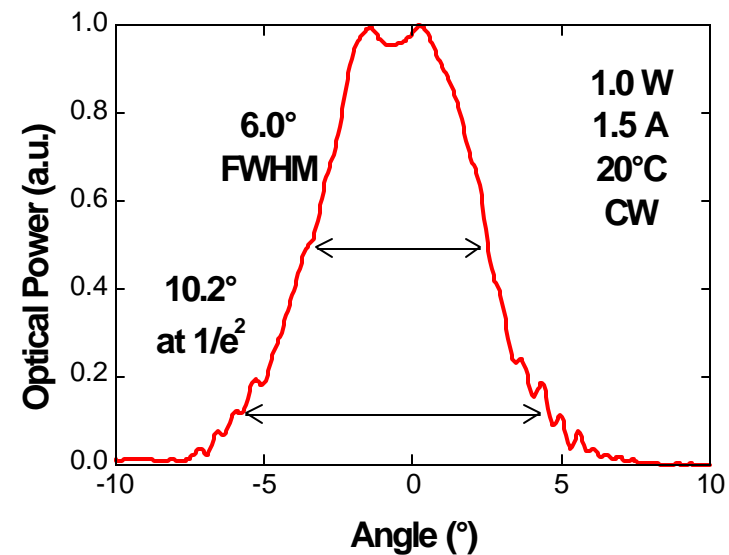
Beam profiles at 1W CW (slow axis)

Near-field at waist



M^2 at $1/e^2 < 3.0$
 $M^2_{SS} < 3.0$

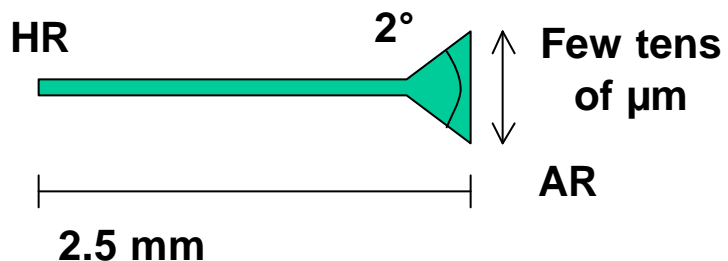
Far-field



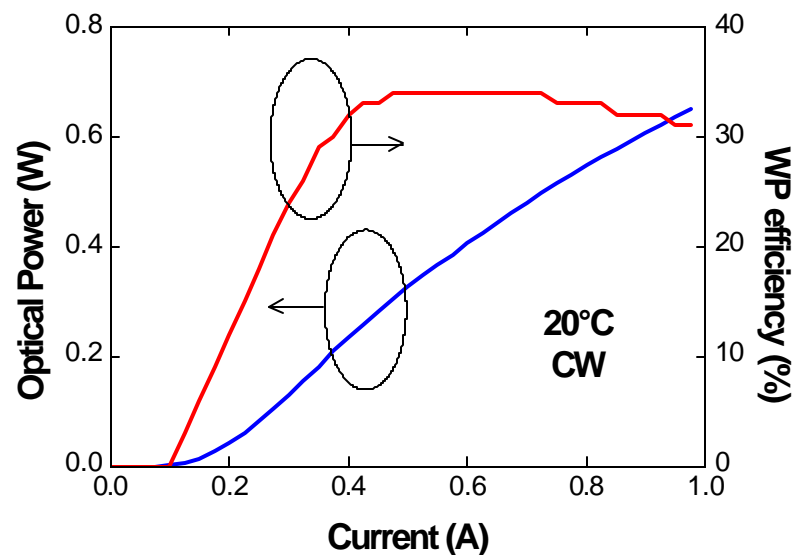
Angle $\sim 10^\circ$ at $1/e^2$
at 1W CW



Power characteristics (CW)



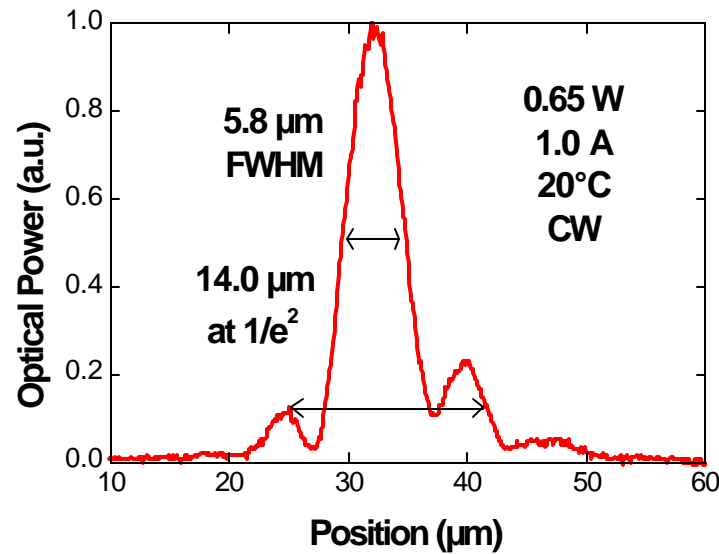
Borrueal et al.
APL 87, p. 101104 (2005)
Borrueal et al.
CLEO Europe 2005,
Paper CB6-4



Temp. (°C)	I_{th} (mA)	h_d (W/A)	R_s (W)	T_0 (°C)	P_{opt} (mW)	Current (mA)	Lambda (nm)
20	177	1.10	0.63	121	680	1000	917.3

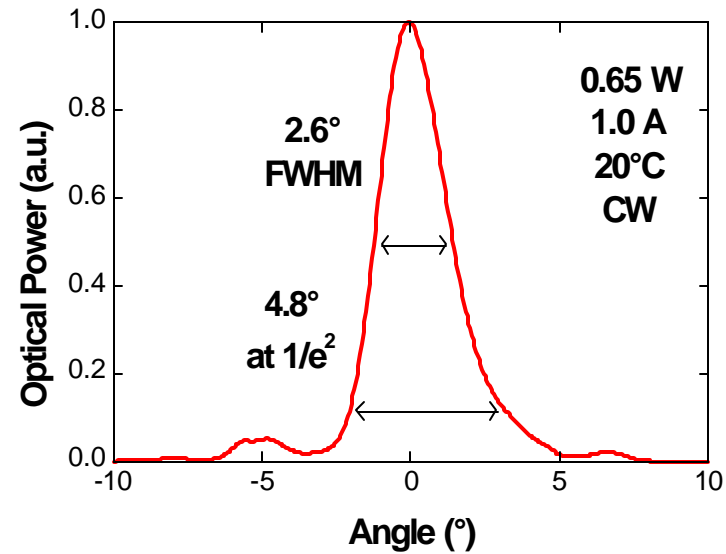
Near max. power

Near-field at waist



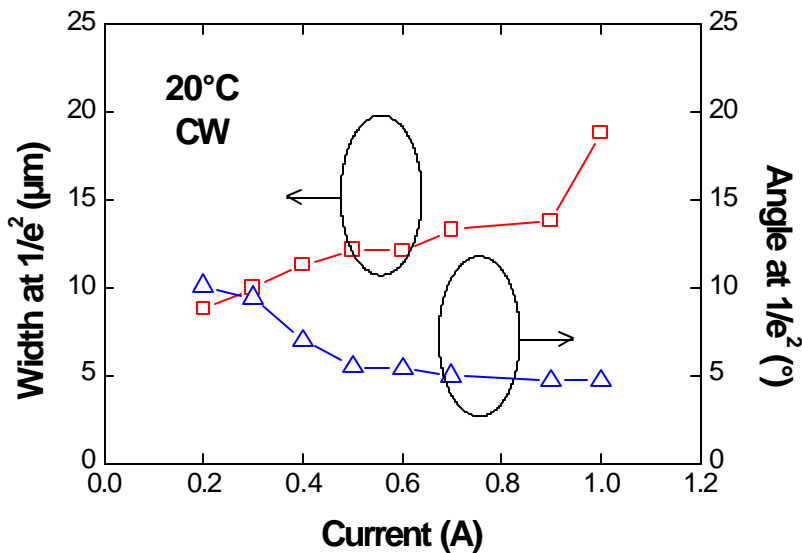
M^2 at $1/e^2 < 1.4$
 $M^2_{SS} < 2.5$

Far-field



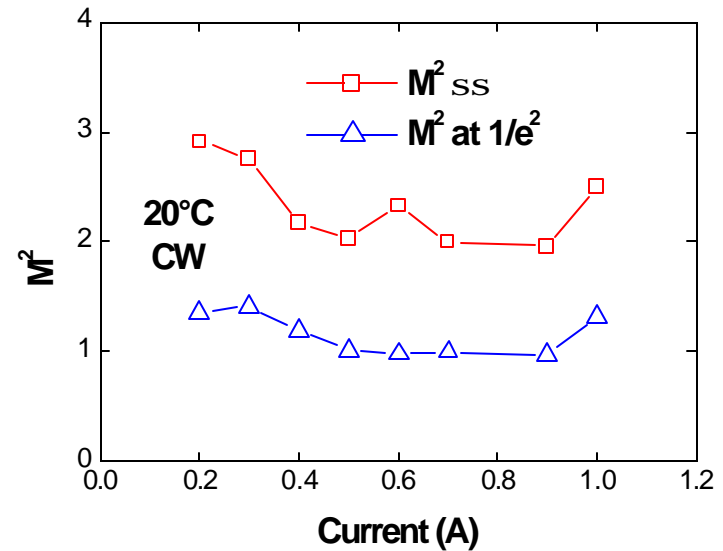
Angle $\sim 5^\circ$ at $1/e^2$
at 0.65W CW

Evolution of apertures with current



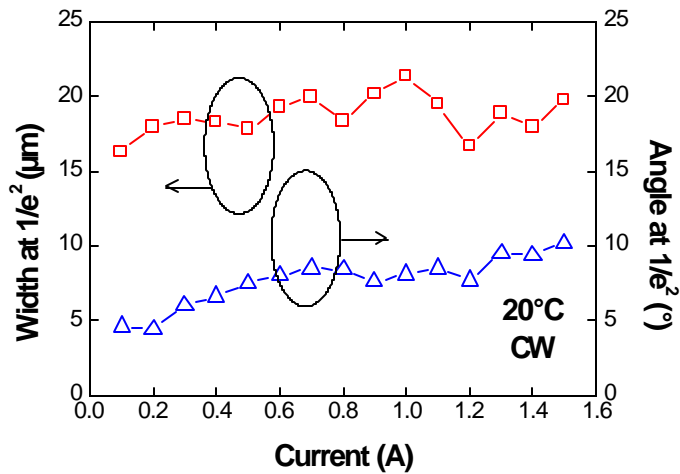
Low and stable angle of $\sim 5^\circ$ at $1/e^2$

Evolution of M^2 with current

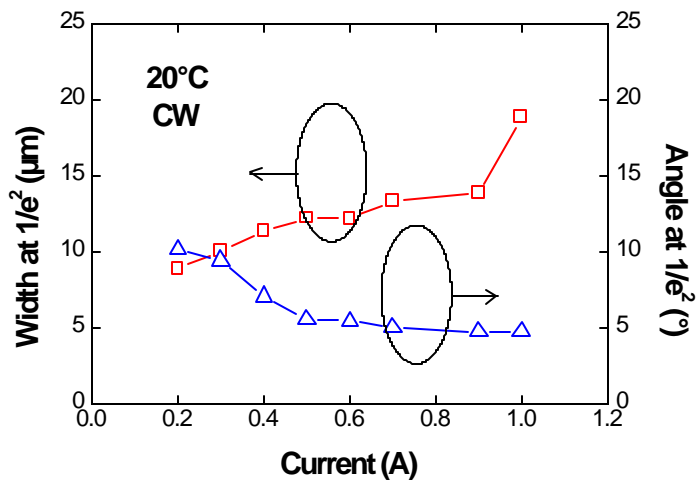


M^2 at $1/e^2 < 1.4$
 $M^2_{SS} < 2.5$
 at 0.65 W

Interest for the Clarinet lasers for bars



IG1: Divergence increases with current



Clarinet: Divergence Stable with current

Very advantageous for bars

Comparison of single emitters

$$B = \frac{P(W)}{S(cm^2) \cdot \Omega(sr)}$$

$$= \frac{P}{I^2 M_{//}^2 M_{\perp}^2}$$



High P and Low $M_{//}^2$
 High B

Structure	Power (W)	M^2 at $1/e^2$	Brightness (MW/cm ² /sr)
BA Laser	0.60	13.7	5.2
	1.00	15.3	7.8
	5.00	18.0	33.2
Ridge*	0.15	1.5	11.9
IG1	0.60	2.6	27.6
	1.00	3.0	39.8
Clarinet	0.65	1.3	59.7



Highest B
 + narrowest $q_{//}$

* Per facet





High power Laser structure

Very low internal losses ($a_i < 0.5 \text{ cm}^{-1}$)

Very low J_0 (86 A/cm^2)

High brightness on single emitters

IG1 lasers

1.0 W CW at 1.5 A. At 1 W. $M^2 = 3.0$ at $1/e^2$ $B = 40 \text{ MW/cm}^2/\text{sr}$

Clarinet lasers

0.65 W CW at 1.0 A, $M^2 = 1.3$ at $1/e^2$ $B = 60 \text{ MW/cm}^2/\text{sr}$

Interest of low angles for bars

Small arrays and bars were realised

6xIG1 array: 4W CW

6 mm bar (16 groups of 4xIG1): 20W CW

Future work New laser structure with GaAlAs claddings

