

# Wet etching technique for fabrication of GaSb based mid infrared single lateral mode lasers

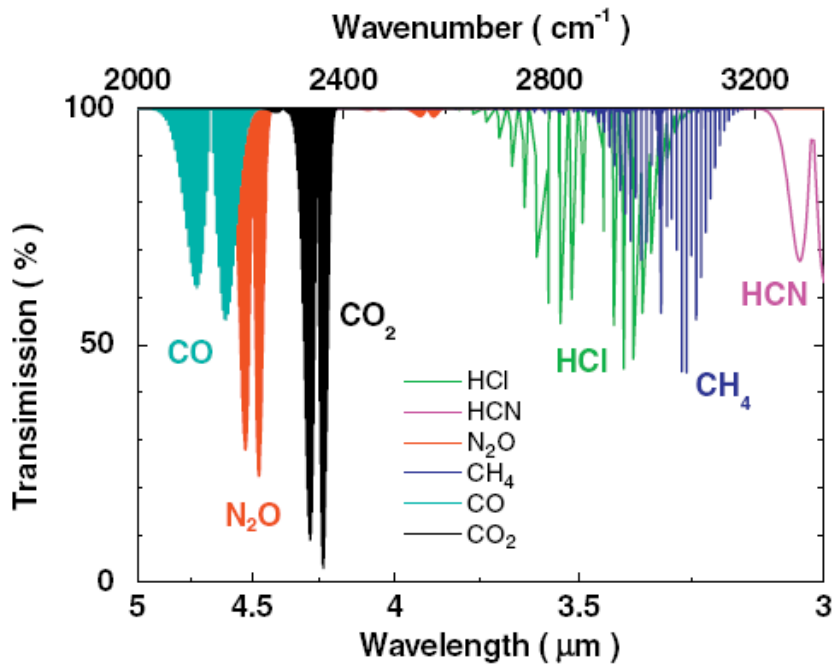
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Leon Shterengas, Gela Kipshidze,  
and Gregory Belenky

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# Outline

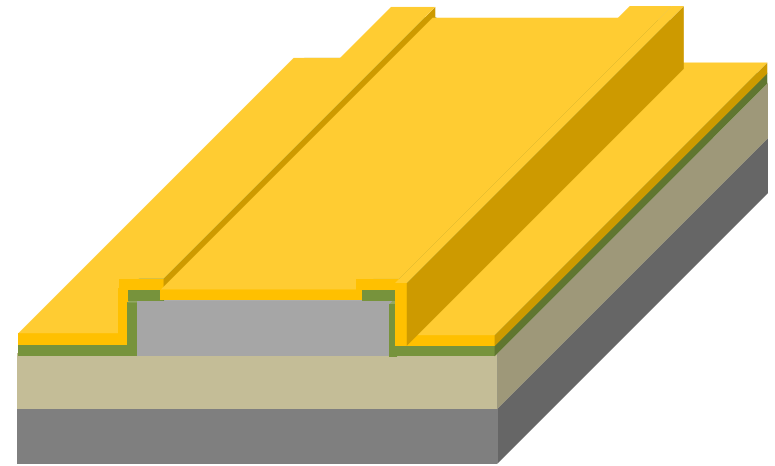
- Motivation
- Technology description
- Device fabrication
- Result and discussion
- Summary

# Applications of Mid IR Lasers



A. Krier et al, *phys. stat. sol. (a)* 205, No. 1, 129–143 (2008)

Absorption spectra of various gases  
within Mid IR (2 ~ 5 μm) range

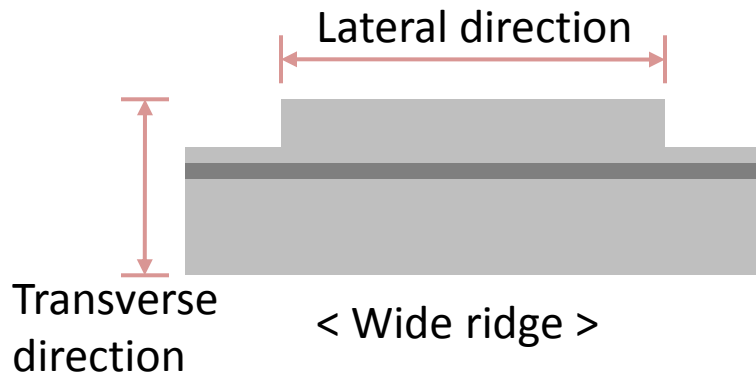


<Schematic of the narrow ridge laser>

## <Applications>

- Gas detection
- Free space communication
- Medical diagnostics

# Wide ridge vs. Narrow ridge lasers



## ***Characteristics***

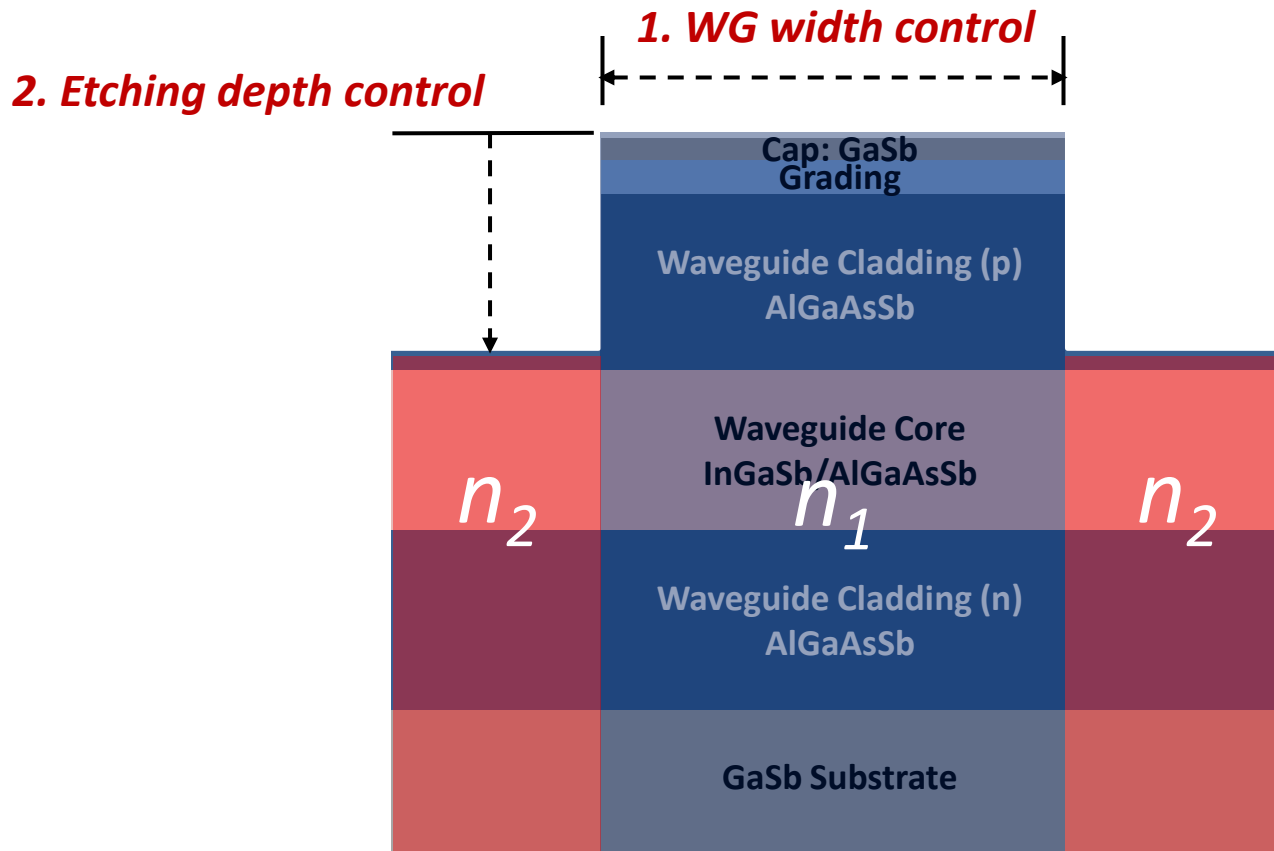
- Wide mesa width  $\sim 100 \mu\text{m}$
- High power
- Lateral multimode operation
- Relatively easy fabrication



## ***Characteristics***

- Narrow mesa width  $< 10 \mu\text{m}$
- Low threshold
- Lateral single mode operation
- Relatively difficult fabrication
- Necessary step for the longitudinal single mode operation

# Crucial points to fabricate the narrow ridge



< Typical GaSb based mid IR laser QW laser structure >

*Lateral single mode requires the precise refractive index step ( $n_1-n_2$ ) control together with the mesa width.0*

# Fabrication of narrow ridge

## <Dry etching>

### Advantages

- Precise control of etching depth
- High degree of Directivity
- High degree of non-selective etching

### Disadvantages

- High cost
- Low throughput

## <Wet etching>

### Advantages

- Cost effective
- High throughput
- Relatively easy implementation
- High degree of material selectivity

### Disadvantages

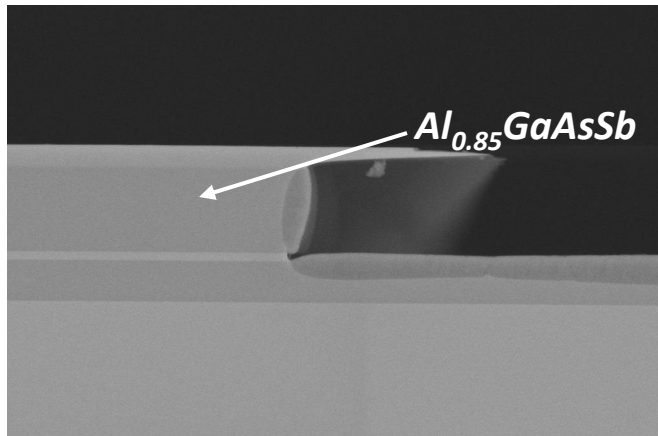
- Low degree of directivity
- High degree of material selectivity



*Could be preferred to industrial process.*

# Implementation challenges using wet etching

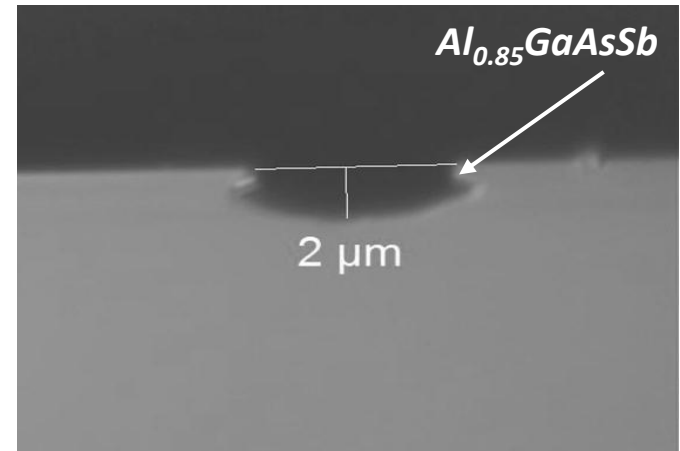
## *Material selectivity*



< Etching test with **HCl** based solution >

→ *Fast etching rate for Al-rich material*

## *Isotropic etching profile*



< Etching test with **Tartrate** based solution >

→ *Fast etching rate for non Al-rich material*

# Two major points of this technique

## ***Complementary Etching***

- Role:  
To compensate etching selectivity between the GaSb and AlGaAsSb layer.
- Procedure:
  - 1. Etching GaSb with Tartrate solution***
  - 2. Etching AlGaAsSb with HCl solution***

## ***Etch Stopper***

- Role:  
To control precise etching depth
- Requirement:
  1. Slow etching rate with HCl
  2. Need to minimize carrier transport problem

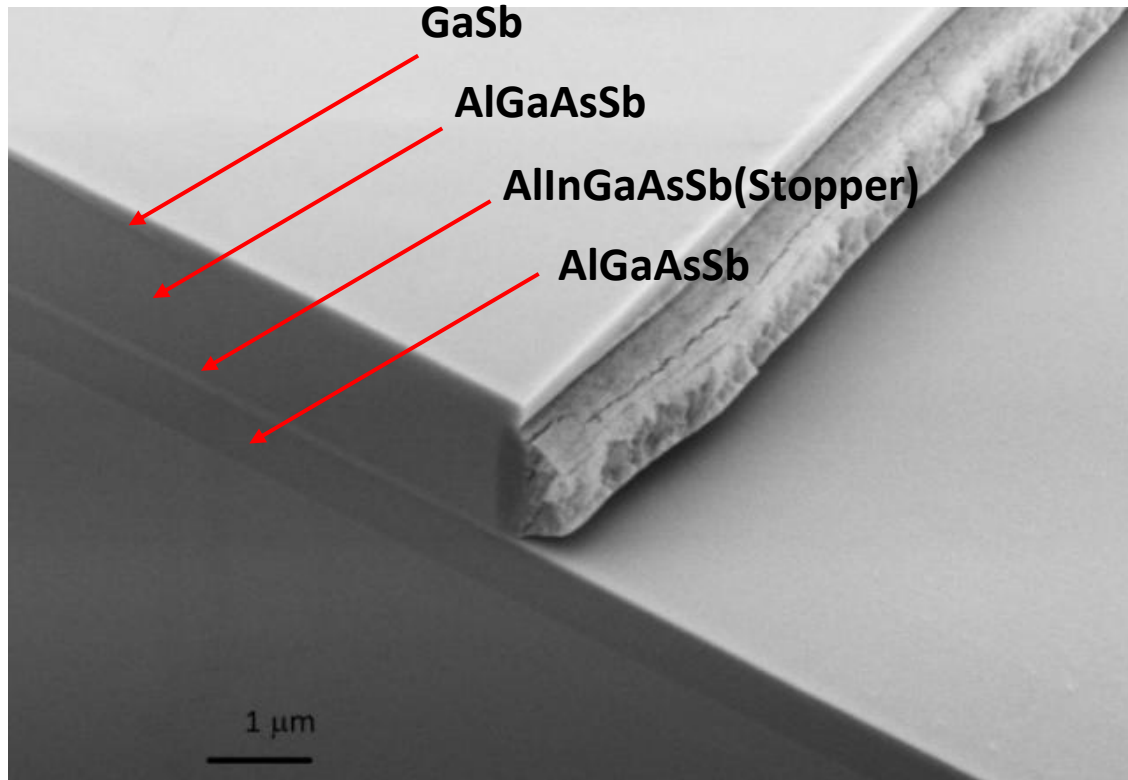
***Proper material selection***



***AllnGaAsSb***



# Preliminary wet etching result



<Etching test with the etch stopper>

# Processing detail: Etchant preparation

## <Tartrate based solution>

Tartrate : DI Water : H<sub>2</sub>O<sub>2</sub> : H<sub>3</sub>PO<sub>4</sub>  
= 5 g : 90 ml : 30 ml : 30 ml



Under stirring for 2 days

## <HCl based solution>

HCl : DI Water : H<sub>2</sub>O<sub>2</sub>  
= 50 ml : 50 ml : 1 ml



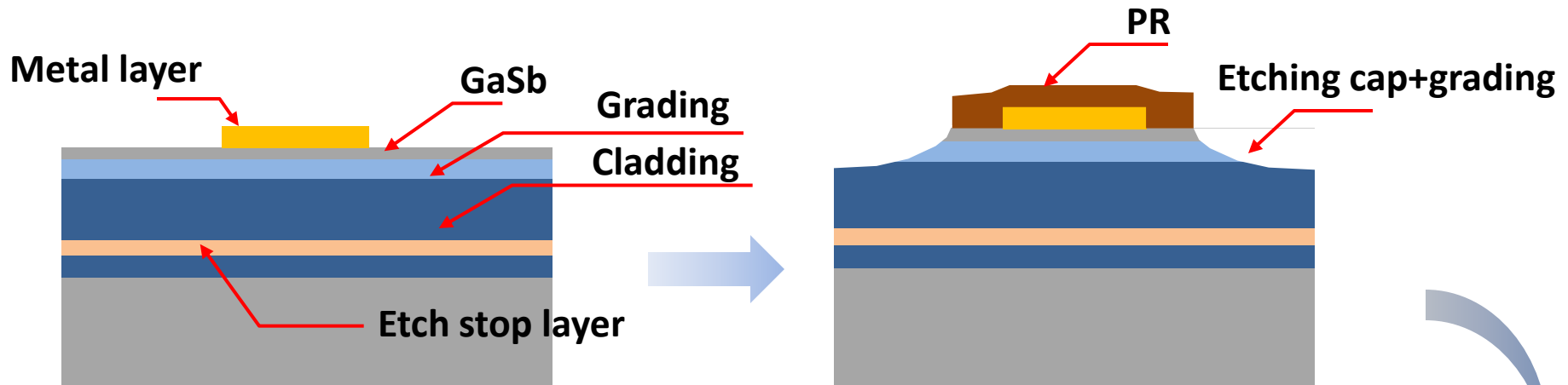
H<sub>2</sub>O<sub>2</sub> was added just before used.

## <Etching rate of etch etchant>

<i>Material</i>	<i>GaSb</i>	<i>AlGaAsSb</i>	<i>AllnGaAsSb</i>
<i>Role</i>	<i>Cap</i>	<i>Cladding</i>	<i>Etch stopper</i>
<i>Etching rate of Tartrate (nm/sec)</i>	16.6	5	-
<i>Etching rate of HCl (nm/sec)</i>	3.2	30	1.1

*Highly selective!*

# Processing detail: Etching Procedure

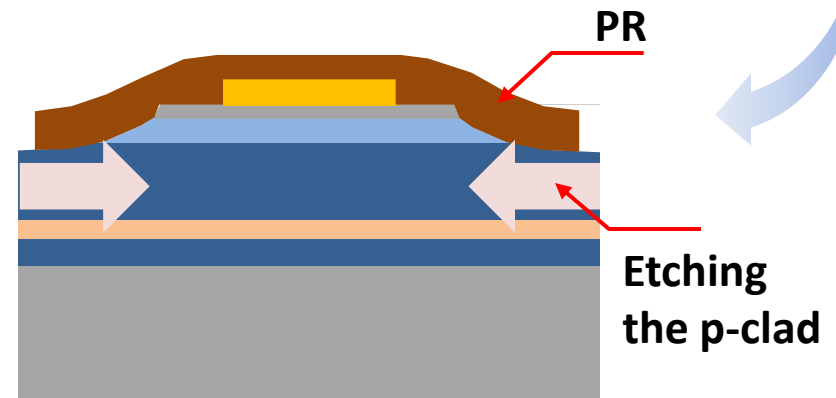


*<1. Metal deposition>*

*<2. Etching with the Tartrate solution>*

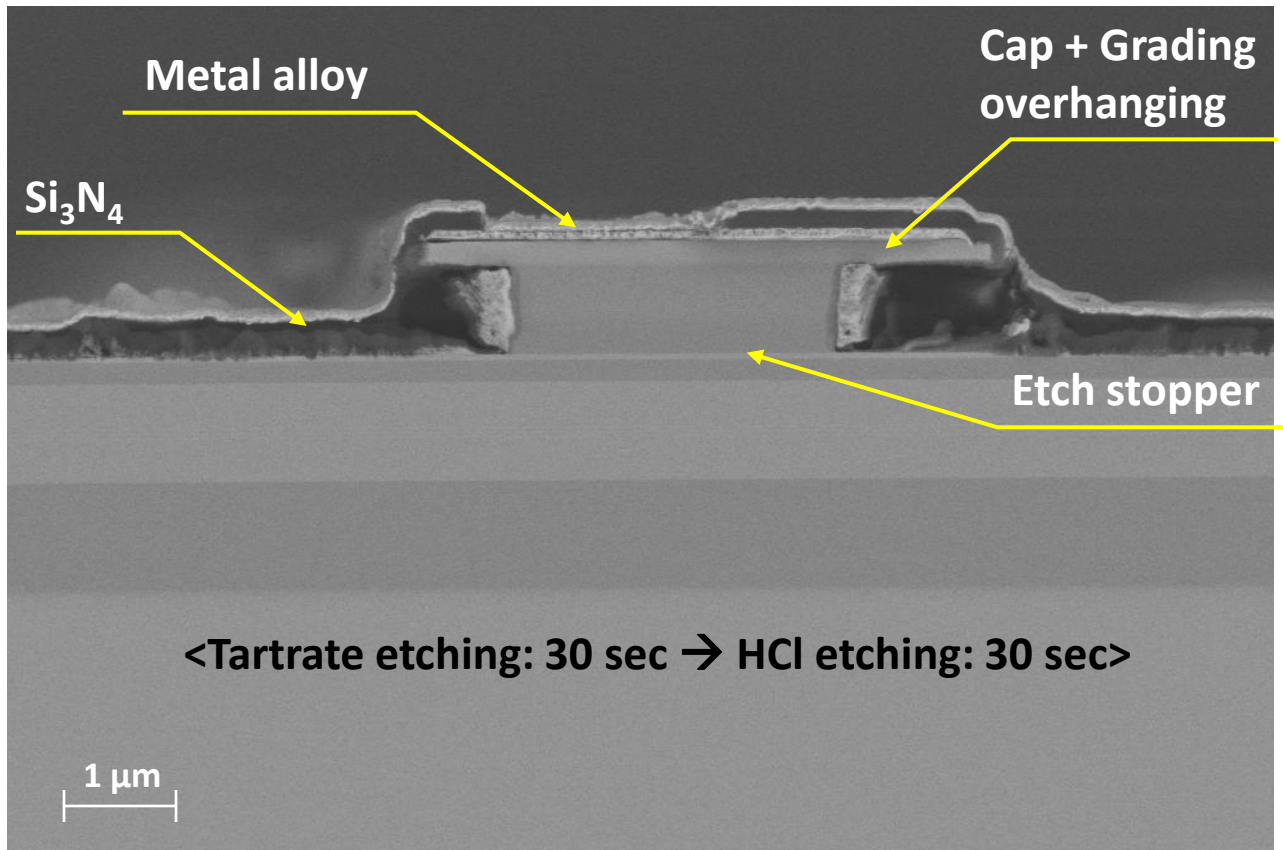


*<4. Photo-resist removal>*



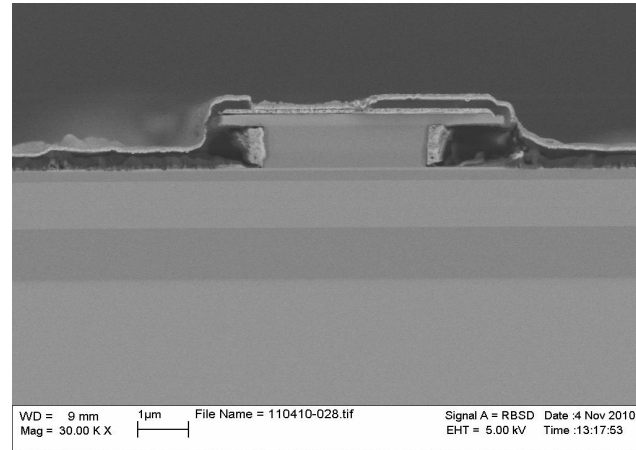
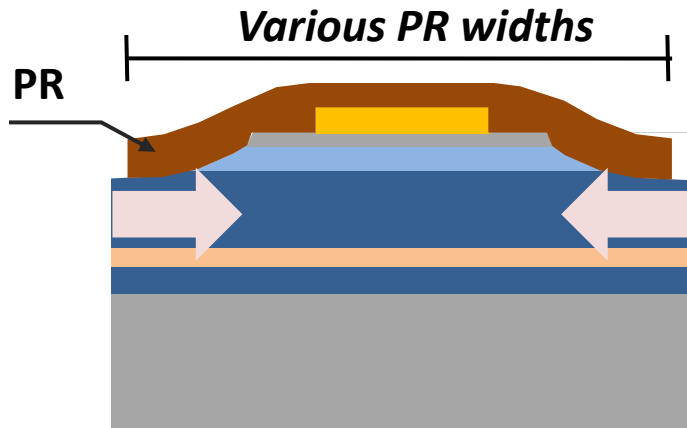
*<3. Etching with the HCl solution>*

# Vertical wall narrow ridge with wet etching

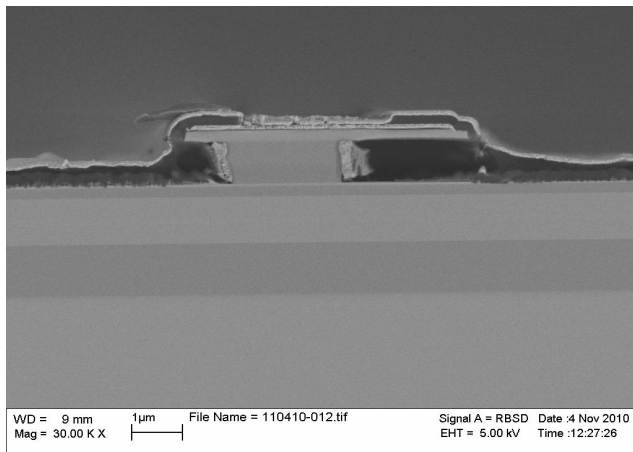


< SEM image of the complete laser device >

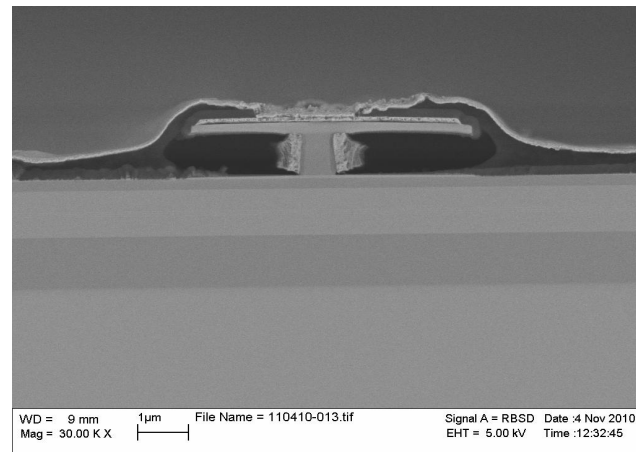
# Mesa width control



<4.2 μm (12 μm)>

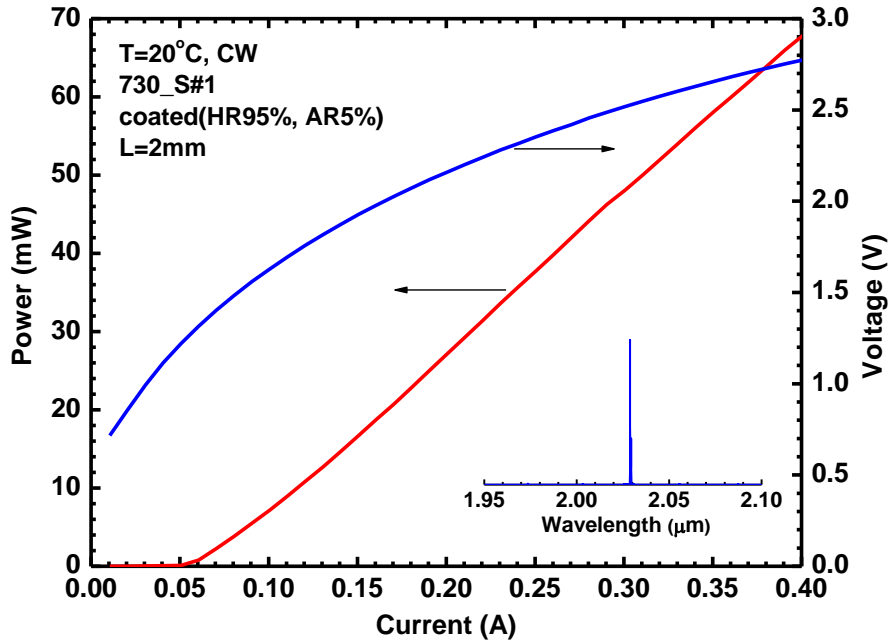


<2.4 μm (10 μm)>

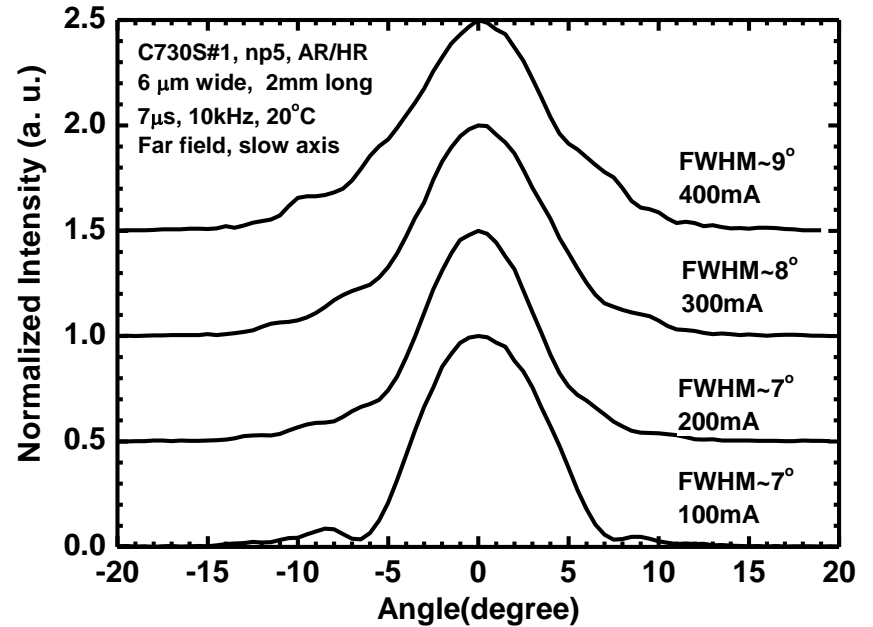


<0.5 μm (8 μm)>

# Laser performance



*RT cw power: ~70mW*



*Far field at slow axis: ~8° (FWHM)*

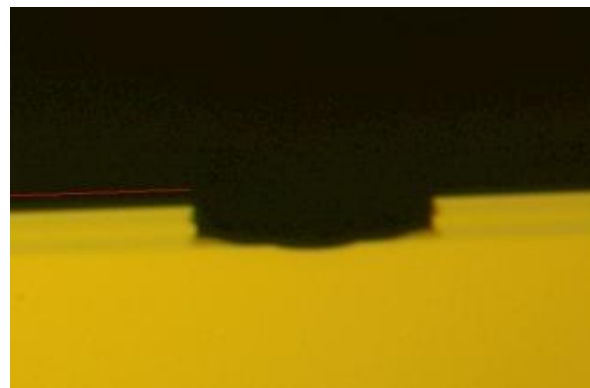
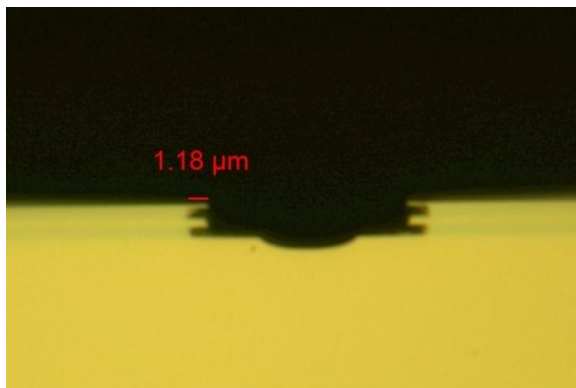
# Summary and Future work

## <Summary>

- *The lateral single mode laser has been fabricated by cost effective wet etching technique.*
- *Complementary etching with the etch stopper demonstrated effective mesa width and etching depth control.*
- *This technique can be used for sidewall smoothing, standing free 2D wire, etc. consisting of Al-rich and InGaAsSb sequential layers.*

## < Future work >

- *Optimization of the etching process for precise etching control.*



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