ENHANCED THz EMISSION IN ErAs:GaAs

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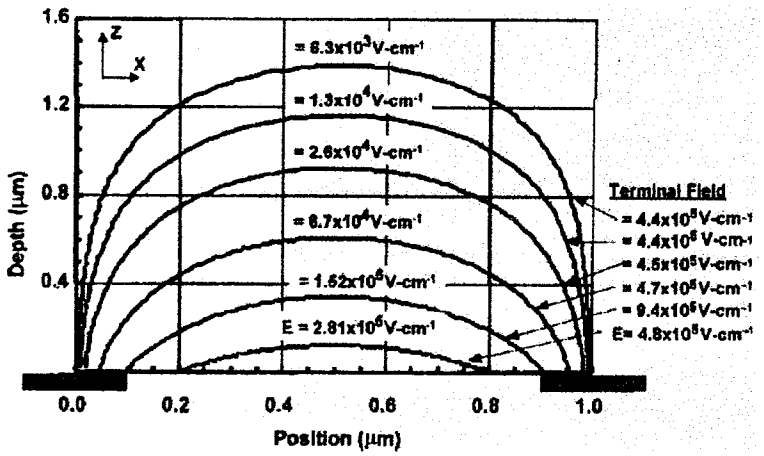
Overview

- **Embedded electrodes fabrication**
- **Performance comparison: LTG-GaAs versus ErAs:GaAs**
- **Anisotropic carrier transport in ErAs:GaAs**

Embedded Electrodes



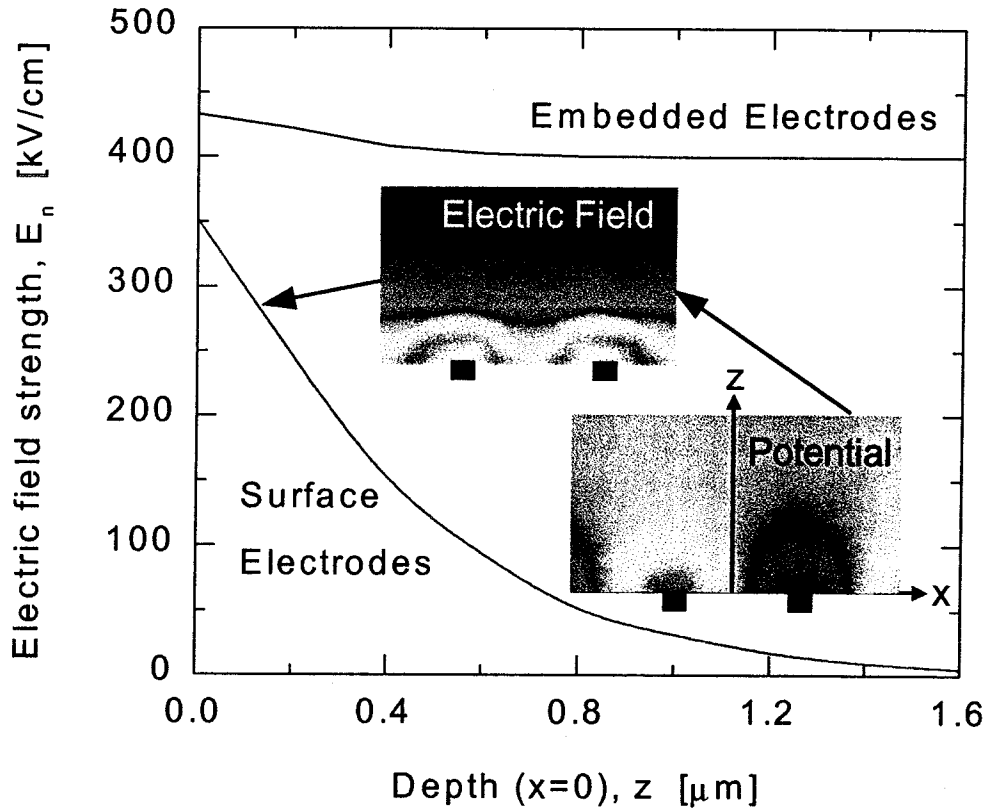
E.R.Brown, *Appl. Phys. Lett.* **75**, 769 (1999).

Surface electrodes:

Electric field strength decreases rapidly with depth into photomixer material

Advantage:

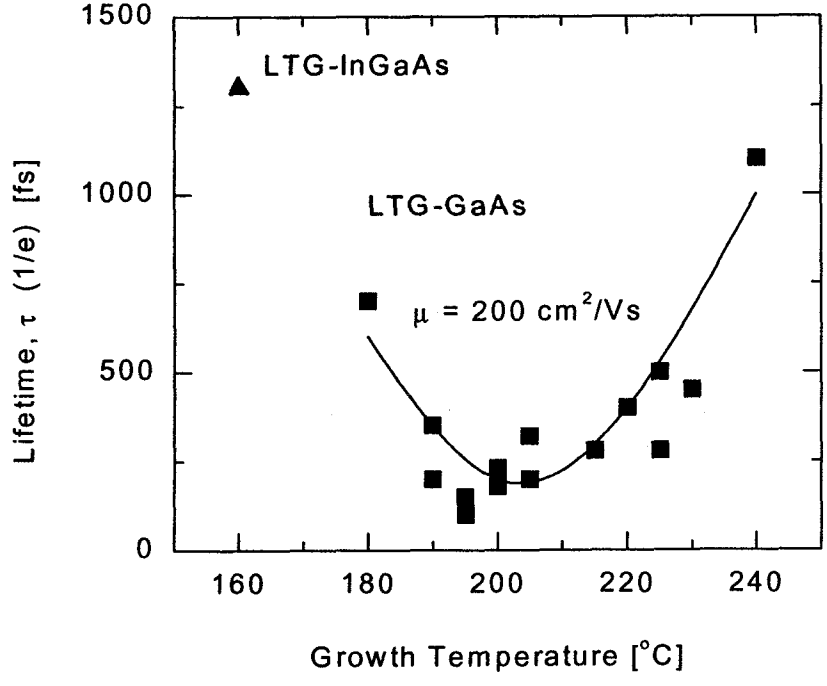
increases electric field in bulk of photomixer



LTG-GaAs versus ErAs:GaAs

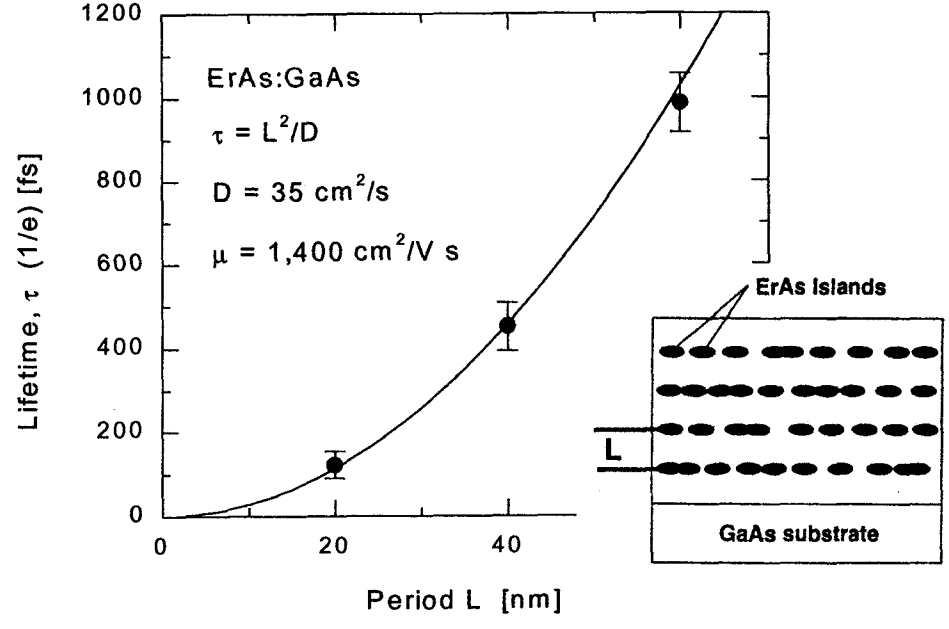
lifetime set by:

- **growth temperature**
- **anneal conditions**



lifetime set by ErAs layer coverage and spacing

- **growth parameters ONLY**



LTG-GaAs

Layer Description	Material	Thickness [nm]	Comments
substrate	GaAs		semi-insulating
buffer	GaAs	50	
etch stop	AlAsAs	600	$x_{Al} = 0.55$
	GaAs	1500	
digital alloy	AlAs/GaAs	300 x (49 + 1) = 1500	digital alloy; 98% Al
smoothing	GaAs	30	
active layer	LTG-GaAs	1000	$T_{growth} = 225°C$; annealed *in situ* at 580°C for 3 min

ErAs:GaAs

Layer Description	Material	Thickness [nm]	Comments
substrate	GaAs		semi-insulating
buffer	GaAs	50	
etch stop	AlAsAs	600	$x_{Al} = 0.55$
	GaAs	1500	
digital alloy	AlAs/GaAs	300 x (49 + 1) = 1500	digital alloy; 98% Al
smoothing	GaAs	10	
active layer	ErAs/GaAs	50 x (1.2ML, 20 nm) = 1000	

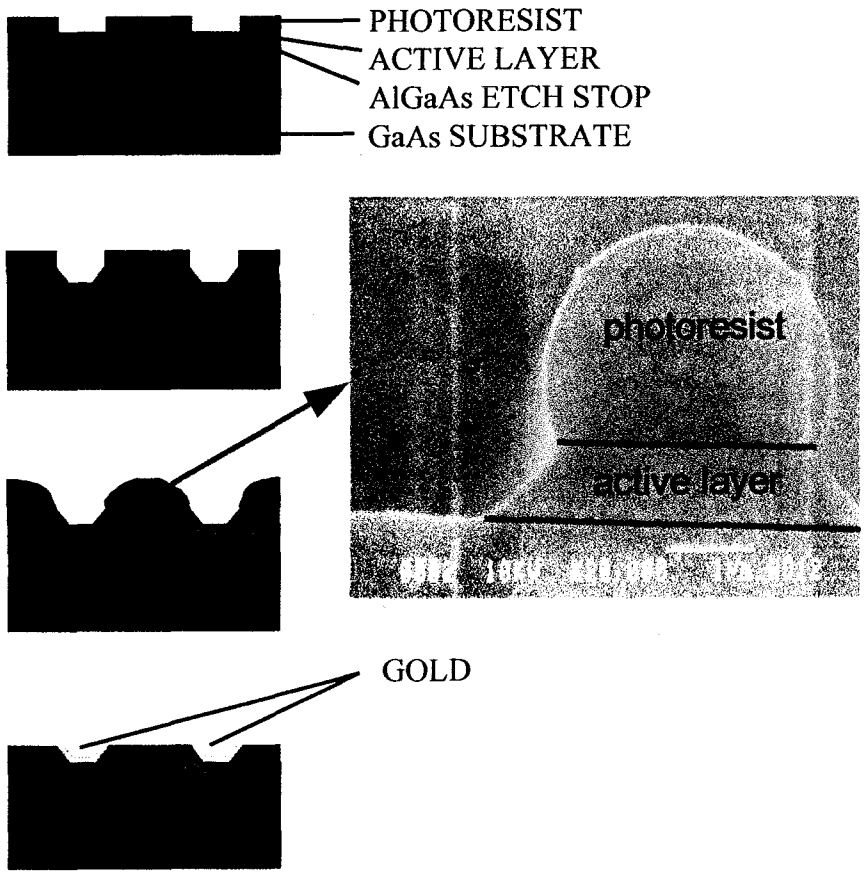
Fabrication Steps

I
CPS and antenna definition with photoresist

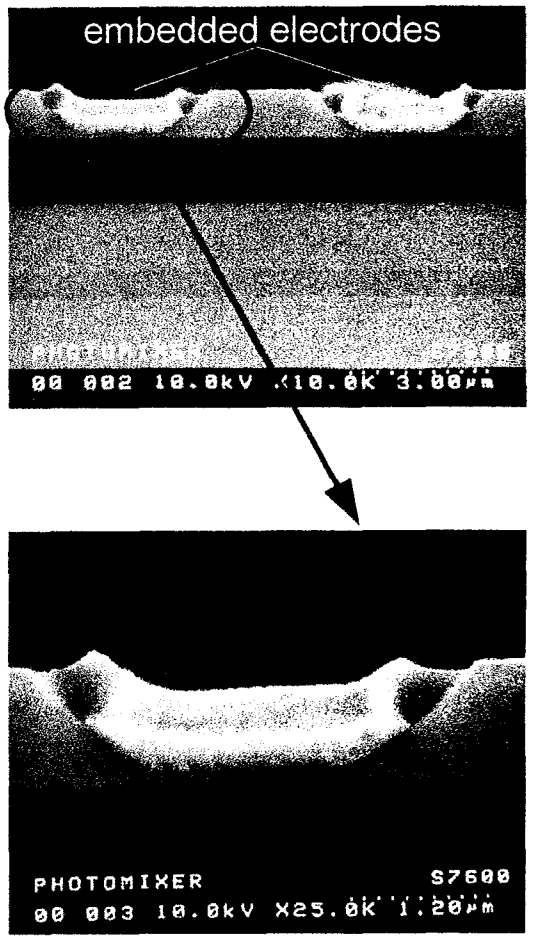
II
Selective removal of GaAs ($NH_4OH:H_2O_2$ etch)

III
Reflow of photoresist

IV
Deposition of metal

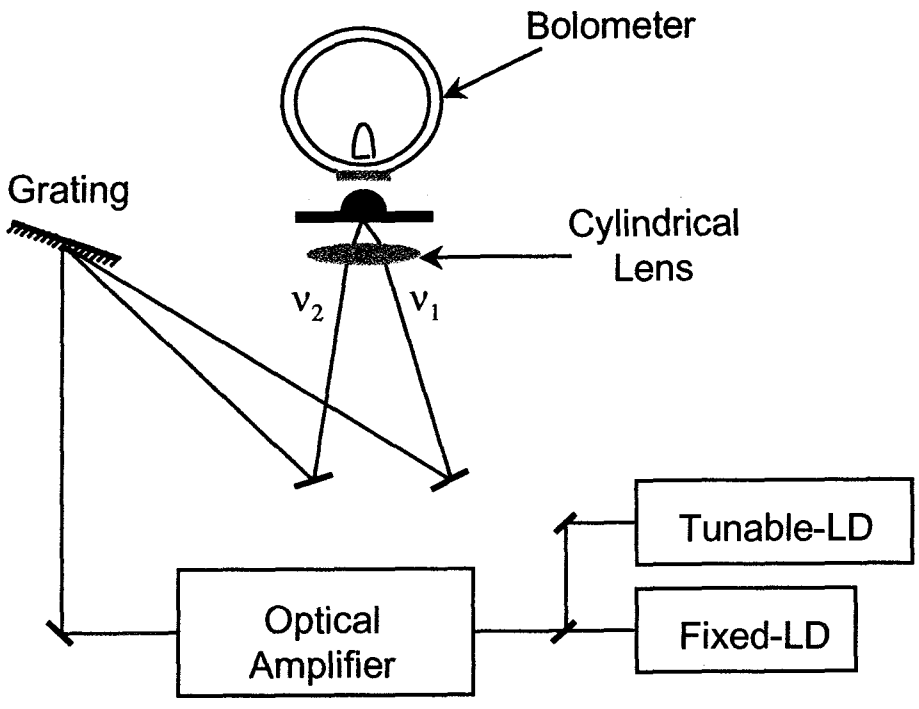


Cross-section of device



Measurement

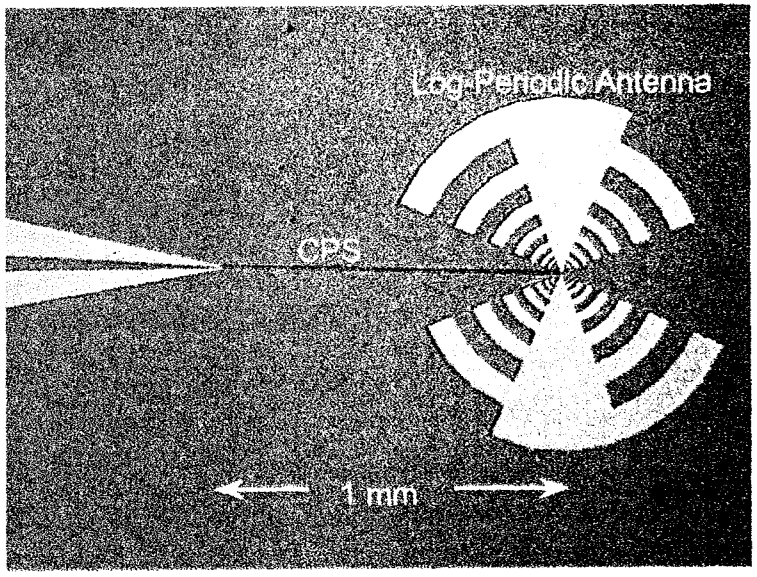
Caltech setup



λ_{nom}=850 nm

P_{out}=500 mW

Device geometry

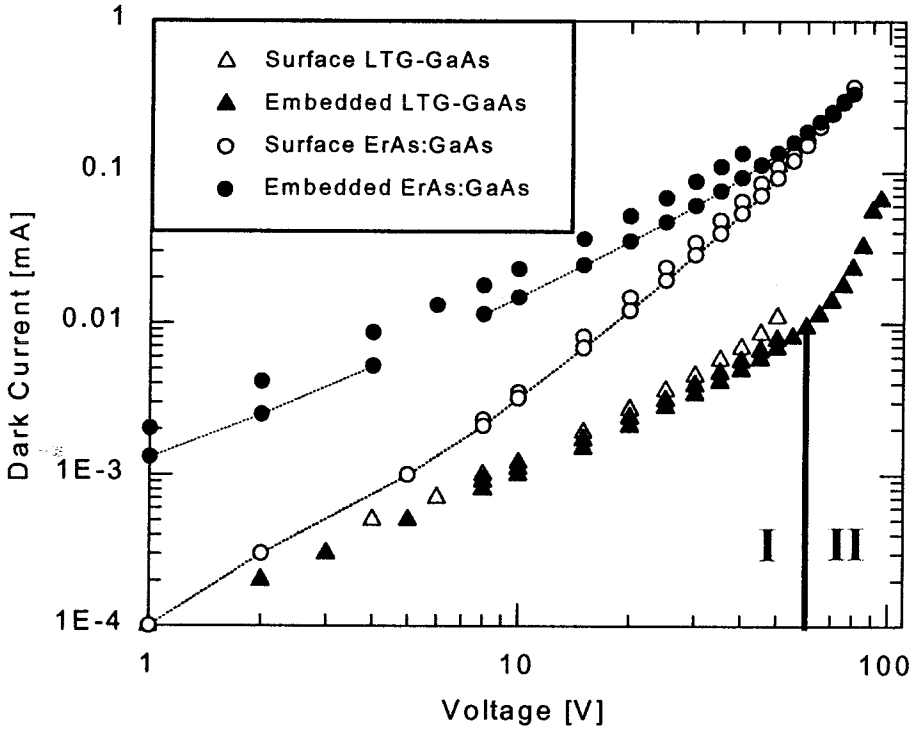


Coplanar strips (CPS) dimensions:

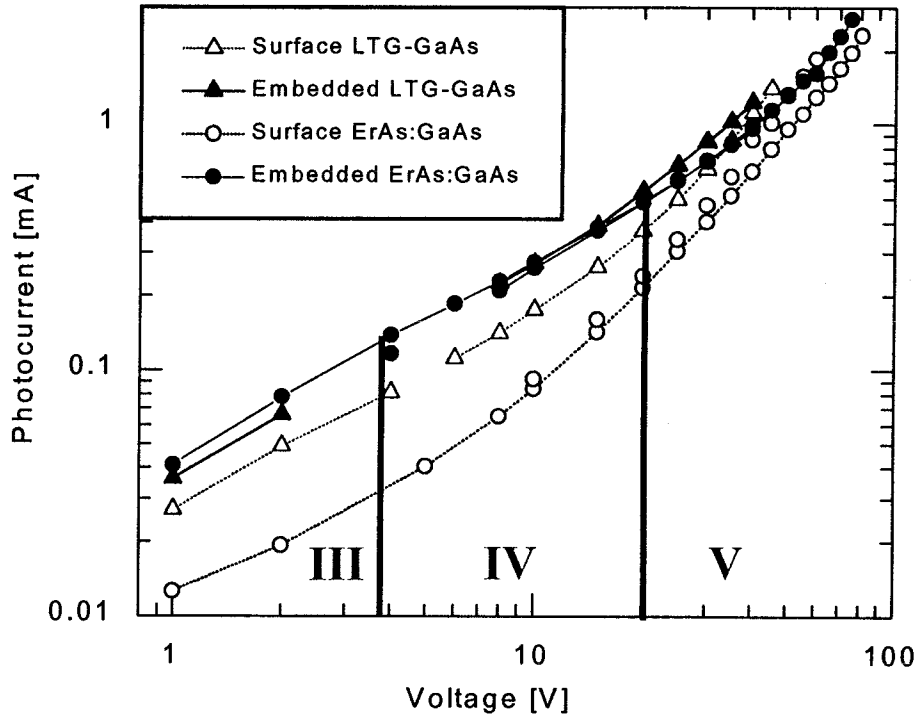
- Gap = 2 μm
- Metal width = 4 μm
- Z (cps) ≈Z (antenna) = 72 Ω

Embedded Coplanar Strips Traveling-wave Photomixers

Dark current



Photocurrent

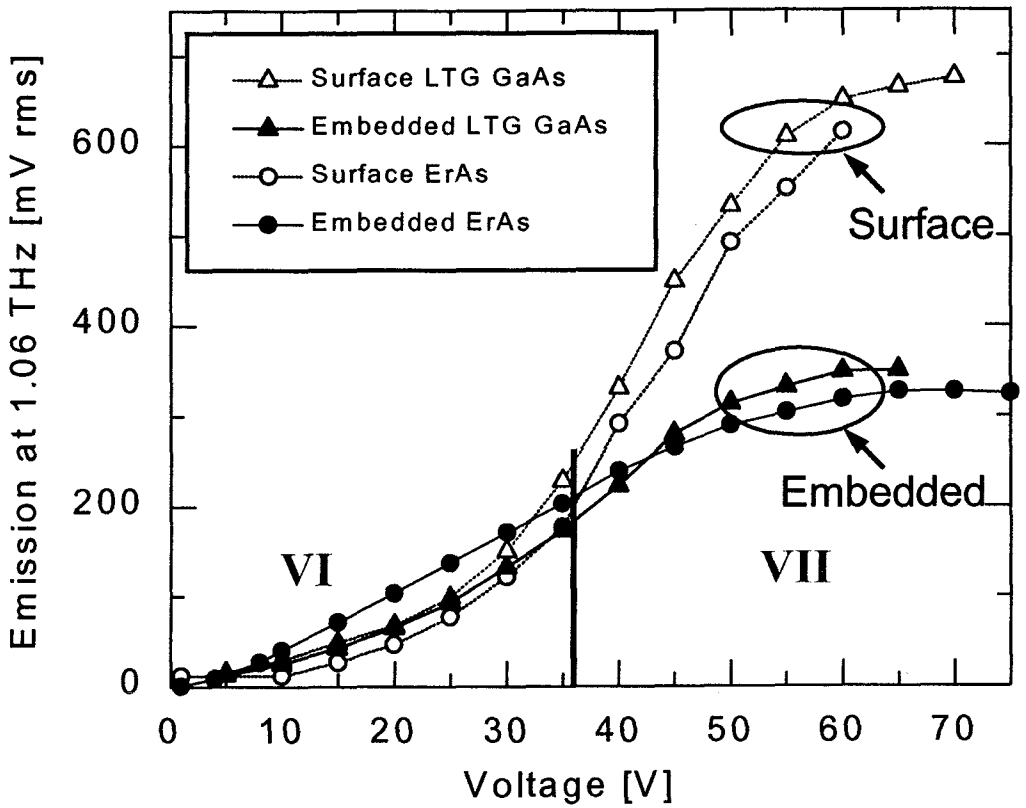


Transport Domains:

I Hopping conduction
II Impact ionization
III Low-field free carrier
IV Velocity saturation
V Trap barrier lowering

Embedded Coplanar Strips Traveling-wave Photomixers

RF Power at 1 THz



Saturation level depends only on electrode geometry:

- **NOT MATERIAL DEPENDENT**

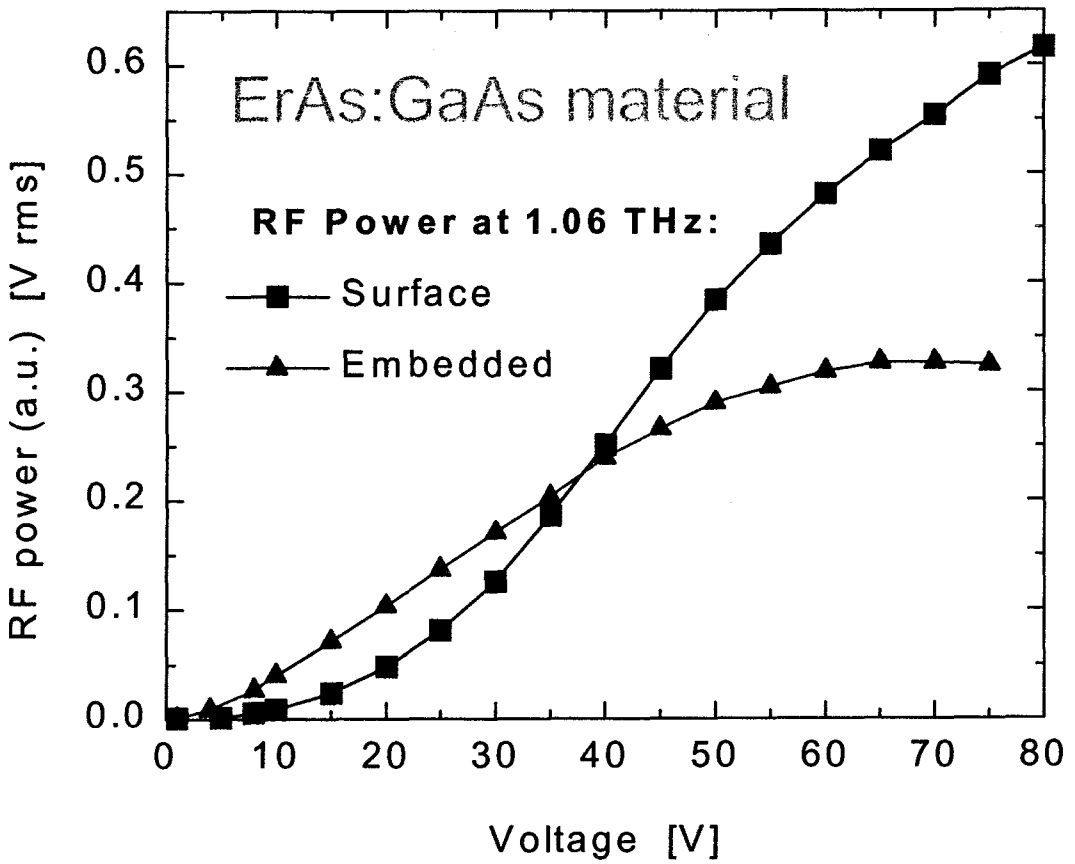
Possible cause:

- **IMPEDANCE MISMATCH BETWEEN CPS AND ANTENNA**

Domains:

VI **Low-field**
VII **High-field**

Photomixer transport equations



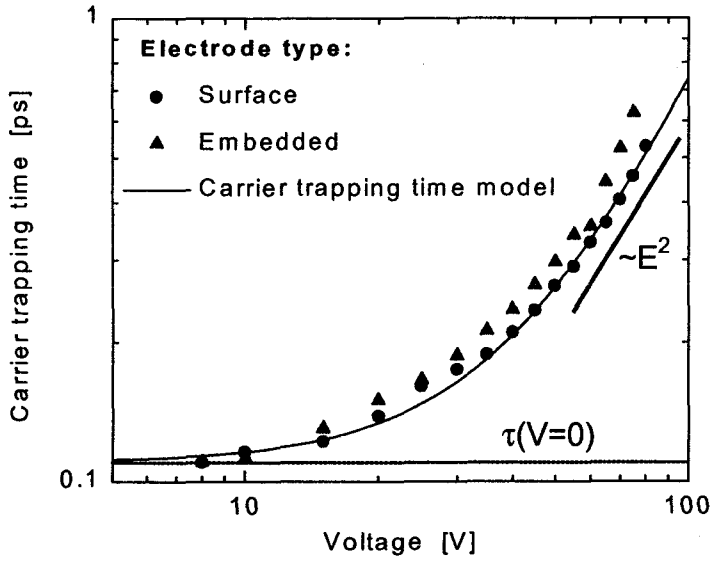
Photocurrent

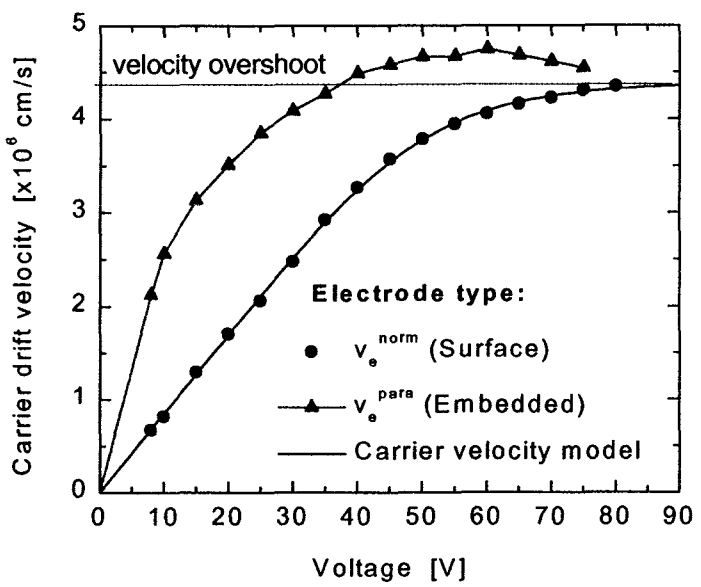
$$I_{ph} \sim v(E)\tau(E) \quad (1)$$

RF Power

$$P_{\omega} \sim \frac{I_{ph}^2(E)}{1+\omega^2\tau(E)^2} \quad (2)$$

Embedded Coplanar Strips Traveling-wave Photomixers





Trap barrier lowering lengthens carrier trapping time:

$$\tau(V) = \tau_0 \cdot \left[1 + (V / V_{th})^n\right]$$

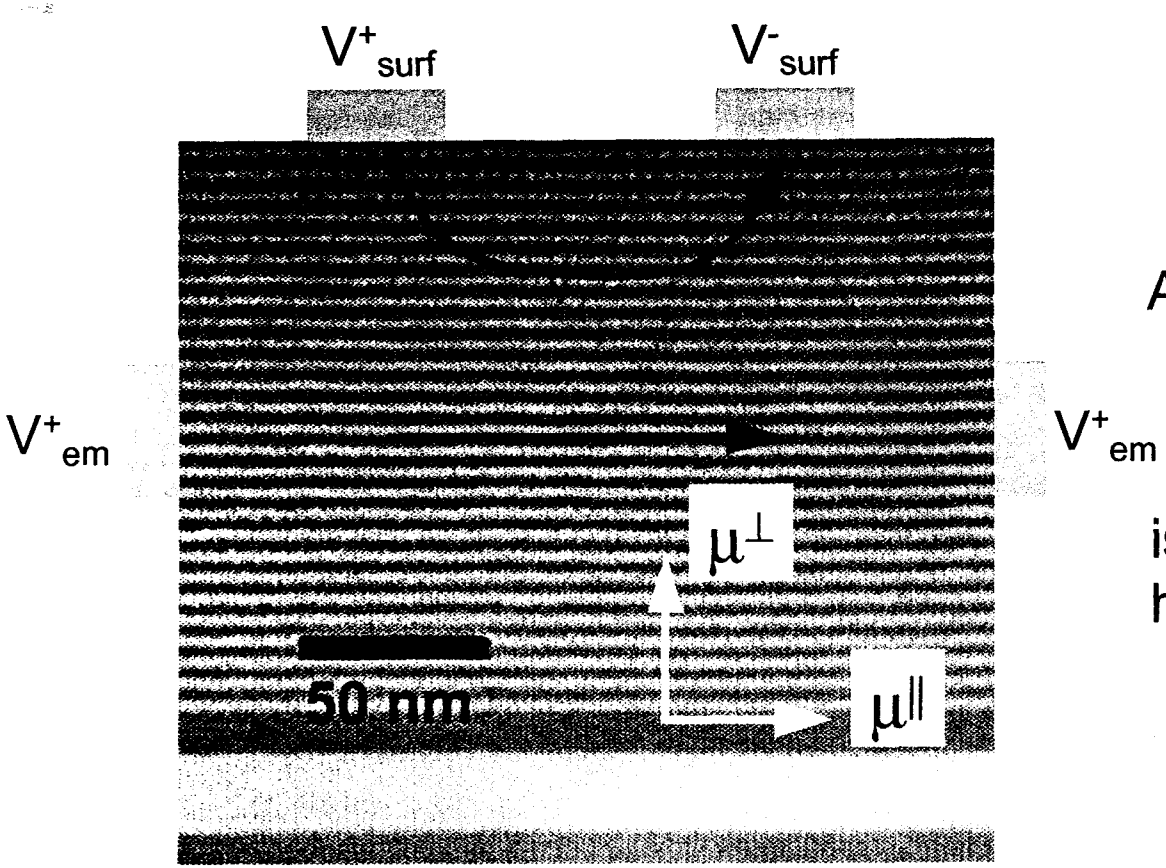
V_{th}~ 43 V, n ~ 2

Carrier drift velocity saturates at high electric fields:

$$v(V) = \frac{V_{sat}}{\left[1 + \left(\frac{V_{sat} W_g}{\mu_{low} V}\right)^{\beta}\right]^{1/\beta}}$$

v_{sat}~ 4.4×10^6 cm/s, β ~ 5.2

Carrier Transport in ErAs:GaAs



Anisotropic carrier mobility

$$\mu^{||} > \mu^\perp$$

is not surprising since material has a uniaxial crystal structure

Summary

- Achieved higher RF power at low bias with embedded electrodes in ErAs:GaAs material
- No direction-dependent transport observed for LTG-GaAs

Additional findings:

- Velocity overshoot observed in ErAs:GaAs
- RF power saturation caused by field-dependent carrier trapping time
- Improved model enables more accurate predictions