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H4.SMR/453-46

TRAINING COLLEGE ON PHYSICS AND CHARACTERIZATION OF LASERS AND OPTICAL FIBRES

(5 February - 2 March 1990)

HIGH POWER QUANTUM WELL LASERS FOR OPTICAL STORAGE

Prof. H. Jaeckel
IBM Zurich

HIGH POWER QUANTUM WELL LASERS FOR OPTICAL STORAGE

H. Jaeckel

IBM Research Division, Zurich Research Laboratory

Laser Science and Technology

OUTLINE

- POWER LASERS FOR DIGITAL OPTICAL STORAGE
- QUANTUM WELL LASER DESIGN
- AlGaAs MULTIPLE QUANTUM WELL POWER LASERS
- DRY ETCHED MIRROR FABRICATION TECHNOLOGY
- SHORT WAVELENGTH SOURCES WITH SEMICONDUCTOR LASERS
- CURRENT AND FUTURE TOPICS

THANKS TO MY COLLEAGUES:

- G.L. Bona
- P. Buchmann
- F. Gfeller
- H.P Meier
- P. Vettiger
- D.J. Webb

and all the members of the IBM ZRL Laser Science and Technology Department

POWER LASERS FOR MAGNETO-OPTICAL STORAGE

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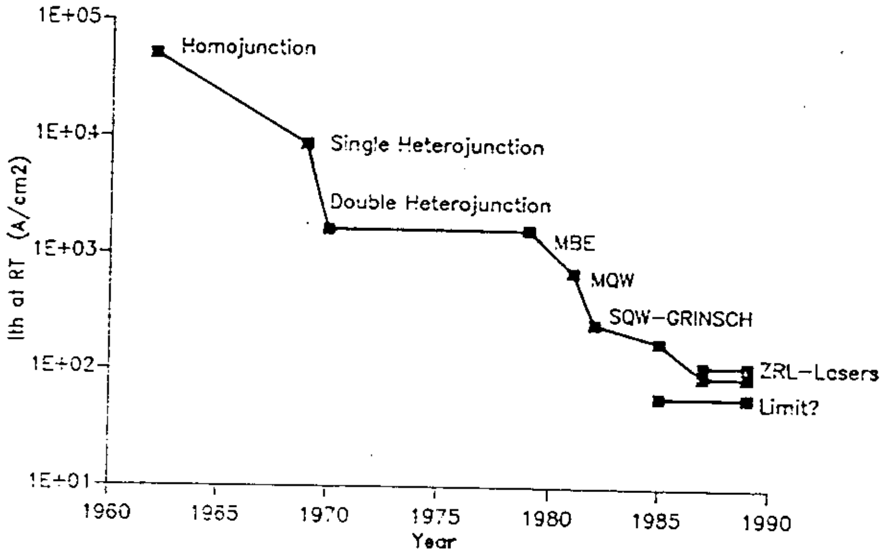
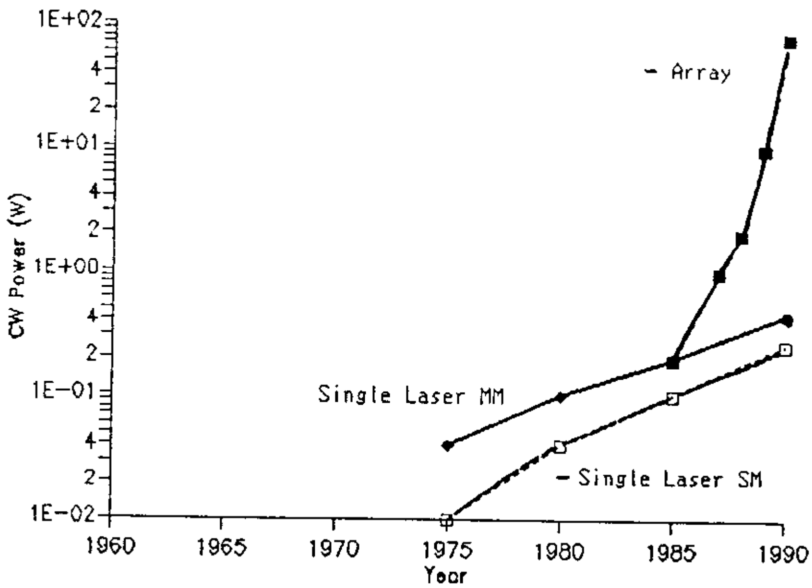
EVOLUTION OF AlGaAs POWER LASERS

■ THRESHOLD CURRENT DENSITY:



■ OPTICAL POWER OUTPUT:



■ EPITAXIAL GROWTH TECHNIQUE:

Transition from LPE to MBE and MOVPE for mass fabrication

APPLICATIONS FOR POWER AND/OR SHORT WAVELENGTH LASERS

- OPTICAL DISK STORAGE (< 30 - 100mW)
- OPTICAL TAPES (< 30mW)
- OPTICAL PRINTER SYSTEMS (< 30mW)
- OPTICAL BAR CODE SCANNERS (< 30mW)
- CD and VIDEO PLAYERS (< 5mW)
- Nd:YAG PUMP SOURCE (> 1W)
- MINIATURE BLUE LASERS BY OPTICAL SHG (> 100mW)
- HeNe-LASER REPLACEMENT (mW)
- SPACE COMMUNICATION (> 1W)
- SHORT DISTANCE PLASTIC FIBER COMMUNICATION (mW)

DIODE LASER MARKET REVIEW

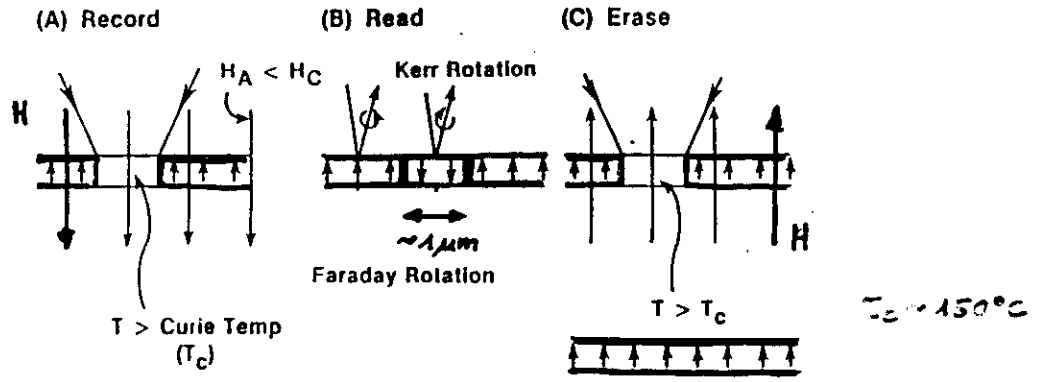
- WORLDWIDE COMMERCIAL DIODE LASER SALES (after D. Kales)

	1988	1989	1988	1989
Material Processing	0	0	0	0
Therapeutic Medicine	1464	0	0.7	0
Diagnostic Medicine	0	0	0	0
R&D	13,704	13,000	20.0	20.0
• Printers	4,100,000	5,500,000	23.0	22.0
Color Separation	0	0	0	0
• Communications	154,000	234,000	70	75
• Optical Memories	14,192,000	18,619,000	50	68
Barcode Scanners	150,000	300,000	6.0	14.0
Alignment & Control	14,000	19,000	0.17	0.20
Test & Measurement	5675	5000	10.0	12.0
Entertainment	0	0	0	0
TOTAL COMMERCIAL	18,630,843	24,690,000 Units	180	211 M$

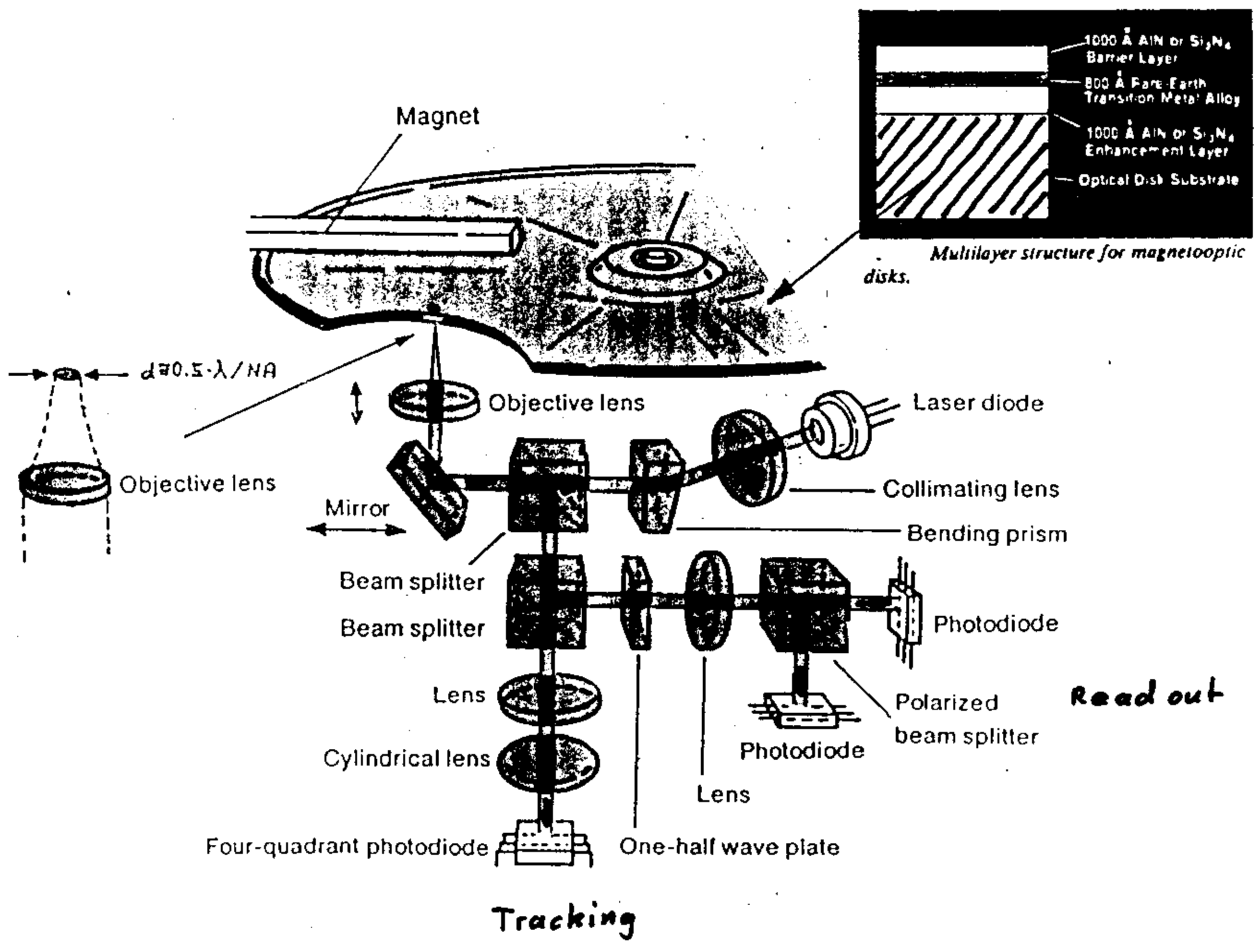
==> Diode Lasers share about 30% of the total Laser Market Volume!

PRINCIPLE OF MAGNETO-OPTIC RECORDING

- MAGNETO-OPTIC RECORDING WRITE/ERASE/READ



- SCHEMATIC MAGNETO-OPTIC RECORDING SYSTEM



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POTENTIAL OF DIGITAL OPTICAL STORAGE

ADVANTAGES:

- High Areal Density (High End: ~10x, Low End: ~100x)
- Removable Storage Media
- Contamination Tolerant Media
- Large Head Clearance (mm instead of 0.1um)
- Multiple Beam, High Data Rate Systems

APPLICATIONS:

- READ ONCE (CD-ROM)
  - Data Base Distribution, Images and Graphics
  - Software and Electronic Information Distribution
- WRITE ONCE READ MANY (WORM)
  - Personal Archives, Libraries
  - Image and Graphics Storage
- ERASABLE
  - Mainstream DASD
- OPTICAL TAPES
  - Data Mass Storage
  - Optical Personal Cards

QUANTUM WELL POWER LASER DESIGN

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DIODE LASERS ARE KEY FOR OPTICAL STORAGE ?

- SHORT WAVELENGTH improves DENSITY
- HIGH OPTICAL POWER improves DATARATE
- DIFFRACTION LIMITED BEAM QUALITY
- LASER ARRAYS provide DIRECT READ AFTER WRITE capability
- LASER ARRAYS provide DIRECT OVERWRITE capability
- LASER ARRAYS allow MULTIPLE BEAM HEADS for high datarates
- OPTICAL POWER SOURCE for SECOND HARMONIC GENERATION
- FUNCTIONALITY FOR INTEGRATED HEADS

POWER LASER FUNCTIONAL REQUIREMENTS

- IDEAL BEAM PROPERTIES
  - ★ Fundamental Transverse Mode Operation
  - ★ Low optical Phase- and Intensity Distortion, low Astigmatism
  - ★ Stable Beam Pointing
  - ★ Low Temporal Coherence
  - ★ High Polarization Purity

- HIGH OVERALL ELECTRICAL/OPTICAL EFFICIENCY
  - ★ Low Threshold Current
  - ★ High Differential Quantum Efficiency
  - ★ Low Temperature Sensitivity

- HIGH RELIABLE OPTICAL POWER OUTPUT
  - ★ Large optical Mode Crossection Design
  - ★ High Quality Mirror Passivation and Reflection Modification

- HIGH RELIABILITY AND LIFETIME

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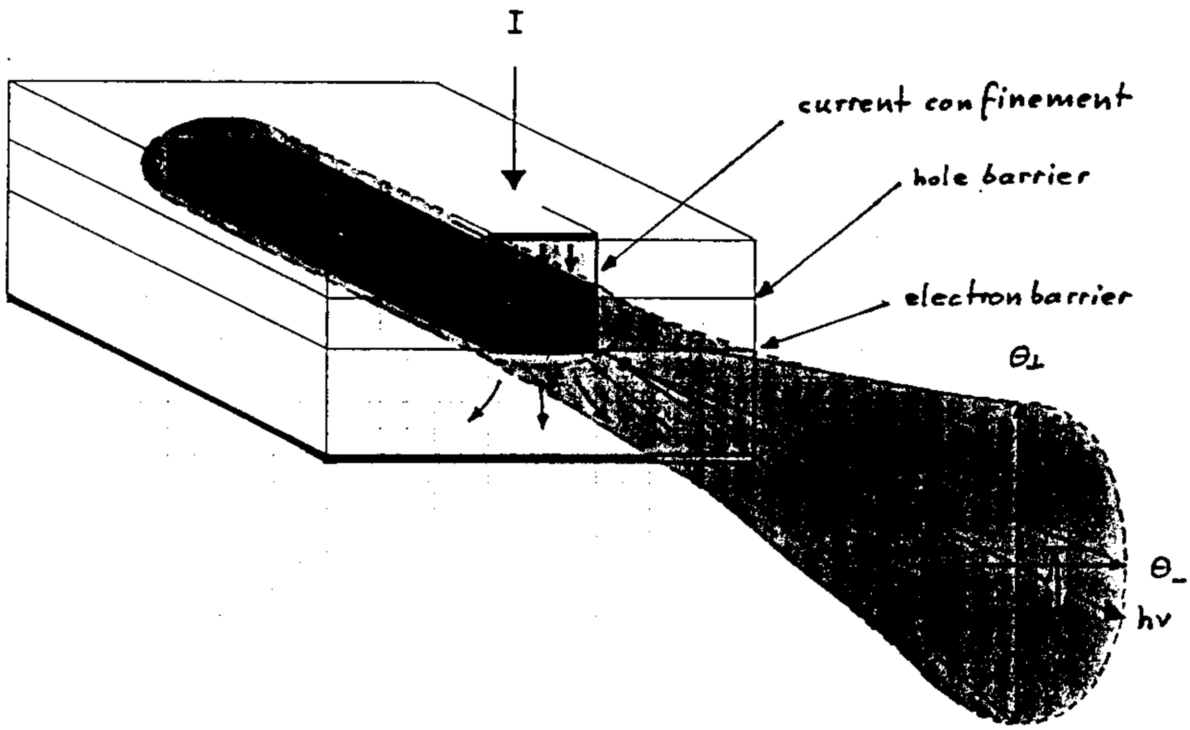
OPTICAL MODE CONFINEMENT AND SELECTION

DESIGN TARGETS

- FUNDAMENTAL TRANSVERSE MODE at HIGH OPTICAL POWER
- LARGE OPTICAL MODE CROSSECTION for LOWEST OPTICAL FLUX DENSITY
- LOW OPTICAL BEAM DISTORTION IN THE FAR FIELD (Astigmatism,...)
- EFFICIENT CARRIER INJECTION STRUCTURE / CONFINEMENT

SCHEMATIC LASER STRUCTURE

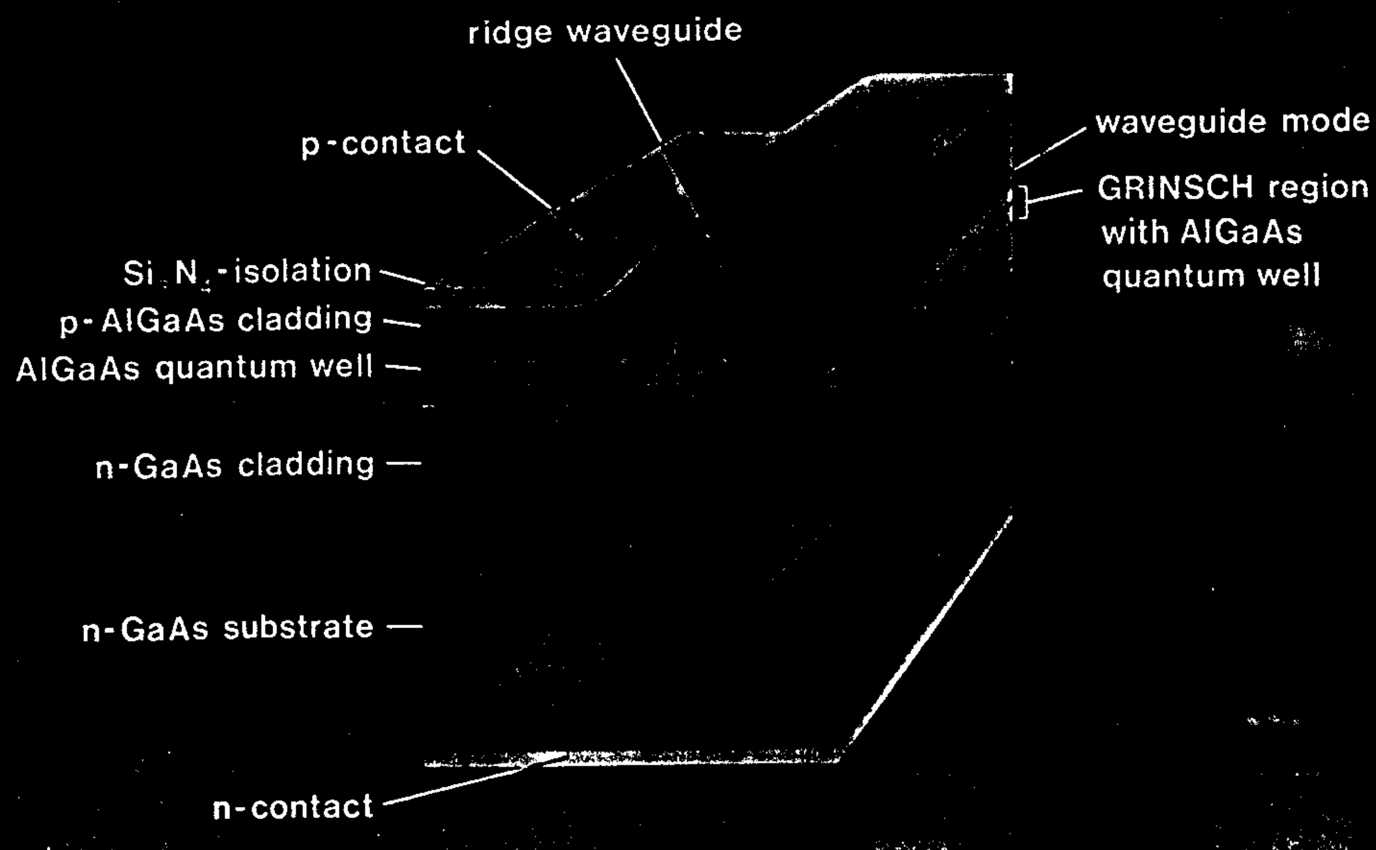


DESIGN STRATEGIES

- LARGE OPTICAL CAVITY or THINN OPTICAL CAVITY
- FUNDAMENTAL MODE ONLY WAVEGUIDE DESIGN
- MULTIMODE WAVEGUIDE with MODE SELECTIVE LOSSES
- CONTROL of LATERAL CURRENT FLOW by GEOMETRY and BLOCKING JUNCTIONS

AlGaAs Quantum Well Ridge GRINSCH Laser

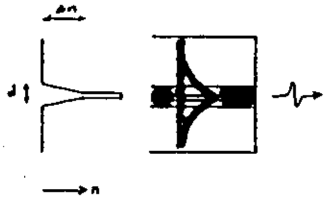
Expanded View

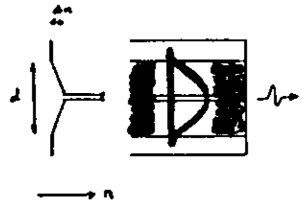


OPTICAL MODE CONFINEMENT STRUCTURES

VERTICAL MODE CONFINEMENT

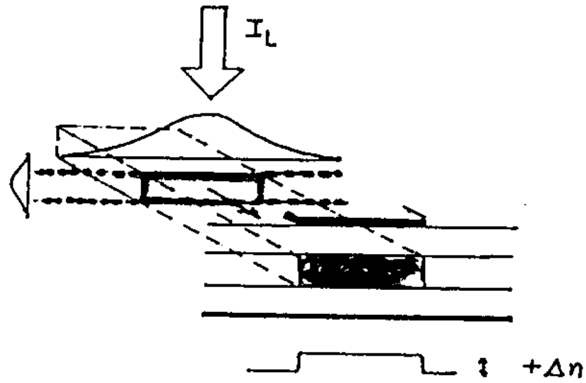
- THIN OPTICAL CAVITY
- LARGE OPTICAL CAVITY





LATERAL MODE CONFINEMENT

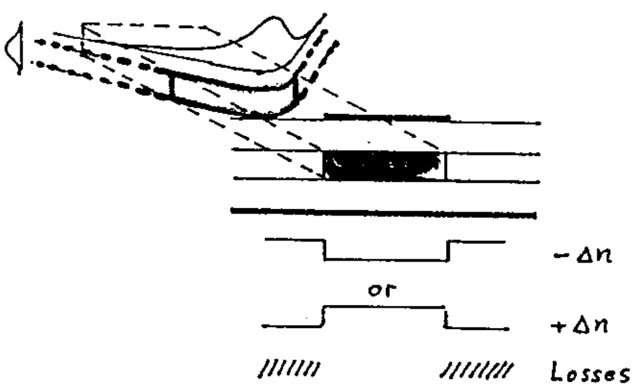
- TRUE FUNDAMENTAL MODE WAVEGUIDE (Positve Index Guide)



Small Lateral Guide Dimensions, No Astigmatic Beam

- MULTIMODE WAVEGUIDE WITH MODE DEPENDENT LOSS

- Leaky Waveguide
- Absorption losses



Larger Lateral Guide Dimensions, Astigmatic Beam

LIMITS OF FUNDAMENTAL MODE POWER

- MODAL INSTABILITIES

  Gain-Guiding and Refractive Index Depression

  Injection Current Redistribution

  Beam Pointing Instabilities

  Thermal Guiding Effects

- THERMAL SATURATION

  Overall Efficiency, Heatsinking (thermal run away)

- FACET DEGRADATION

  Catastrophic Mirror Degradation

  Gradual Mirror Degradation and Dark Line Formation

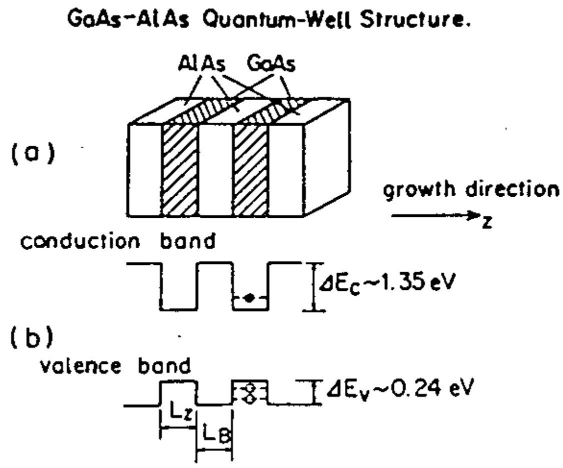
- BULK DAMAGE

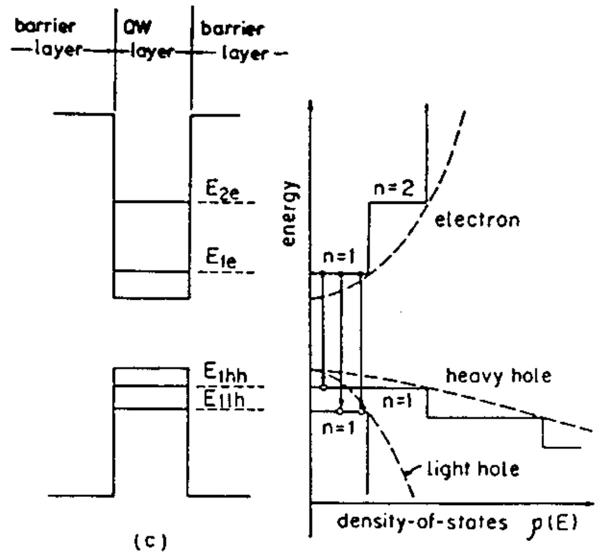
  Bulk Damage Level 10x Surface Damage Level ?

QUANTUM CONFINEMENT IN COMPOUND SEMICONDUCTORS

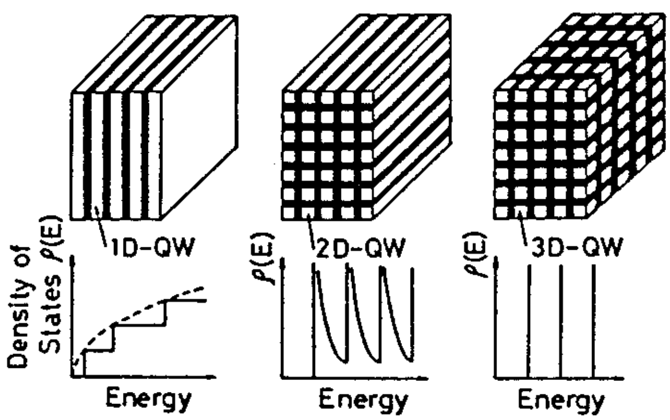
- MODIFICATION OF DENSITY OF STATE FUNCTION
- ROOM TEMPERATURE 2-DIMENSIONAL EXCITONS
- MODULATION DOPING
- COMPOSITIONAL MODIFICATION BY LOCAL DISORDERING

DENSITY OF STATE IN QUANTUM FILMS:





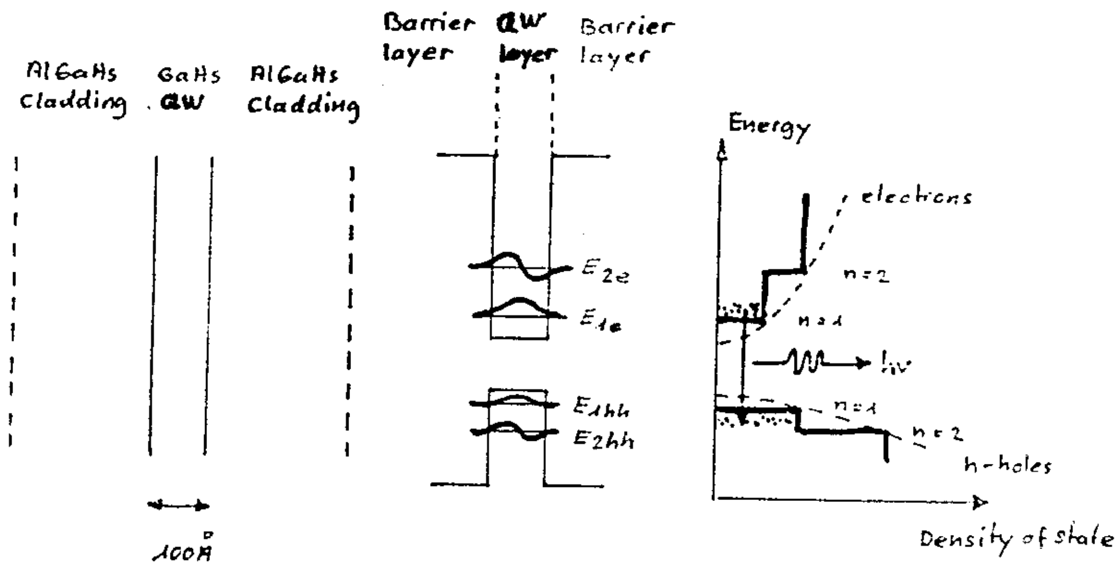
DENSITY OF STATE MODIFICATION FROM BULK TO QUANTUM BOX:



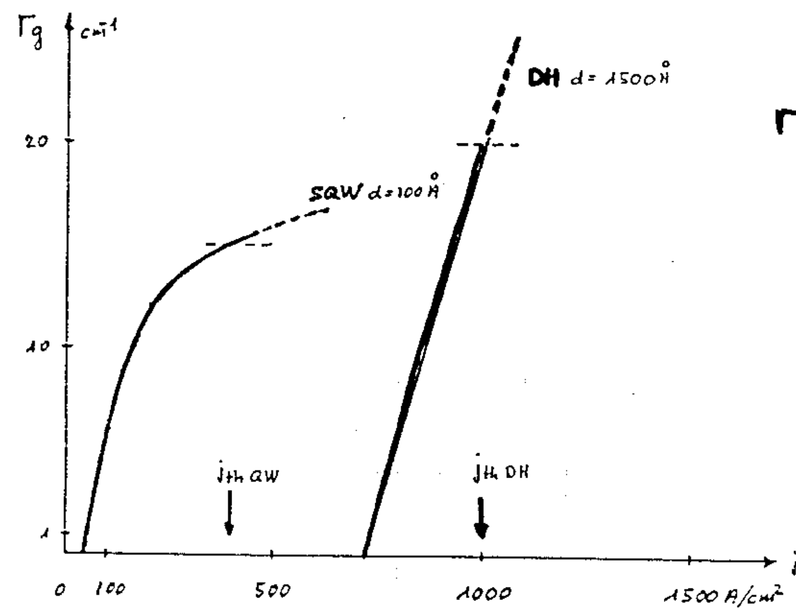
PRINCIPLES OF QUANTUM WELL LASERS

- Reduction of active layer thickness leads to Quantum size effects:

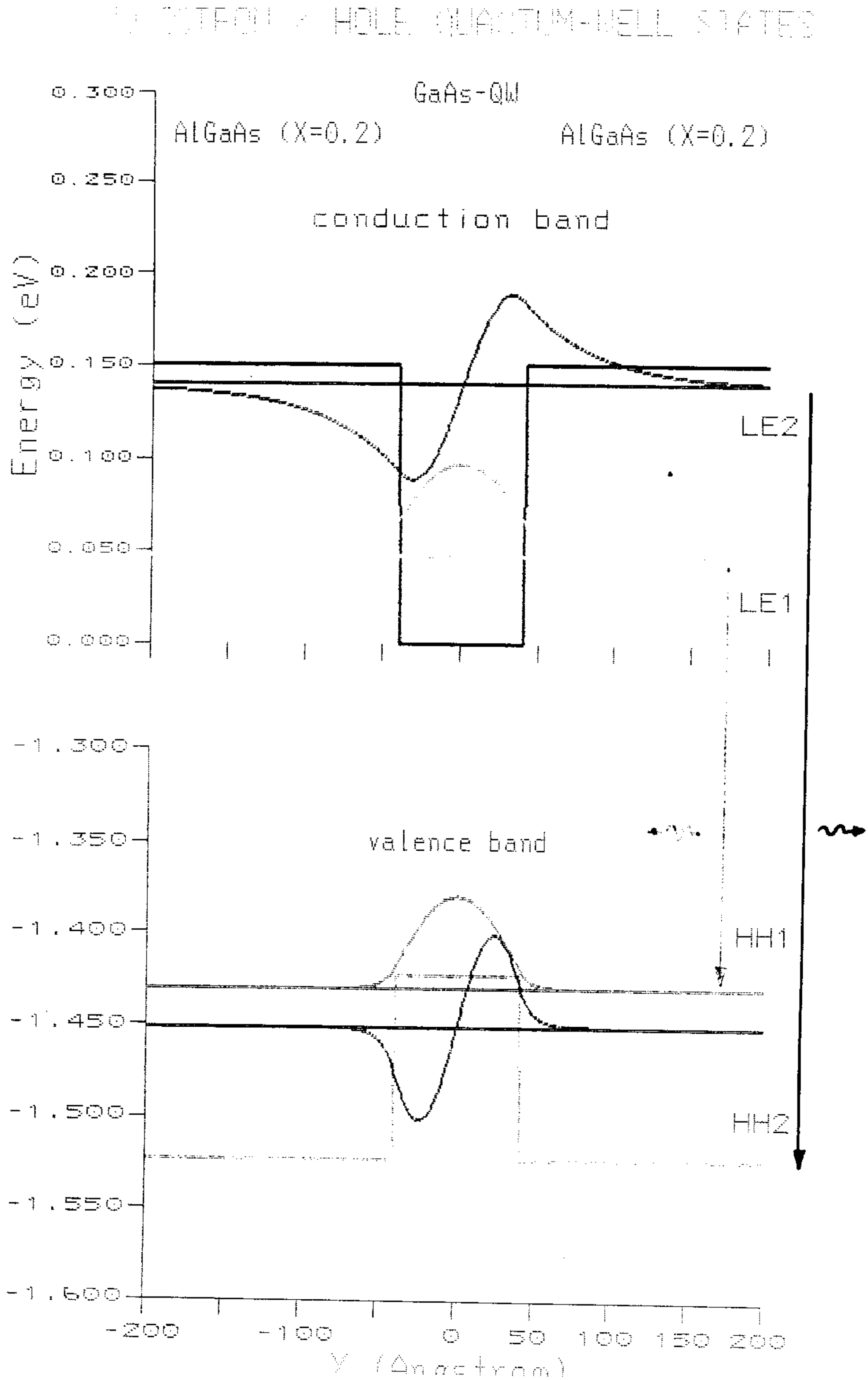
  ★ Modification of Density of States (Sub-Bands)

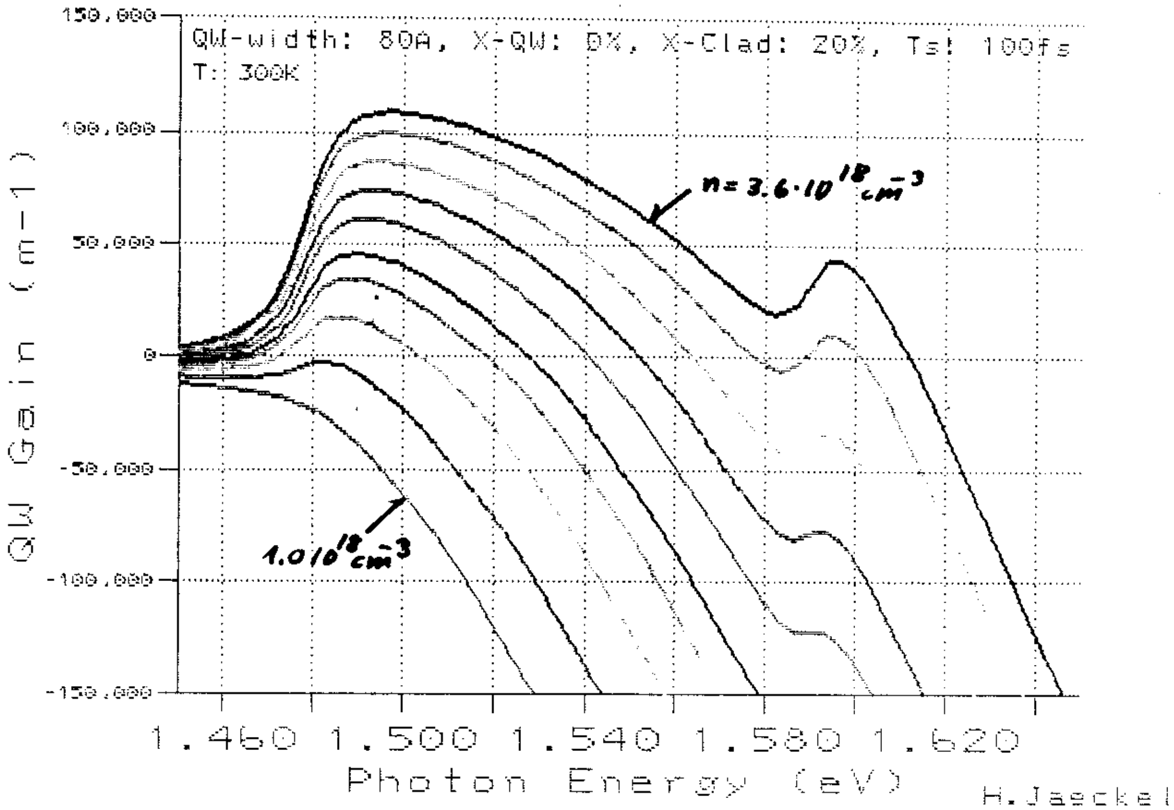


- Decreased Transparency Current (Gain-Volume Reduction)
- Gain-Linewidth Narrowing and Reduced Temperature Sensitivity



$$\Gamma g = \alpha + \frac{1}{L}\ln\left(\frac{1}{R}\right)$$


HOLE QUANTUM-WELL STATES
GaAs-QW
AlGaAs (X=0.2)
AlGaAs (X=0.2)
conduction band
Energy (eV)
0.300
0.250
0.200
0.150
0.100
0.050
0.000
LE2
LE1
valence band
-1.300
-1.350
-1.400
-1.450
-1.500
-1.550
-1.600
HH1
HH2
-200
-100
0
50
100
150
200
Y (Angstrom)


QW-width: 80A, X-QW: 0%, X-Clad: 20%, Ts: 100fs
T: 300K
n=3.6·10^18 cm^-3
1.0·10^18 cm^-3
QW Gain (m-1)
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
1.460 1.500 1.540 1.580 1.620
Photon Energy (eV)
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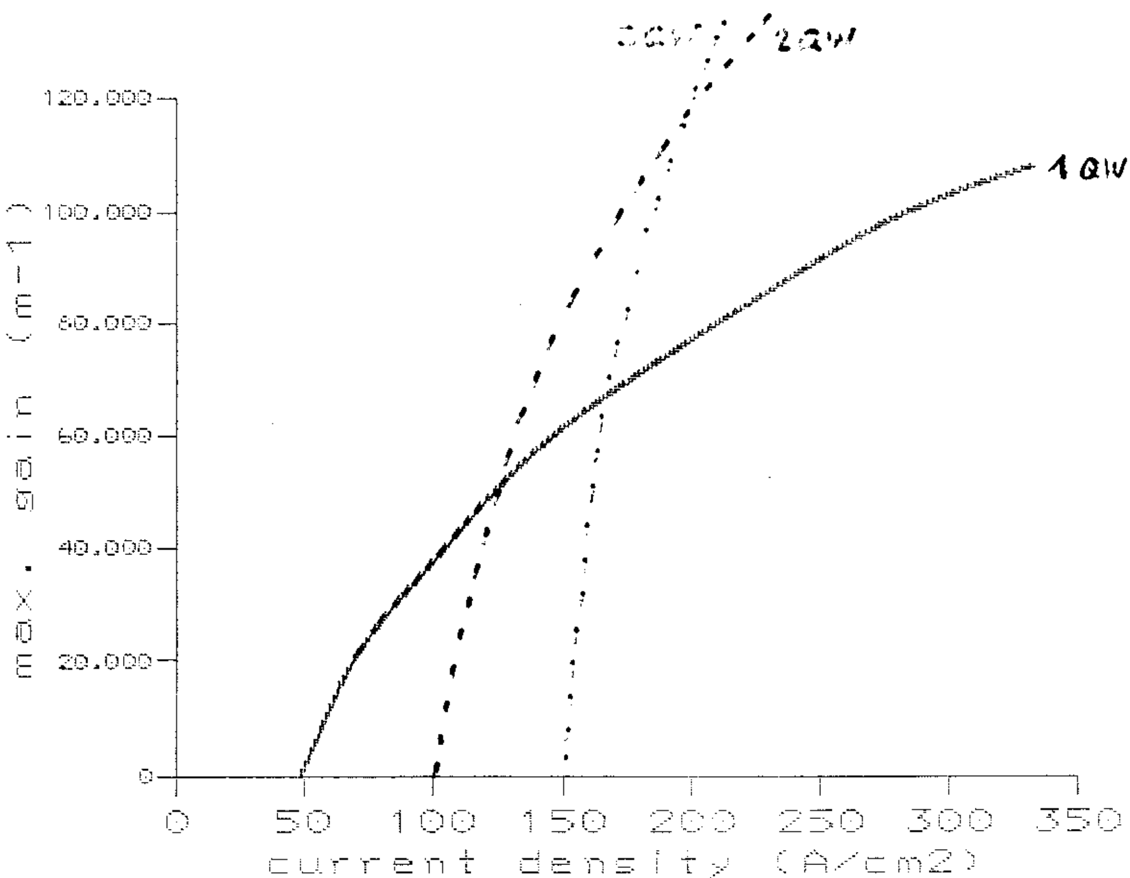
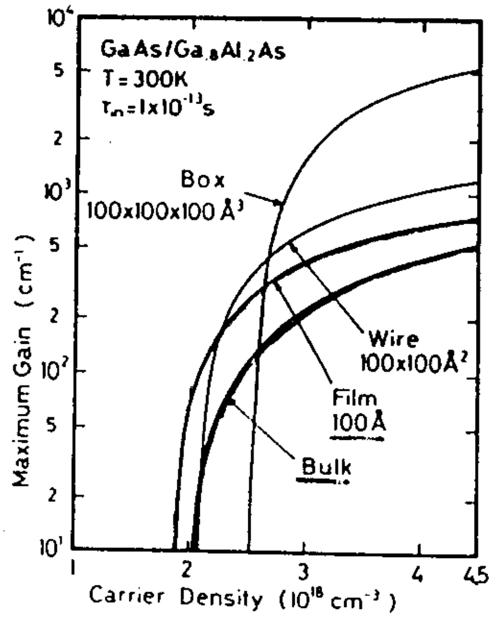
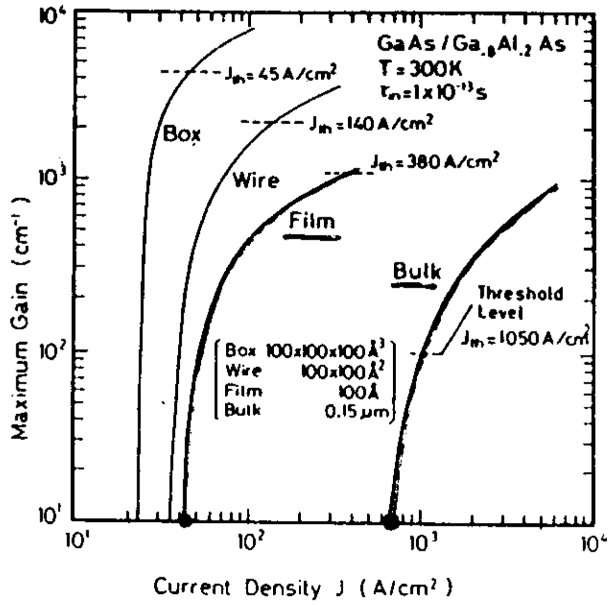

3QW
2QW
1QW
max. gain (m-1)
120,000
100,000
80,000
60,000
40,000
20,000
0
0 50 100 150 200 250 300 350
current density (A/cm2)

■ LASER GAIN MODIFICATION BY QUANTUM CONFINEMENT

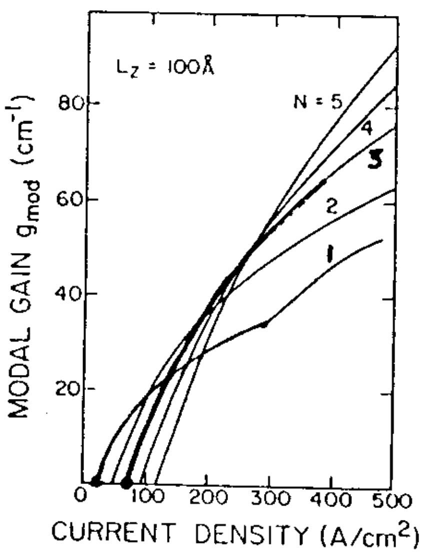
(after Asada et al.)

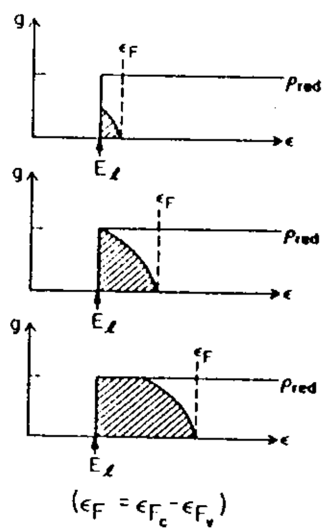




■ LASER GAIN MODIFICATION BY MULTIPLE QUANTUM WELLS

(after Arakawa et al.)





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MULTI-QUANTUM WELL HIGH PERFORMANCE LASERS

GAIN MEDIUM OPTIMIZATION BY:

Quantum Well Number

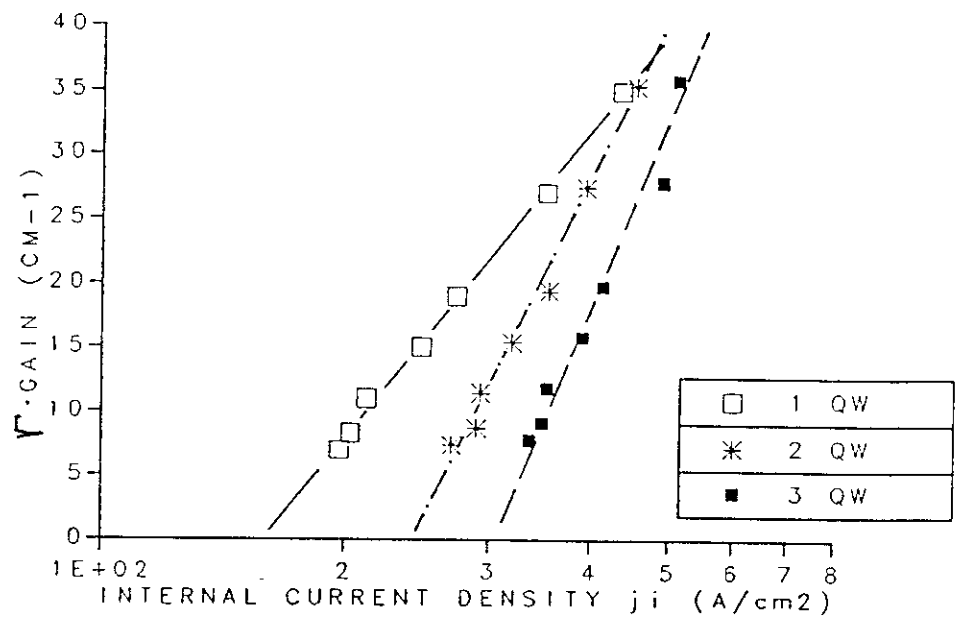
Quantum Well Width

Quantum Well Coupling

Quantum Well Doping

■ GAIN / LOSS OPTIMIZATION WITH MQW:

Comparison of 1,2 and 3 QW



- Gain: $g = \alpha + 1/L*\ln(1/R)$
- Internal Current Density: $j_i = jth*\eta$
- T= 25°C: $j_{tr}(n) = (n \times 67 + 94)\,A/cm^2$
- Fit: $g(j_i) = g_0 \times \ln(j_i/j_{tr})$ with $g_0 = 35, 46, 58\ cm^{-1}$

QUANTUM CONFINEMENT IN OPTO-ELECTRONIC DEVICES

- **DIODE LASERS:**
  - ★ GAIN MODIFICATION
  - ★ THRESHOLD CURRENT REDUCTION
  - ★ REDUCED TEMPERATURE SENSITIVITY OF THRESHOLD
  - ★ NARROW SPECTRAL GAIN WIDTH
  - ★ POLARIZATION DEPENDENCE OF OPTICAL GAIN
  - ★ REDUCED OPTICAL CHIRP
  - ★ HIGH MODULATION FREQUENCY DUE TO HIGH DIFFERENTIAL GAIN
  - ★ REDUCED REFRECTIVE INDEX DEPRESSION BY CARRIER INJECTION
  - ★ LOW WAVEGUIDE LOSSES BY BANDGAP SHRINKAGE

- MODULATORS:
  - ★ QUANTUM CONFINEMENT STARK-EFFECT BANDGAP SHIFT

- PHOTODETECTORS:
  - ★ IONIZATION RATE TAYLORING

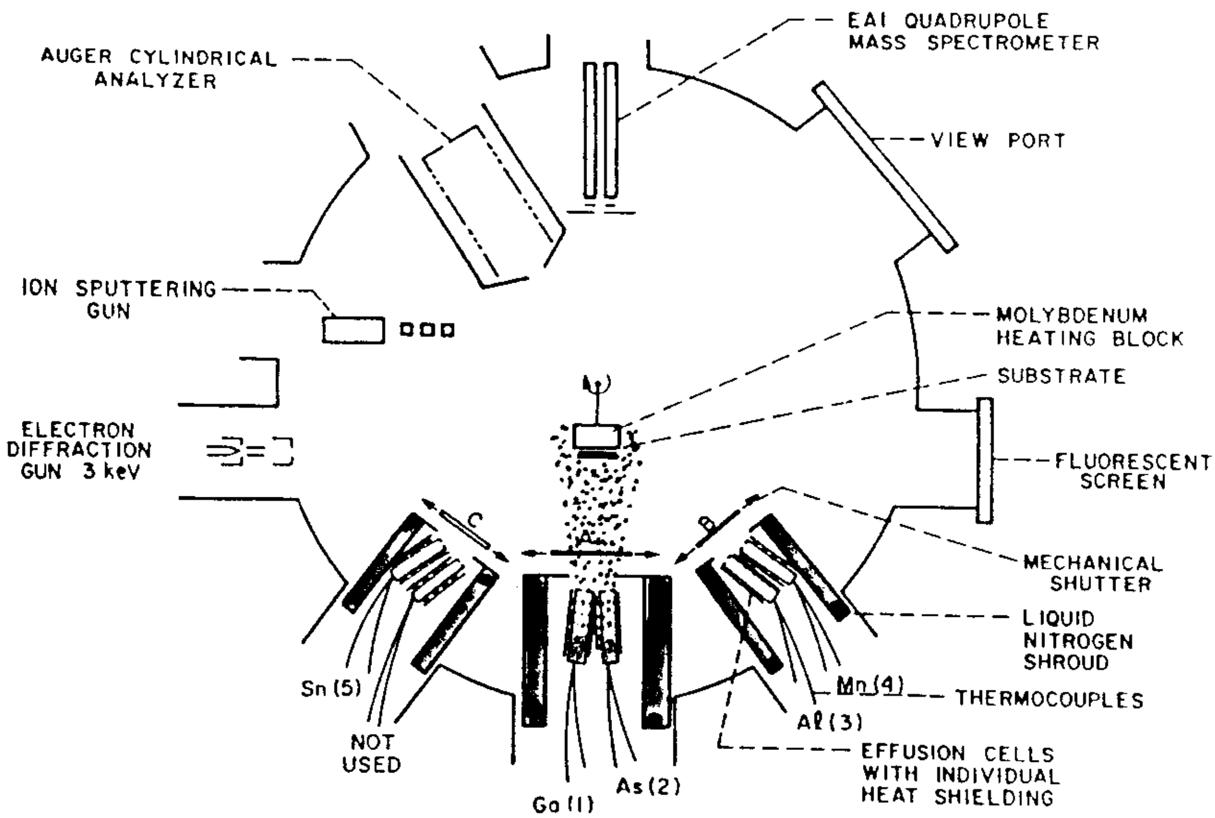
- NON-LINEAR DEVICES:
  - ★ OPT. NONLINEARITY OF RT EXCITONS DUE TO SATURABLE ABSORPTION

- MESFET / HETERO BIPOLAR TRANSISTORS:
  - ★ HIGH MOBILITY BY MODULATION DOPING
  - ★ BANDGAP TAILORING / THIN BASE LAYERS

MOLECULAR BEAM EPITAXY

- Quantum Well Growth Capability
- Excellent Composition and Doping Control
- Monolayer abrupt Interfaces, Monolayer Growth Resolution
- Low Inerface Recombination Velocity
- In Situ Growth Control
- Excellent Growth Uniformity and Reproducibility

MBE GROWTH CHAMBER



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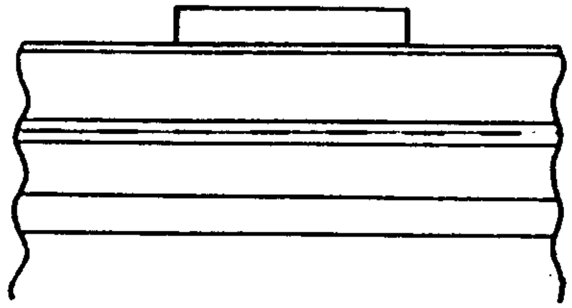
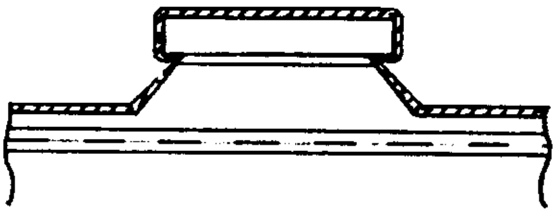
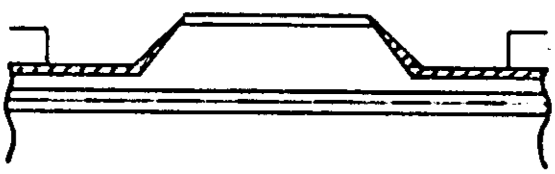
GRIN-SCH RIDGE LASER PROCESS



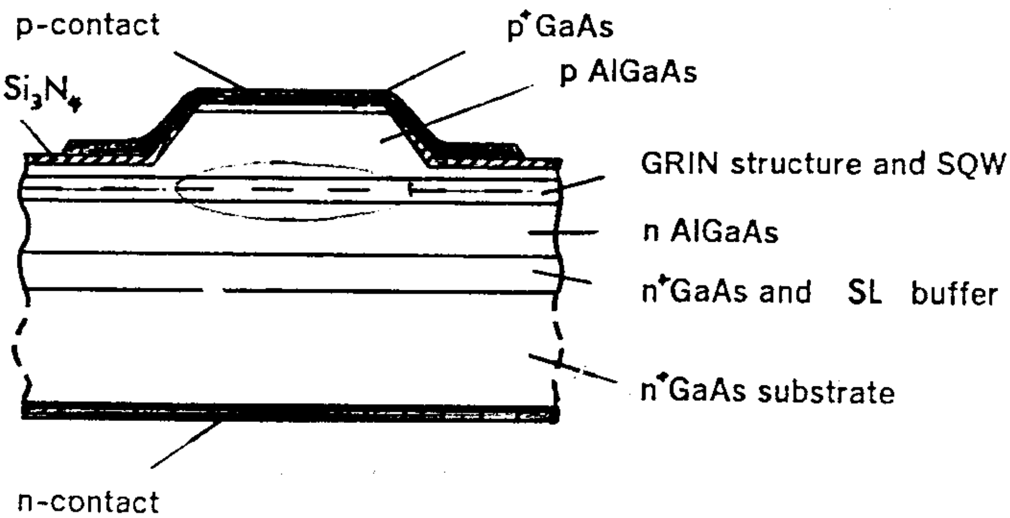
layer growth by MBE (MOVPE)



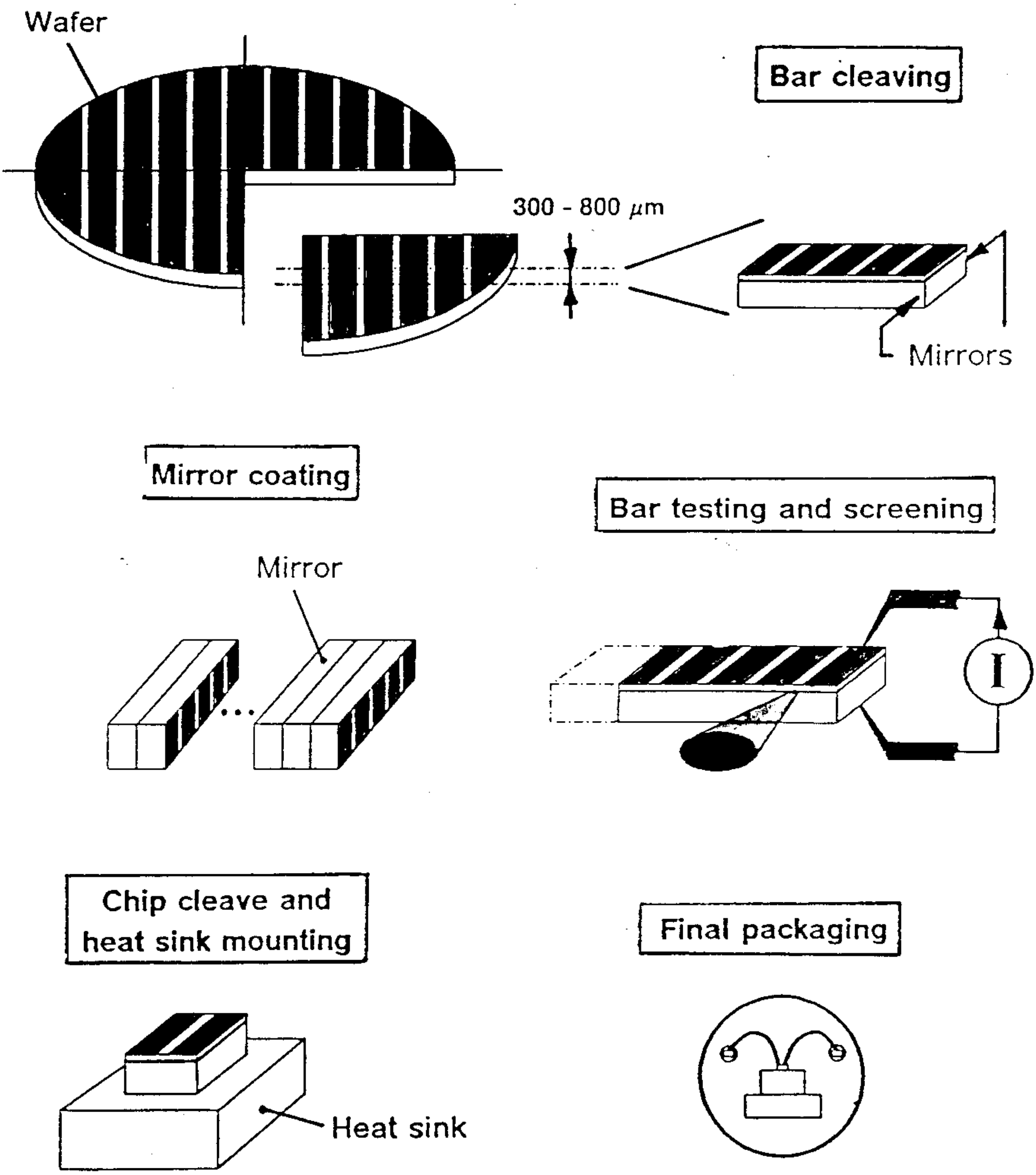
ridge etching
Si_3N_4 deposition



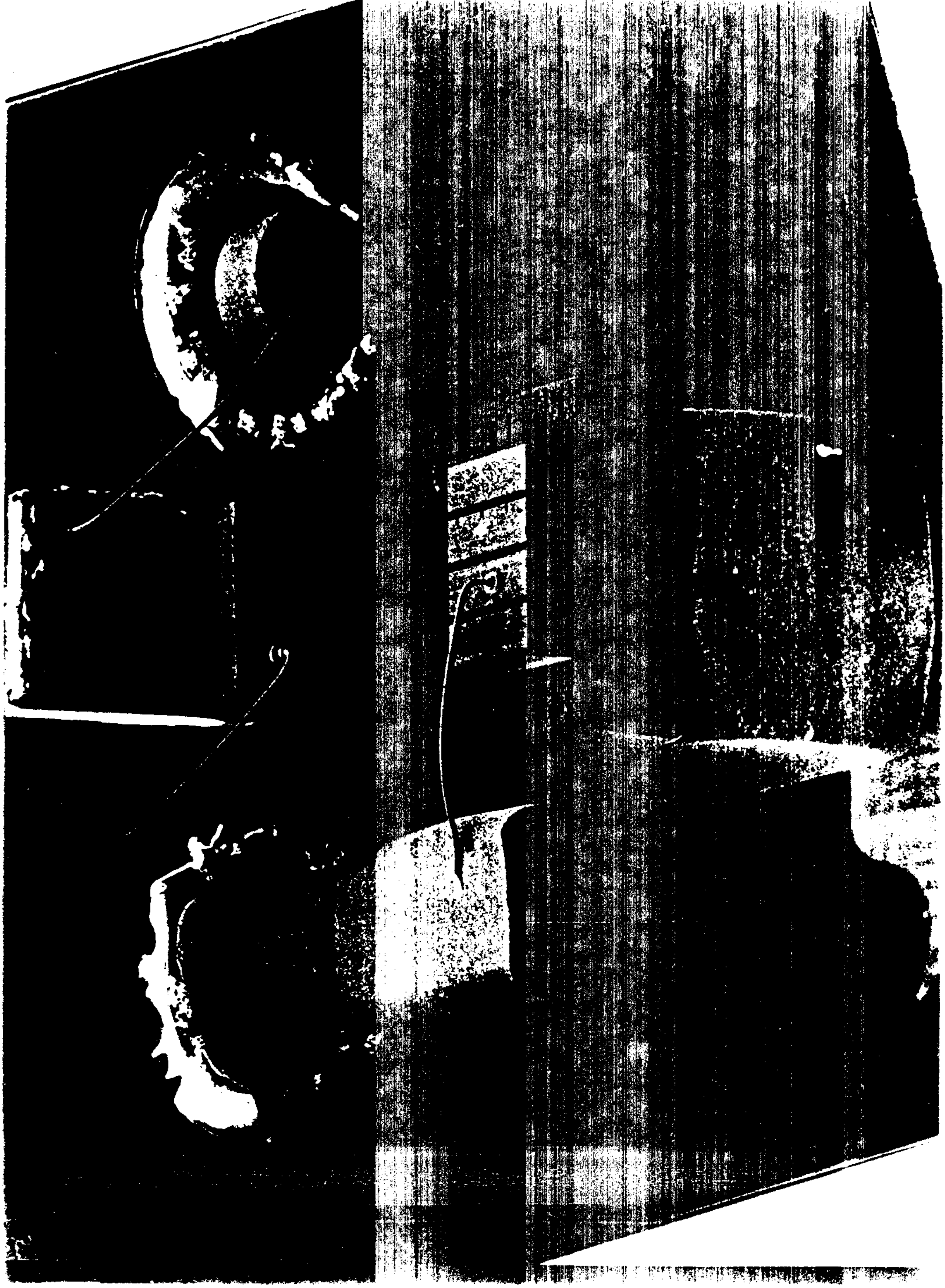
p-contact deposition
wafer lapping
n-contact formation
solder metal deposition



CURRENT LASER MANUFACTURING



06/89 (Y.Galeuchet)



AlGaAs QUANTUM WELL LASERS

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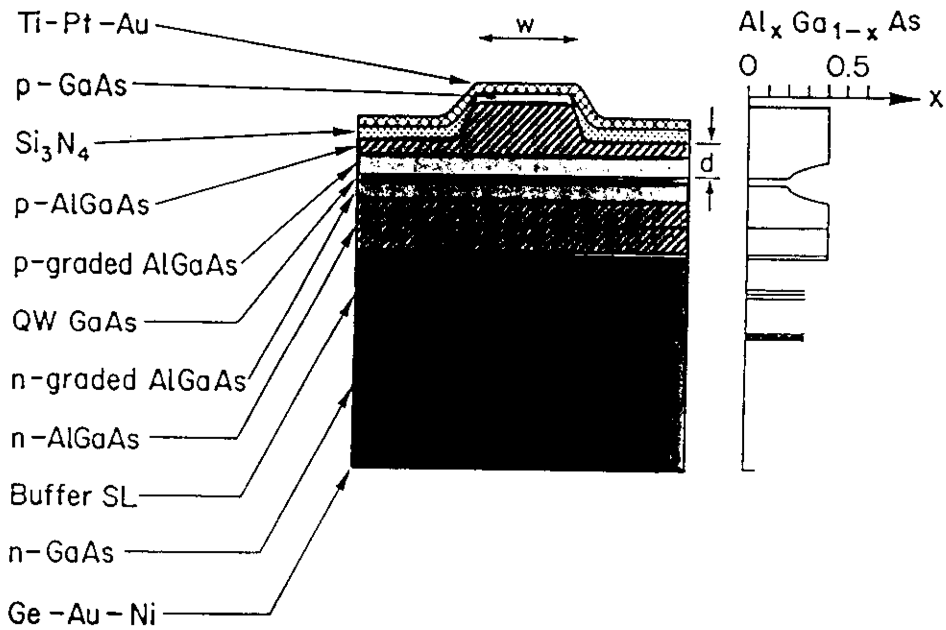
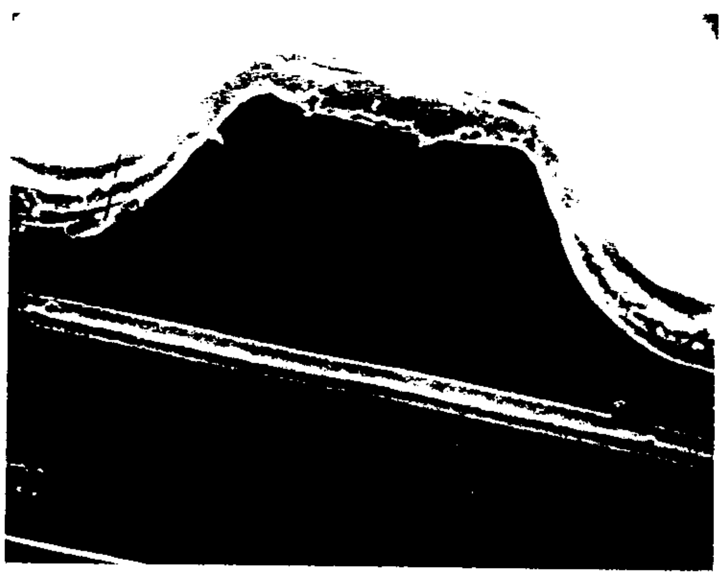
AlGaAs TOC SQW RIDGE GRINSCH LASER

- RIDGE WAVEGUIDE for positive index dielectric waveguide
- QUANTUM WELLS (QW) for high optical gain and low threshold
- THIN OPTICAL CAVITY (TOC) for high power capability

DEVICE STRUCTURE:



SEM-MICROGRAPH:



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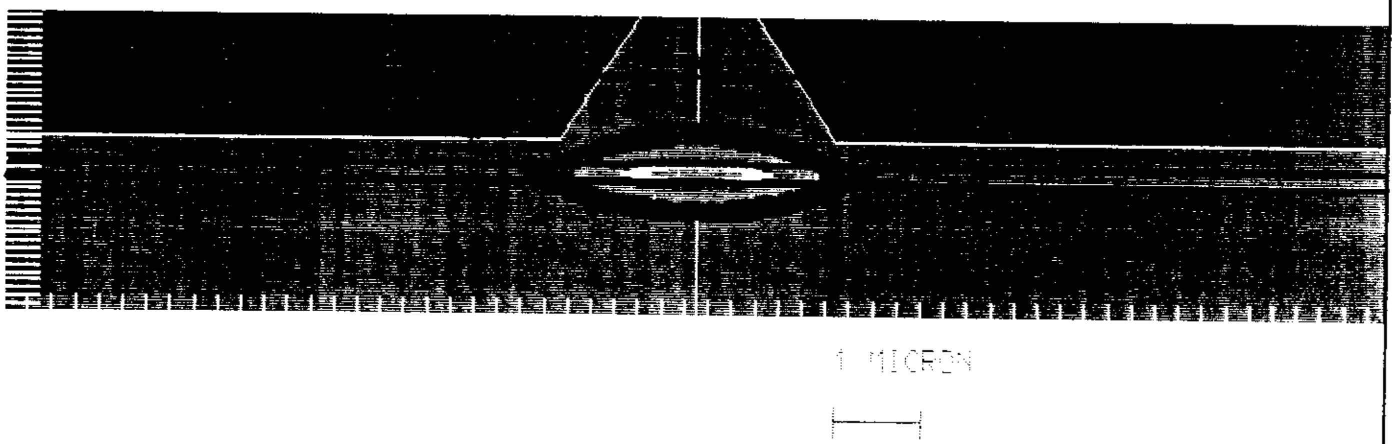
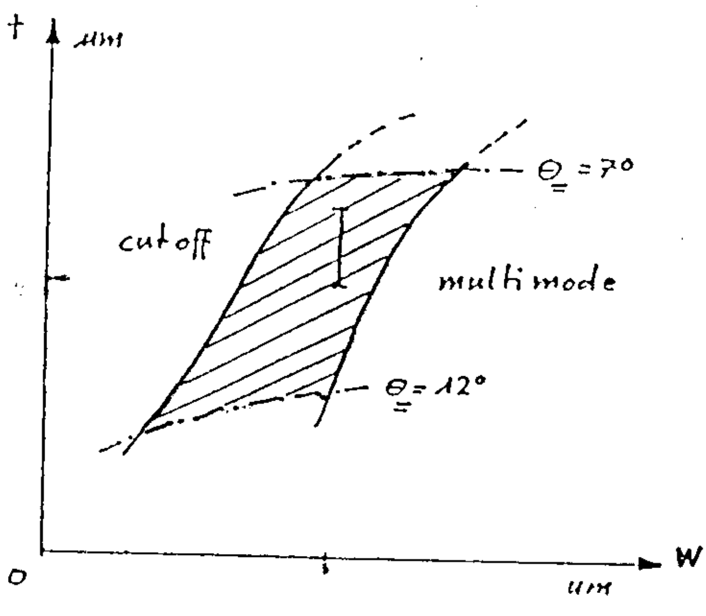
MODE STABILITY OF RIDGE-GRINSCH POWER LASER

- DEVICE STRUCTURE: **(2D, Scalar Field)**



- DEVICE PARAMETER WINDOW:

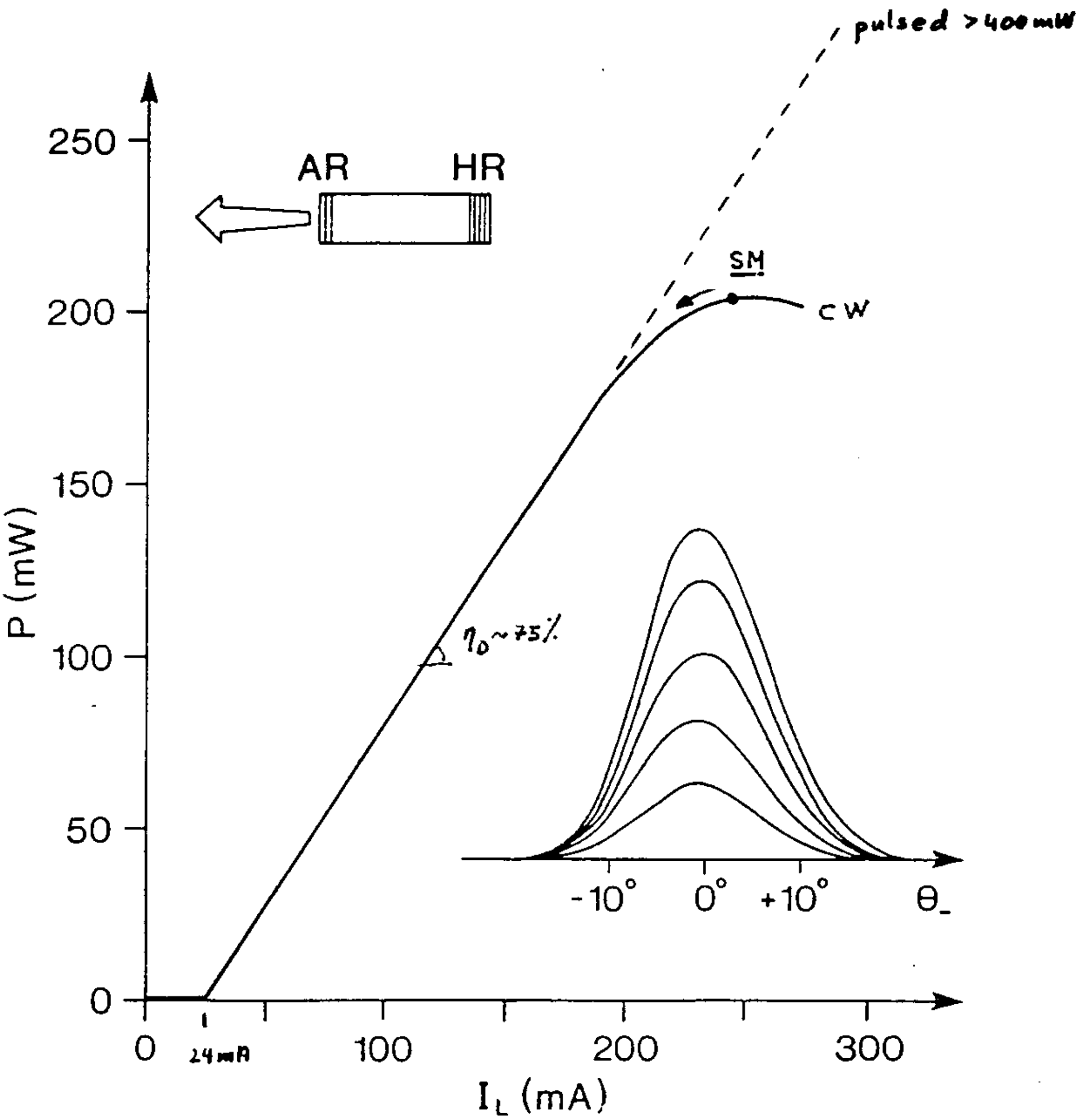


//// FUNDAMENTAL MODE

200mW FUNDAMENTAL MODE POWER LASER

OPTICAL POWER VERSUS LASER CURRENT

REFLECTION MODIFIED LASER: AR = 6% , HR = 95%



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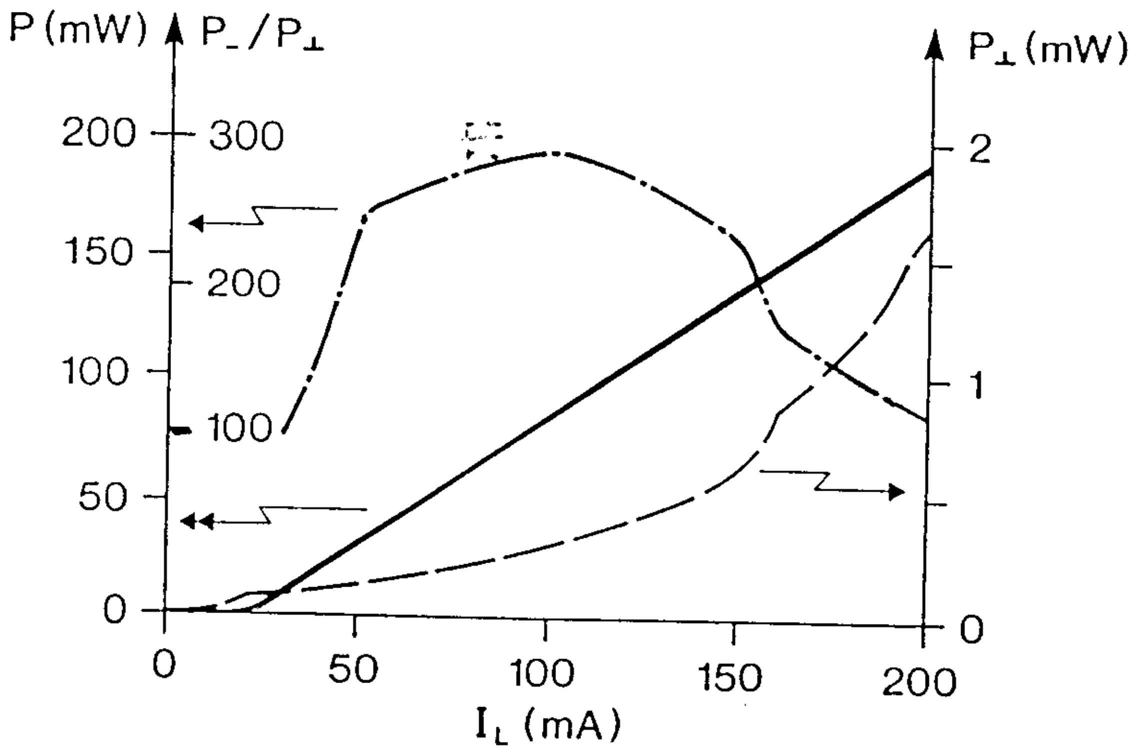
200mW FUNDAMENTAL MODE POWER LASER

POLARIZATION PURITY VERSUS LASER CURRENT

REFLECTION MODIFIED LASER: AR = 6% , HR = 95%

P_{-} = Optical Power polarized in Junction-plane

$P_{\perp}$ = Optical Power polarized vertical to Junction-plane



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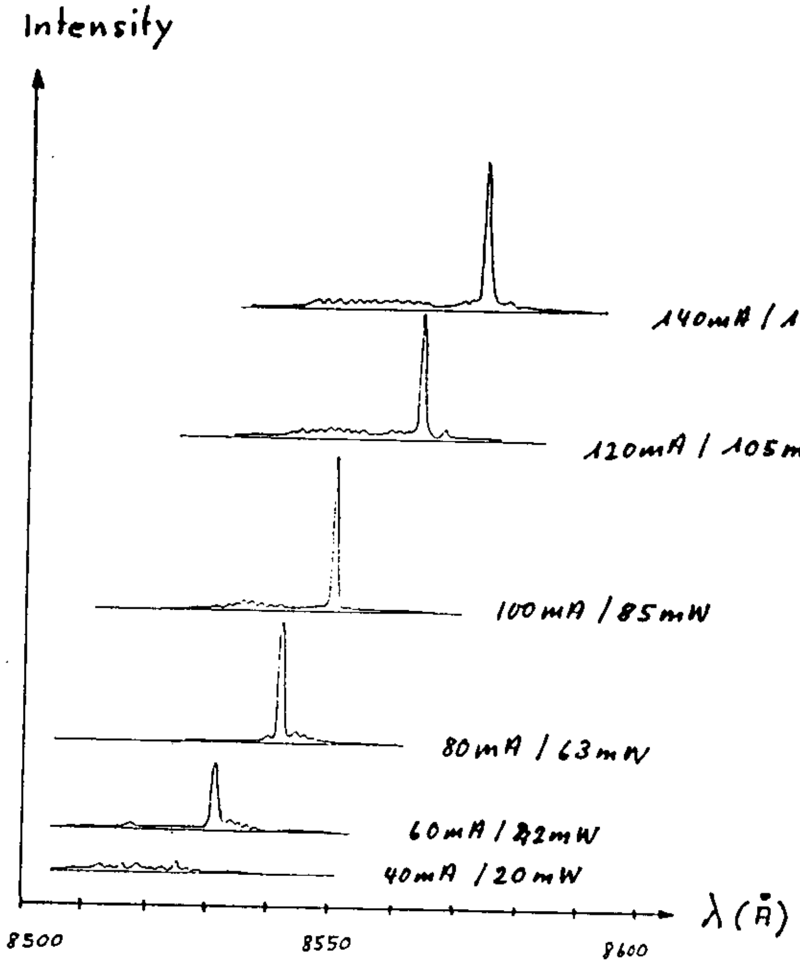
200mW FUNDAMENTAL MODE POWER LASER

OPTICAL SPECTRUM versus LASER CURRENT:



- Low Power Spectrum (< 20mW) contains about 8 longitudinal modes
- High Power Spectrum (> 20mW) is single longitudinal mode
- Longitudinal Mode Separation is about 1.2 Å

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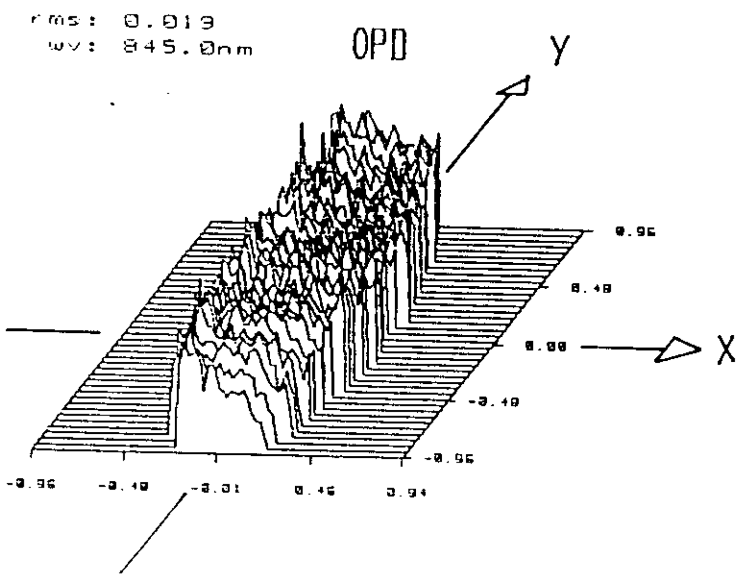
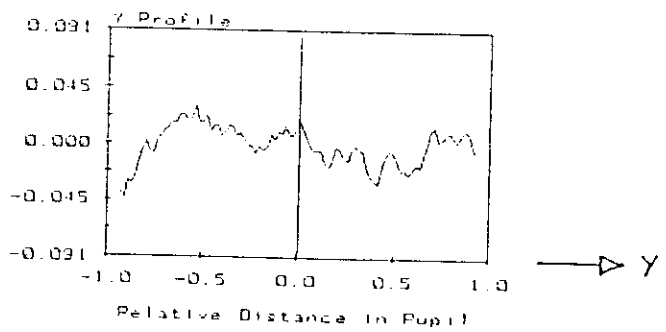
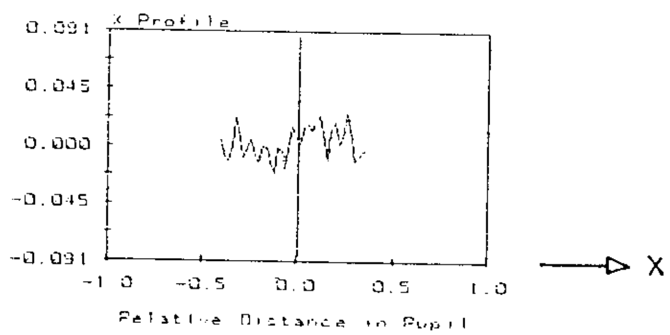
200mW FUNDAMENTAL MODE POWER LASER

2-DIMENSINAL OPTICAL PHASE DISTRIBUTION: (120mW)







- Very low Phase Distortion of less than 0.02λ RMS
- High Strehl Ratio of 0.985
- Astigmatism < 1μm

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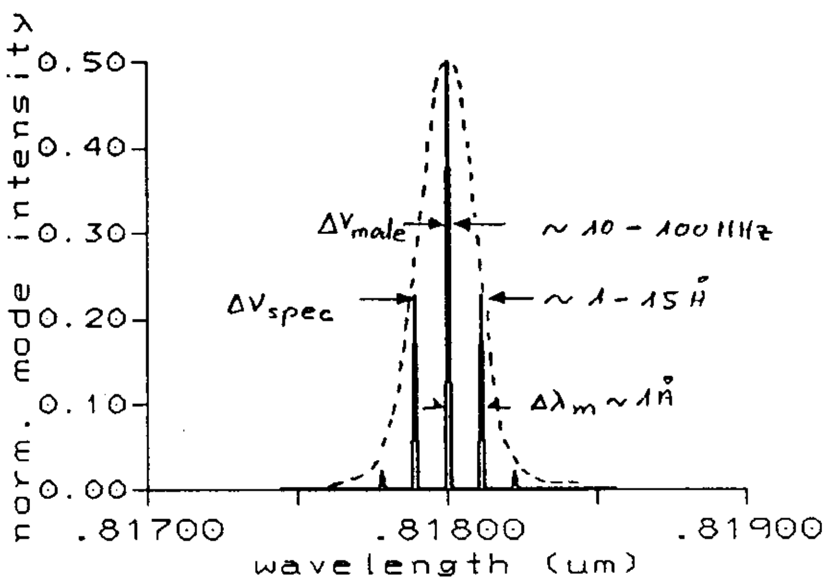
OPTICAL COHERENCE OF AlGaAs QW POWER LASERS

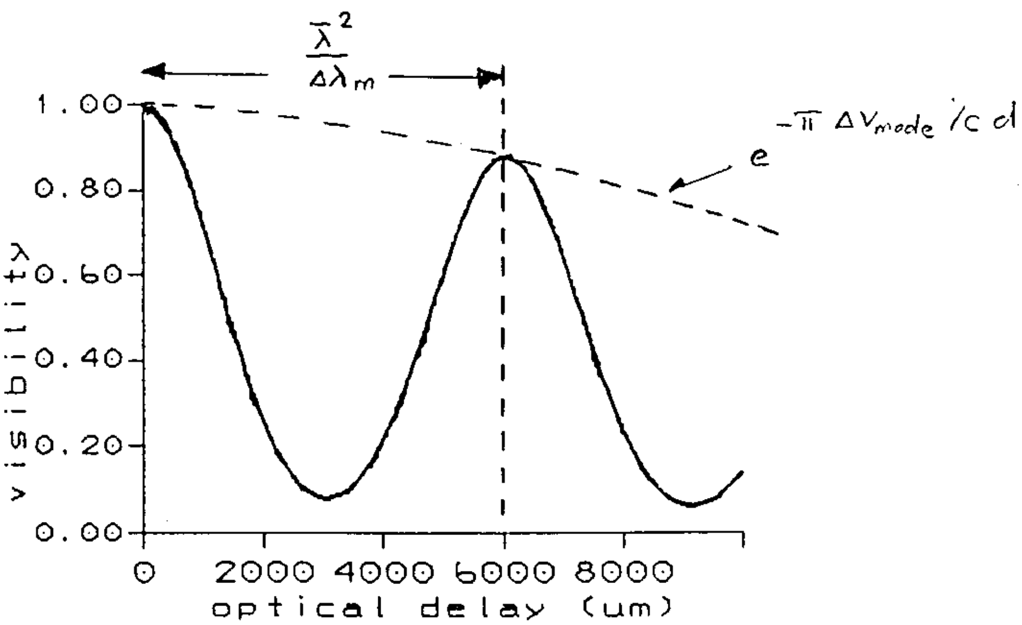
★ Low Coherence Length for Low Optical Feedback-Sensitivity

★ External Modulation or Laser Self-Pulsation for low Coherence

■ Optical Spectrum: (schematic)



■ Calculated Coherence Function: (Gaussian line functions)



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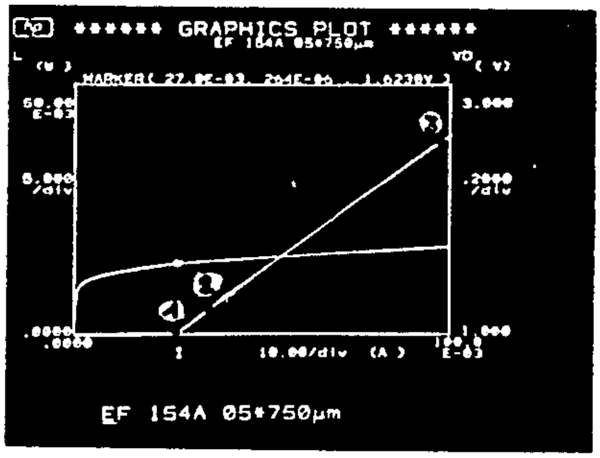
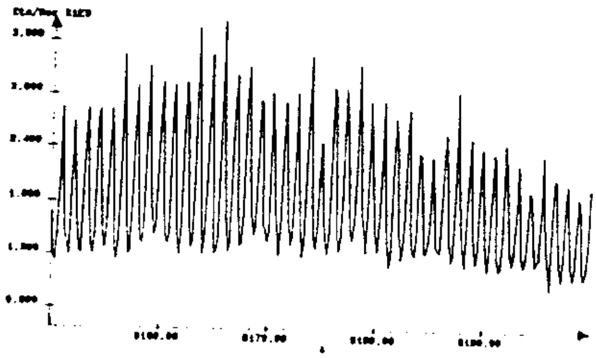
OPTICAL COHERENCE OF AlGaAs QW POWER LASERS

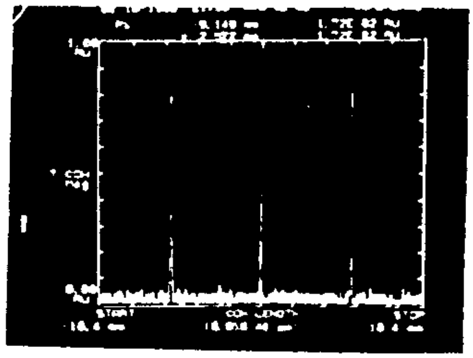
- PI-Characteristic:

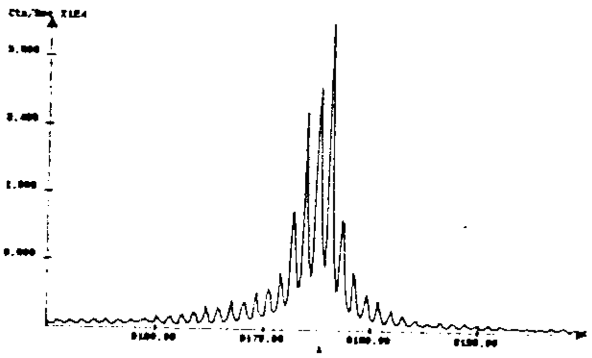


- Optical Spectrum:
- Coherence Function:



(1)





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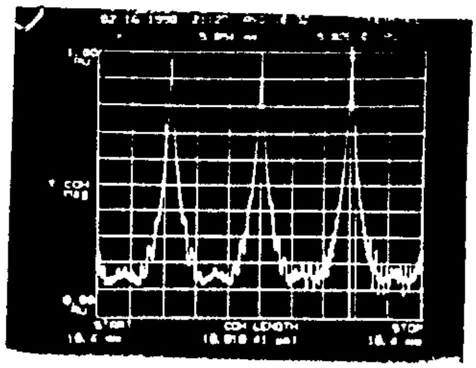

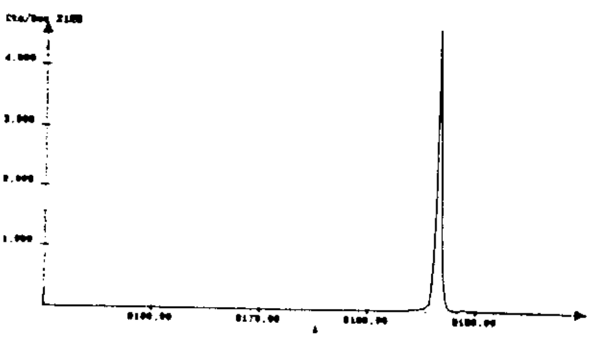

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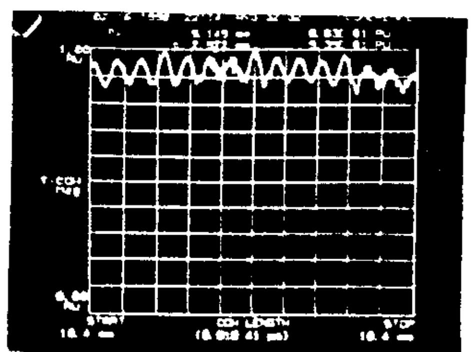

815nm 820nm

-10.4 mm 0 10.4 mm

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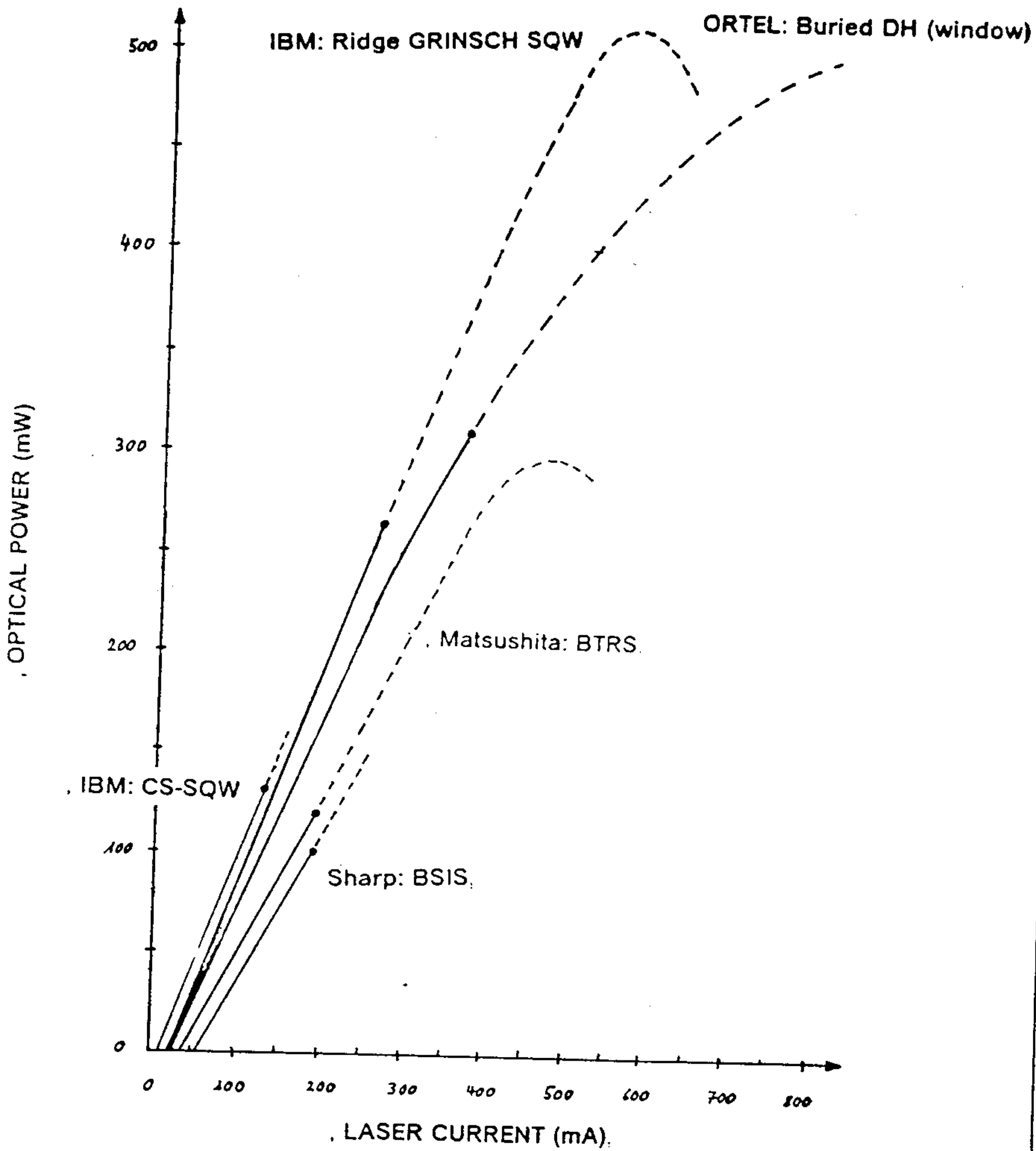
AlGaAs POWER LASER OVERVIEW

- OPTICAL POWER VERSUS LASER CURRENT



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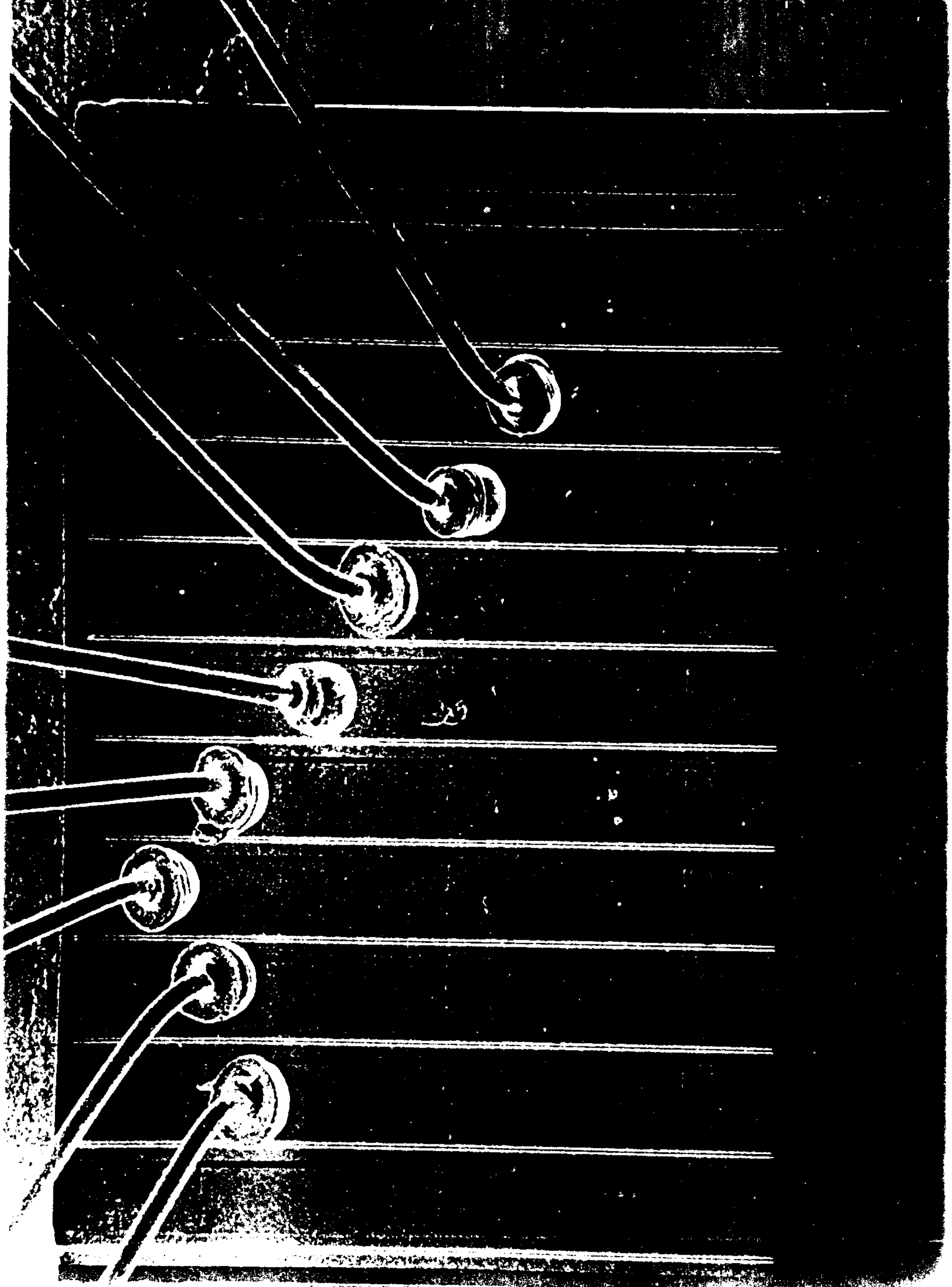
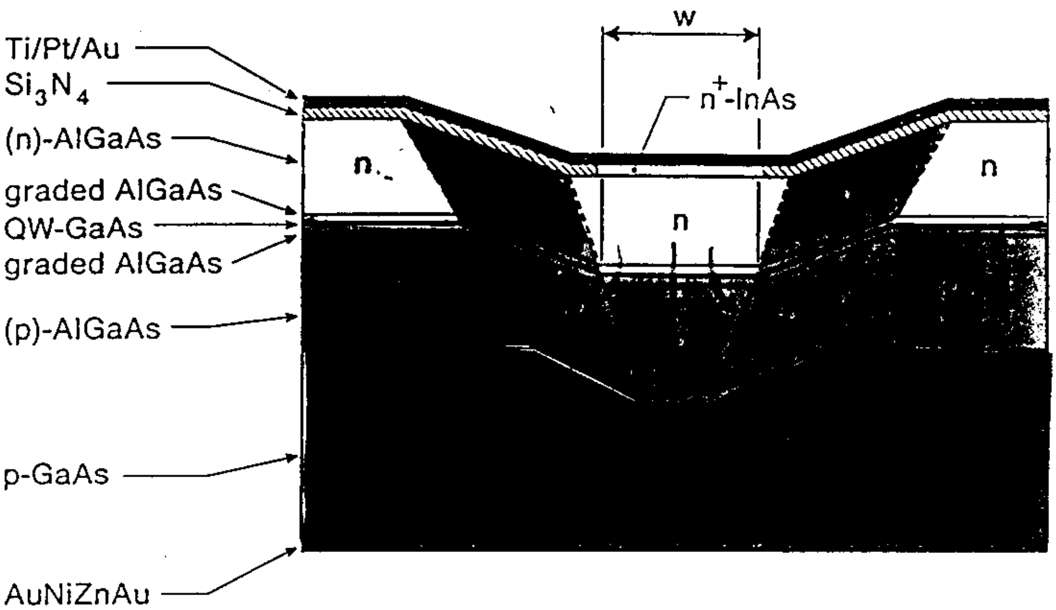
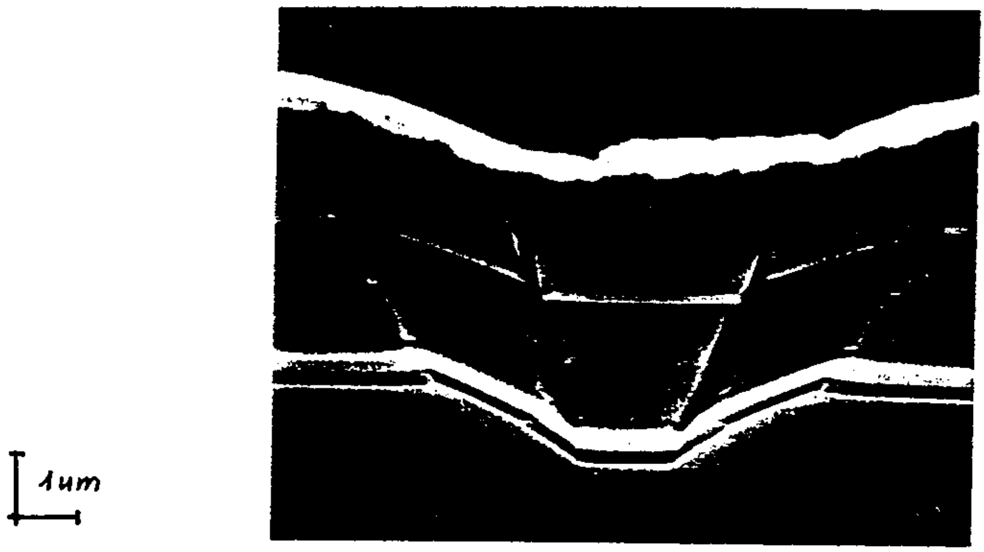


CHANNELLED SUBSTRATE AlGaAs POWER LASER

- CURRENT CONFINEMENT BY LATERAL CLADDING JUNCTIONS
- WAVEGUIDE GEOMETRY BY STRUCTURED SUBSTRATE AND GROWTH CONTROL
- HIGH QUALITY QUANTUM WELL GROWTH ON STRUCTURED SUBSTRATE BY MBE
- QUASI-PLANAR STRUCTURE





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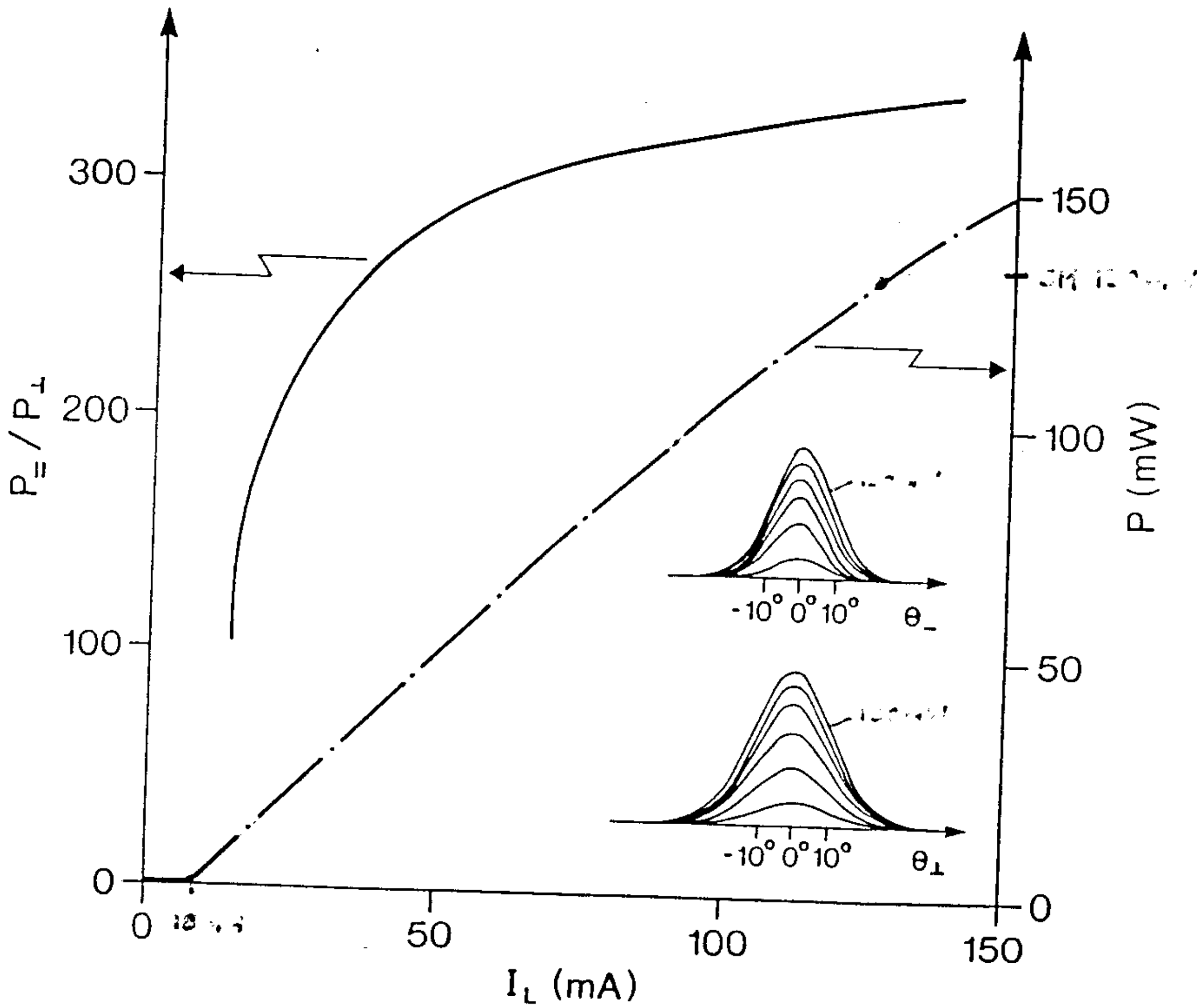
CHANNELLED SUBSTRATE AlGaAs POWER LASER

OPTICAL POWER, POLARIZATION AND FARFIELD VERS. LASER CURRENT

(REFLECTION MODIFIED LASER: AR = 10%, HR = 95%)



- SPATIAL FUNDAMENTAL MODE OPERATION UP TO 130mW !
- THRESHOLD CURRENT 10mA !

$\eta_D \sim 80\%$

$\eta_{tot} \sim 55\%$

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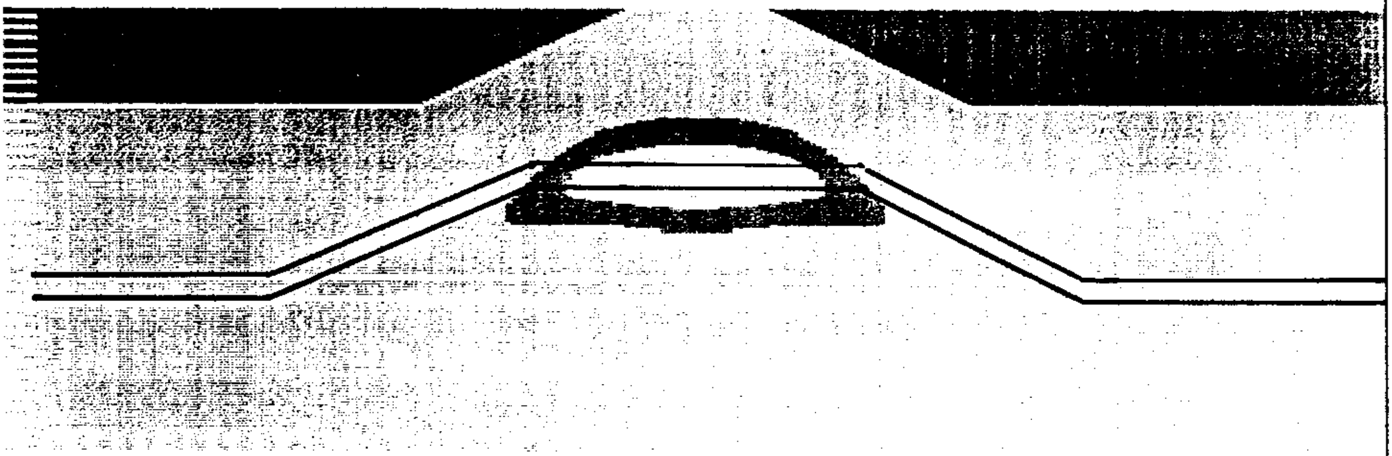
WAVEGUIDE DESIGN FOR CS AlGaAs POWER LASER

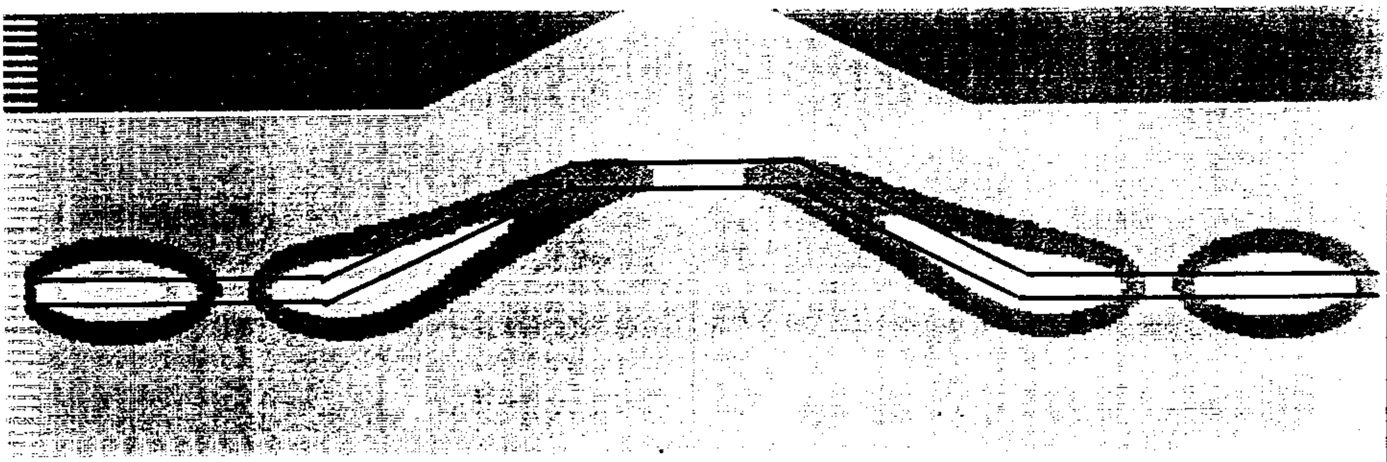
BENT WAVEGUIDE FUNDAMENTAL MODE SIMULATION

- Maximal Waveguide Width for Fundamental Mode Operation
- Influence of Waveguide Bending Angle
- Fundamental Mode Stability Region in Parameter Space

FUNDAMENTAL MODE



FIRST ORDER MODE



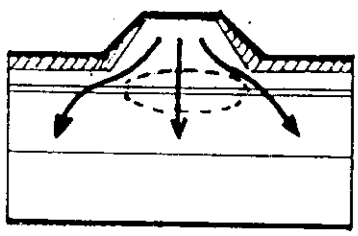
cut off by low mode gain

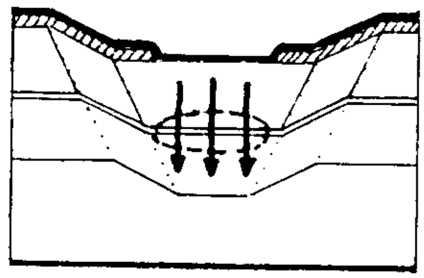
= = > CHANNEL WAVEGUIDE WIDTH < 3um FOR FUNDAMENTAL MODE OPERATION

CHANNELLED SUBSTRATE AlGaAs POWER LASER

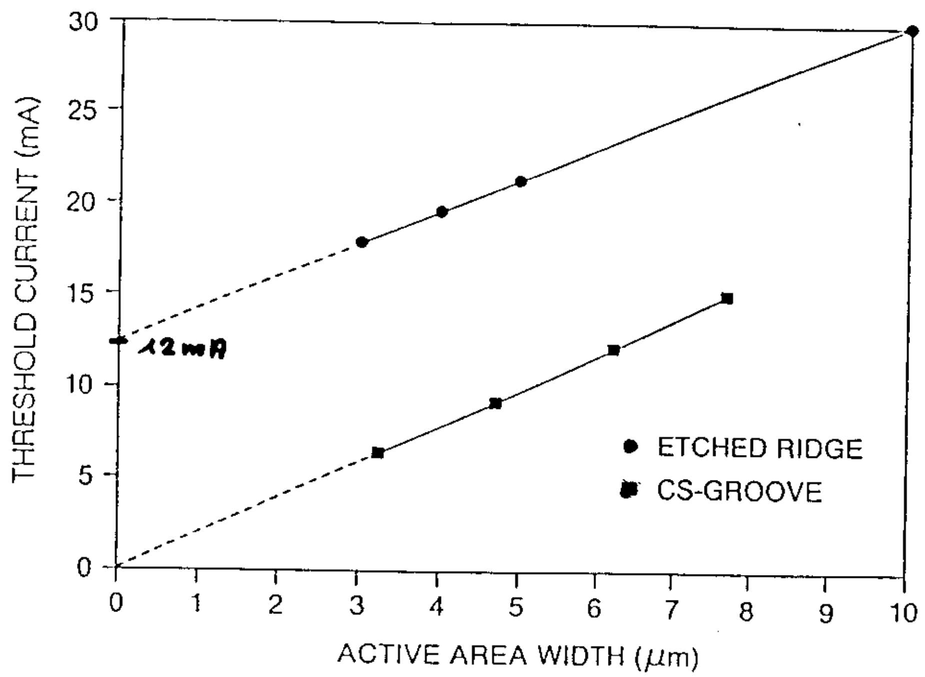
LATERAL CURRENT CONFINEMENT

- LATERAL AlGaAs PN-BLOCKING JUNCTIONS BY PLANE SELECTIVE DOPING
- VERY LOW THRESHOLD CURRENTS OF ABOUT 6mA FOR POWER LASERS (0.65 mA)
- VERY HIGH DIFFERENTIAL QUANTUM EFFICIENCY OF 80%
- HIGH OVERALL POWER EFFICIENCY OF ABOUT 55%





THRESHOLD CURRENT VERSUS LASERWIDTH FOR RIDGE AND CS-LASERS:



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DRY ETCHED MIRROR LASERS TECHNOLOGY

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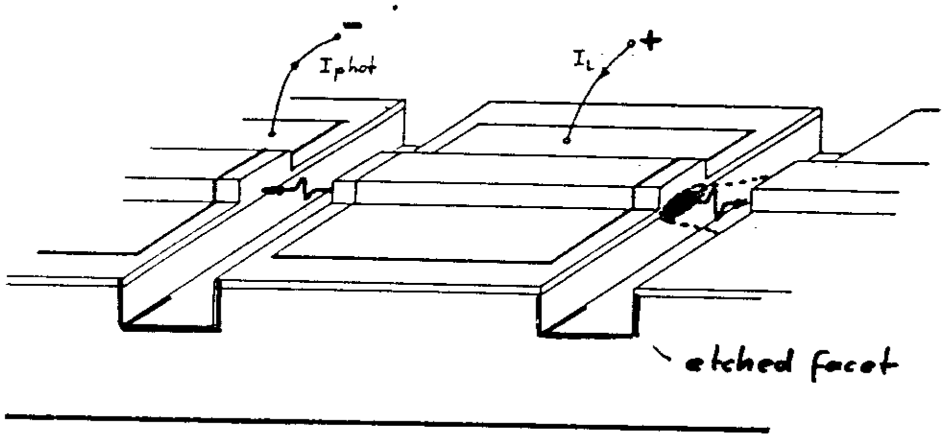
ETCHED LASER MIRROR TECHNOLOGY

- BASIC CONCEPT:



- POTENTIAL:

  Full Wafer Processing & Testing

  High Yield, low handling

  Integrated Functions

  Vertical Output Beam Deflectors

  Novel, Non-planar Mirror Structures

- REQUIREMENTS:

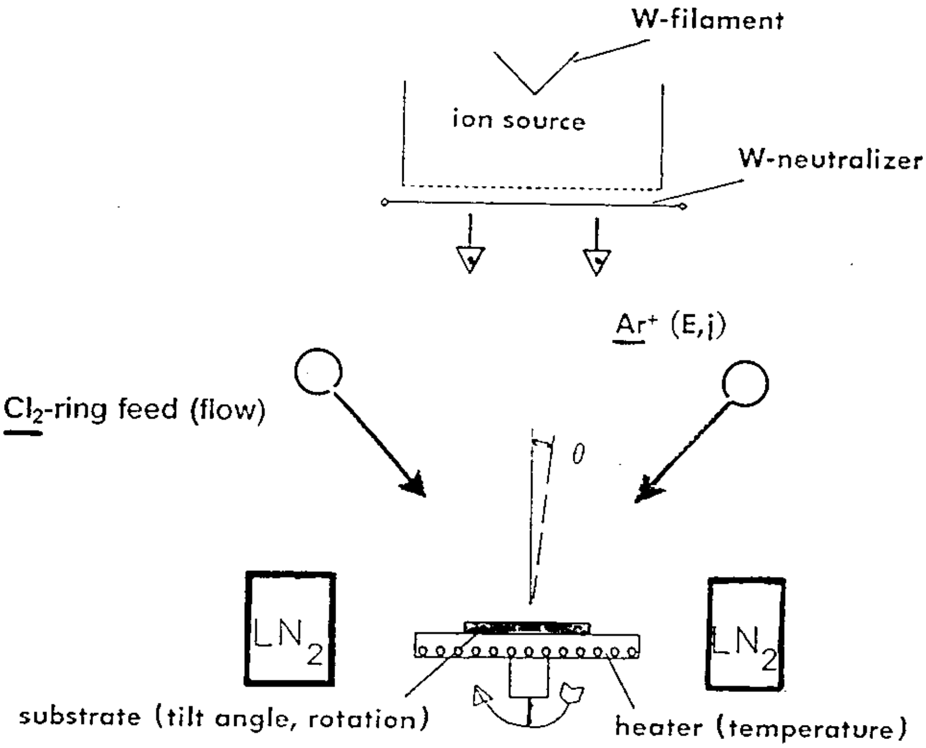
  Optically Flat Mirrors ($< \lambda/10$; $\sim$ 300Å)

  Vertical Mirror Angle

  Low Etch Damage Process

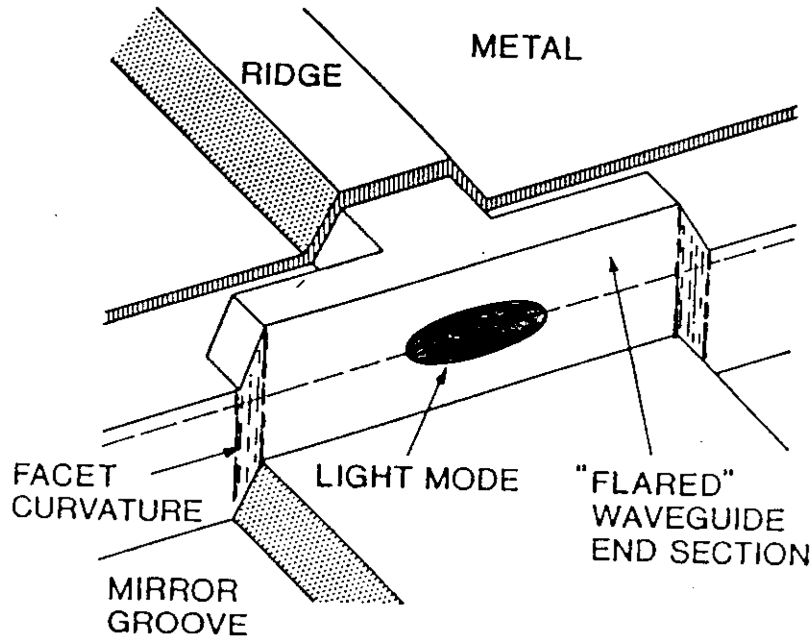
Cl/Ar CHEMICALLY ASSISTED ION BEAM ETCHING

- High Etching Directivity
- Nonselective Etching of AlGaAs and GaAs
- High Etch Rate (etch depth ∼ 3-6um)
- Low Etch Damage
- Etching Resistant, High Resolution Resist System



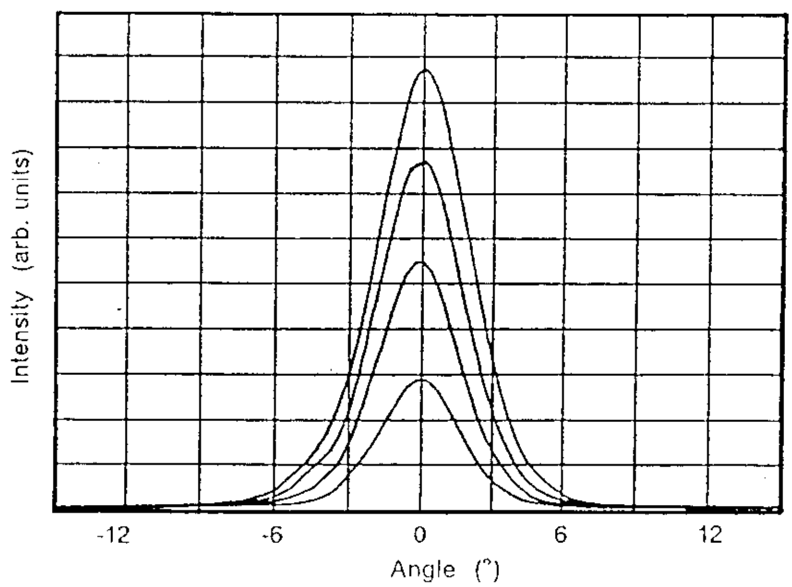
FLARED ETCHED AlGaAs LASER MIRROR

FLARED RIDGE



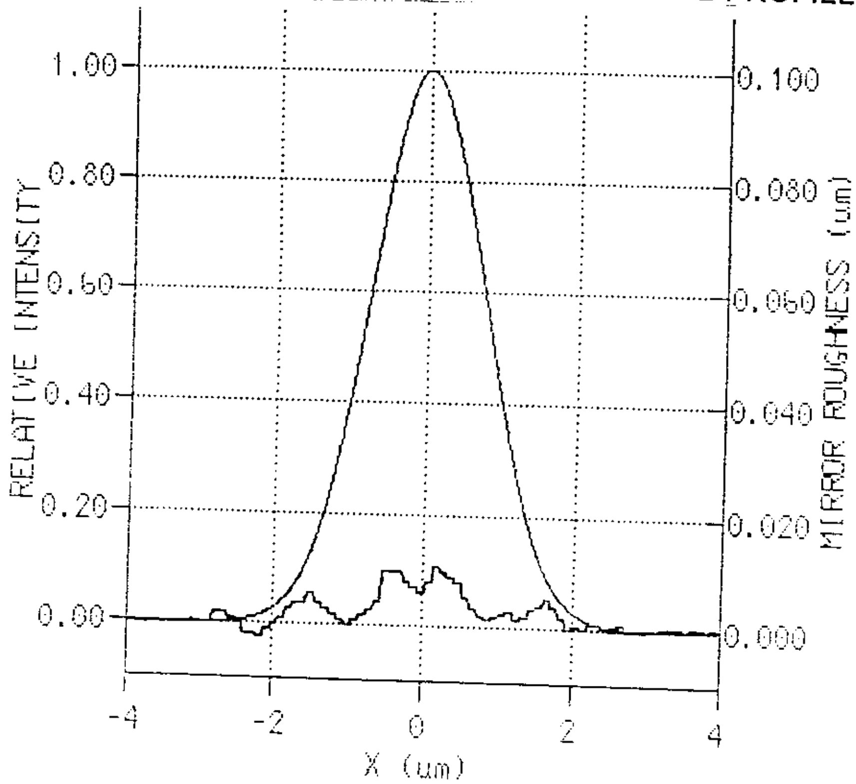
HORIZONTAL FAR-FIELD

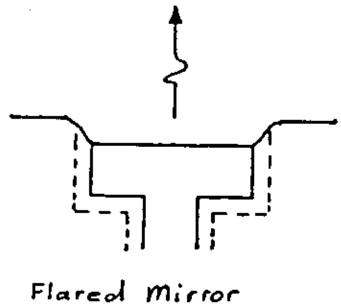
FAR FIELD AT POWER LEVELS OF 10, 20, 30 AND 40mW PER FACET



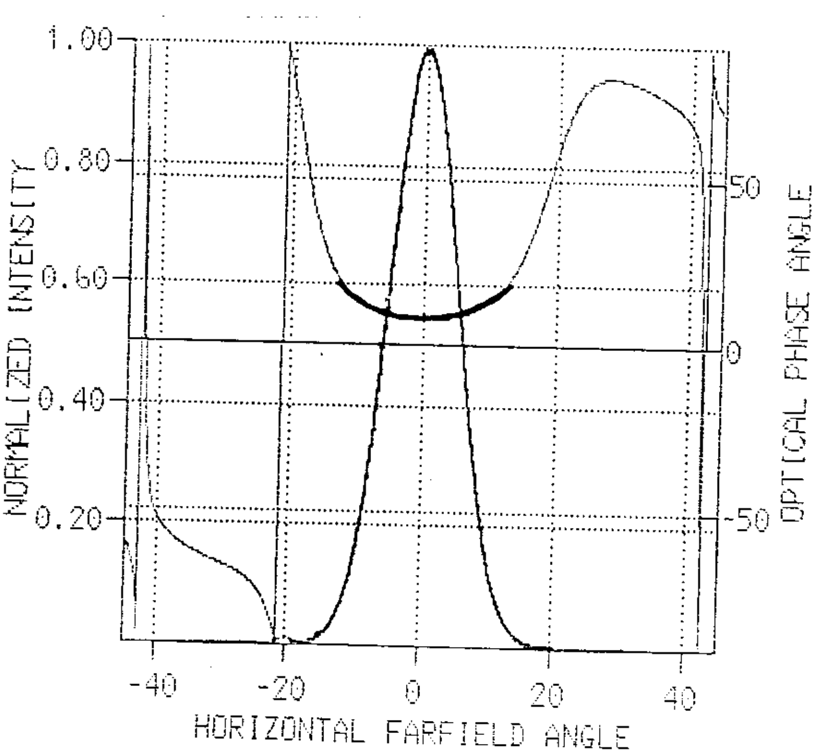
SIMULATION OF FLARED ETCHED MIRROR

- NEARFIELD INTENSITY and MIRROR SURFACE PROFILE





- FARFIELD INTENSITY and PHASE DISTRIBUTION



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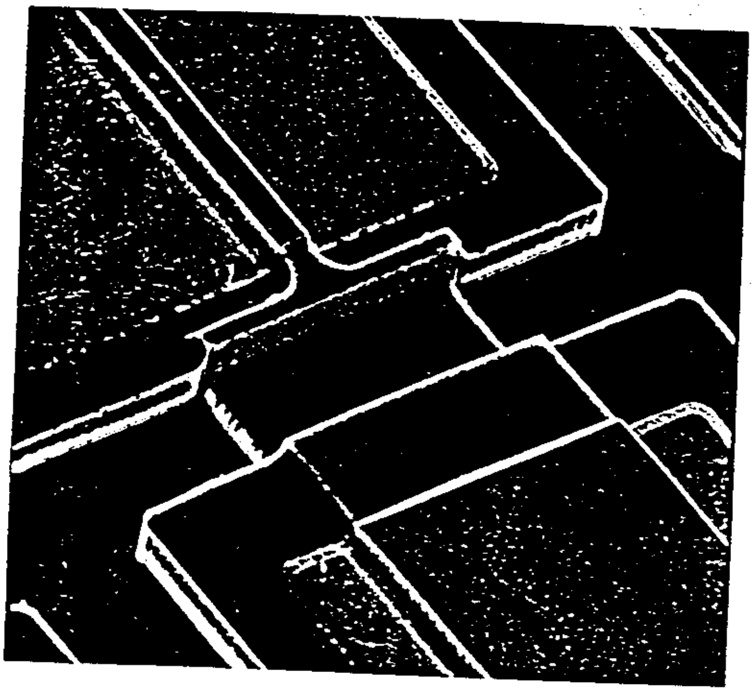
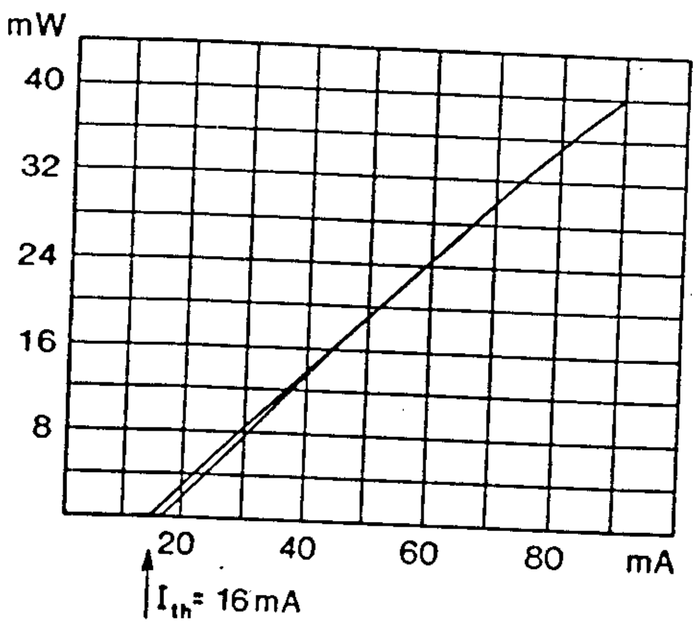
FLARED RIDGE

• ETCHED MIRRORS

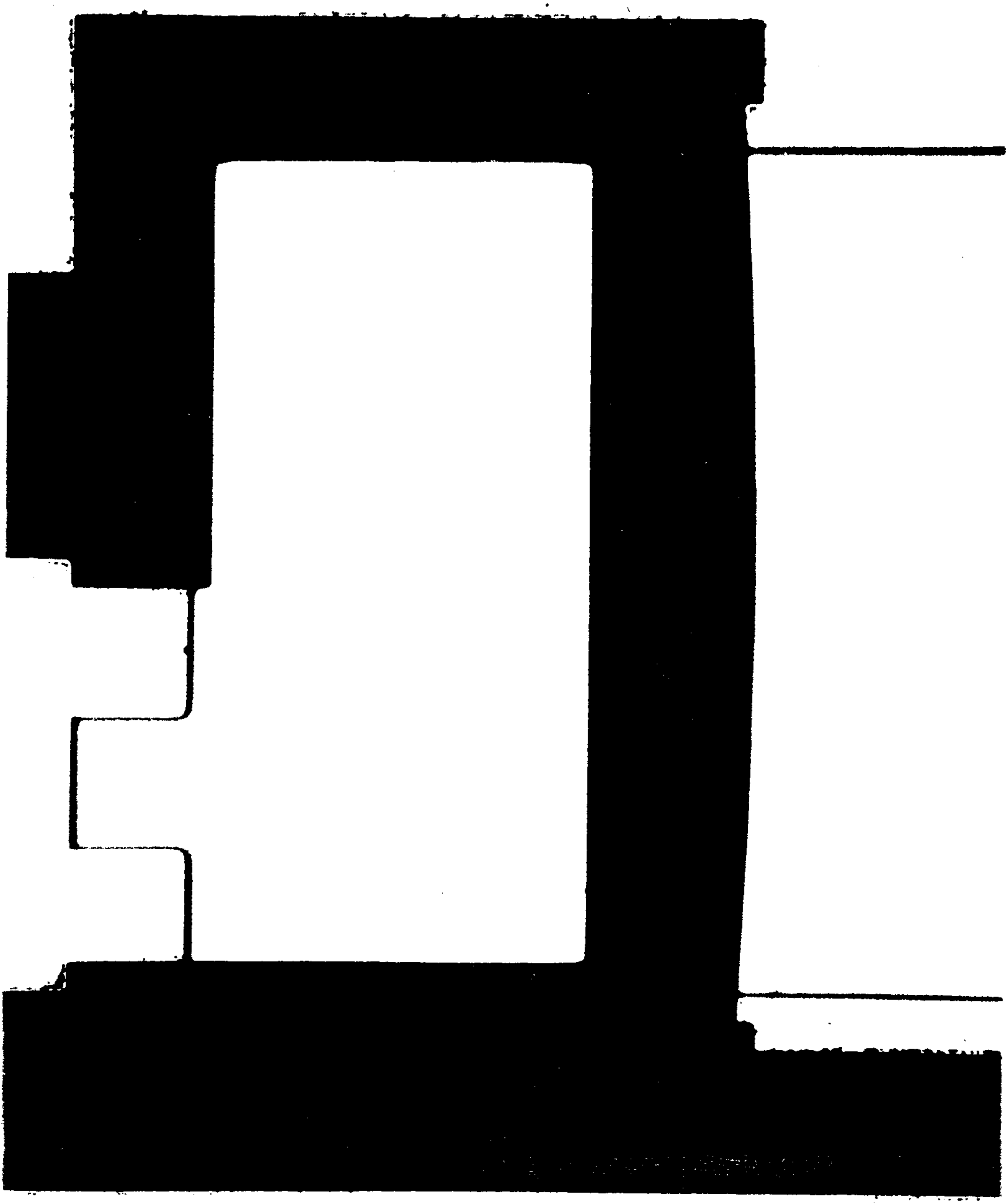


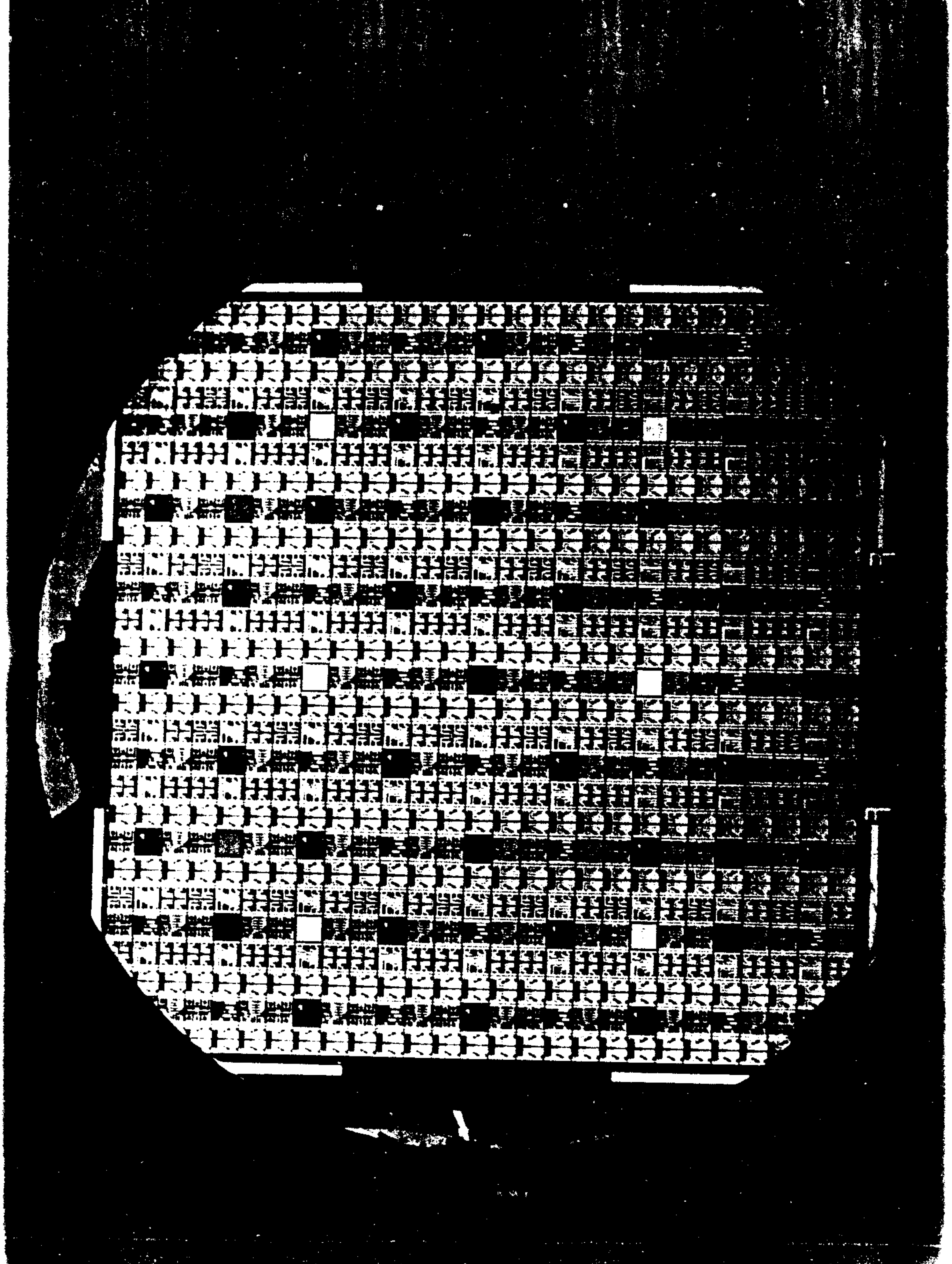
ROUGHNESS < 200 Å



- EQUIVALENT TO CLEAVED

- GOOD BEAM QUALITY





SHORT WAVELENGTH SOURCES WITH DIODE LASERS

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SHORT WAVELENGTH SEMICONDUCTOR LASERS

APPLICATIONS:

- HIGH DENSITY OPTICAL STORAGE SYSTEMS
- PRINTER SYSTEMS
- HeNe REPLACEMENT
- DISPLAY and POINTING SYSTEMS
- SHORT DISTANCE PLASTIC FIBER DATA TRANSMISSION

MATERIAL SYSTEMS FOR SHORT WAVELENGTH DIODE LASERS:

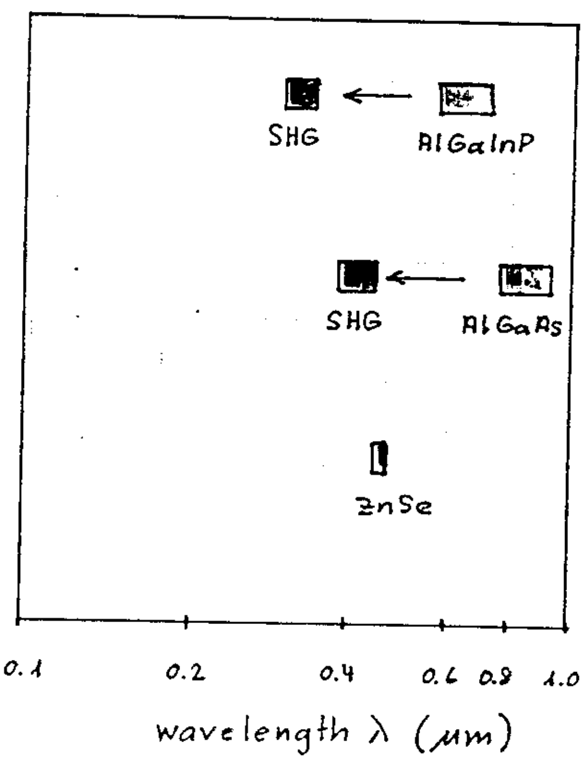
- III-V COMPOUNDS

AlGaAs	λ => 700 nm (red) (theoretical: 680nm)
AlGaInP	λ => 650 nm (orange) (theoretical: 580nm)

- II-VI COMPOUNDS

ZeSe	λ = 460 nm (blue,green)

?



AlGaAs SHORT WAVELENGTH POWER LASERS

■ MATERIAL LIMITATIONS IN THE AlGaAs SYSTEM

--- Increasing Al-content increases the direct bandgap faster than the indirect gap

--- At high Al-content the carrier loss into the indirect, high density valley increases the THRESHOLD CURRENT

--- At high Al-content the carrier loss into the indirect, high density valley increases the TEMPERATURE SENSITIVITY

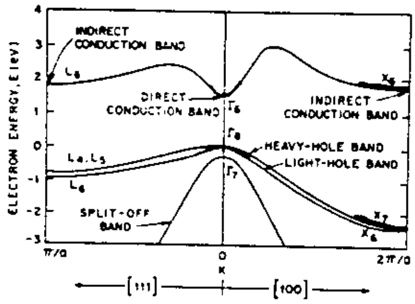
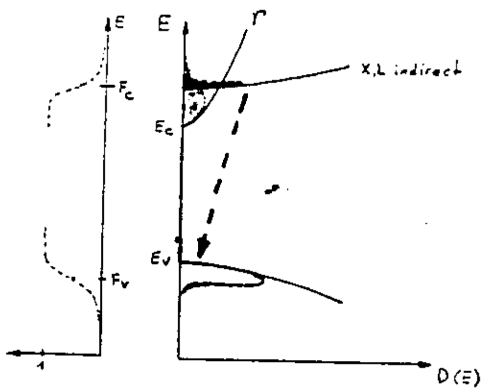


FIG. 4.2-1 The band structure of GaAs with the energy E plotted as a function of momentum wave vector k along the [100] and [111] directions. The Γ, X, and L designations identify the interband energy gaps.



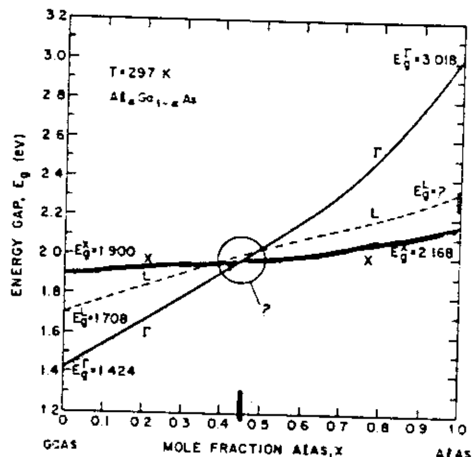


FIG. 4.2-2 The compositional dependence of the direct $\Gamma_6 \rightarrow \Gamma_8$ and the indirect $\Gamma_8 \rightarrow X_6$ and $\Gamma_8 \rightarrow L_6$ energy gaps for $Al_xGa_{1-x}As$.

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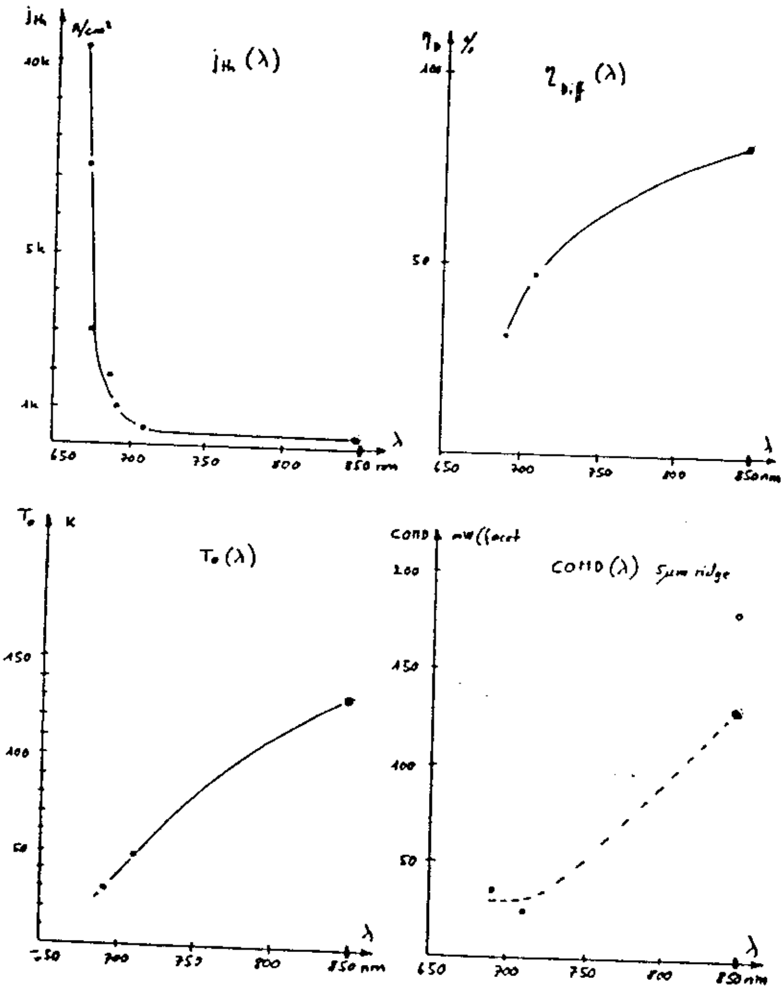
SHORT WAVELENGTH LIMIT OF VISIBLE AlGaAs LASERS

- THEORETICAL LIMIT at λ = 680nm (AlGaAs becomes indirect)
- DECREASE IN LASER PERFORMANCE DUE TO INDIRECT CARRIER LOSS
- INCREASED MIRROR CORROSION AT SHORTER WAVELENGTH
- ACHIEVED VERY LOW THRESHOLD VISIBLE POWER LASER AT 716nm

★ Jth / η_D / To / COMD versus Wavelength λ



==> PRACTICAL DEVICE LIMIT FOR AlGaAs IS AT 720-750 nm

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SHORT WAVELENGTH AlGaInP DIODE LASERS

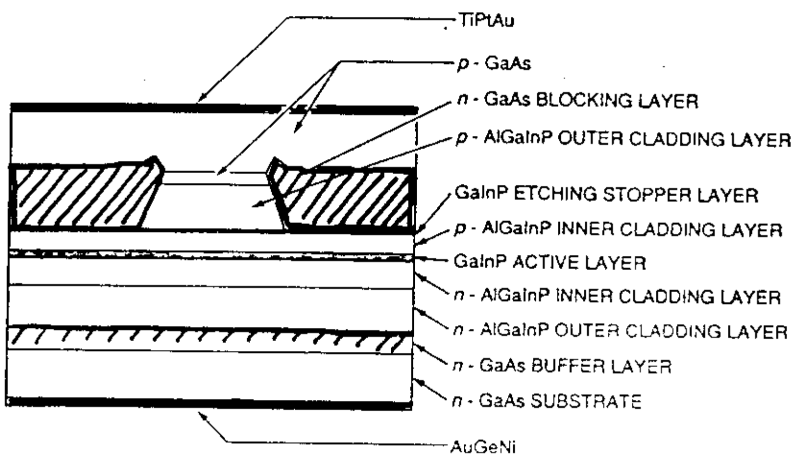
MATERIAL CHALLENGES:

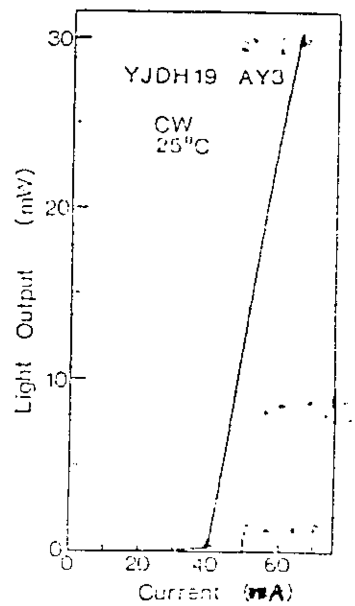
- Lattice Matching to GaAs requires Compositional Control of 1% !
- High Binding Energy of P-Dopants (Zn, Mg) --> High Series Resistance
- Low Lasing Efficiencies, Low Overall Efficiency (Arrays?)
- Low Mirror Damage Threshold (5-10x less than AlGaAs)
- No efficient Quantum Wells realized yet
- Assessement of practical Short Wavelength Limit

STATUS:

- 30mW Power Output at 680nm demonstrated
- Projected MTTF >250kh at 3mW and RT
- Limited Commercialization of 3mW Lasers
- First attempts at Single Frequency DFB Lasers
- First attempts at Coherent Array Lasers

STATE OF THE ART AlGaInP LASER: (K.Kobayashi)





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SHORT WAVELENGTH GENERATION WITH OPTICAL NONLINEAR MATERIALS

TECHNICAL SOLUTIONS:

- FREQUENCY DOUBLED, DIODE PUMPED MINI-Nd:YAG LASERS
- DIRECT FREQUENCY DOUBLING OF LASER DIODES

ADVANTAGES:

- TODAY ONLY PRACTICAL MINIATURE SOURCE AT λ: 400-500nm
- HIGH OPTICAL BEAM QUALITY

DRAWBACKS:

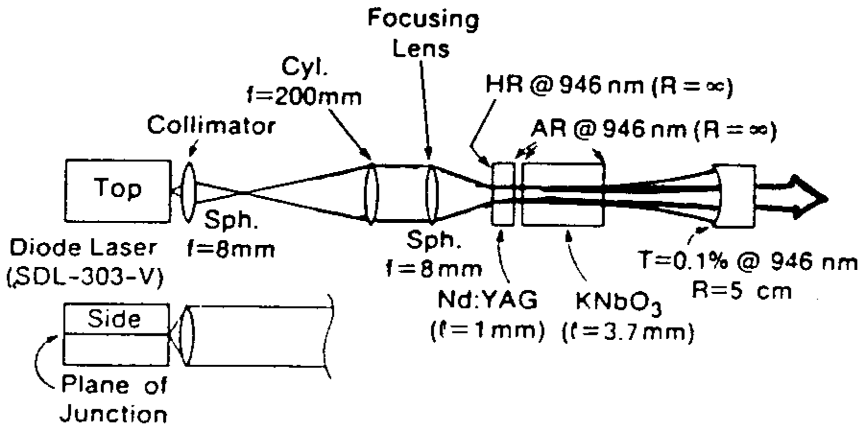
- EXPENSIVE COMPONENTS, HIGH MASS
- LOW OVERALL EFFICIENCY
- HIGH POWER DIODE LASER SOURCE (100-300mW, Arrays, FM)
- MECHANICAL AND THERMAL SENSITIVITY

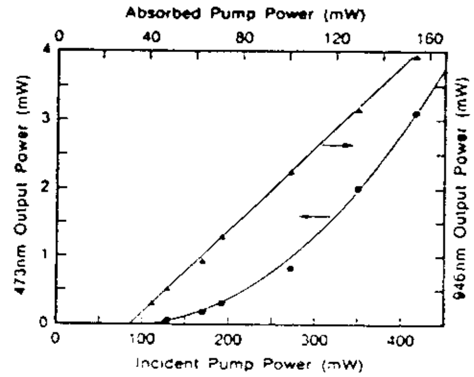
NEW DEVELOPMENTS:

- INTENSE RESEARCH ON EFFICIENT ORGANIC NL MATERIALS
- WAVEGUIDE STRUCTURES

SHORT WAVELENGTH GENERATION WITH OPTICAL NONLINEAR MATERIALS

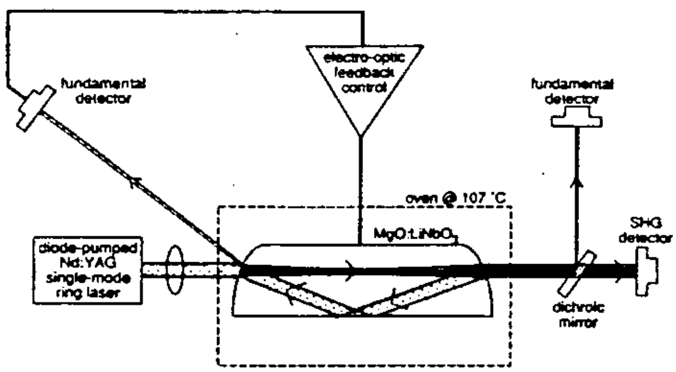
- MINIATURE DIODE PUMPED Nd:YAG LASER (W.Risk et al.)

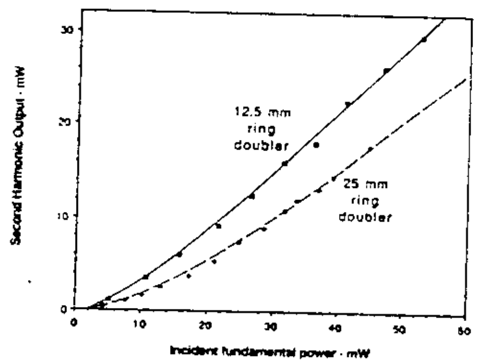




- DIRECT FREQUENCY DOUBLING OF LASER DIODES (W.Kozlovsky)

Second Harmonic Generation with Resonant SHG-Cavity





Record value 41mW at 430nm with 150mW at 860nm (IBM)

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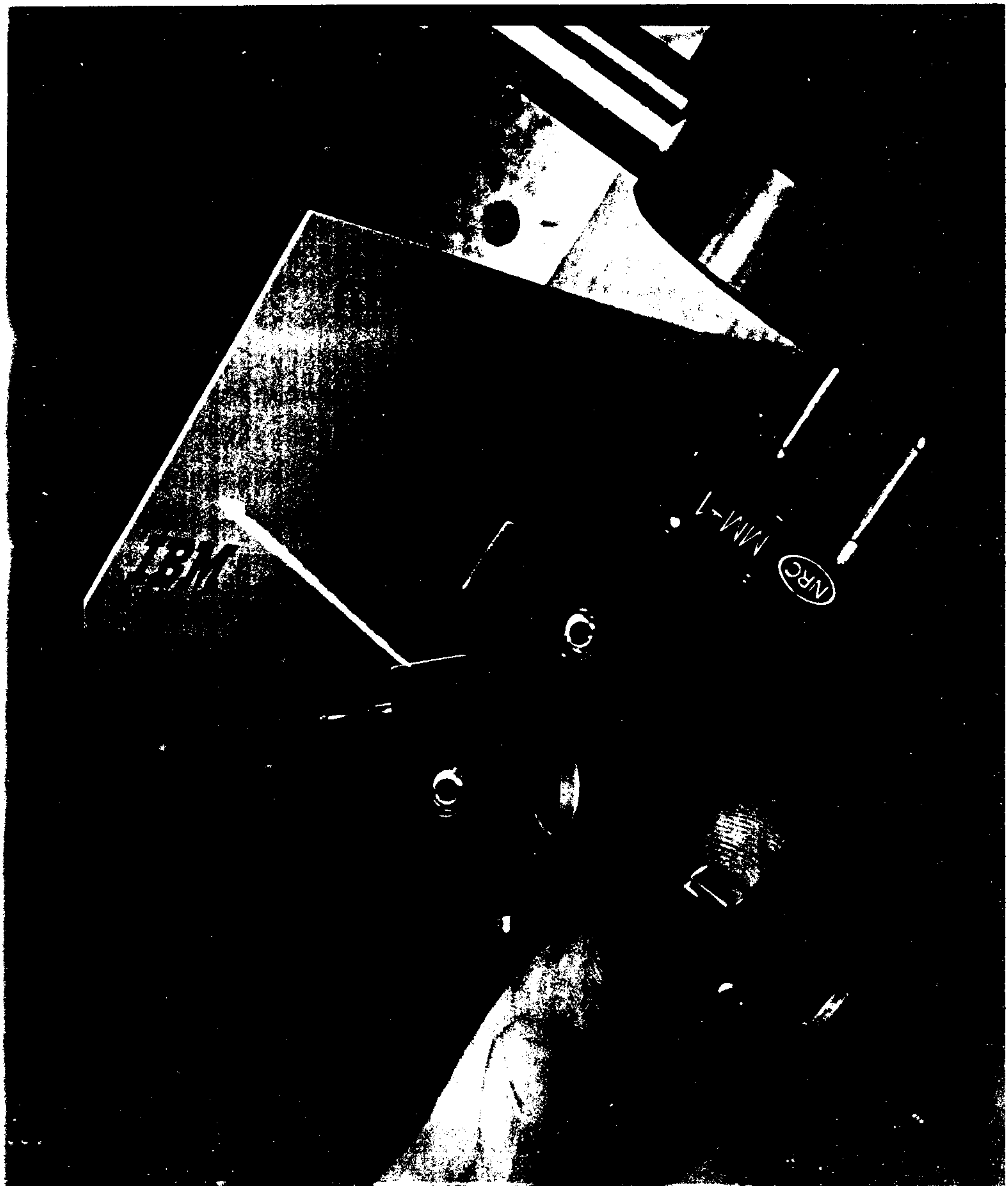
IBM
MM-1
NRC

CURRENT AND FUTURE TOPICS FOR POWER LASERS

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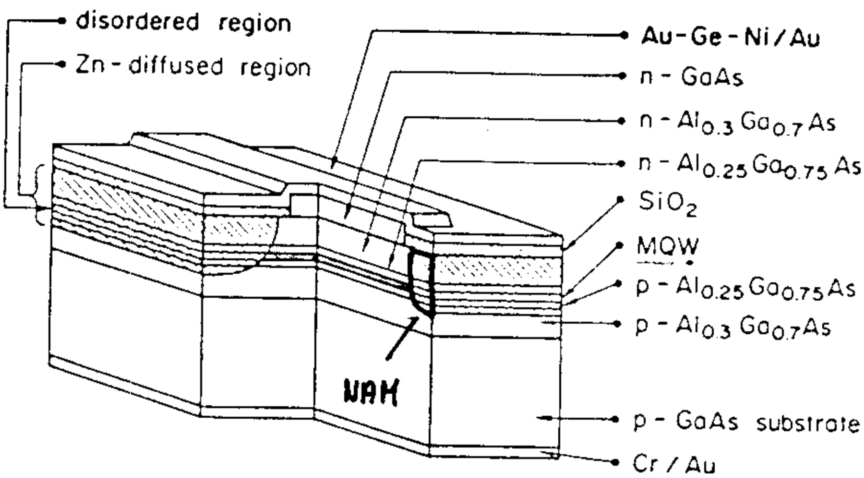
NON-ABSORBING LASER MIRRORS (NAM)

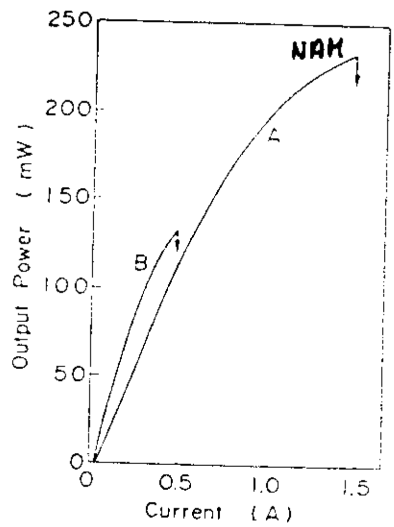
Reduction of Mirror Absorption and Heating

Increase of Mirror Damage Threshold

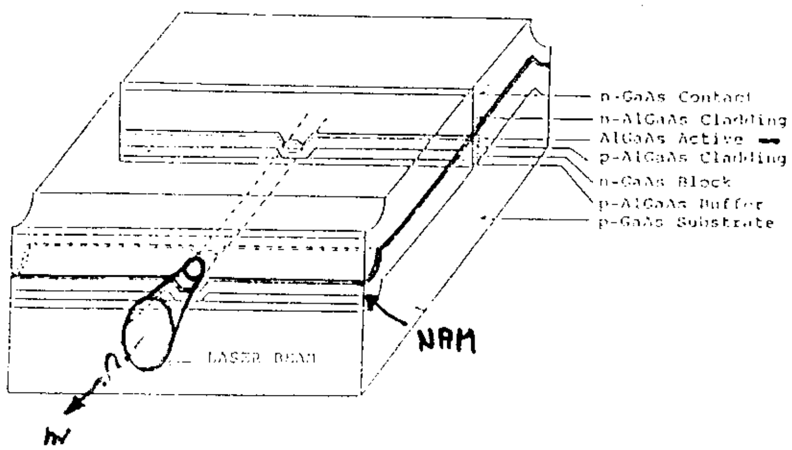
Improvement of High Power Long-term Degradation

- AlGaAs WINDOW STRIPE BURIED MQW LASER (H. Nakashima et al.)





- AlGaAs BENT ACTIVE-LAYER LASER WITH SA WINDOW STRUCTURE (T. Yagi et al.)



SURFACE EMITTING LASERS

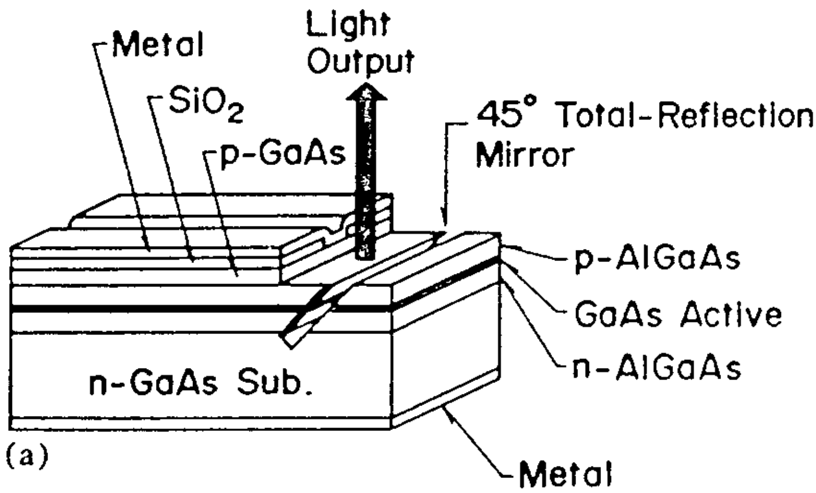
Two-Dimensional Arrays for Multiple Beam MO-Storage Systems

Coherent Two-Dimensional Arrays

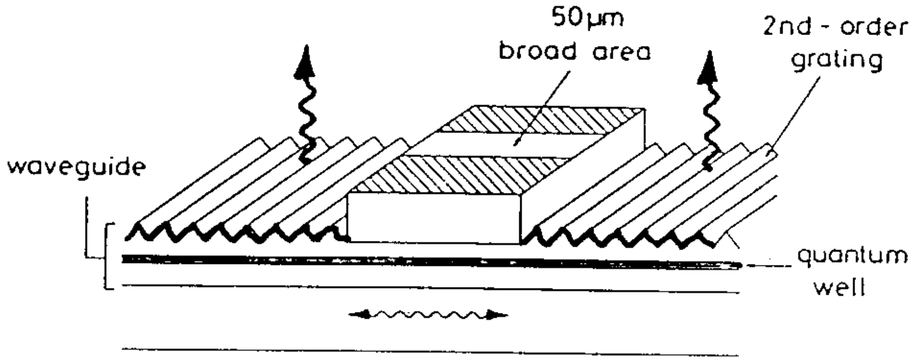
Optical Parallel Processing

On-Wafer Testing

- 45° MIRROR SURFACE EMITTING LASER (after N.Hamao et al.)



- GRATING-COUPLED SURFACE EMITTING LASER (after D.Welch et al.)



HIGH POWER COHERENT LASER DIODE ARRAYS

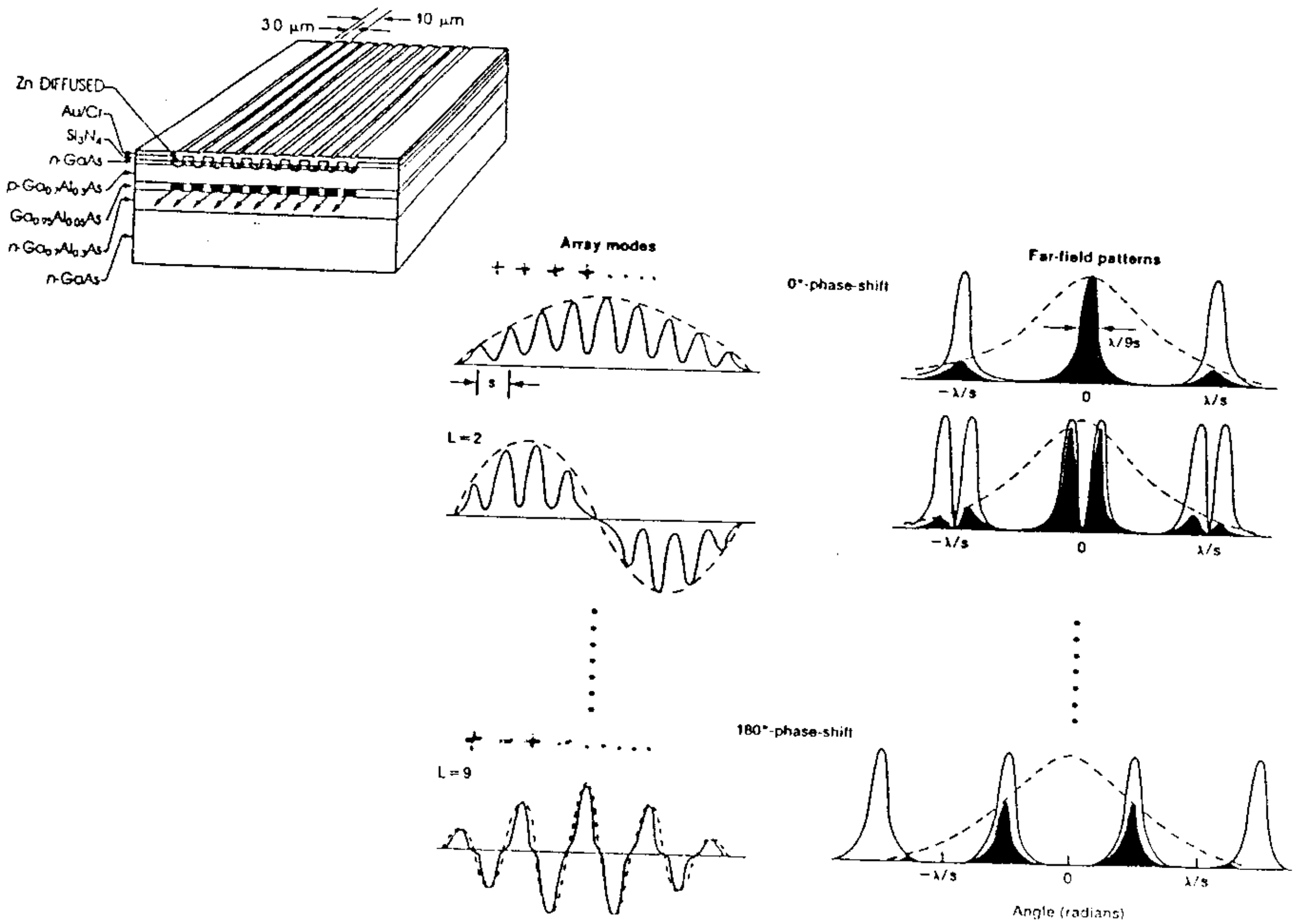
APPLICATIONS:

- EFFICIENT SOURCE FOR SECOND HARMONIC GENERATION
- MATCHED AND VERY EFFICIENT SOURCE FOR Nd:YAG LASERS
- SPACE COMMUNICATION

TARGET:

- HIGH POWER OUTPUT IN A SINGLE DIFFRACTION LIMITED BEAM
- GOOD MODULATION CAPABILITY
- HIGH DEVICE EFFICIENCY FOR OVERALL EFFICIENCIES OF 30 - 50%

DEVICE STRUCTURES FOR OPTICAL PHASE COUPLING:



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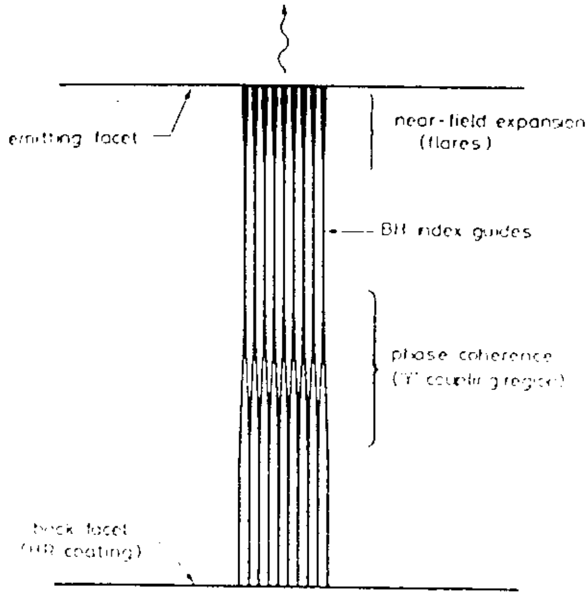
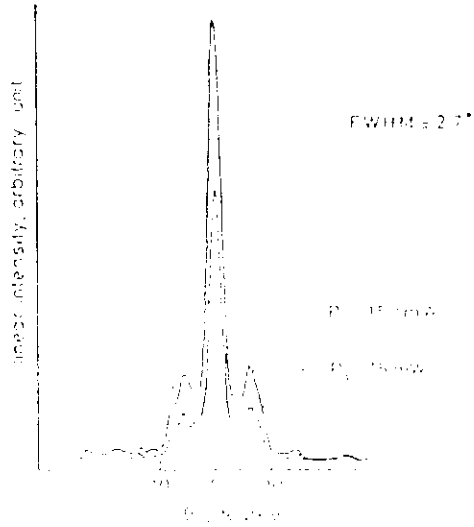
HIGH POWER COHERENT LASER DIODE ARRAYS (cont.)

LINEAR Y-COUPLED LASER ARRAY:

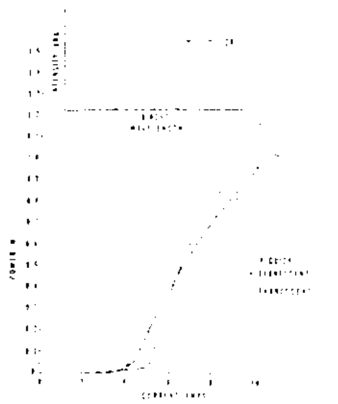
after D.F. Welch et al., 1986

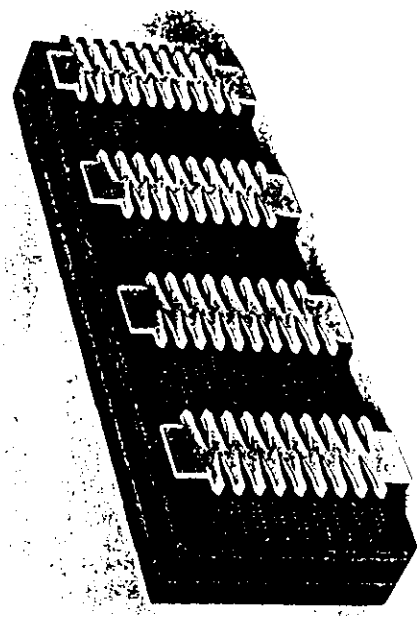


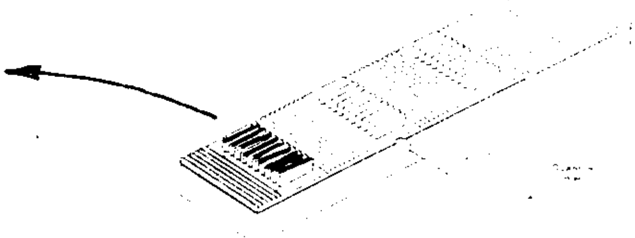


2-DIMENSIONAL Y-COUPLED LASER ARRAY: (10×10)

after G.A. Evans et al., 1988







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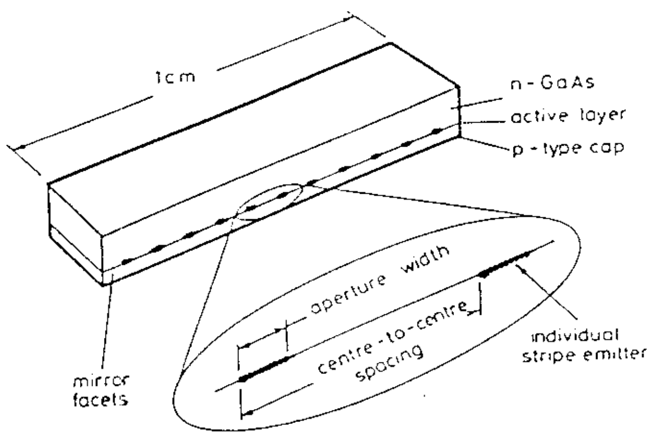
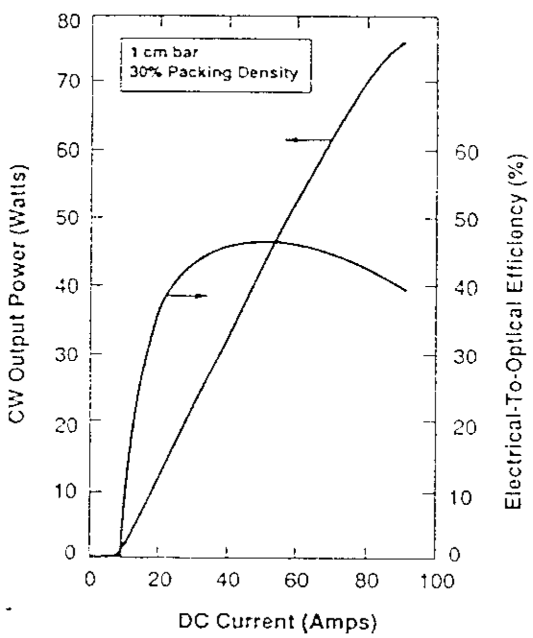
VERY HIGH POWER INCOHERENT LASER ARRAYS

APPLICATIONS:

- Optical Pumping of Nd:YAG Solid State Lasers
- Laser Soldering
- Infrared Illumination
- Eye Surgery

300 SQW SCH AlGaAs LASER ARRAY (M. Sakamoto et al.):

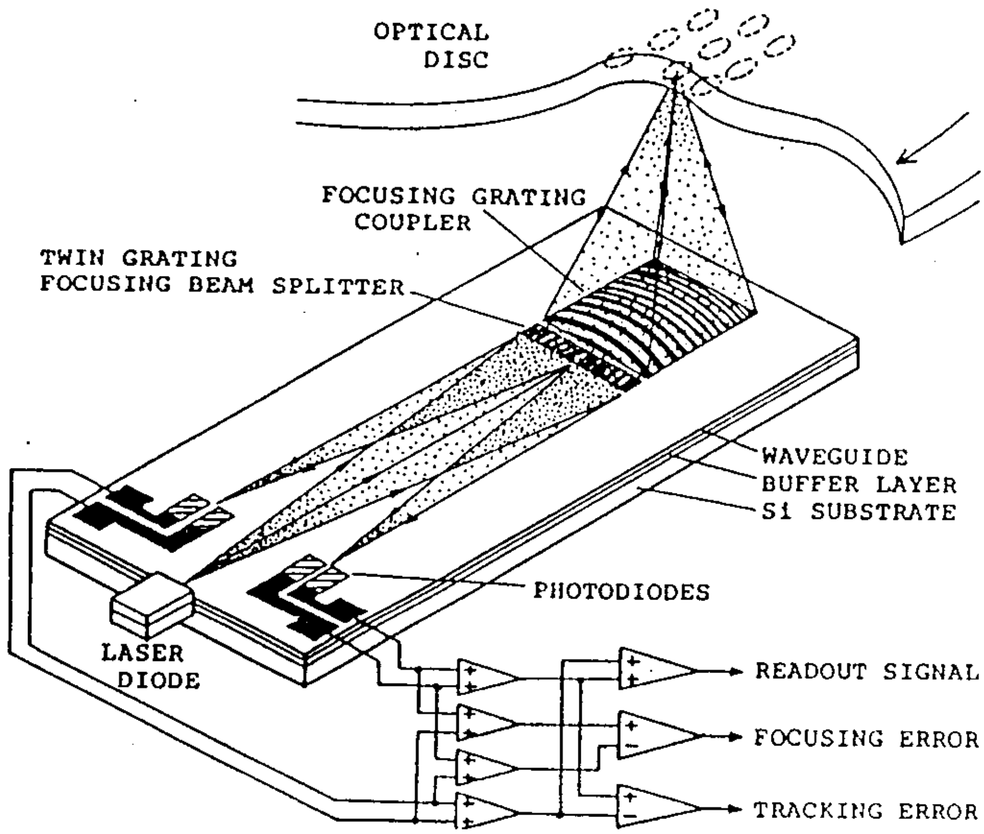




- CW Powers of 76W (0°C), 55W (25°C) obtained
- 45% (0°C), 40% (25°C) Overall Power Efficiency
- Aperture Length 1cm

INTEGRATED OPTICAL DISC HEAD

- ADVANTAGES:
  - ★ Low Mass Head
  - ★ Low Profile Head ---> high volumetric density
  - ★ Electronic Integration
  - ★ Solid State Reliability
- UNSOLVED ISSUES:
  - ★ Not Polarization Preserving (Phase Change Media only)
  - ★ Overall Head Efficiency, Diffraction Limited Spot
- EXPERIMENTAL DEVICE (after T. Suhara et al., 1985)



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SUMMARY / OUTLOOK

- Substantial Power Diode Laser Market in:

  Magneto-Optical Storage, Optical Tapes

  Printers

  Barcode Scanners

  Pump Source for Nd:YAG Lasers

  HeNe Replacement

- AlGaAs is Main-Stream Technology for 50mW Power Lasers for MO-Storage
- Record Fundamental Mode CW Power of 500mW for AlGaAs Lasers
- Transition to MBE-/MOVPE-grown Quantum Well Lasers in Production
- AlGaInP demonstrates 30mW at 670nm in Research
- Diode Laser pumped "blue" Sources demonstrate 41mW at 425nm

- "Blue" Injection Lasers still await realization
- 1-Dimensional Laser Array are promising for Multiple Beam Heads
- 2-Dimensional Laser Array are demonstrated in Research

- Integrated Heads and Micro-optic are key for Volumetric Density
- Integration of Electronic Functions
- 2,3-D Modelling of Diode Lasers and Optoelectronic devices needed