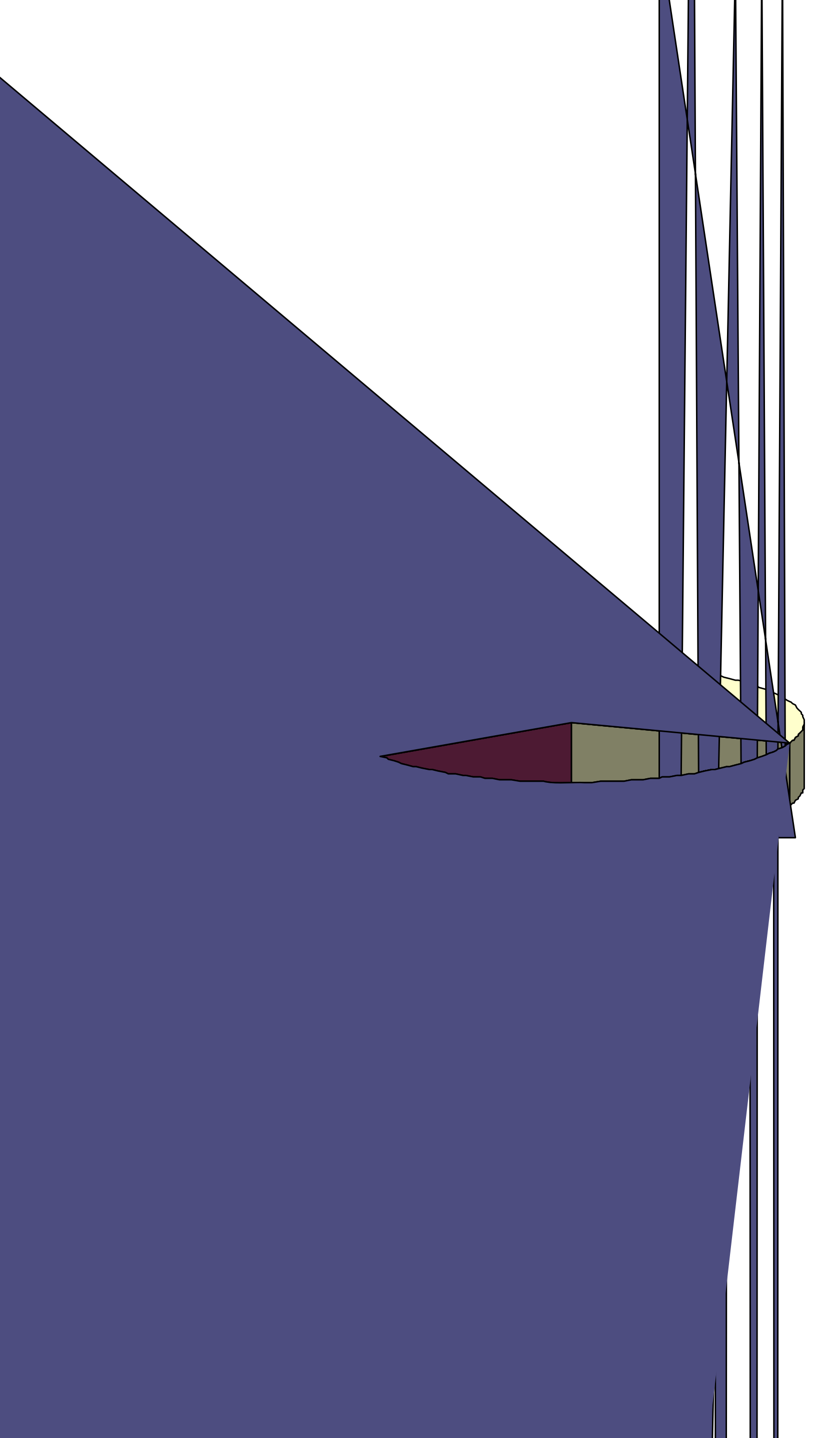
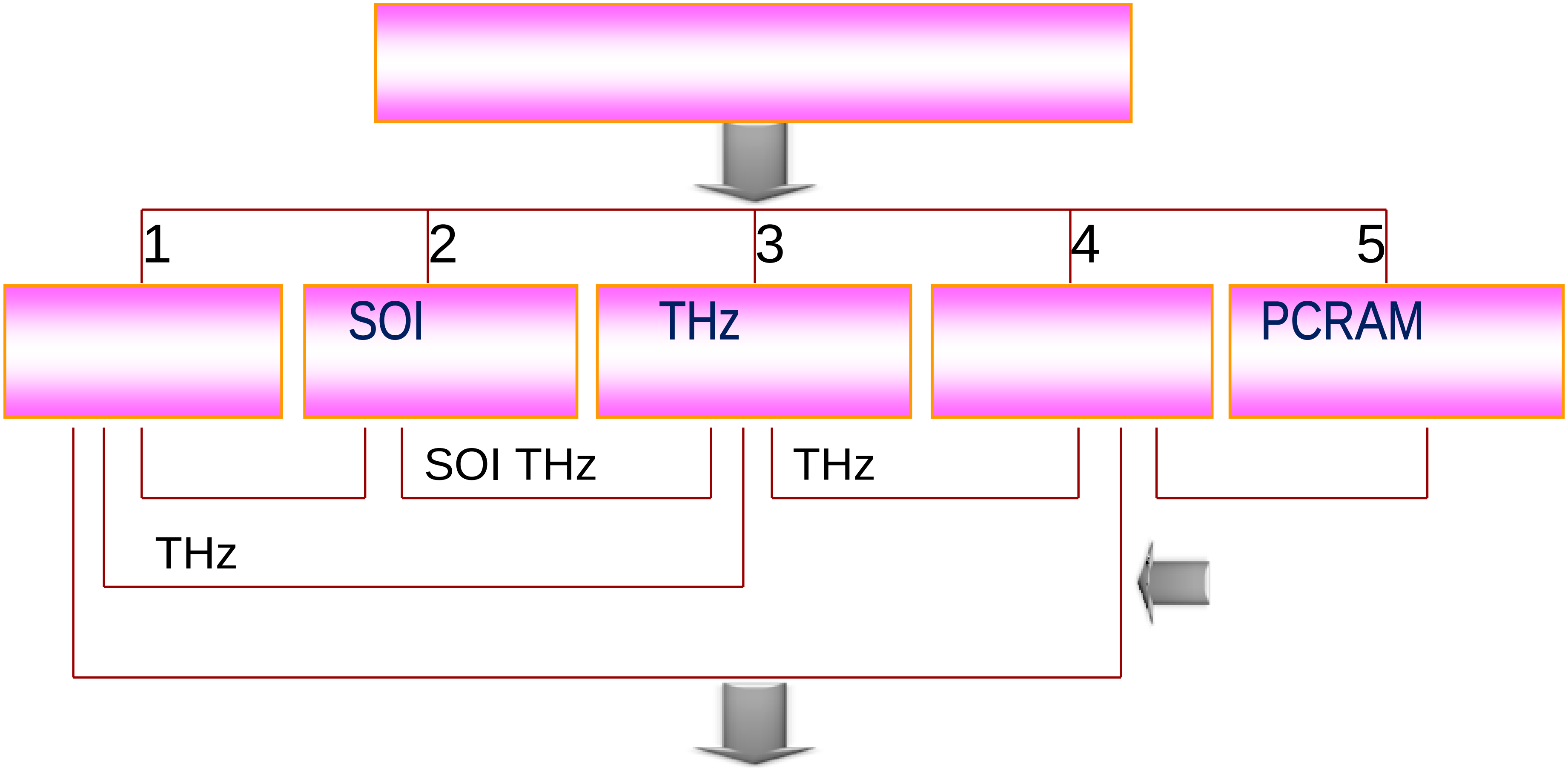
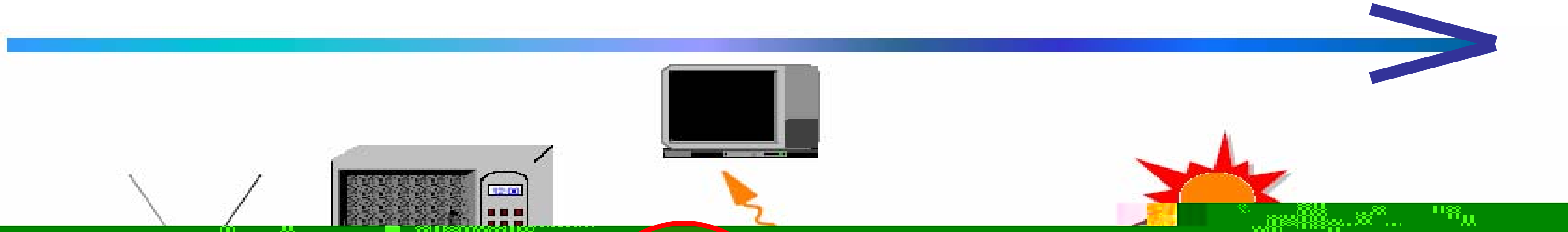
THz





1
2
3
4
5
SOI
THz
PCRAM
SOI THz
THz
THz

THz



Hz

0.1-10THz

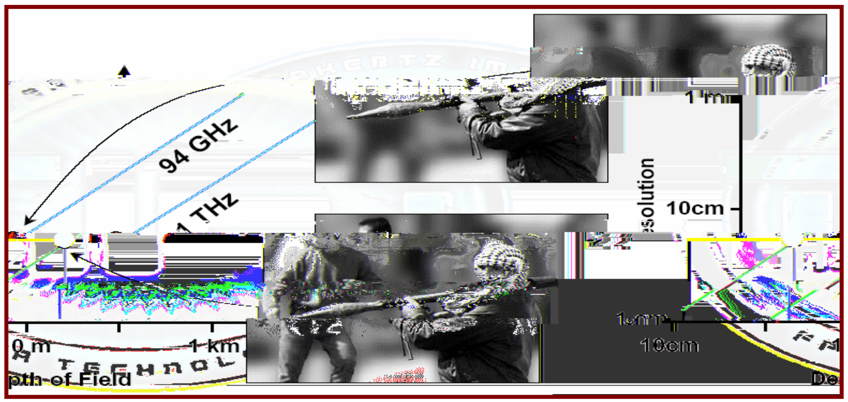
3 -30

T-

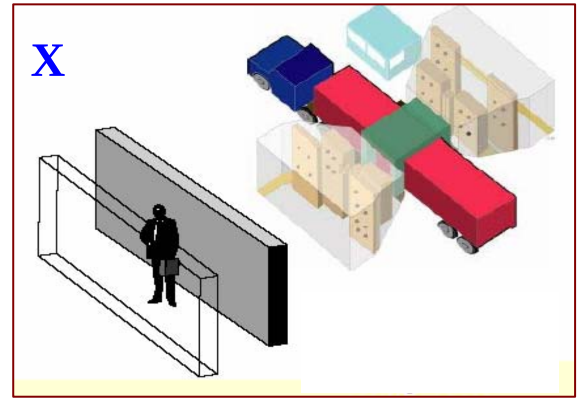
THz

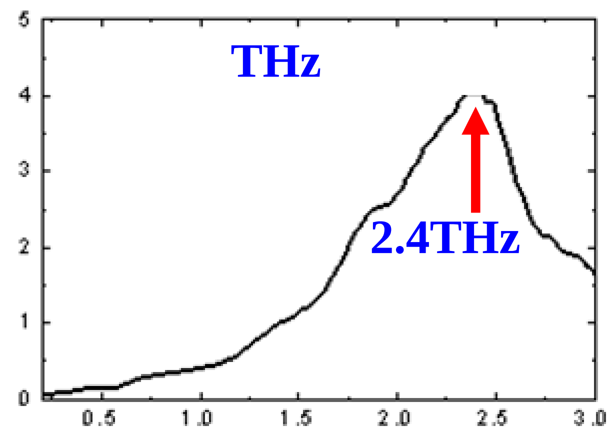
✓ X THz

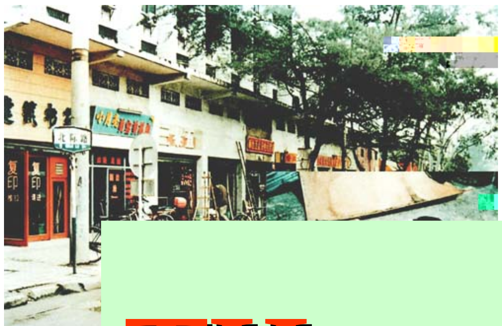
✓ THz THz



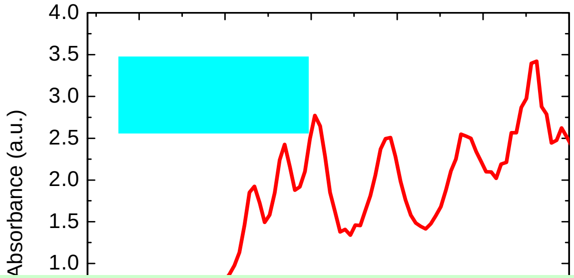
✓ THz







THz



THz

By Alan Levin and Traci Watson
USA TODAY

HOUSTON — NASA investigators have concluded that a piece of foam that hit Columbia during its launch is what caused a hole to open in the front edge of the shuttle's left wing and allowed superheated air to burn it apart on re-entry.

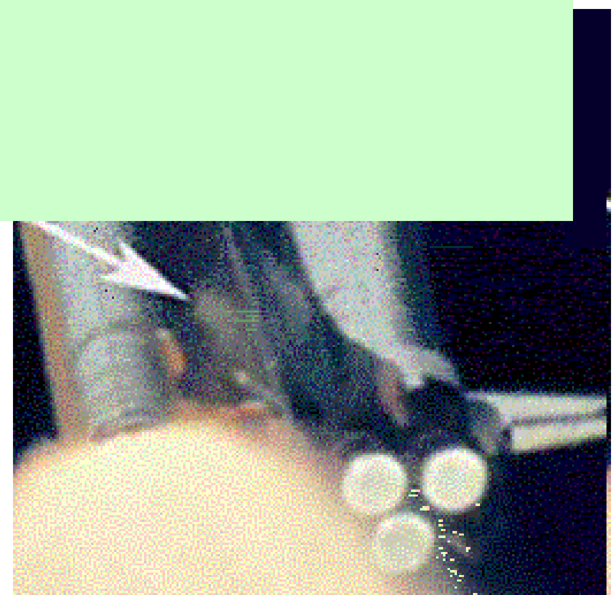
The conclusion is a turnaround for NASA. In the early days after Columbia disintegrated on Feb. 1, NASA's top officials said they did not see how the foam insulation that fell off the external fuel tank could have significantly damaged the shuttle's heat-protective skin. Administrator Sean O'Keefe derided critics who had placed blame on the foam as "foamologists." NASA also relied on an engineering analysis conducted before Columbia's re-entry that said the foam hit would not pose a danger.

Space agency engineers plan to brief the independent Columbia Accident Investigation Board, which is in charge of the probe, about their findings in a closed meeting Thursday.

The foam impact quickly became a key suspect in the investigation, but other possible causes were not ruled out. Now, NASA investigators believe they have enough evidence to push aside other theories, officials and sources familiar with the investigation said.

Officials said the board also suspects that the foam impact probably caused the disaster, but it does not agree entirely with NASA. The sources cautioned that

At launch: Insulating foam strikes left wing.



THz

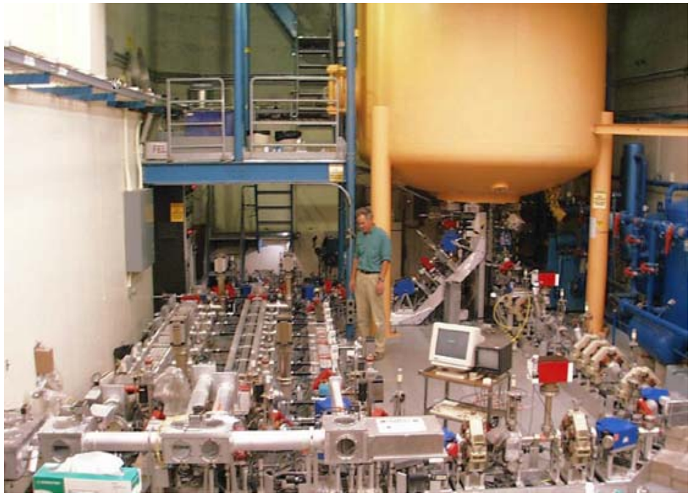
- **THz :**

Gunn **Bloch**

THz

THz **THzQCL**

- **THz :**



UCSB

THzQWP

THz

-
-
-
-

BWO

- <1.11THz
- 1-10
- 0.5 × 0.4 × 0.5
- 600 45

Gunn

- <1.0 THz
-

•100-300 GHz 1-30mW
•300-600 GHz 0.1-8mW
•600-900 GHz 10-500
•1.0-1.7 THz 1-60

CO_2 THz

- 0.3-7.0THz
- >50
-
- 70
- 3

THz

- <3.0THz
- <
-

P-Ge

THz

Bloch

-

THz

- <2.5THz
- THz

THz

- 20-50K

- <1.5 THz
- 4K
- THz

Bolometer Pyroelectric detector

THz

THz

THz

THz

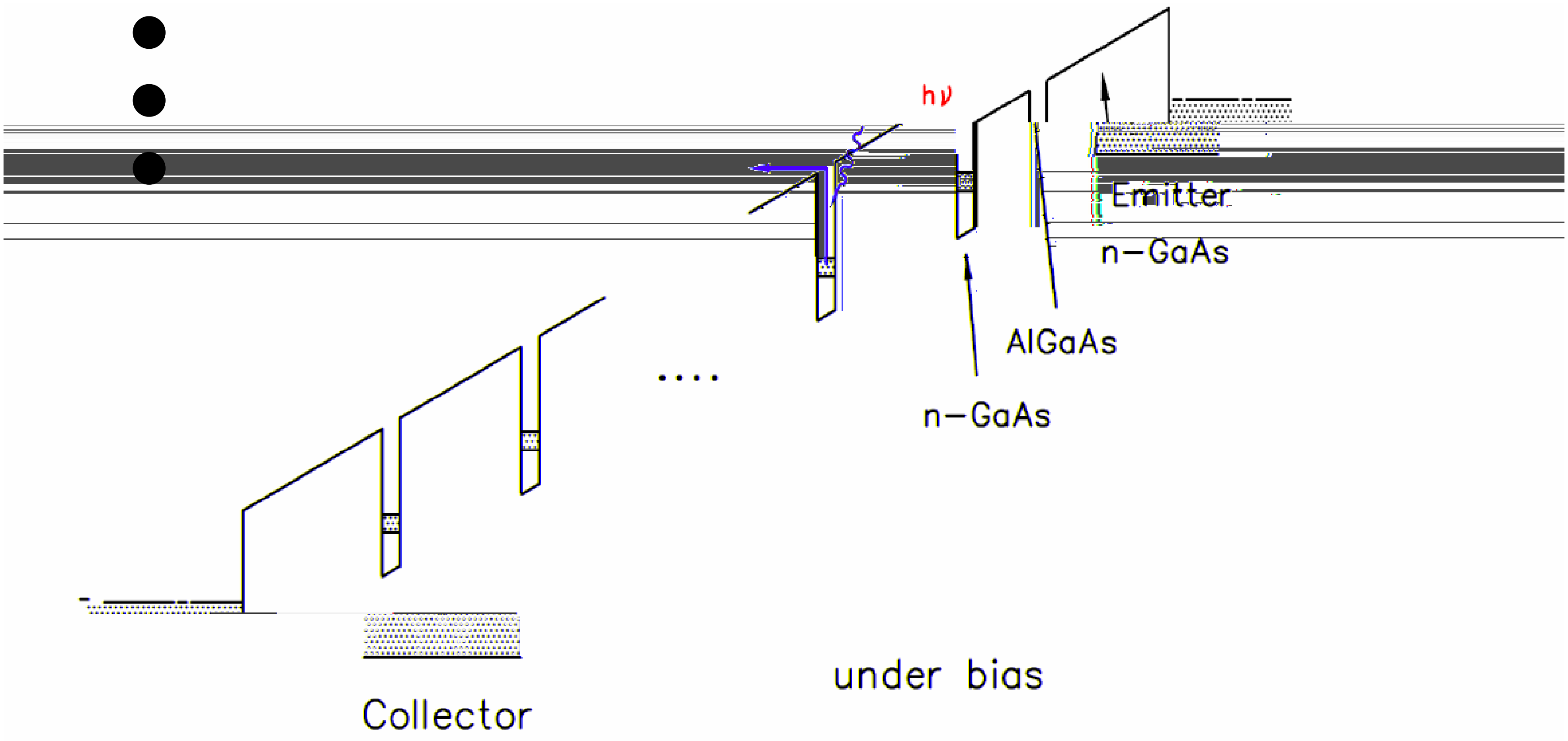
THz

(THzQWP)

THz

THz **THzQWP**

-
-
-
-
-



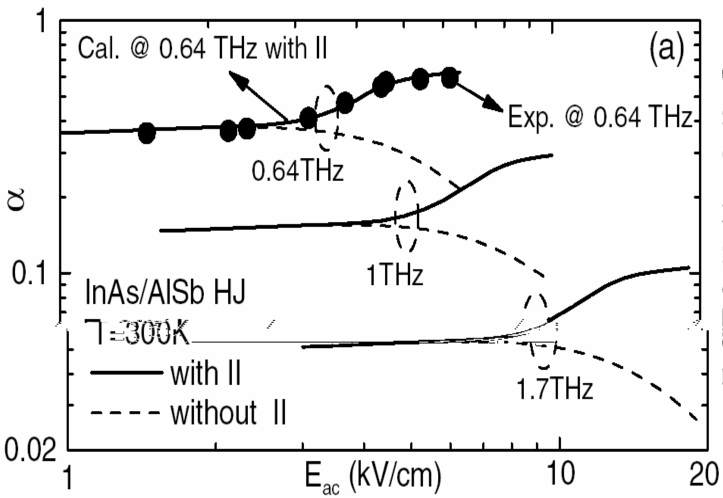
THzQWP

- THz THz
  2-7 THz QWP
  - Phys. Rev. Lett. 91, 237401 (2003)
  - Phys. Rev. B 69, 165203 (2004).
  - Appl. Phys. Lett. 84, 4068 (2004)
- GaAs THzQWP
  ; THzQWP (
) 20%
  - Infrared Physics and Technology 47, 169 (2005)
  - IEEE J Sel Top Quant Elect 14, 374 (2008)
- THzQWP
  - Appl. Phys. Lett. 94, 201101 (2009)

THz

VOLUME 91, NUMBER 23 PHYSICAL REVIEW LETTERS week ending 5 DECEMBER 2003

Interband Impact Ionization and Nonlinear Absorption of Terahertz Radiation in Semiconductor Heterostructures



J. C. Cao
...formatics, Shanghai Institute of Microsystem and Information Technology,
...angning Road, Shanghai 200050, People's Republic of China

...ruary 2003; published 1 December 2003)

...onlinear free-carrier absorption of terahertz (THz) radiation in ...ring multiple photon process and conduction-valence interband ...ined the field and frequency dependent absorption rate. It is ...erings are important at low to intermediate field, and (ii) most ...n is dominated by II processes. Our theory can satisfactorily ...result on the nonlinear absorption in the THz regime.

PACS numbers: 78.20.Ci, 72.10.Bg, 73.50.Fq, 73.50.Gr

THz THz

1

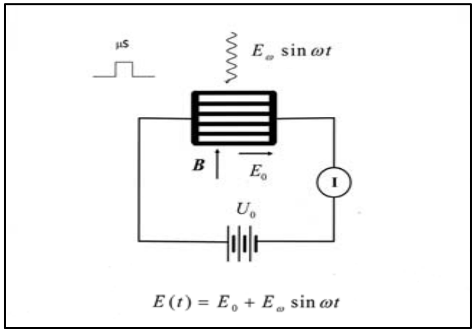
2

J. C. Cao, Phys. Rev. Lett. 91, 237401 (2003).

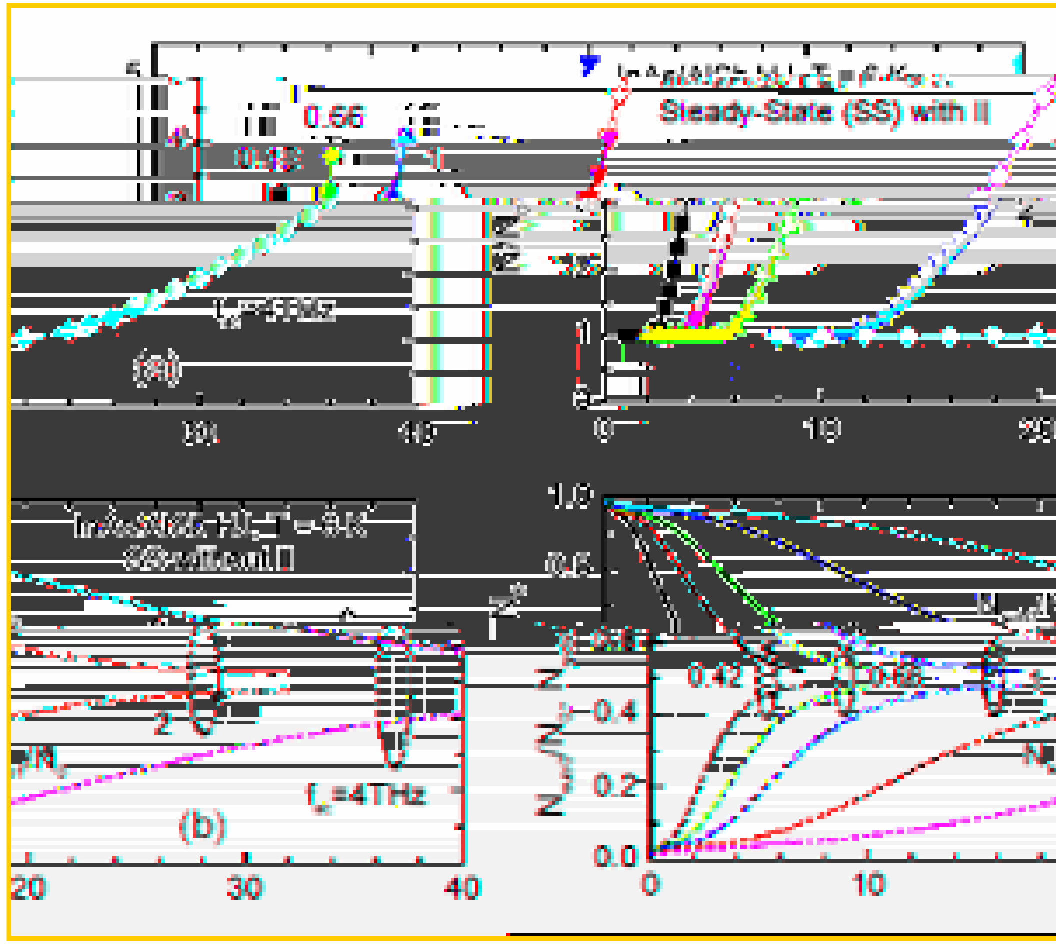
J. C. Cao, Phys. Rev. B 69, 165203 (2004).

THz

THz e-h



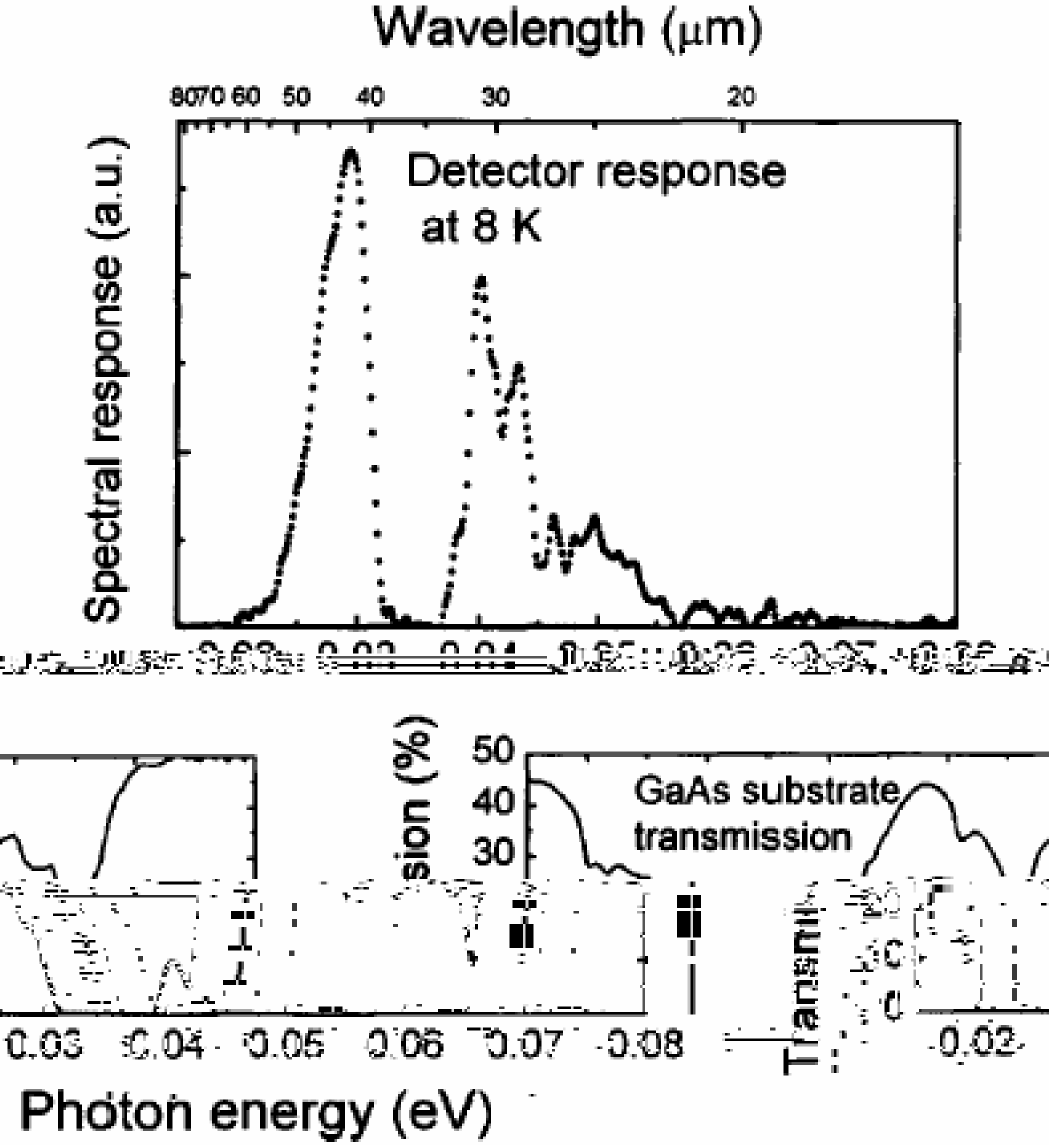
THz



J. C. Cao & X. L. Lei, Phys. Rev. B 67, 085309 (2003).

a
b

THz
THz



THzQWP

34 meV

THzQWP

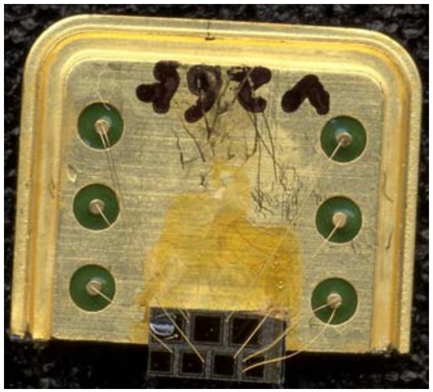
2-7 THz

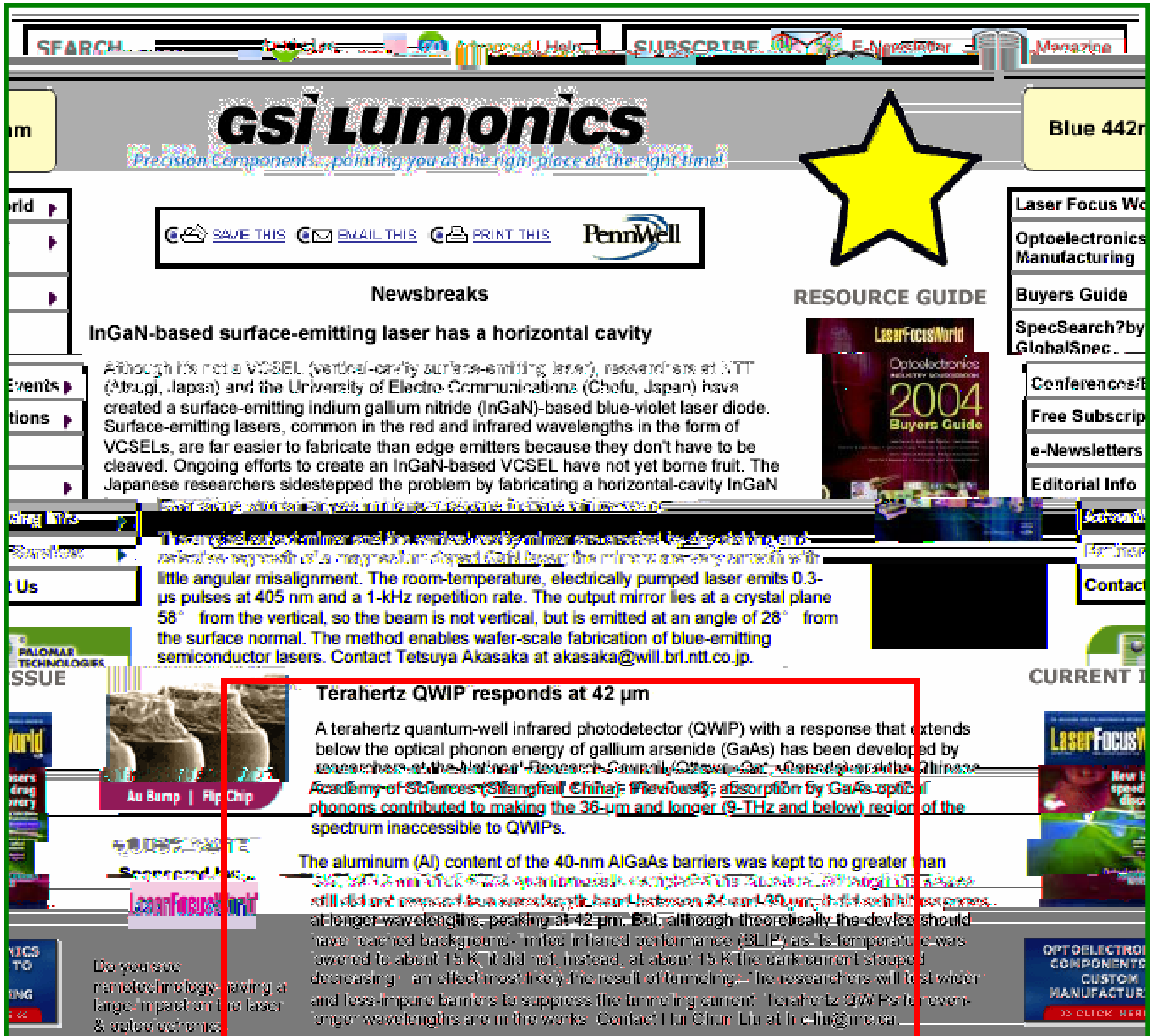
10^{-12}

Appl. Phys. Lett. 84, 4068 (2004).
Infrared Physics and Technology 47, 169 (2005).
IEEE J Sel Top Quant Elect 14, 374 (2008) (Invited paper)

2004 2-7 THzQWP

Laser Focus World





GSI Lumonics

Precision Components... pointing you at the right place at the right time!

SAVE THIS EMAIL THIS PRINT THIS PennWell

Newsbreaks

InGaN-based surface-emitting laser has a horizontal cavity

Although it's not a VCSEL (vertical-cavity surface-emitting laser), researchers at NTT (Atsugi, Japan) and the University of Electro-Communications (Chofu, Japan) have created a surface-emitting indium gallium nitride (InGaN)-based blue-violet laser diode. Surface-emitting lasers, common in the red and infrared wavelengths in the form of VCSELs, are far easier to fabricate than edge emitters because they don't have to be cleaved. Ongoing efforts to create an InGaN-based VCSEL have not yet borne fruit. The Japanese researchers sidestepped the problem by fabricating a horizontal-cavity InGaN ... little angular misalignment. The room-temperature, electrically pumped laser emits 0.3-µs pulses at 405 nm and a 1-kHz repetition rate. The output mirror lies at a crystal plane 58° from the vertical, so the beam is not vertical, but is emitted at an angle of 28° from the surface normal. The method enables wafer-scale fabrication of blue-emitting semiconductor lasers. Contact Tetsuya Akasaka at akasaka@will.brl.ntt.co.jp.

Terahertz QWIP responds at 42 µm

A terahertz quantum-well infrared photodetector (QWIP) with a response that extends below the optical phonon energy of gallium arsenide (GaAs) has been developed by researchers at the National Research Council (Ottawa, Ont., Canada) and the Chinese Academy of Sciences (Shanghai, China). Previously, absorption by GaAs optical phonons contributed to making the 36-µm and longer (9-THz and below) region of the spectrum inaccessible to QWIPs.

The aluminum (Al) content of the 40-nm AlGaAs barriers was kept to no greater than ... at longer wavelengths, peaking at 42 µm. But, although theoretically the device should have reached background-limited infrared performance (BLIP) as its temperature was lowered to about 15 K, it did not. Instead, at about 15 K the dark current stopped decreasing — an effect most likely the result of tunneling. The researchers will test wider and less-impure barriers to suppress the tunneling current. Terahertz QWIPs for even-longer wavelengths are in the works. Contact Hui Chun Liu at h.c.liu@nrc.ca.

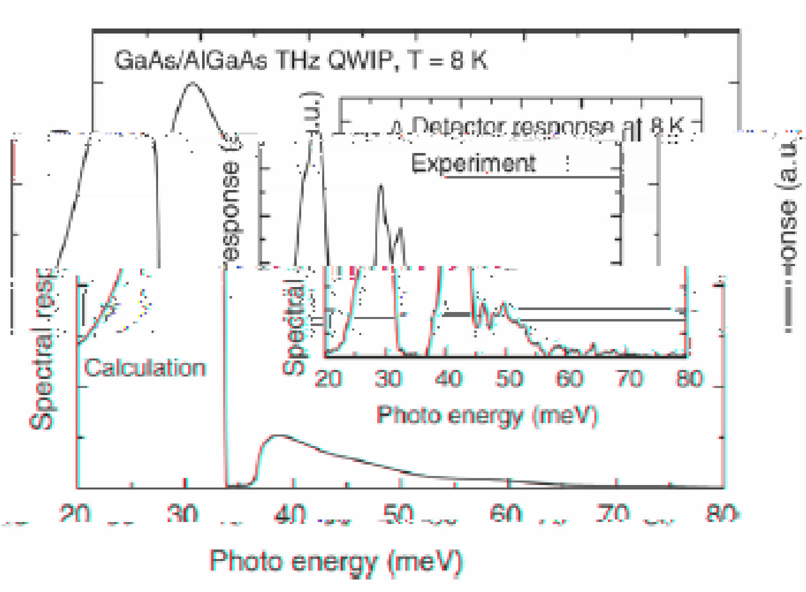
RESOURCE GUIDE

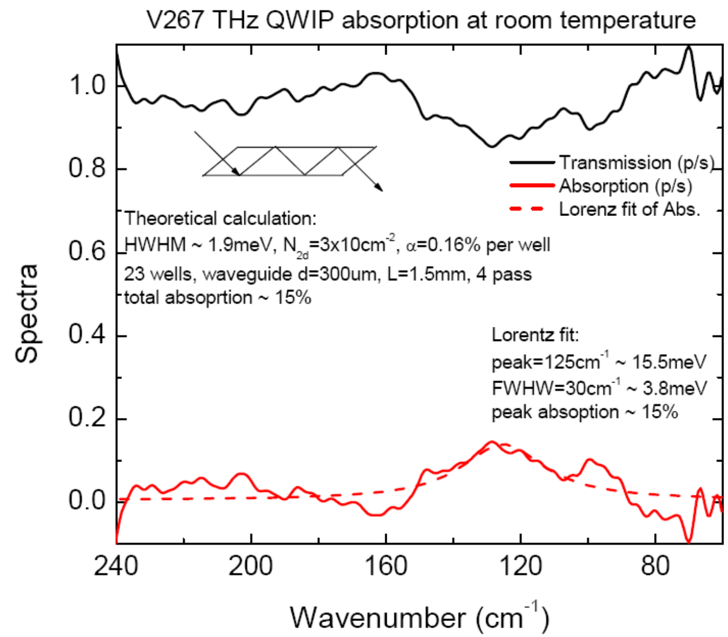
Laser Focus World
Optoelectronics Manufacturing
Buyers Guide
Conferences
Free Subscrip
e-Newsletters
Editorial Info
Contact
CURRENT ISSUE

Au Bump | Flip Chip

Do you see nanotechnology having a large impact on the laser & optoelectronics

THz





GaAs **THzQWP**

GaAs

THzQWP

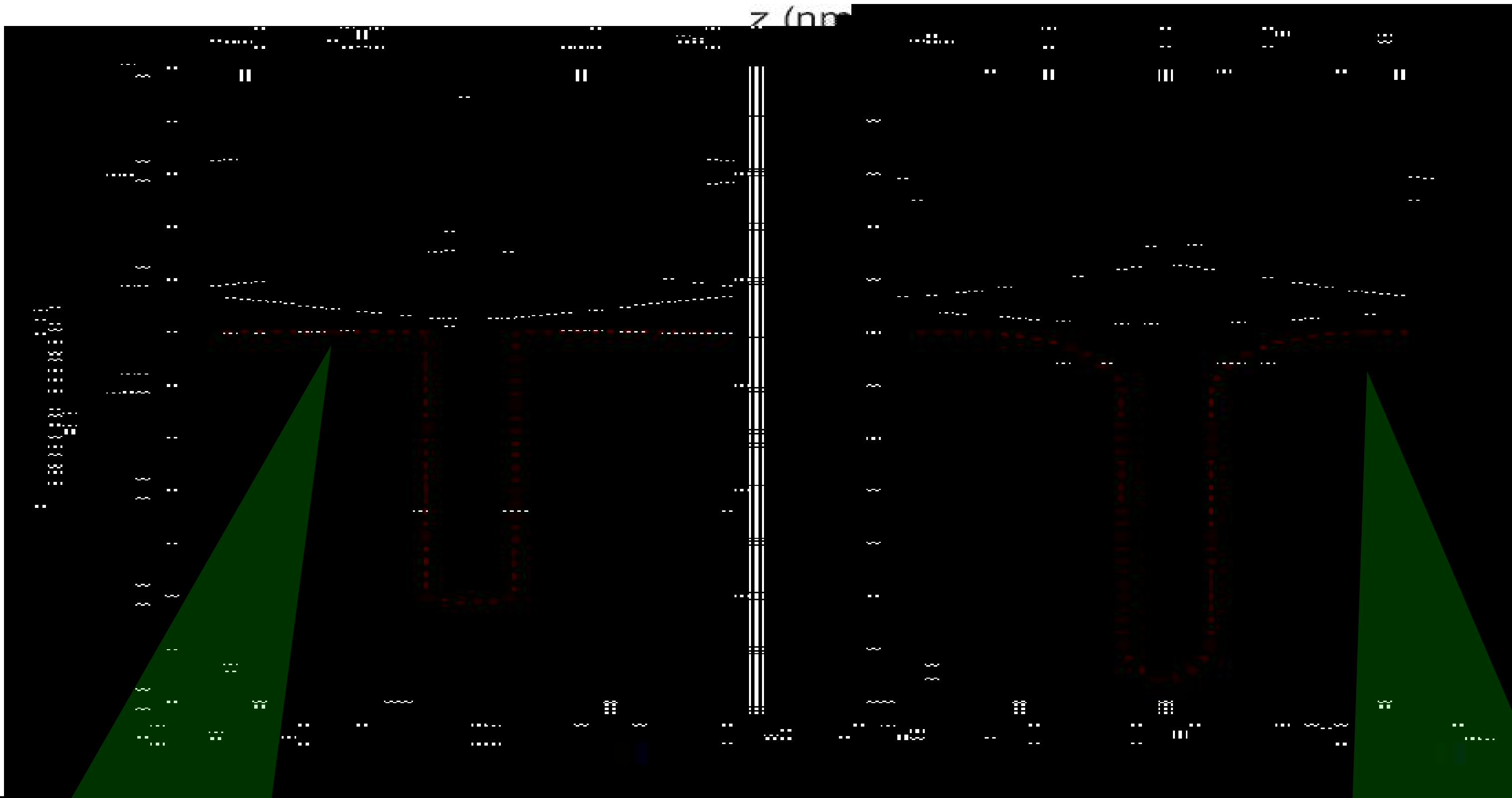
34 36meV

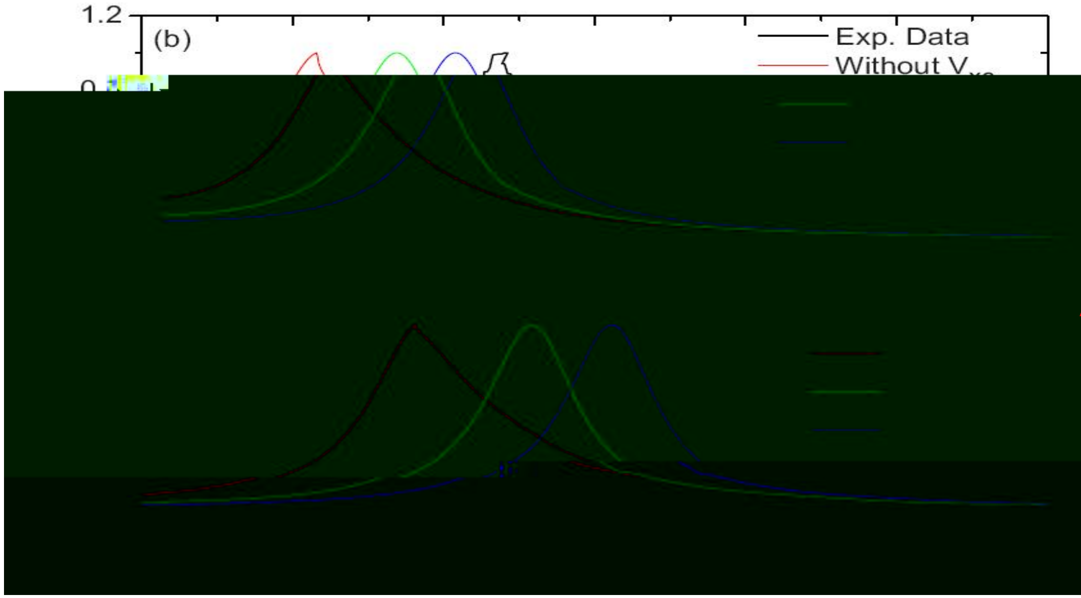
Superlattices and Microstructures 40, 119 (2006).
Infrared Physics & Technology 50, 191 (2007).

THzQWP

Appl. Phys. Lett. 94, 201101 (2009)

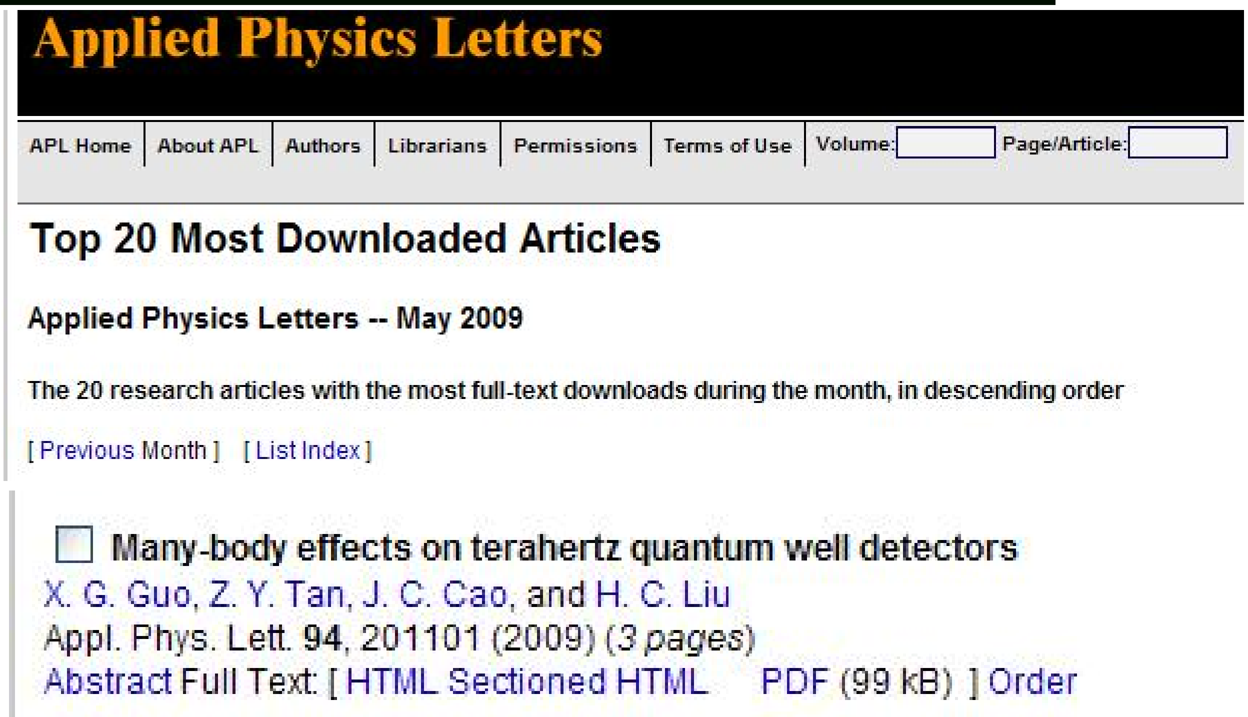
Hartree **30%**





30% → 5%

Appl. Phys. Lett. 94, 201101 (2009)



Applied Physics Letters

APL Home | About APL | Authors | Librarians | Permissions | Terms of Use | Volume: | Page/Article:

Top 20 Most Downloaded Articles

Applied Physics Letters -- May 2009

The 20 research articles with the most full-text downloads during the month, in descending order

[Previous Month] [List Index]

Many-body effects on terahertz quantum well detectors
X. G. Guo, Z. Y. Tan, J. C. Cao, and H. C. Liu
Appl. Phys. Lett. 94, 201101 (2009) (*3 pages*)
Abstract Full Text: [HTML Sectioned HTML PDF (99 kB)] Order

APL(May 2009)

20

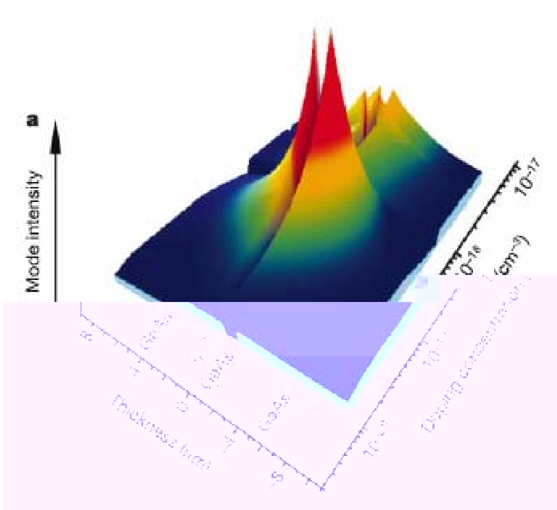
THz

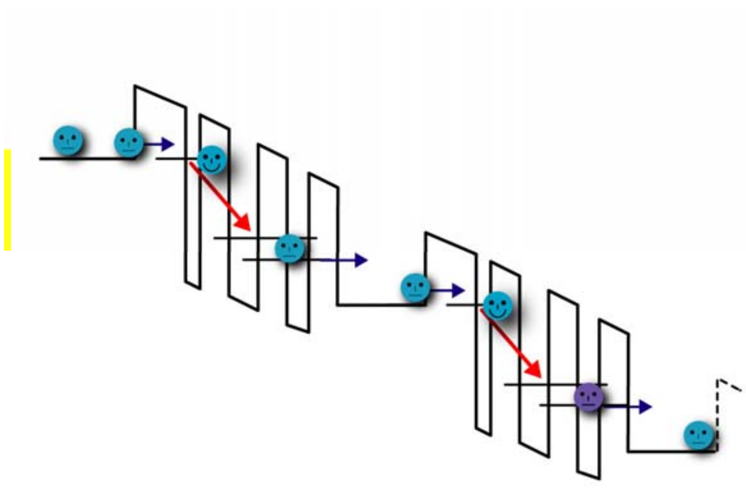
THz

THz

THz

10 THz (2002)





THz

Kohler et al, NATURE 417, 156 (2002)

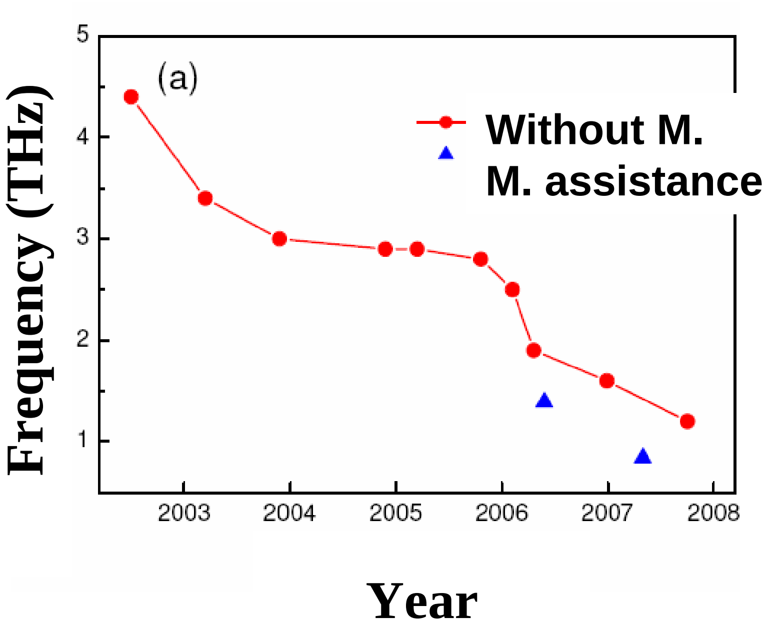
THzQCL

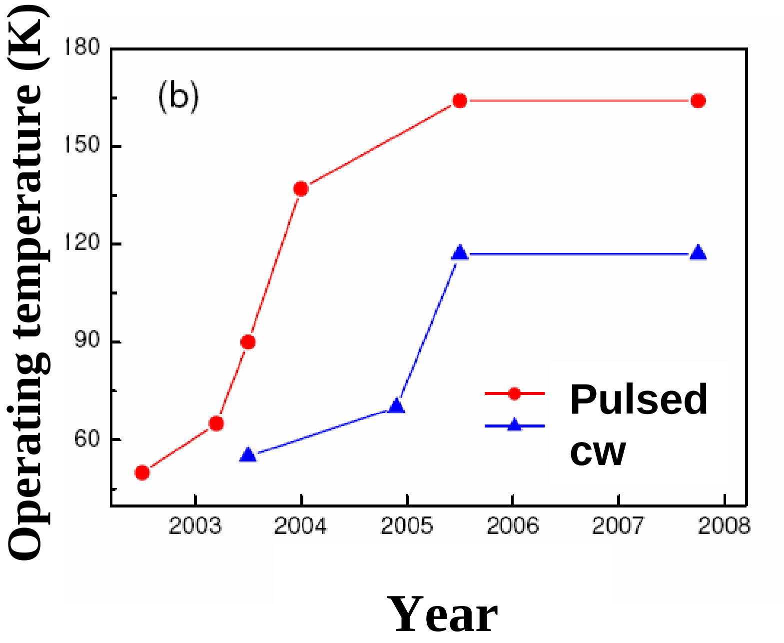
- THzQCL MC
  THzQCL
  - Phys. Rev. Lett. 90, 077402 (2003)
  - Appl. Phys. Lett. 88, 061119 (2006)
  - J. Appl. Phys. 104, 043101 (2008)
- THzQCL
  - Appl. Phys. Lett. 90, 041112 (2007)
  - Appl. Phys. Lett. 92 221105 (2008)
  - J. Appl. Phys. 103, 103113 (2008)
- THzQCL
  - Semicond. Sci. Technol. 23, 125040 (2008)
  - Semicond. Sci. Technol. 24, 065012 (2009)
  - J. Phys. D: Appl. Phys. 42, 025101 (2009)

Roadmap of THzQCL

- ✓ **The first THzQCL - Köhler *et.al*, Nature 2002 (Pisa, Italy)**
  - ***Chirped-superlattice***
  - ***Semi-insulating surface plasmon waveguide***
  - ***Lasing at 4.4 THz***
  - ***Maximum operating temperature of 50 K***
- ✓ **J. Faist, APL 2002**
- ✓ **Q. Hu, APL 2003**
- ✓ **H. C. Liu, NRC, APL 87, 141102 (2005)**
- ✓ **J. C. Cao’s Group, SIMIT, Shanghai, 2007**

Progress of THzQCL





Up to date, the best device performances are:

- **maximum operating temperature**
  186 K (pulsed); 117 K (cw)
- **highest output power**
  250 mW
- **lowest lasing frequency**
  1.2 THz

THzQCL MC

Monte Carlo Method

- Used to solve mathematical problems by random-number technology
- Using random numbers in an essential way to simulate scattering processes
- The differential-integral equations usually include high-order numerical integrations

MC solution of Boltzmann equation

The semi-classical BE for transport of Bloch electrons:

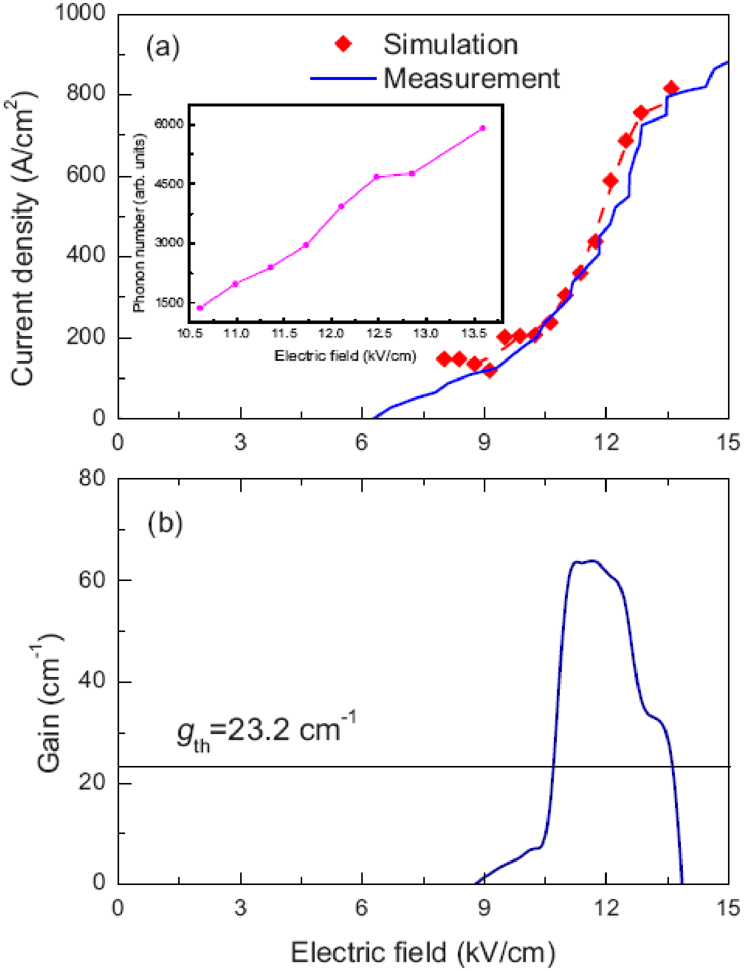
$$\frac{f(r,k,t)}{t} = -\frac{1}{\hbar}\nabla_k E(k)\cdot\nabla_r f - \frac{F}{\hbar}\cdot\nabla_k f + \frac{f}{t}\Big|_{coll},$$

Where $\frac{f}{t}\Big|_{coll}$ can be replaced by collision integral:

$$\frac{f}{t}\Big|_{coll} = \frac{V}{8\pi^3}\int dk\{f(r,k',t)(1-f(r,k,t))\ {}_{k'k} - f(r,k,t)(1-f(r,k',t))\ {}_{kk'}\}.$$

I-V

Appl. Phys. Lett., 89, 211115 (2006)
J. Appl. Phys. 103, 103113 (2008)
J. Appl. Phys. 104, 043101 (2008)
Appl. Phys. Lettt. 92, 221105 (2008)



THzQCL

- - -

LO

I-V

11kV/cm

12V 66cm^{-1}

4.1THz

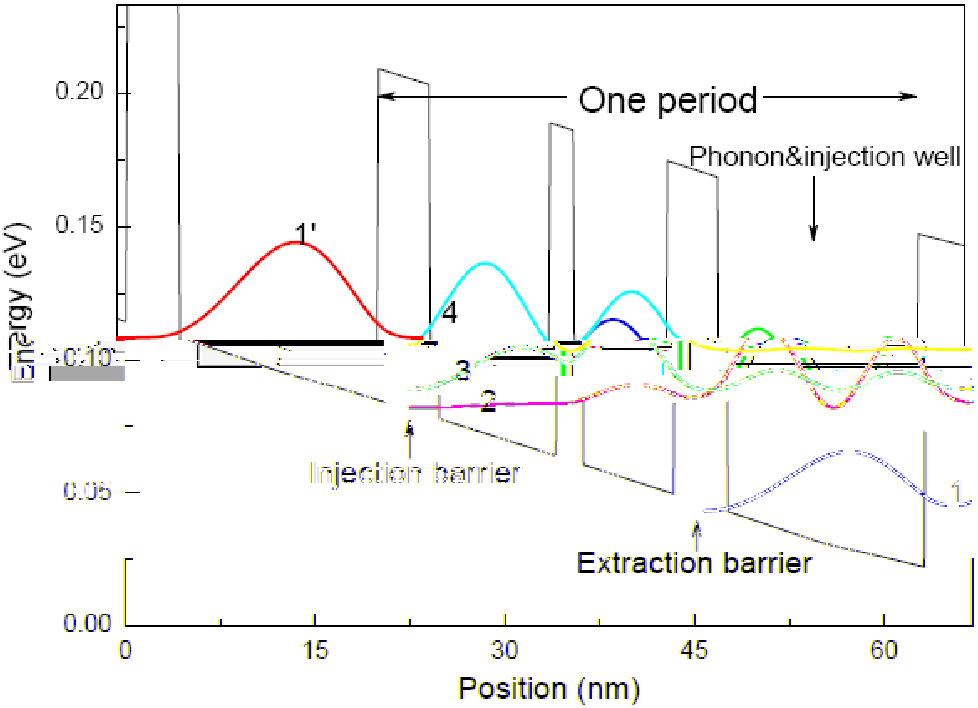
10.2-13 V

10.9-13.3 V

THzQCL

Appl. Phys. Lett. 92, 221105 (2008).
Semicond. Sci. Technol. 23, 125040 (2008)
Semicond. Sci. Technol. 24, 065012 (2009)

DUT: Three-well resonant-phonon THz QCL
We have simulated the effects of three parameters, i.e., doping concentration, injection and extraction barrier width, and phonon extraction level separation on the device performance.



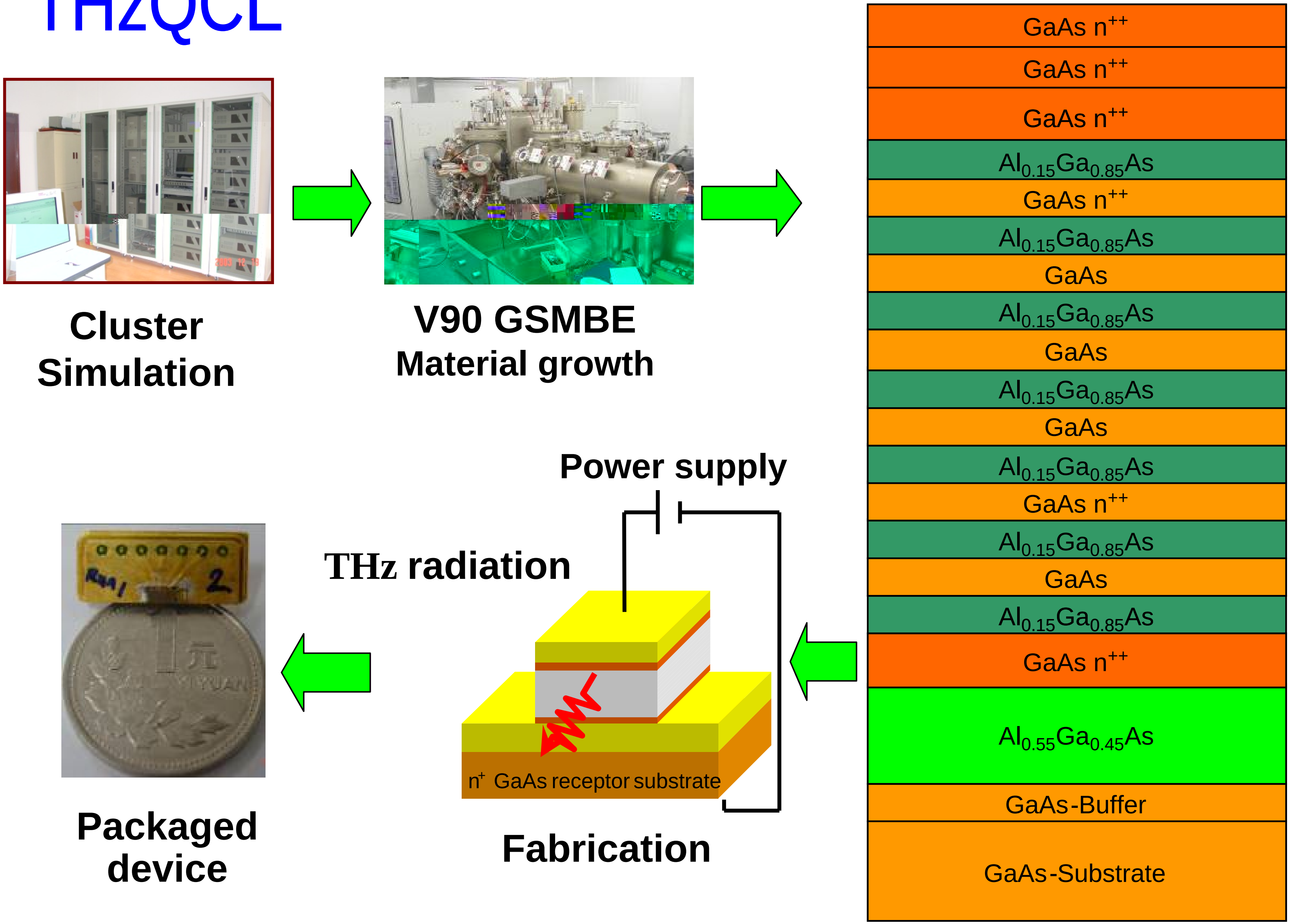
Designed bias: 14.4 kV/cm
Lasing transition occur from level 4 to 3, and levels 3 (2) to 1 are for LO-phonon depopulation

Optimizing process:
Injection barrier width
→extraction barrier width
→doping concentration

THzQCL

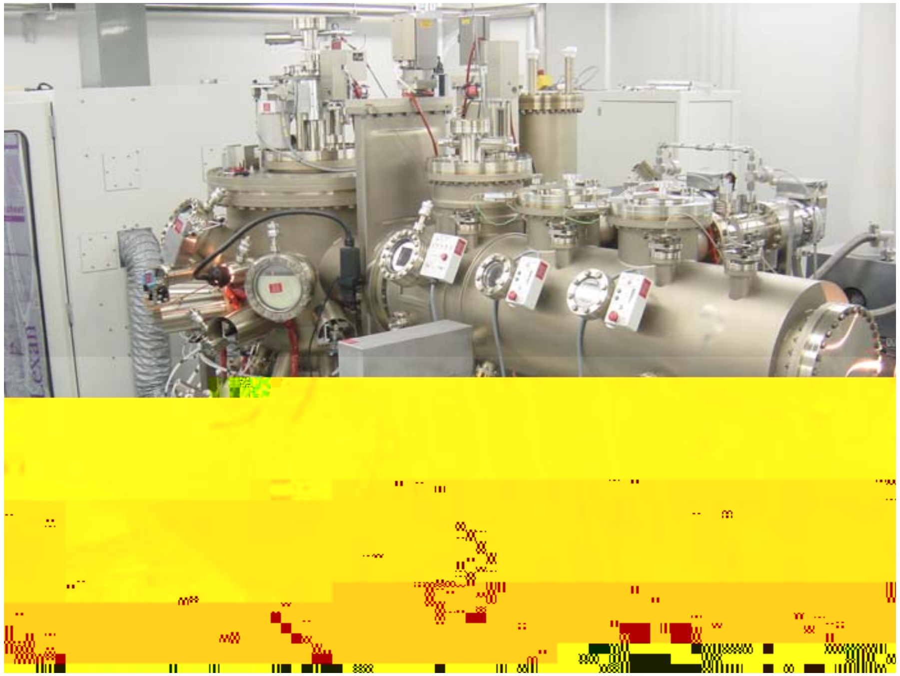
THzQCL

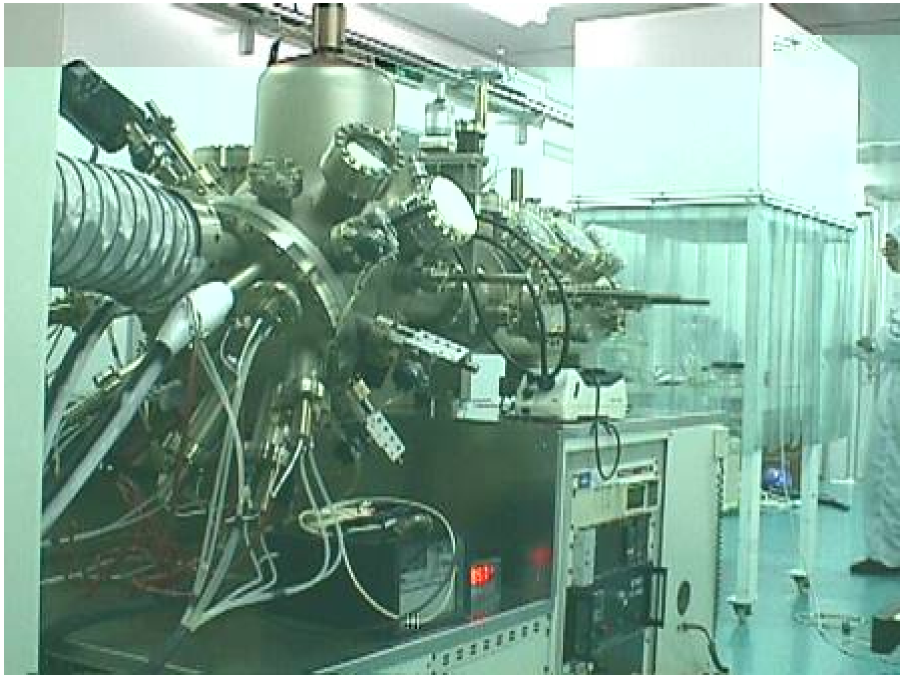
THzQCL



Cluster Simulation
V90 GSMBE
Material growth
$GaAs\ n^{++}$
$GaAs\ n^{++}$
$GaAs\ n^{++}$
$Al_{0.15}Ga_{0.85}As$
$GaAs\ n^{++}$
$Al_{0.15}Ga_{0.85}As$
GaAs
$Al_{0.15}Ga_{0.85}As$
GaAs
$Al_{0.15}Ga_{0.85}As$
GaAs
$Al_{0.15}Ga_{0.85}As$
$GaAs\ n^{++}$
$Al_{0.15}Ga_{0.85}As$
GaAs
$Al_{0.15}Ga_{0.85}As$
$GaAs\ n^{++}$
$Al_{0.55}Ga_{0.45}As$
GaAs-Buffer
GaAs-Substrate
Power supply
THz radiation
n^{+} GaAs receptor substrate
Fabrication
Packaged device

THz





GSMBE)

V90 GSMBE

V80 GSMBE

THz

FTIR Spectroscopy

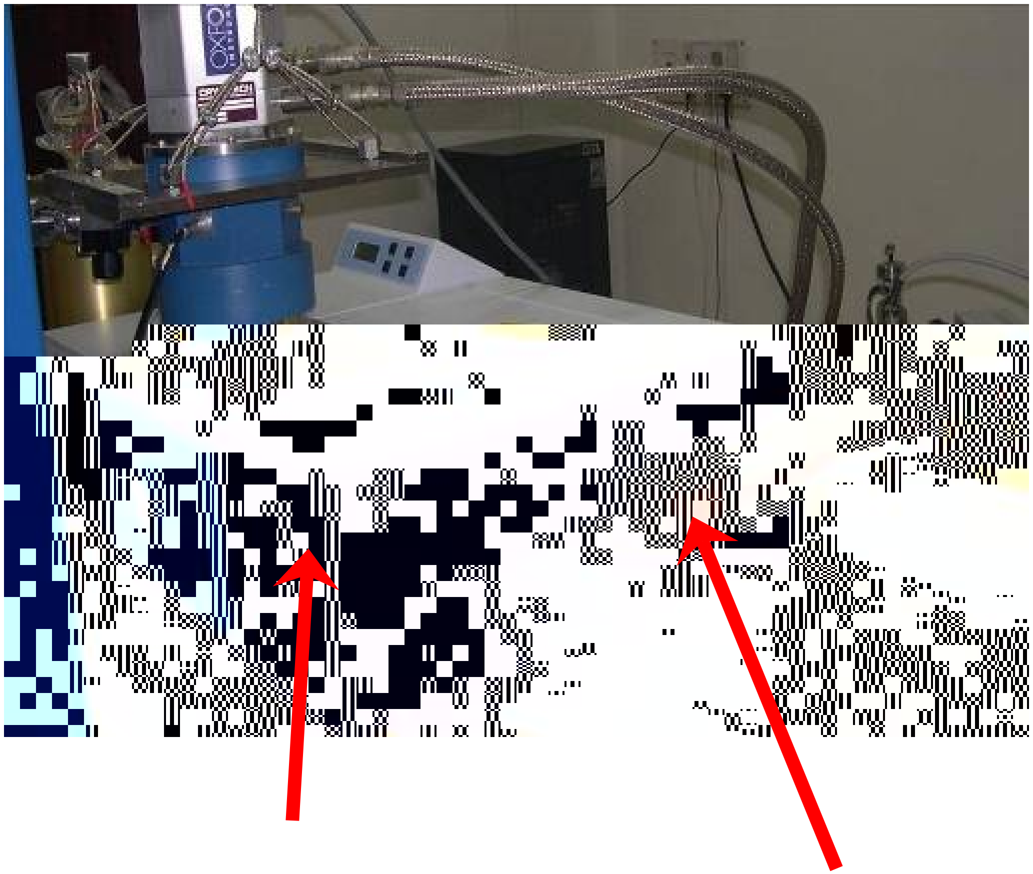
UV-Vis Spectroscopy

X-ray Diffraction

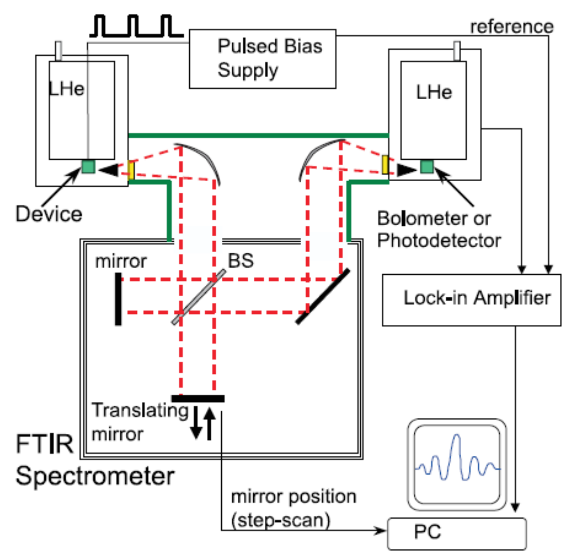
ECV, PVS & Hall

I-V, I-P & C-V

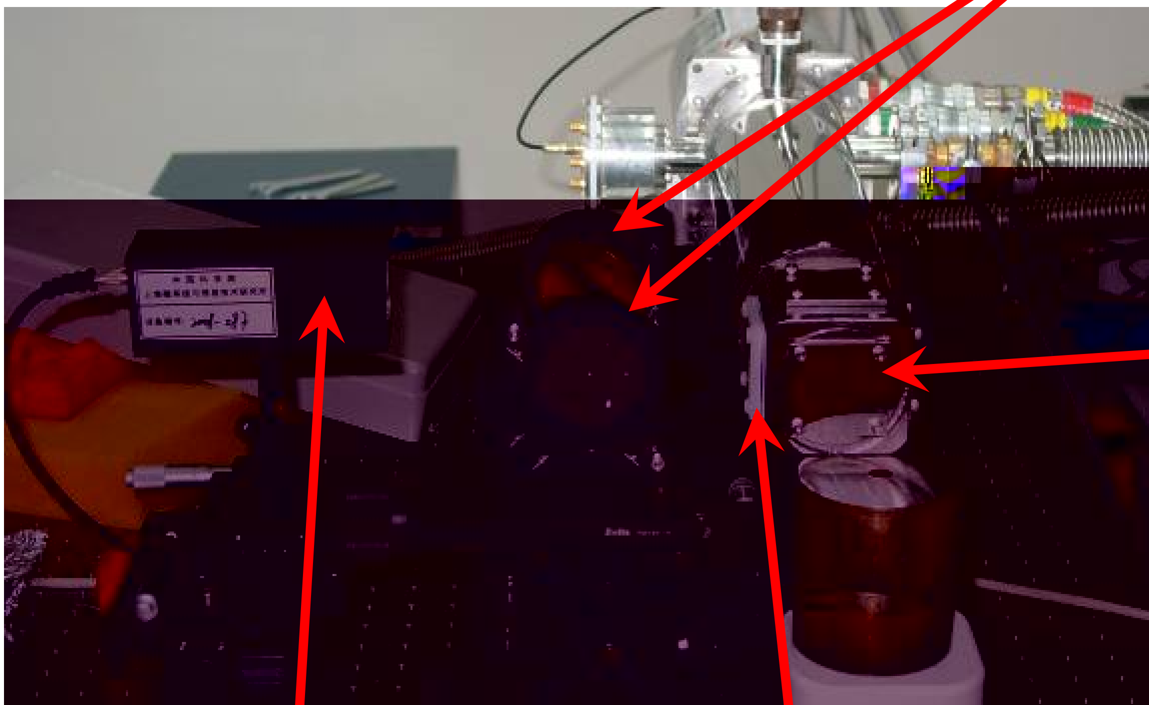
THz

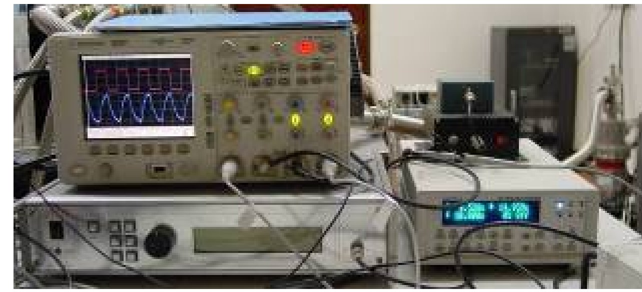


DTGS THzQCL

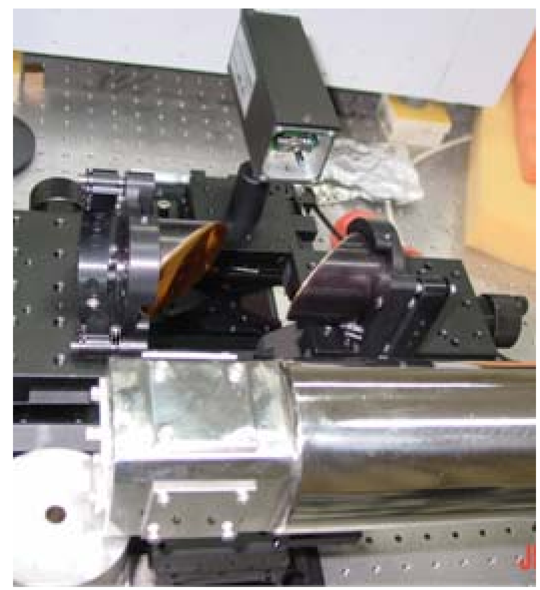


THz

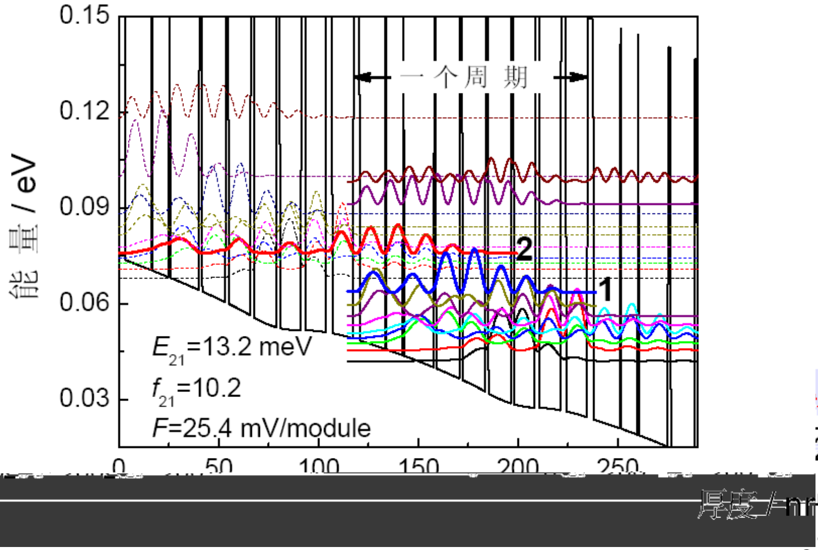


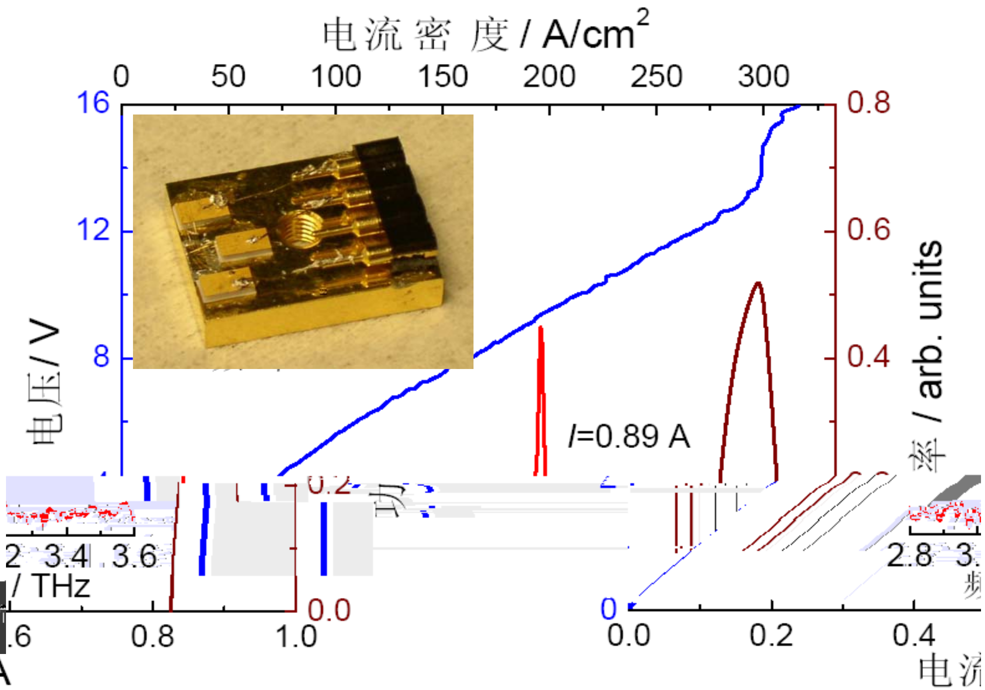


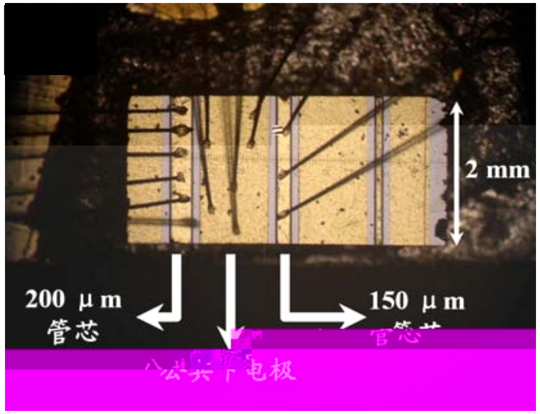
THzQCL



3.2 THz QCL







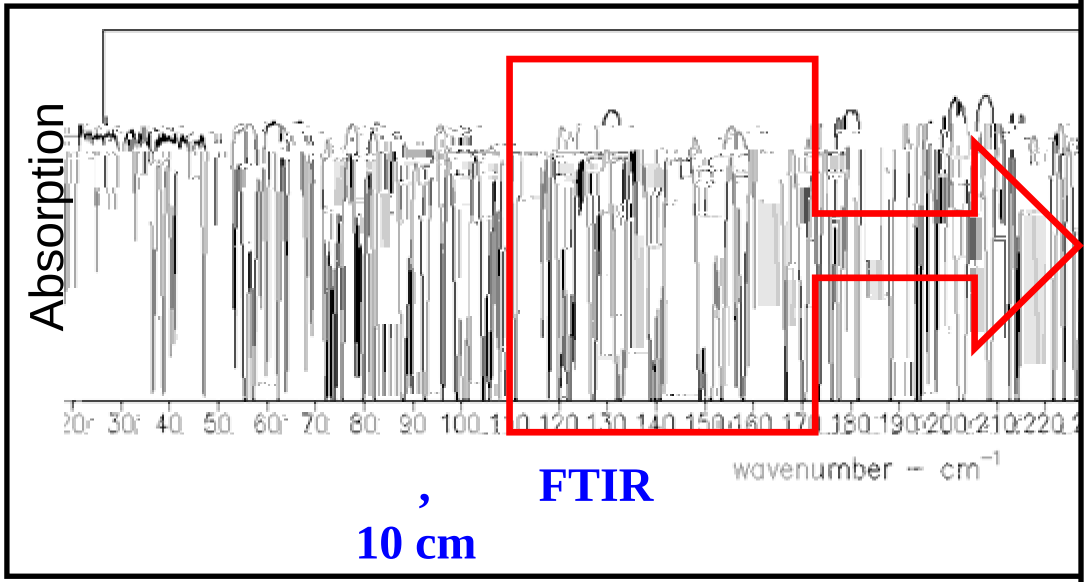
Lasing at 3.2 THz in pulsed mode

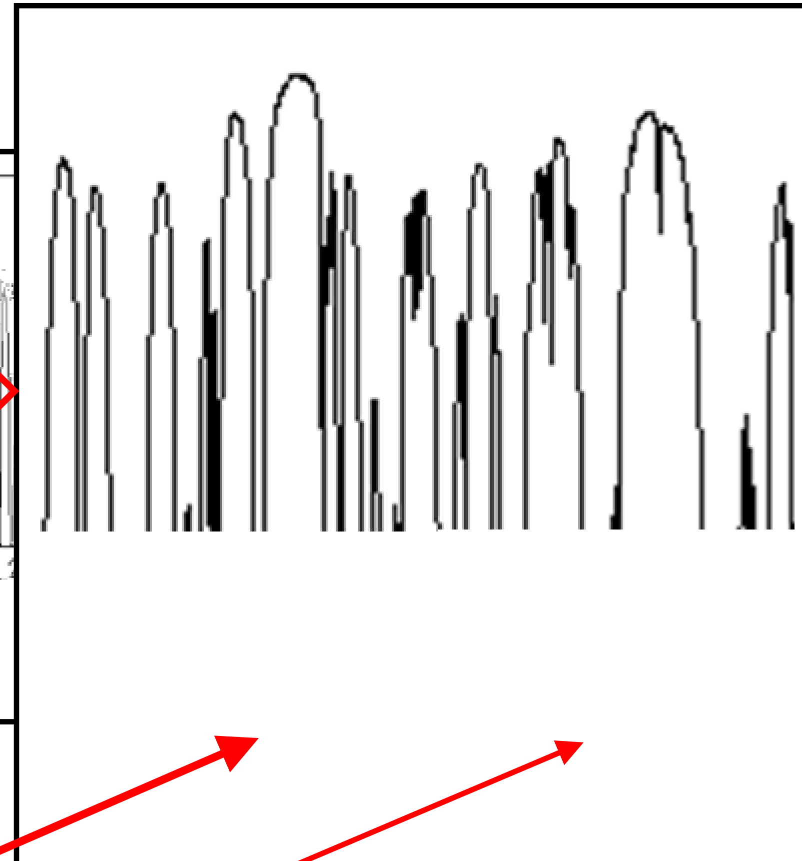
Pulse width: 3 μs, repetition rate: 1 kHz;

Measured at 10 K

Device size: 150 μm × 2 mm

THz





2007

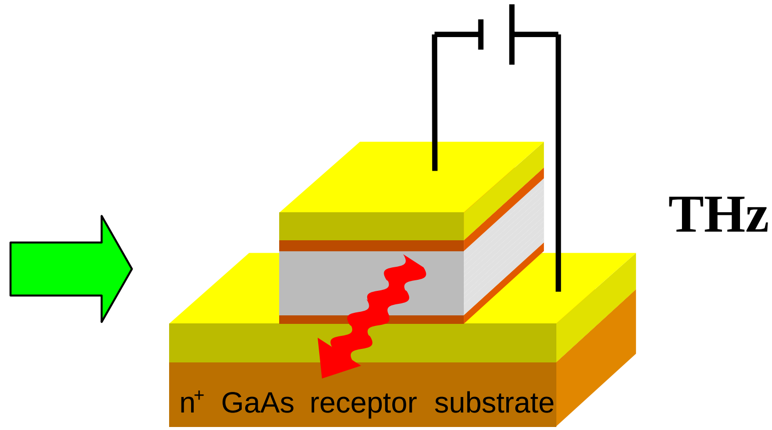
3.39 THz (113 cm^{-1})

4.1 THz (138 cm^{-1})

2008 THz

4.1THzQCL

THzQCL



- ~100K (p), 40K (cw)
- ~10mW
- 4.1 THz
-
- 5-12 W

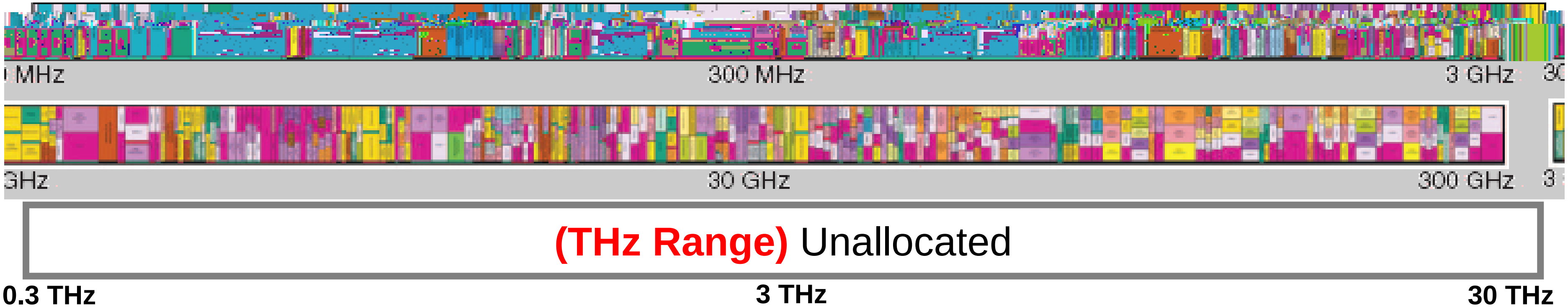
GaN NEM T

THz

THz

THz

THz—



THz

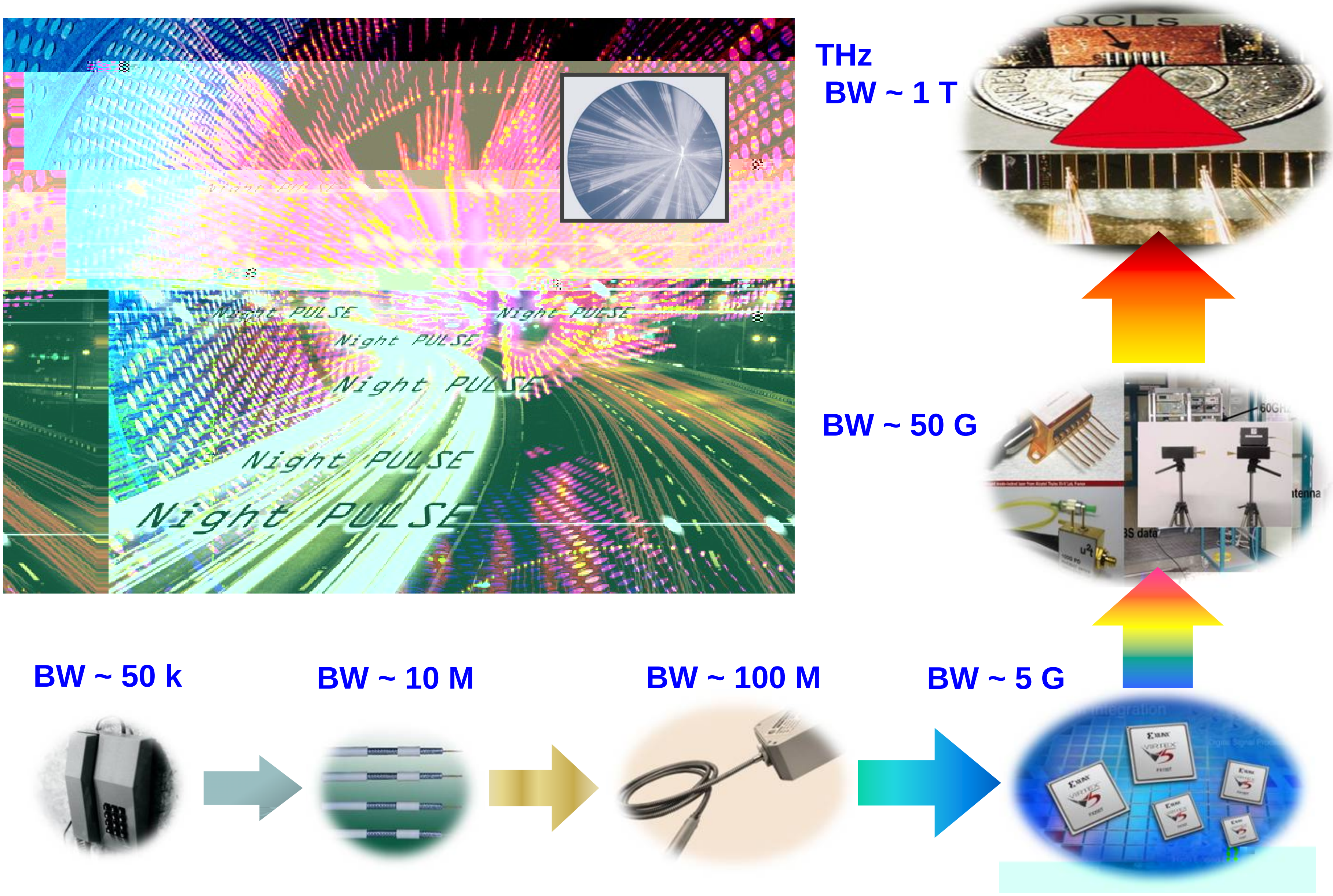
•

- IEEE 802.11g, **54 Mbps**, 2400-2483.5 MHz
- IEEE 802.11a, **54 Mbps**, 5150-5350 MHz, 5470-5725 MHz, 5725-5825 MHz
- **IEEE 802.11n, 100 Mbps, optional bis zu 600 Mbps**, Freq. like 802.11a
- **WIGWAM Project, up to 1 Gbps**, 5, 17, 24, 60 GHz, MIMO

• WPAN (Wireless Personal Area Networks)
- **Bluetooth**, IEEE 802.15.1a, **1 Mbps**, 2400-2483.5 MHz
- High-rate WPANs, **IEEE 802.15.3a**, realized **500 Mbps**, planned **1.3 Gbps @ several meters**, **UWB based**, 3.1-10.6 GHz
- High data rate WPANs, **IEEE 802.15.3c**, planned **2 Gbps @ several meters**, mm-Wave, **60 GHz band** **(57-64 GHz)**

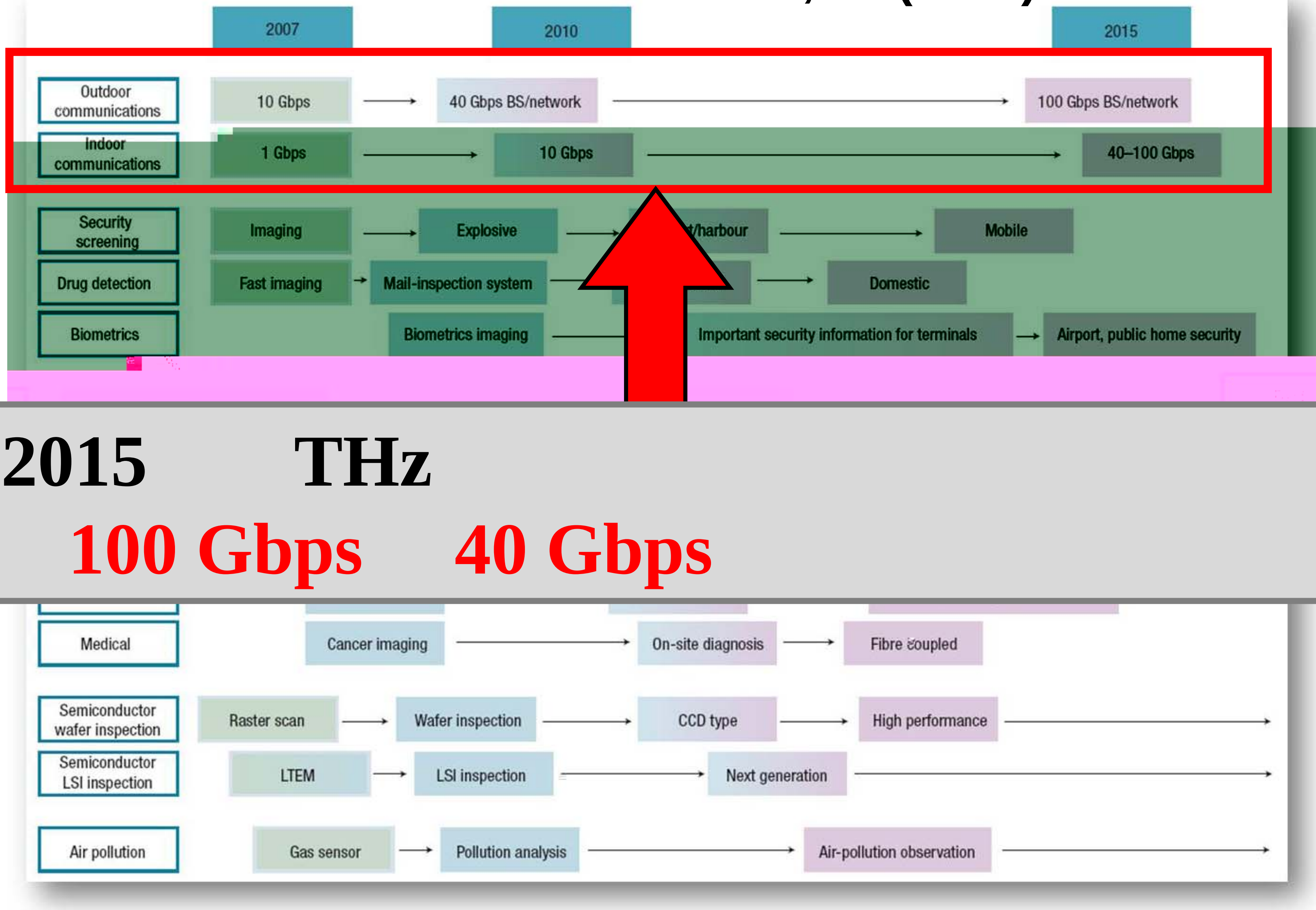
THz

THz —



THz

Nature Photon. Vol. 1, 97 (2007)

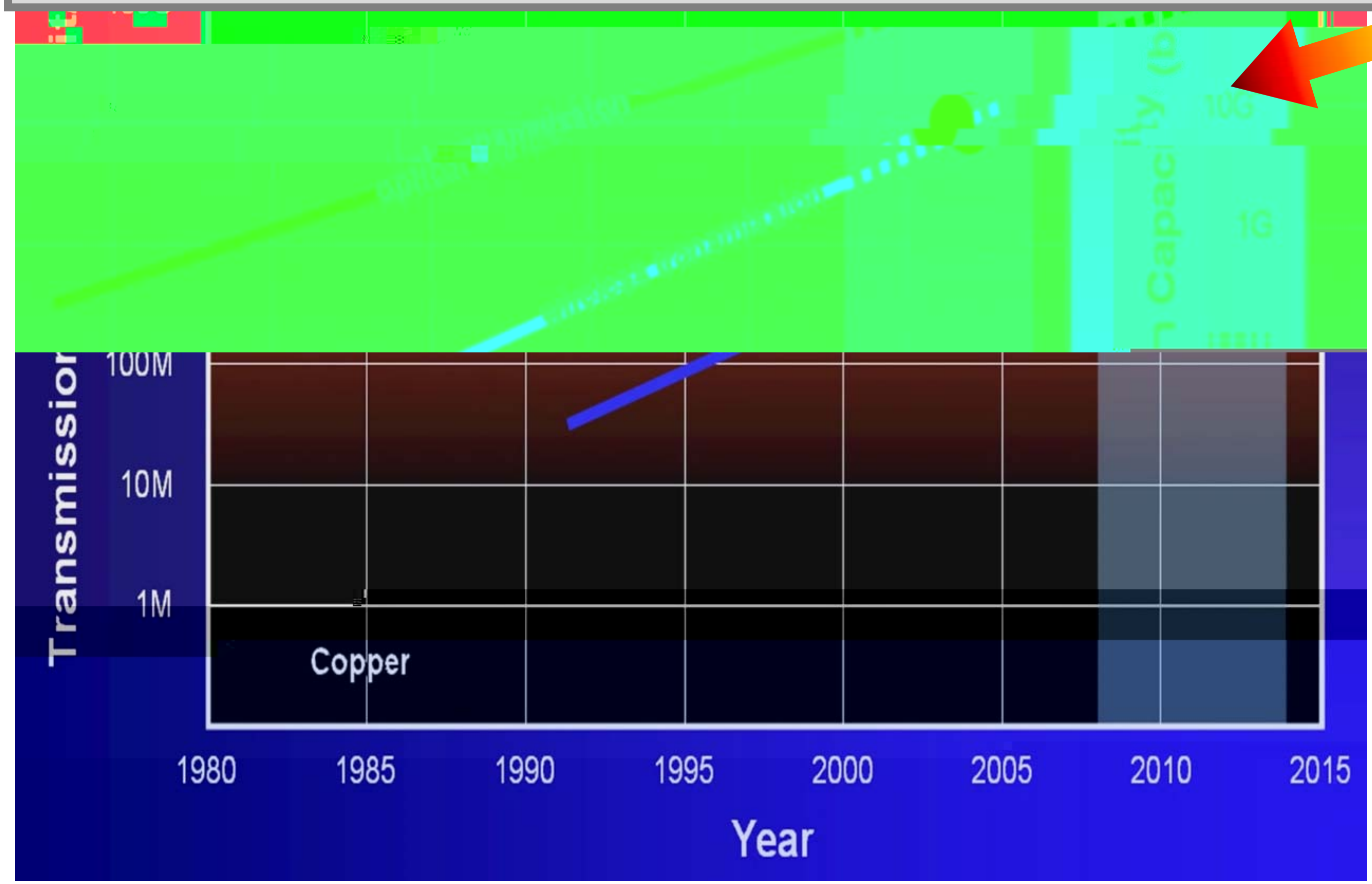


2015 THz

100 Gbps 40 Gbps

IPHOBAC

(Gbps)
THz THz



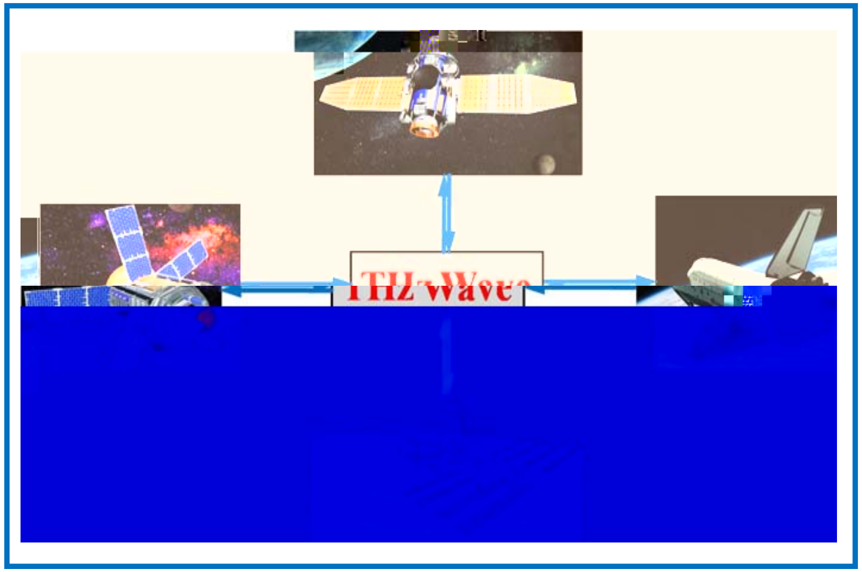
2012 ,

10 Gbps

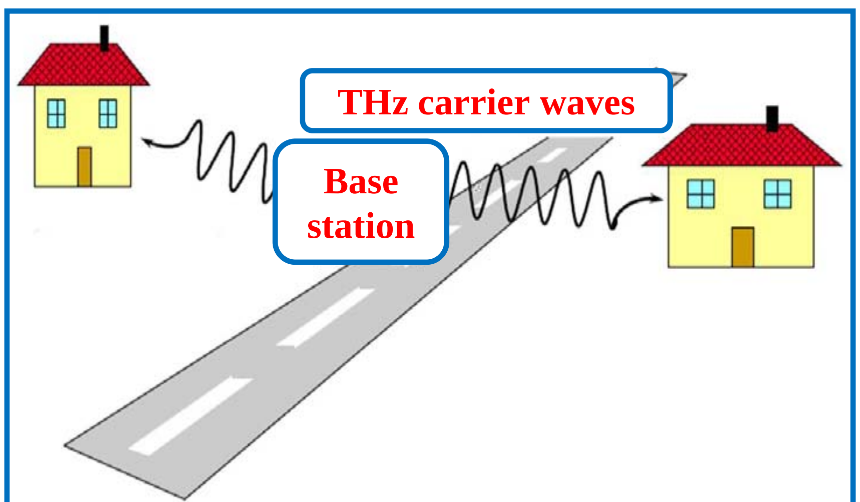
IPHOBAC
2006 (
)

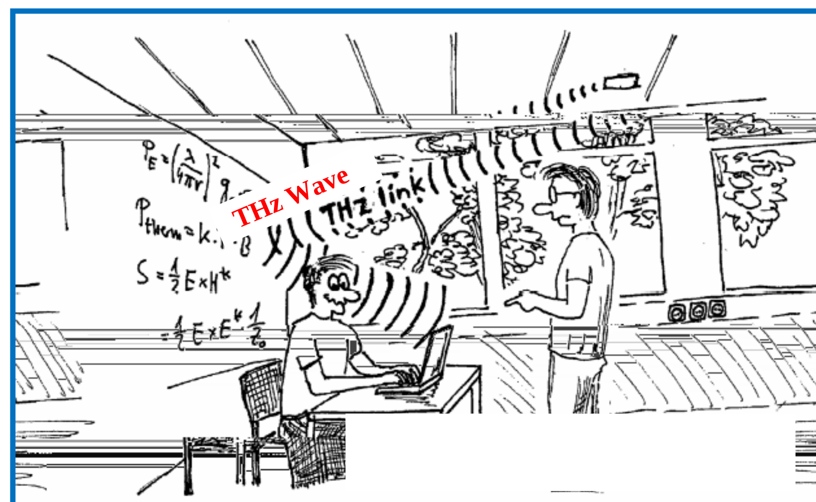
30
GHz
(mmWP)
6
11

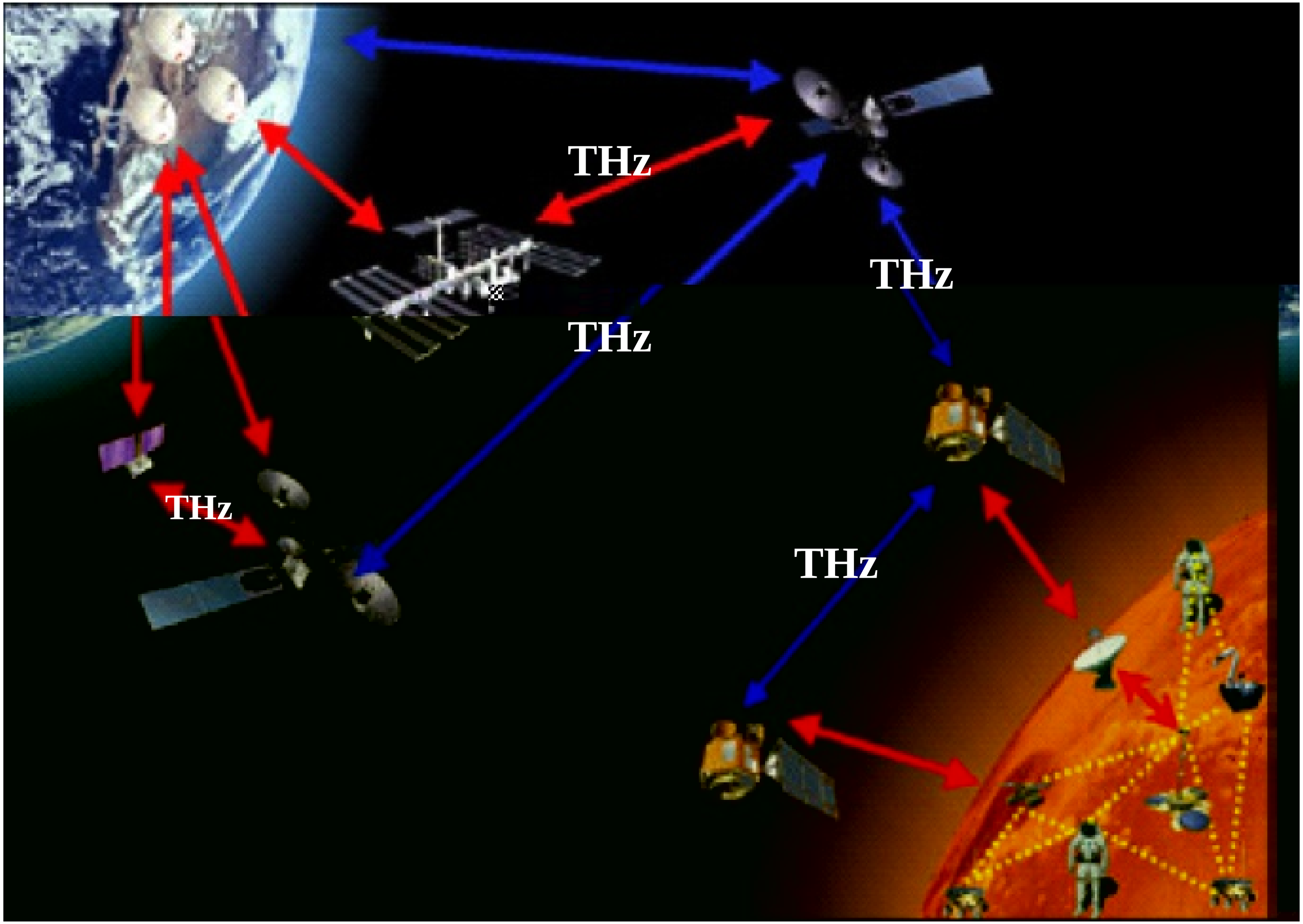
THz

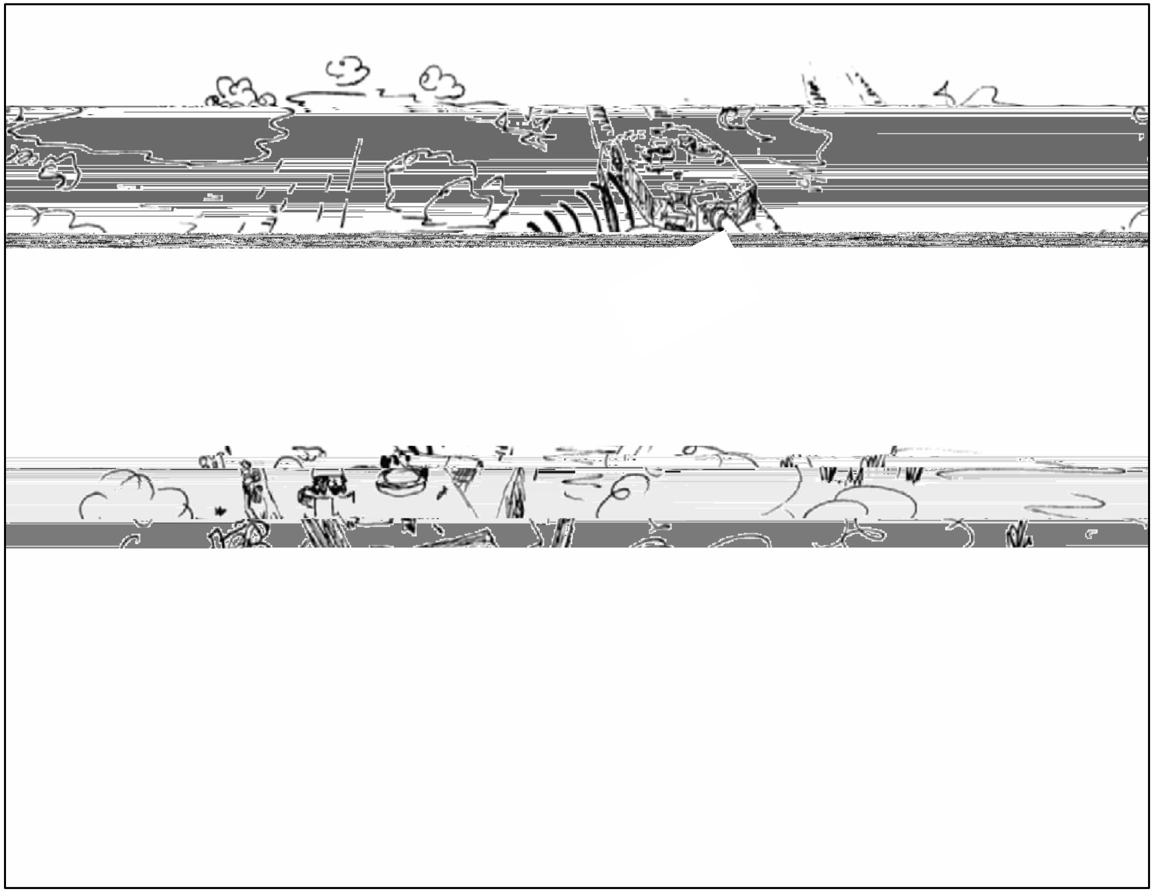

THz Wave


THz


THz carrier waves
Base station


THz Wave
THz link


THz
THz
THz
THz
THz

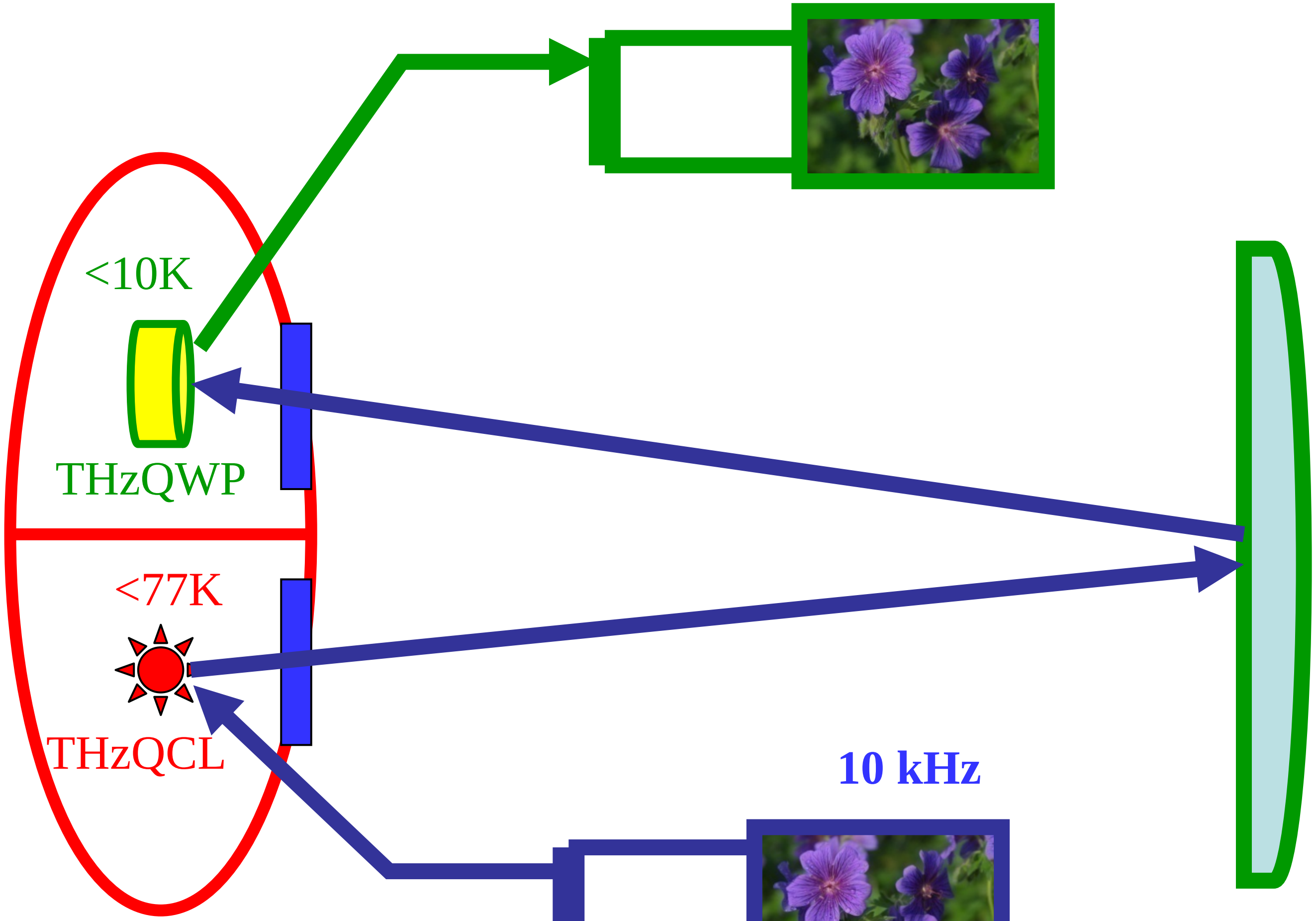


THz

THz

THz

THz



THz — (2008)

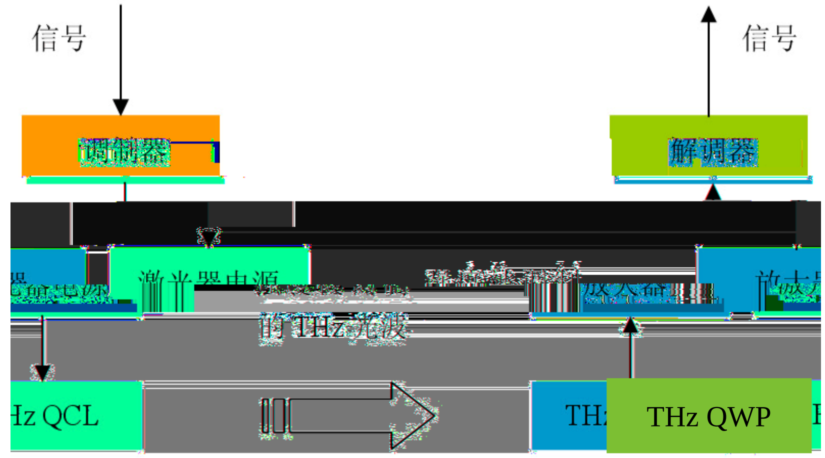
- THzQCL

  QCL

- QCL

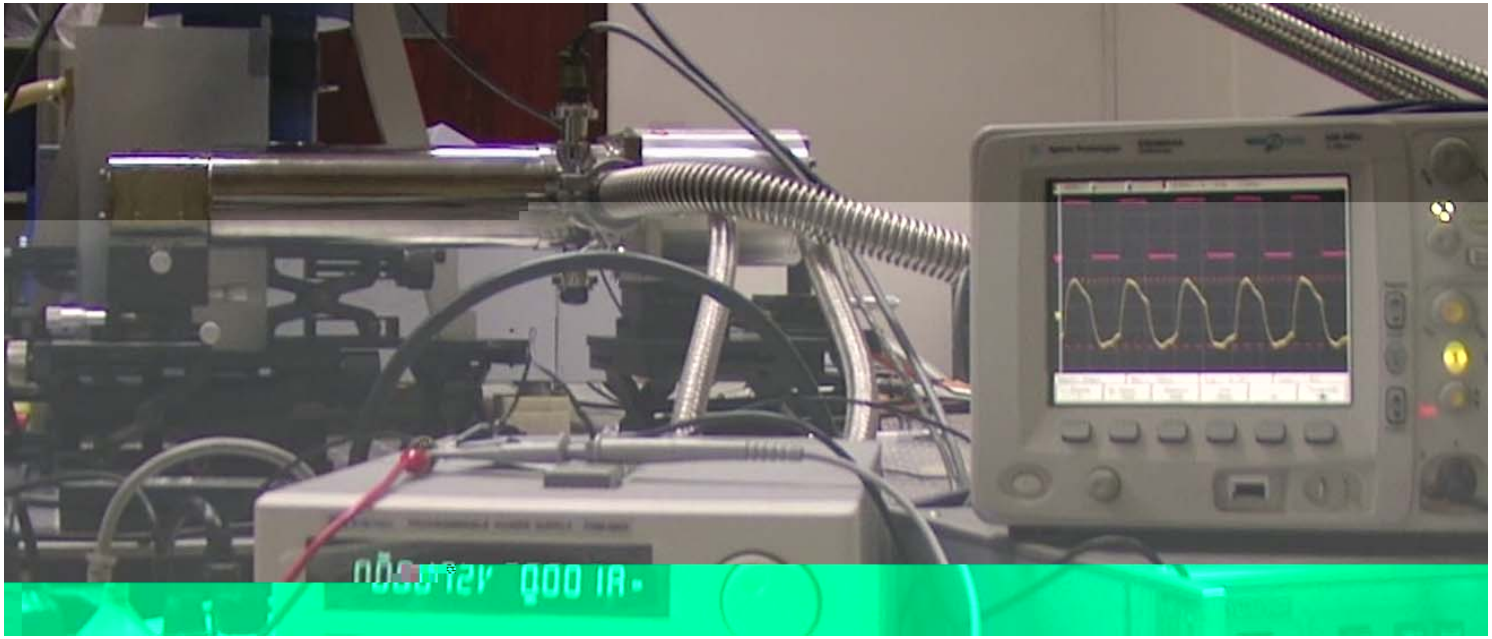
  THz

- 4.1 THz



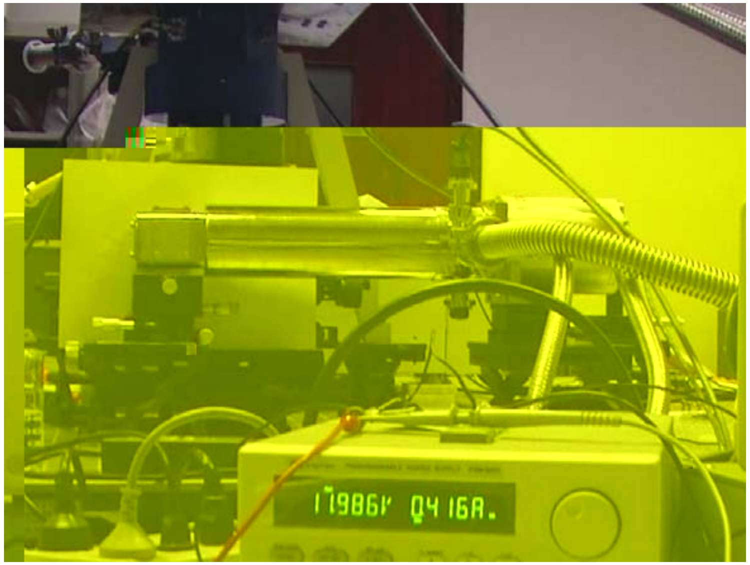
THz通信演示系统2008
(中科院上海微系统所)

双层聚乙烯板遮挡



双层聚乙烯板夹水层后遮挡

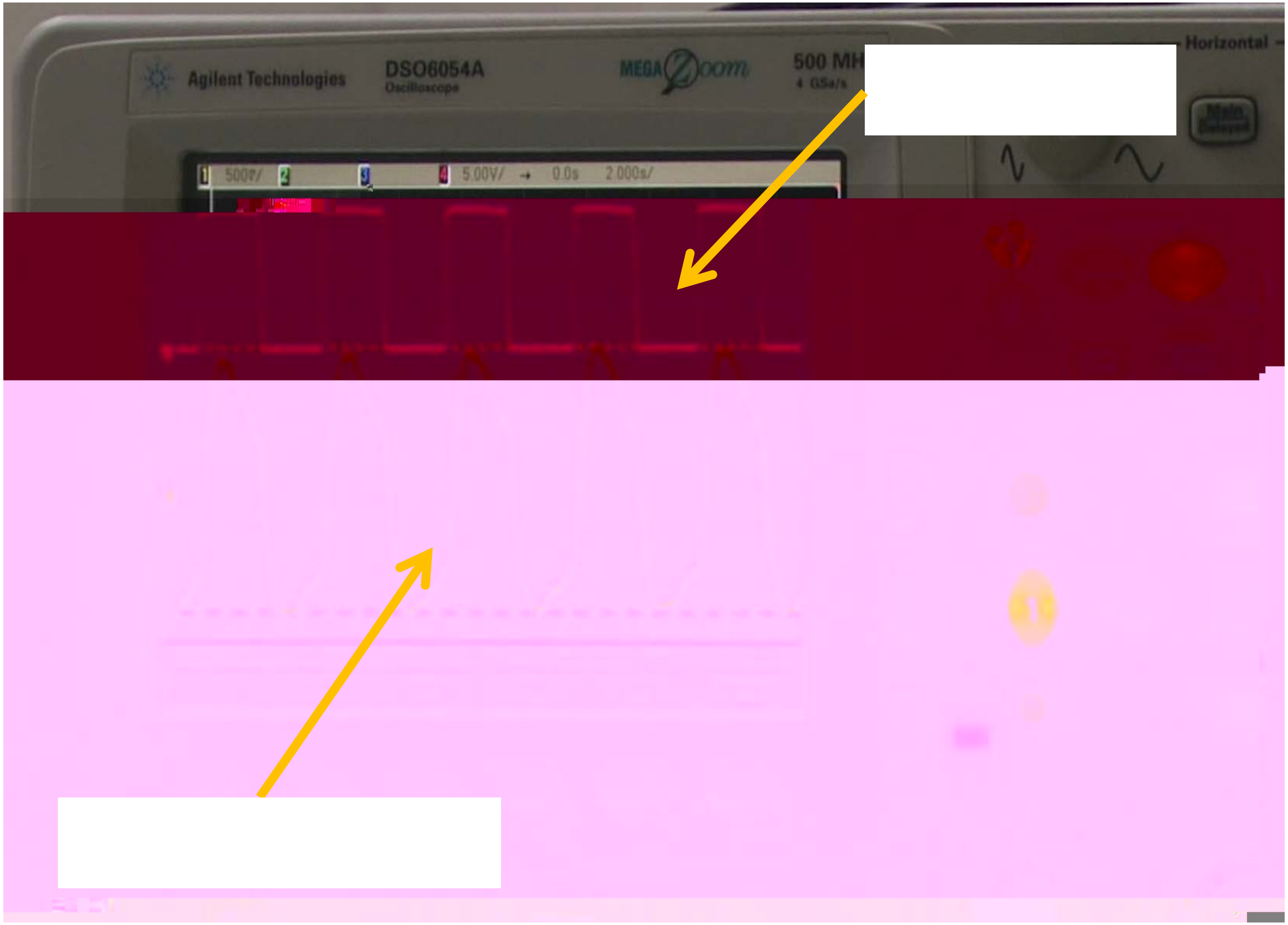
A4纸遮挡



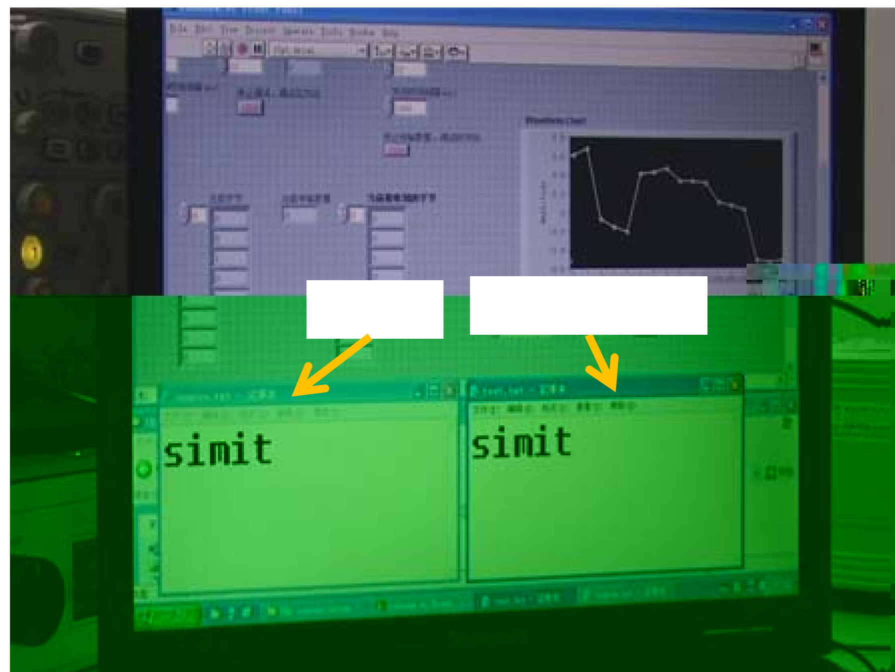
5.00V/
0.0s
2.000s/
Max(1): 260mV
Min(1): -360mV
Avg(1): -80.2mV
Ampl(1): 620mV
Source 1
Select: Ampl
Measure Ampl
Clear Meas
Settings
Thresholds

手遮挡

THzQWP


Agilent Technologies
DSO6054A
Oscilloscope
MEGA Zoom
500 MHz
4 GSa/s
Horizontal
500?/
5.00V/
0.0s
2.000s/

THzQWP **THz**

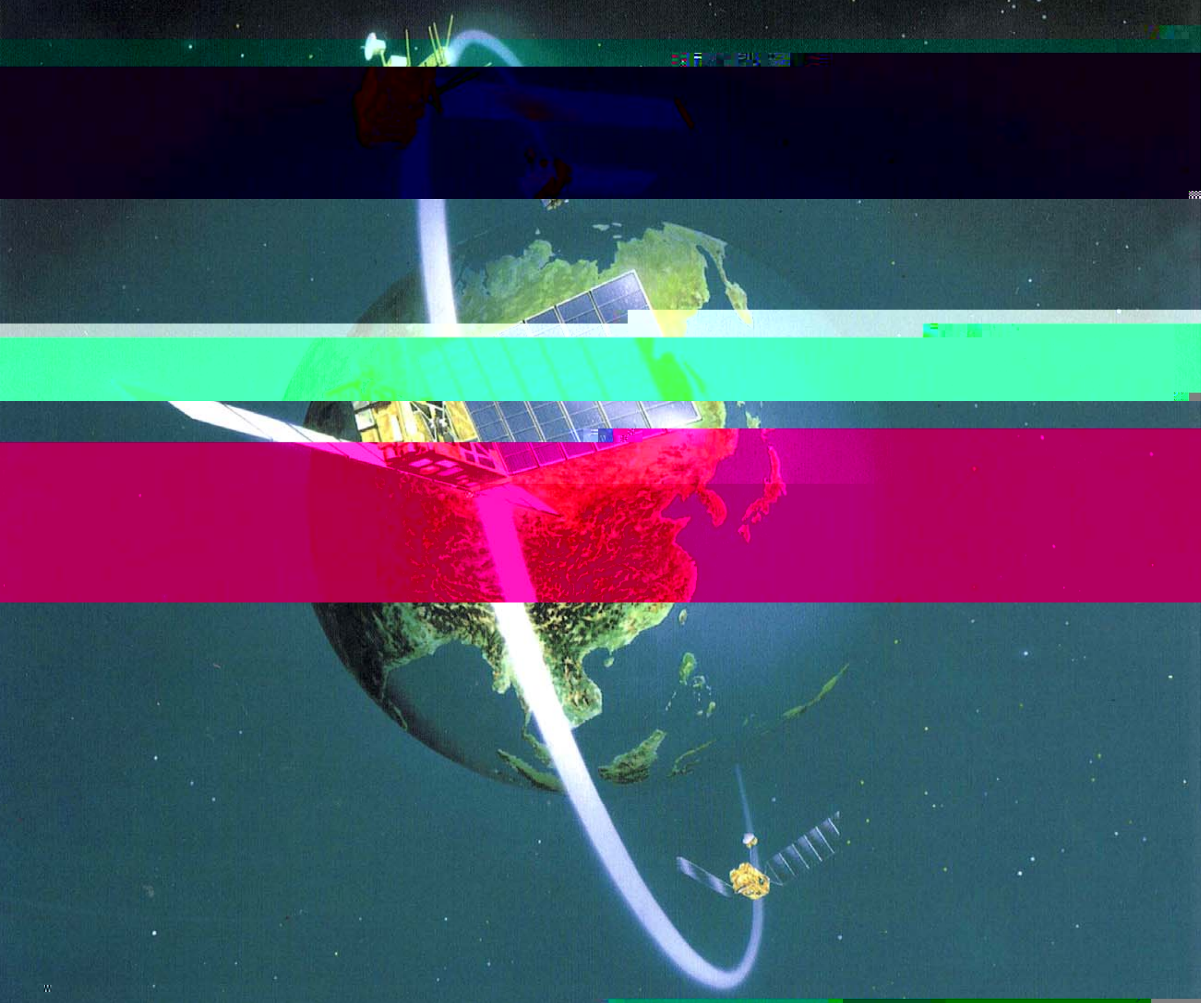


THz

- **THz**
- **THzQCL**
- **THz**

  THz

- **THz**



请指正

谢谢