How to measure packaging-induced strain in high-brightness diode lasers?

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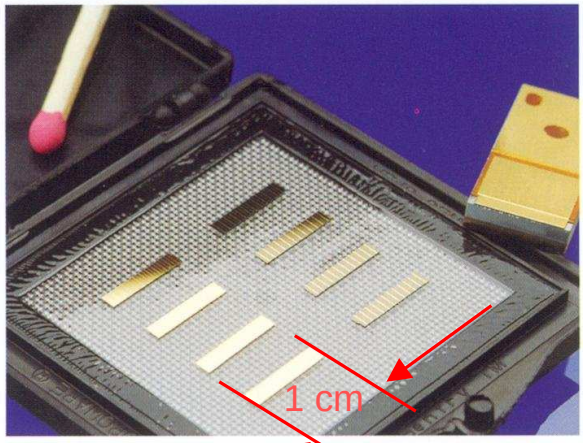
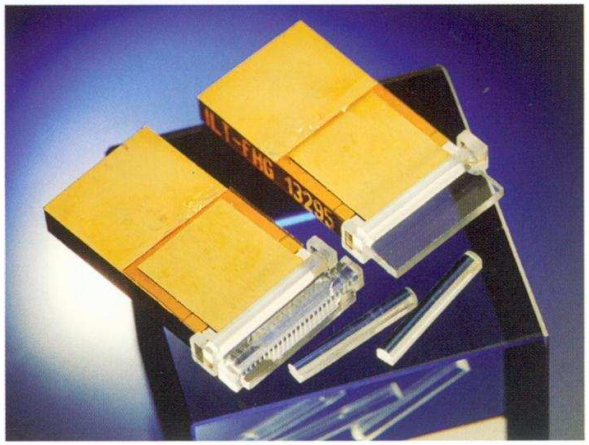
Outline

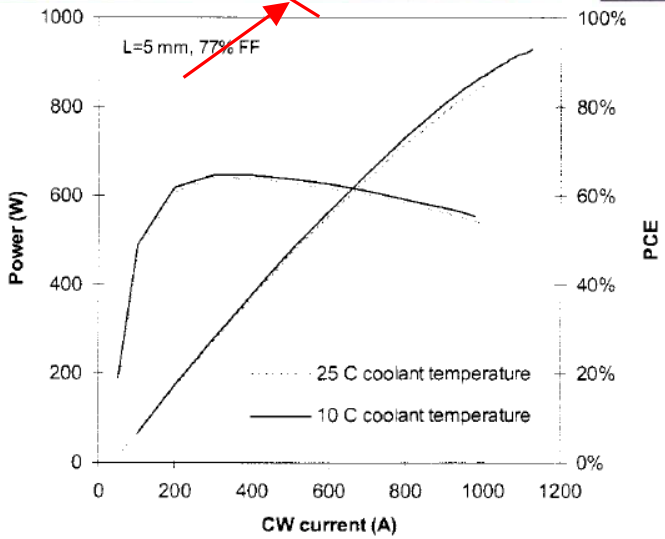
1. **Introduction**
   - 1.1 Experimental
   - 1.2 Approach
2. **Experimental methods and results**
   - 2.1 Micro-Photoluminescence (µPL)
   - 2.2 Photocurrent spectroscopy (PCS)
   - 2.3 Degree-of-polarization PL or R (DoP-PL)
3. **Summary**

Analysis of the electronic bandstructure

1.1 Experimental: High-brightness diode laser arrays: “cm-bars”

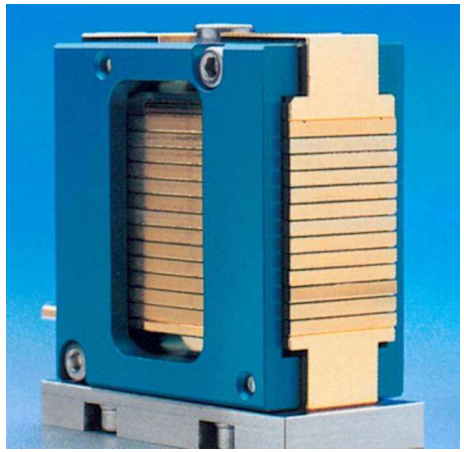






Best values reached so far:

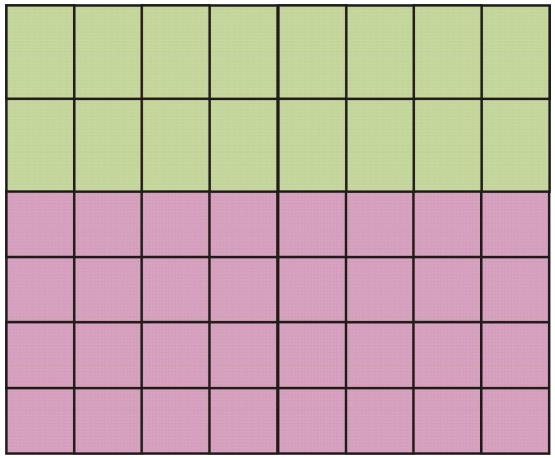
- cw-output from a single bar
  928 W
  H.X. Li, et al. *SPIE Proc.* 64560C-1-9 (2007).
- conversion efficiencies > 73%
  http://www.jold.de/
  nLight 76% (2007)



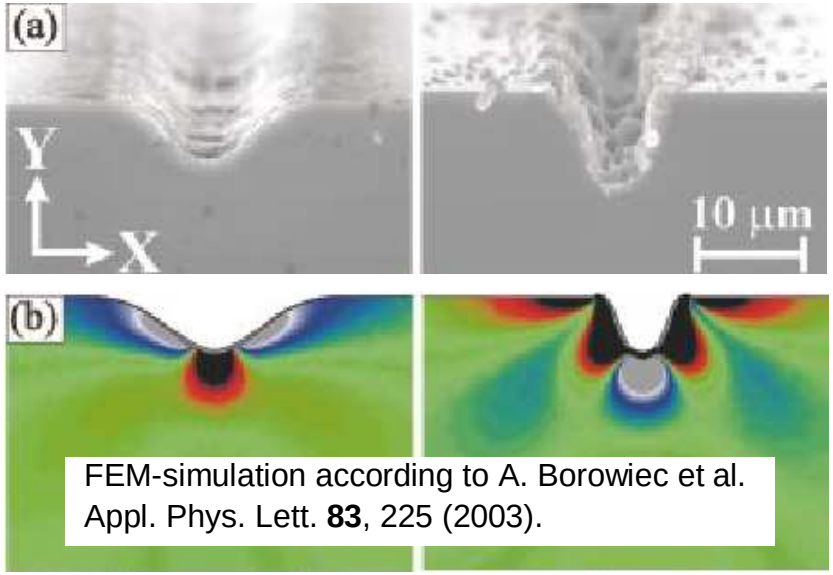
1.2 Approach

Strain creation within the structure or device, e.g., during

1. crystal growth



2. processing

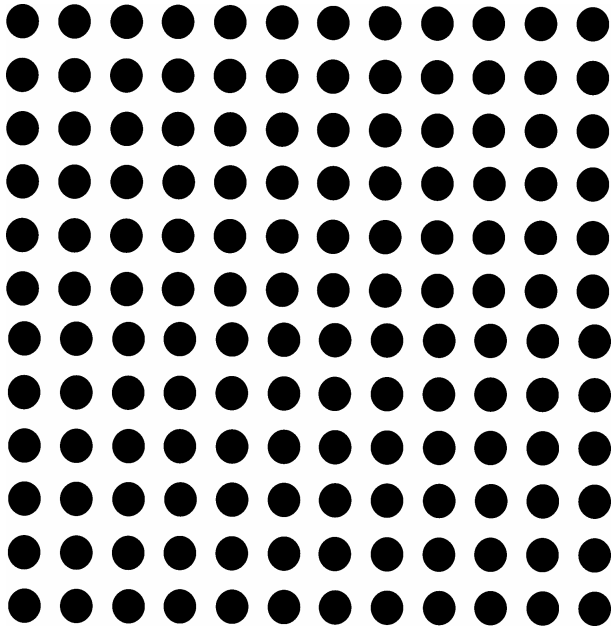


FEM-simulation according to A. Borowiec et al. Appl. Phys. Lett. **83**, 225 (2003).

intrinsic or built-in strain

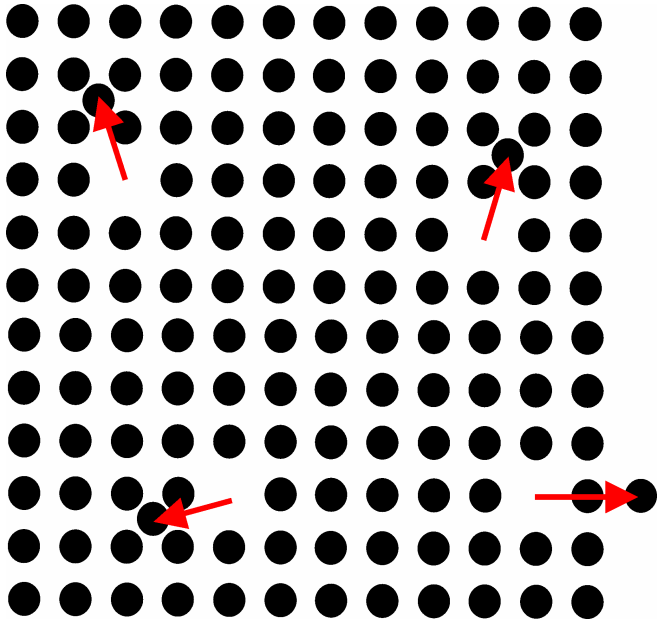
extrinsic processing-induced strain

3. **creation of native point defects**



extrinsic strain caused by defect creation

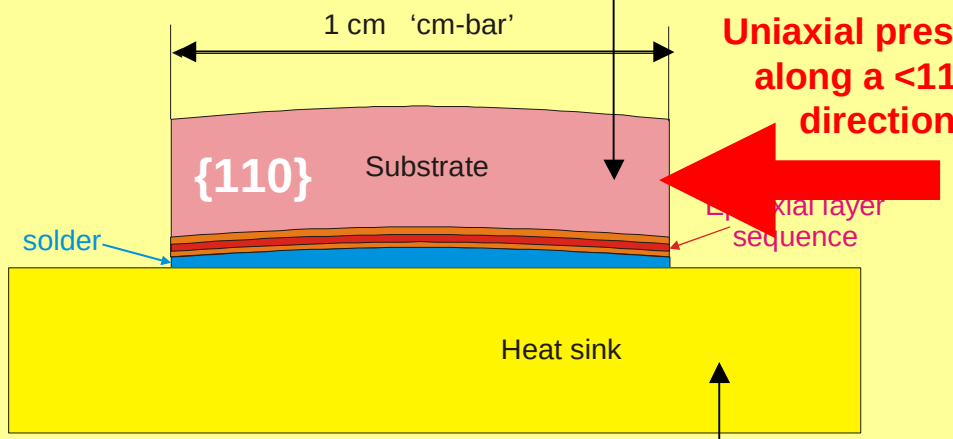
3. creation of native point defects



extrinsic strain caused by defect creation

4. packaging

$\alpha_{GaAs} = 6.9\times10^{-6}\ K^{-1}$



Uniaxial pressure along a <110> direction

soldering temperature > 157 ℃

$\alpha_{Copper} = 16.7\times10^{-6}\ K^{-1}$

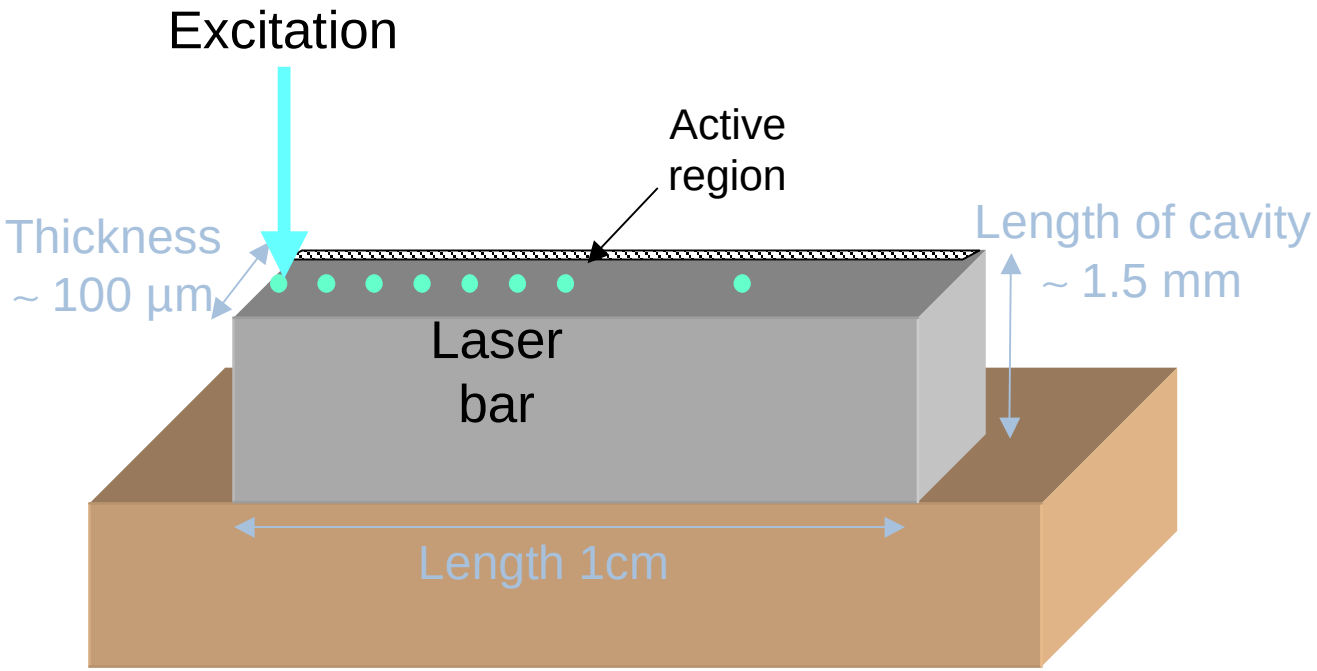
extrinsic packaging-induced strain

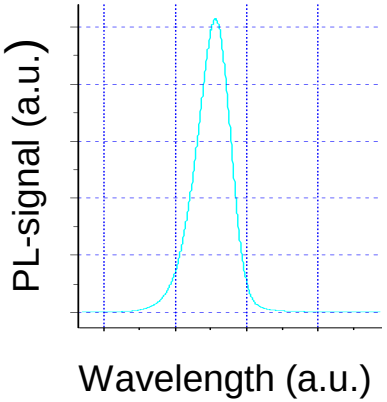
Spectroscopic strain analysis by checking the electronic bandstructure

Outline

1. **Approach and Definitions**
2. **Experimental methods and results**
   - 3.1 Micro-Photoluminescence (µPL)
   - 3.2 Photocurrent spectroscopy (PCS)
   - 3.3 Degree-of-polarization PL or R (DoP-PL)
3. **Summary**

Micro-PL: Methodology



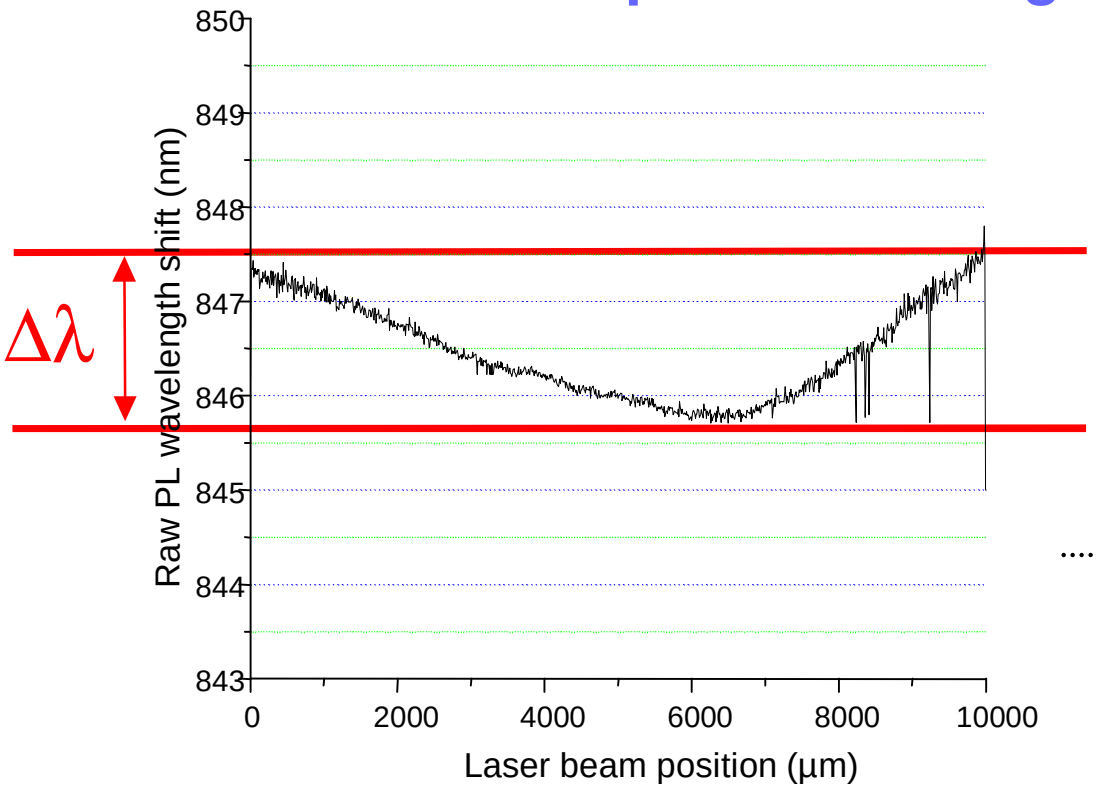


1000 spectra per bar

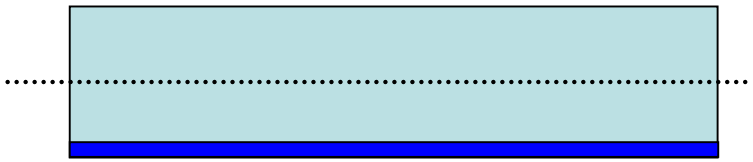
PL-peak position is extracted by a polynomial fit.

MOTORIZED PRECISION GONIOMETER

Plot: Spectral position of the PL-peak position versus local position along a laser bar



P. Martin et al.
Appl. Phys. Lett. **75**, 2521 (1999).



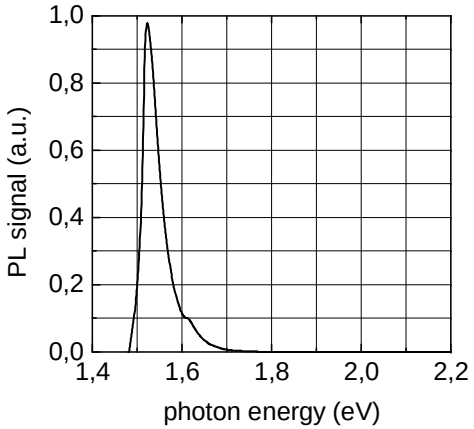
Stress assessment of a mounted bar by the total bent of the curve.

Photocurrent spectroscopy (PCS)

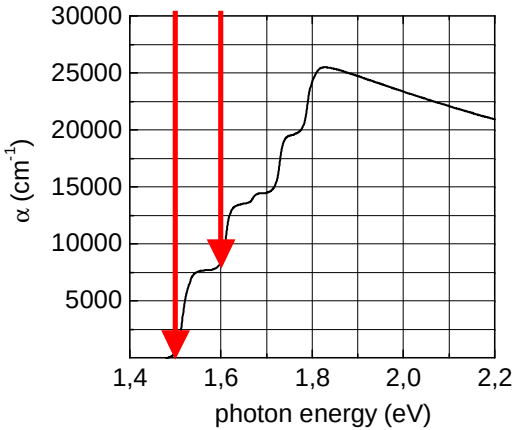
classical optical spectroscopy

Device analysis

Photoluminescence (PL)

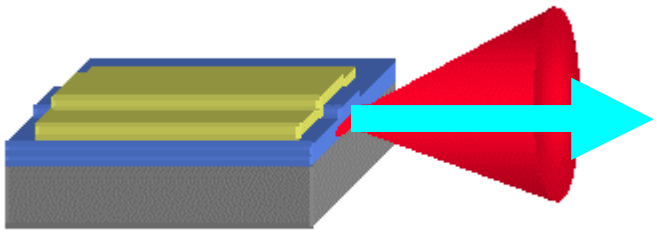


Absorption

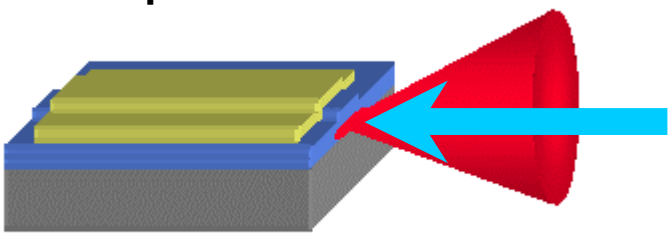


We can not place a detector behind the device.

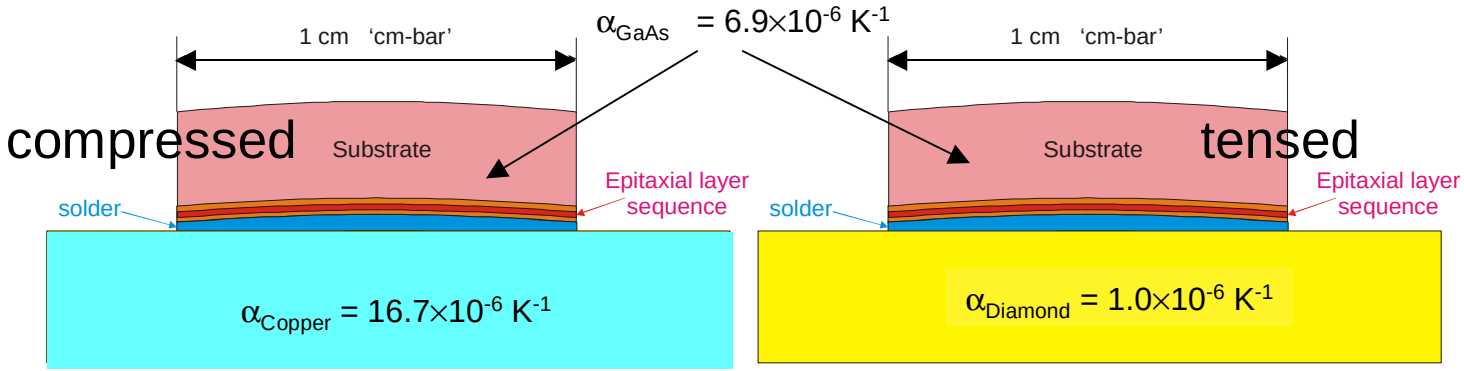
PL or EL emission



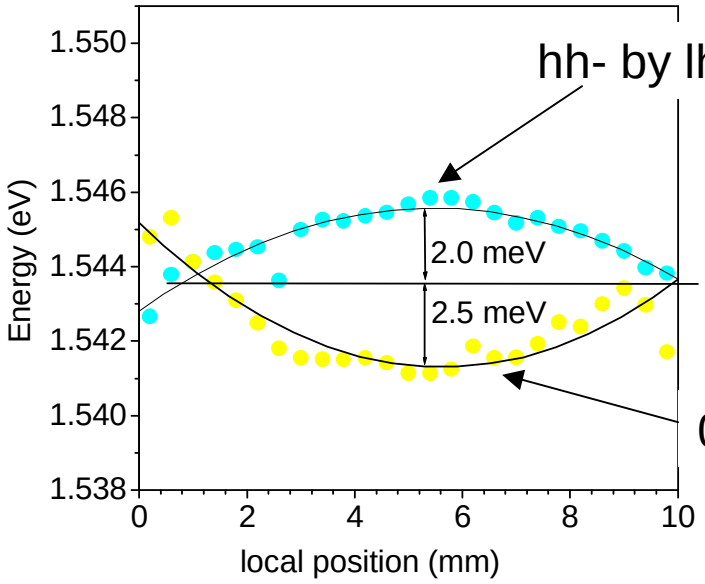
Absorption ~ Photocurrent!



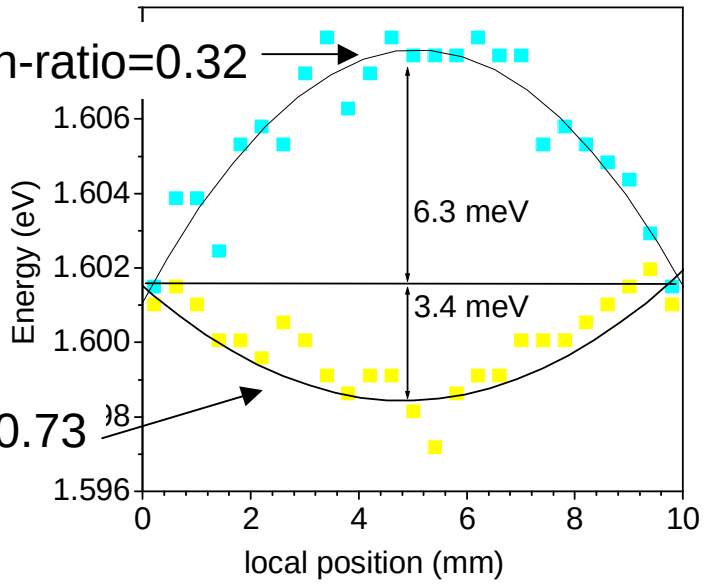
Different heat sinks



1hh-1e



1lh-1e

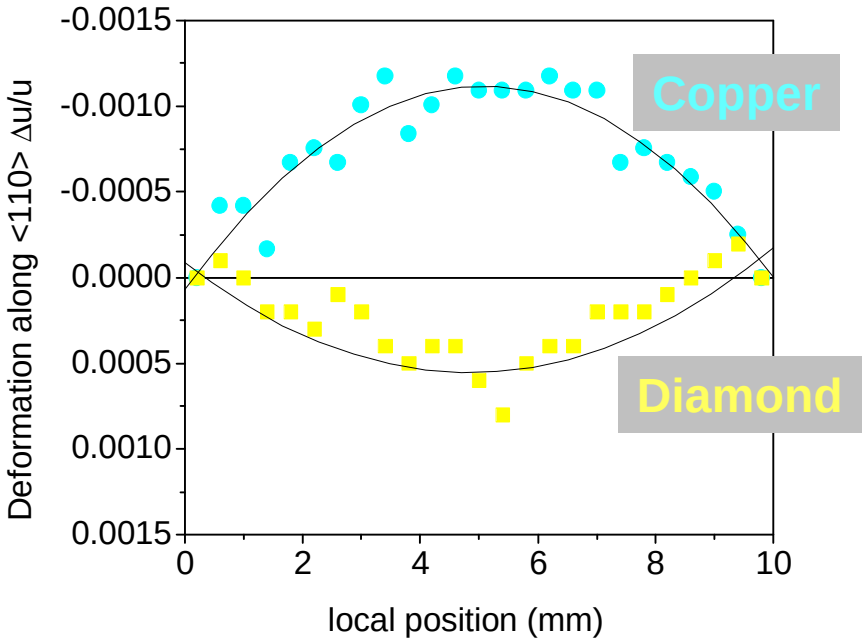


k*p perturbation theory

Compression 0.36

Tension 0.67

1.



Estimate for maximum strain:

Soldering temperature: T_s=157 ℃

Thermal expansion coefficients:

α_{GaAs} = 6.9×10^{-6} K^{-1}

α_{Copper} = 16.7×10^{-6} K^{-1}

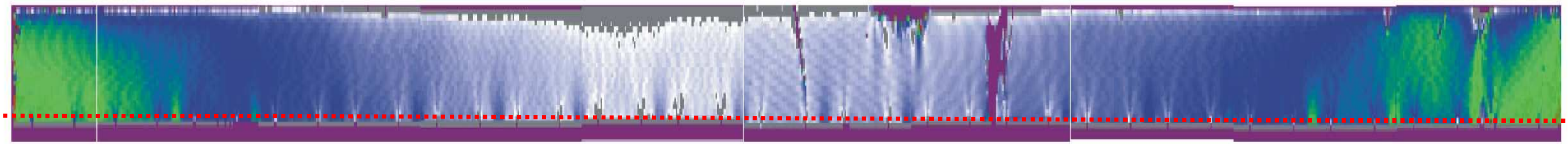
$\alpha_{Diamond}$ = 1.0×10^{-6} K^{-1}

$\Delta x/x = (\alpha_{Device} - \alpha_{heat\ sink})\times(T_s - T_{ambient})$

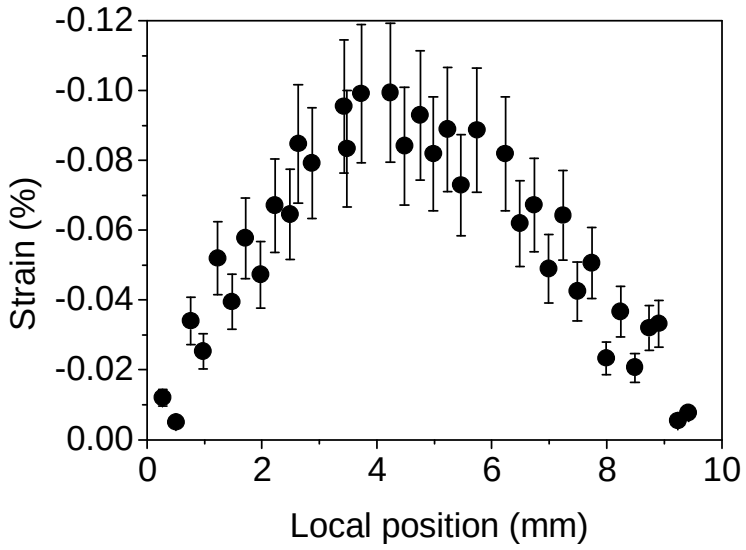
Copper	$\Delta x/x$ = - 0.00134
Diamond	$\Delta x/x$ = 0.00077

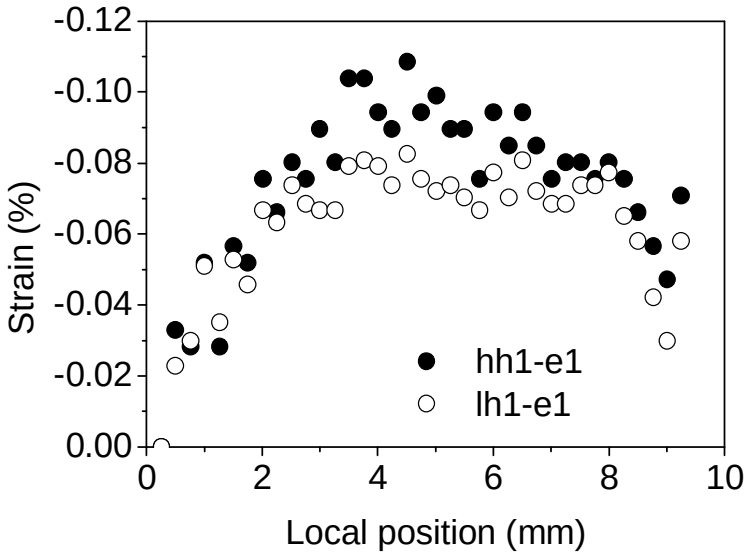
2. At the edges, the devices are unstrained.

Degree-of-polarization PL or R (DoP-PL)



Strain fields of the grooves very nicely visible





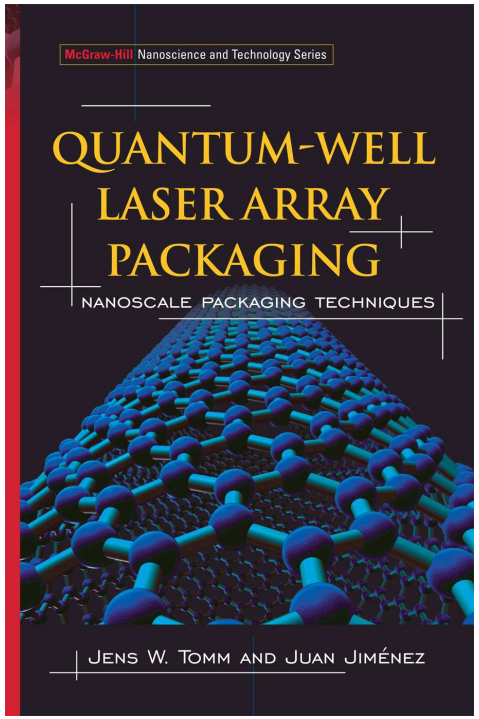
Tomm et al. *Appl. Phys. Lett.* **88**, 1335504, 1-3 (2006).

Check by PCS

3. Summary:

- Spectroscopic strain measurement is an indirect method. It uses the energetic bandstructure of quasi-particles in semiconductors.
- Practically mostly the electronic bandstructure is investigated (exception: built-in strain)
- Each method provides useful but incomplete (!) information.
- If you want to know something special and know what you expect: Apply the right method.
- If you do not know what you expect: Make a concerted approach and try to understand the puzzle.

You can’t fully determine all tensor components by measuring scalars.



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