Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Innovative ultra-BROadband ubiquitous Wireless communications through terahertz transceivers - H2020 iBROW

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Abstract: Presentation of the European H2020-iBROW Project

Purpose: Information of IEEE 802.15 IG THz

Innovative ultra-**BRO**adband ubiquitous **W**ireless communications through terahertz transceivers **iBROW**

Presentation outline

- Key facts
- Consortium
- Motivation
- Project objective
- Project description
- Summary

iBROW Key facts

- Horizon 2020 project funded by the European Commission
  - ICT-6: Smart optical and wireless network technologies
- Budget: c. 4 M€
- Eleven partners
  - 2 Large Industrial, 3 SME, 3 R&D, 3 Academic
- Start date: 01-Jan-2015
- Duration: 3 years
- Coordinator: University of Glasgow
- Project public website: www.ibrow-project.eu

Consortium

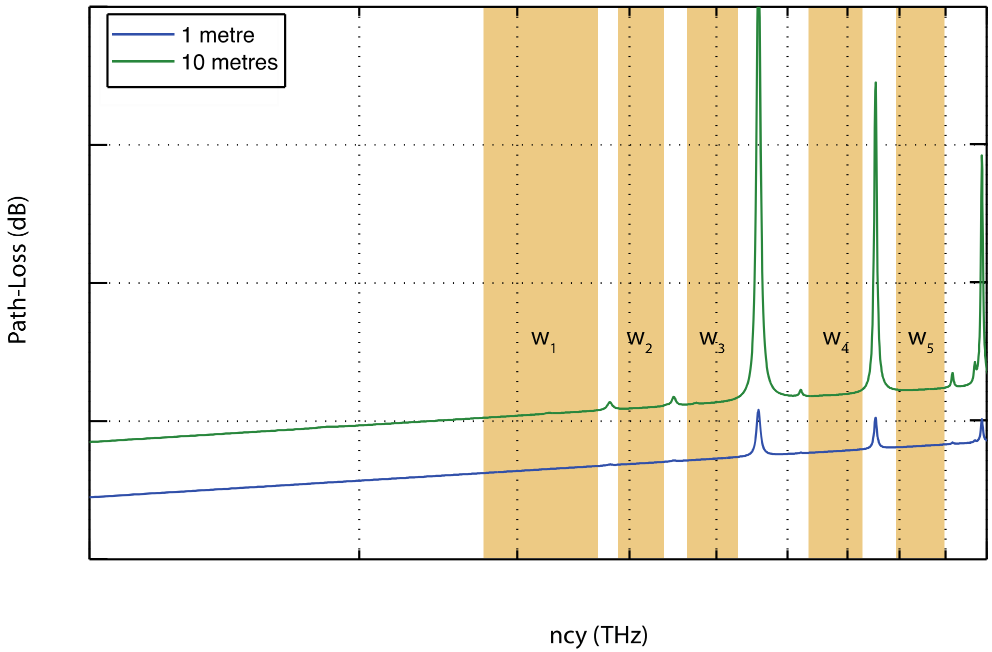
University of Glasgow	Academic	RTD research (device & circuit design, process development)
Alcatel-Lucent	Large Industrial	Component manufacturer (optical/wireless network equipment)
cea	R&D	III-V on Si wafer bonding research
Compound Semiconductor Technologies	SME	Component manufacturer (III-V based devices)
III-V lab	R&D	III-V on Si research (design, processing and validation)
INESCTEC	R&D	Wireless/optical communications research
IQE Silicon Compounds	Large Industrial	Wafer manufacturing (III-V on Si epitaxial growth)
optocap	SME	Component manufacture (packaging solutions)
Technische Universität Braunschweig	Academic	mm-wave & THz wireless communications research
UAlg Universidade do Algarve	Academic	RTD research (design, modelling and characterisation)
VIVID Components	SME	Project management

Motivation 1

- Traffic from wireless devices expected to exceed that from wired devices by end 2015
- High-resolution video will account for 69% of all mobile data by 2018, up from about 53% in 2013
- Wireless data-rates of multiple tens of Gbps will be required by 2020
- Demand on short-range connectivity

Motivation 2

- Significant previous R&D effort in complex modulations, MIMO and DSP up to 60 GHz
- Spectral Efficiency (SE) limits
  - Achieving 10s of Gbps in current bands will require high SE
- Solution?



Project Objective

Develop a novel short range wireless communication transceiver technology that is:

- Energy-efficient
- Compact
- Ultra-broadband
- Seamlessly interfaced with optical fibre networks
- Capable of addressing predicted future network usage needs and requirements.

Project Ambition

- Demonstrate **low cost and simple** wireless transceiver architectures that can achieve at least **10 Gbps** by exploiting the mm-wave and THz frequency spectrum
  - Long term target **100 Gbps.**

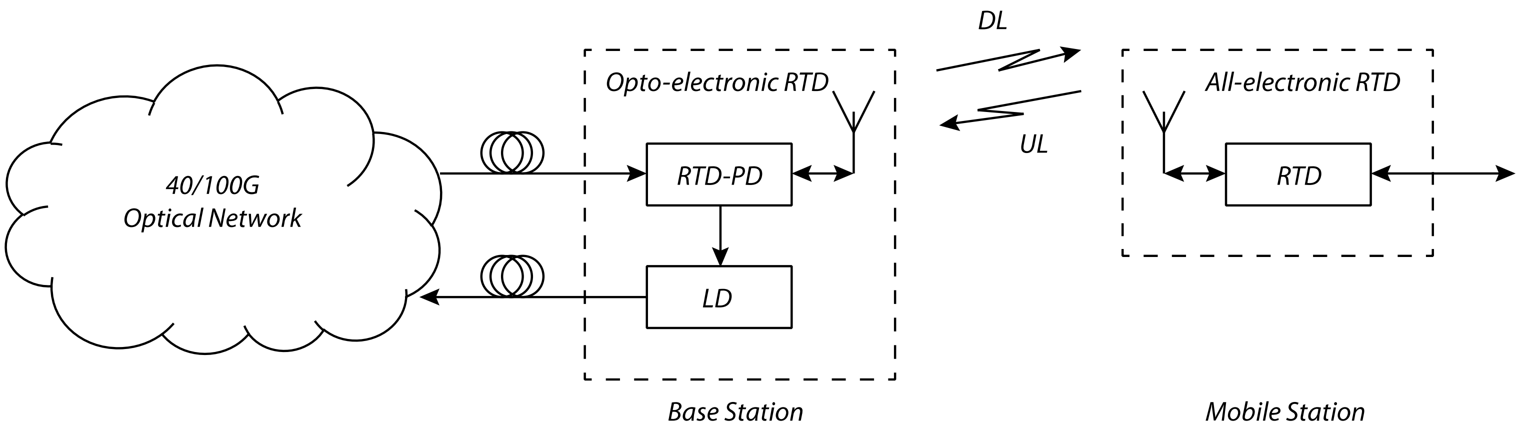
- Demonstrate **integrated semiconductor** emitters & detectors having enough power/sensitivity for exploiting the full potential of THz spectrum, and allowing for **seamless fibre-wireless interfaces**.

- Demonstrate a **highly compact** technology suitable for integration into battery constrained **portable devices**.

- Develop an **energy efficient and low power** wireless communications technology addressing the reduction of the ICT carbon footprint imputed to communication networks.

How?

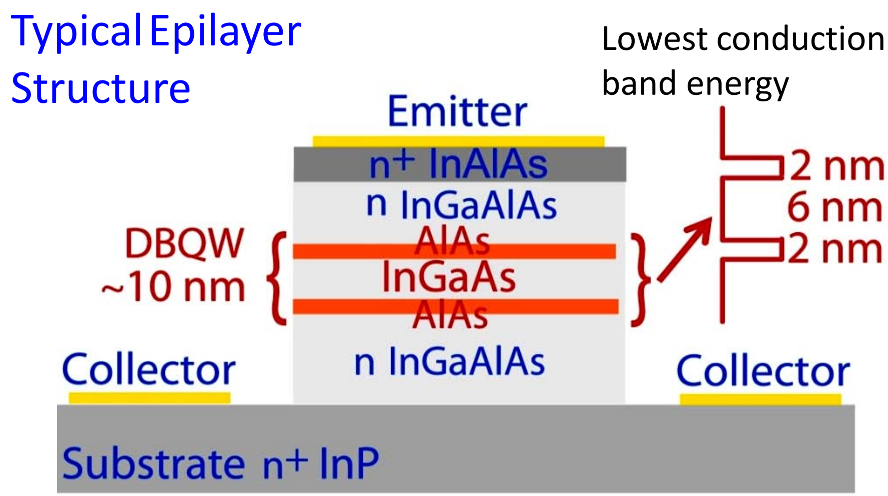
- Exploit Resonant Tunnelling Diode (RTD) transceiver technology.

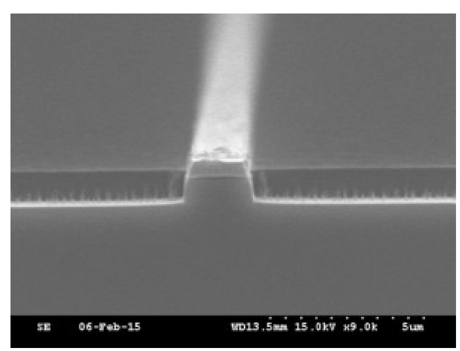


- All-electronic RTD for integration into cost-effective wireless portable devices
- Opto-electronic RTD (RTD-PD-LD) for integration into mm-wave/THz femtocell basestations

What is an RTD?

- RTD first demonstrated in 1974
- Consists of vertical stacking of nanometric epitaxial layers of semiconductor alloys forming a double barrier quantum well (DBQW)
- Oscillations can be controlled by either electrical or optical signals
- Highly nonlinear device
  - Complex behaviour including chaos.





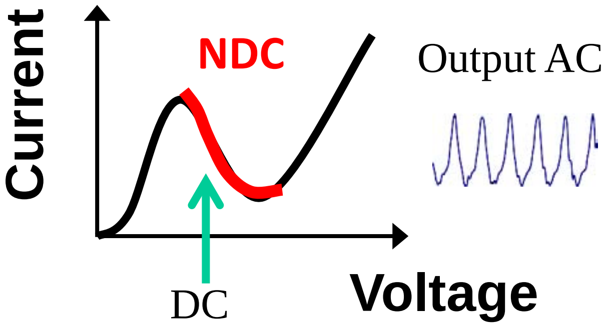
RTD Fabrication using BCB passivation/ planarisation

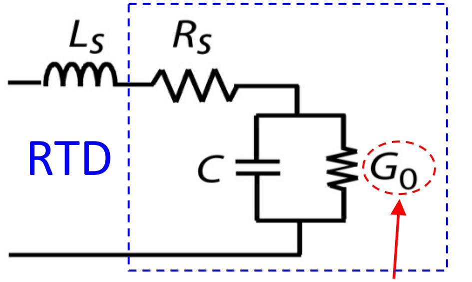
RTD technology

- Exhibit wideband Negative Differential Conductance (NDC)
- Fastest solid-state electronic oscillator at 1.55 THz (2014)
- Output power of 610 μW at 620 GHz has been reported (2013)
- Simple circuit realisation (photolithography works well up to 300 GHz)

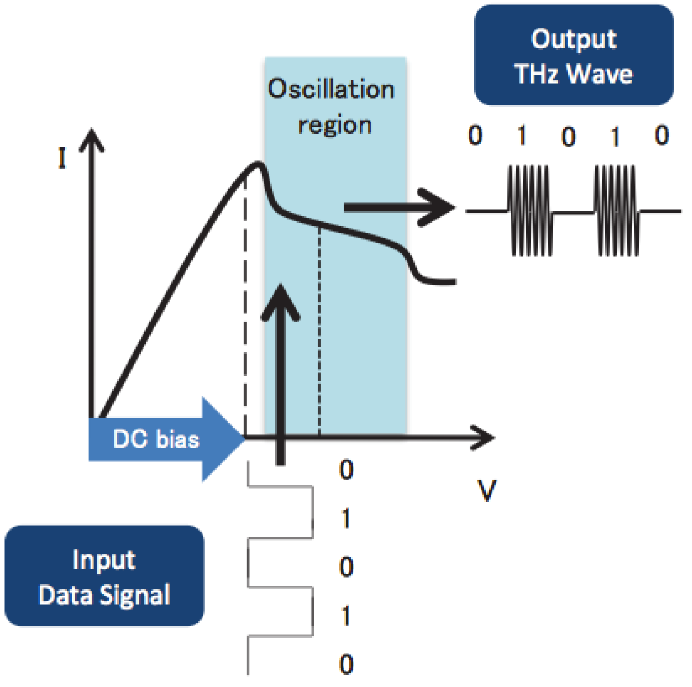
Current-Voltage (I-V) curve

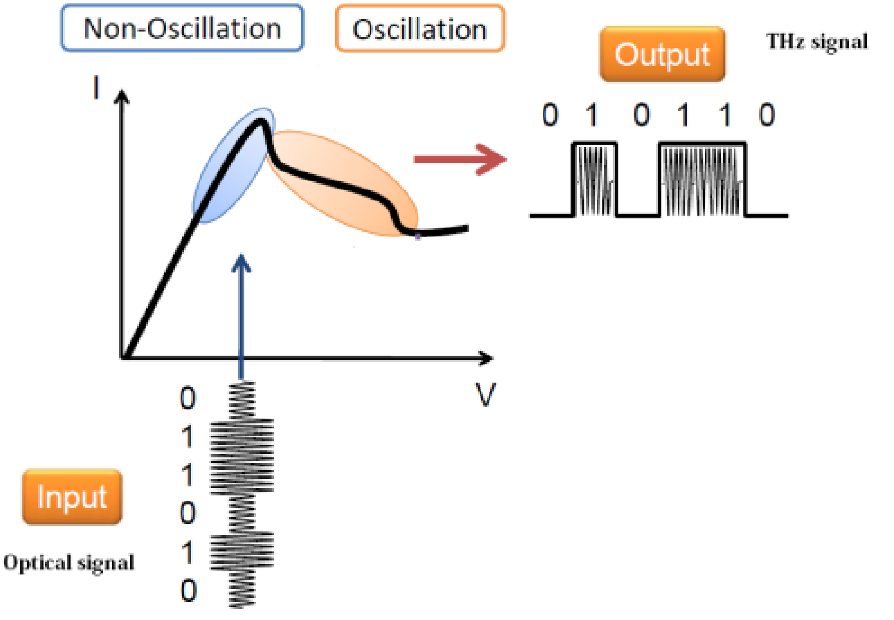
(**NDC** – Negative Differential Conductance)





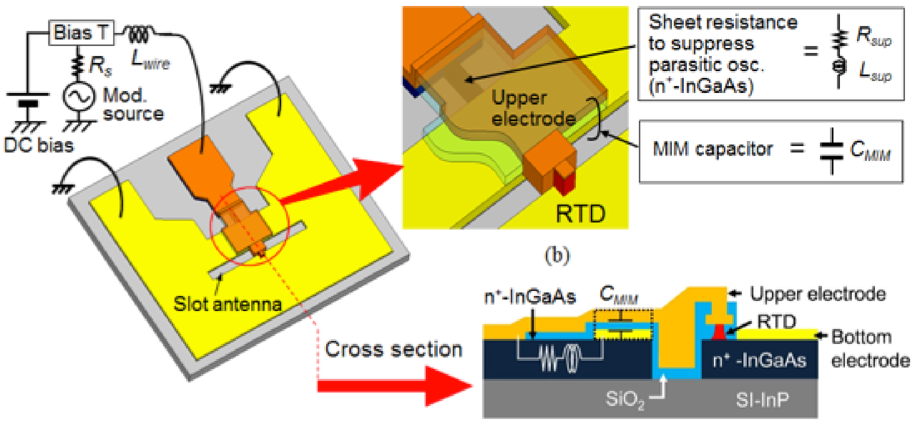
Taking advantage of RTD–based communications: On-off keying modulation

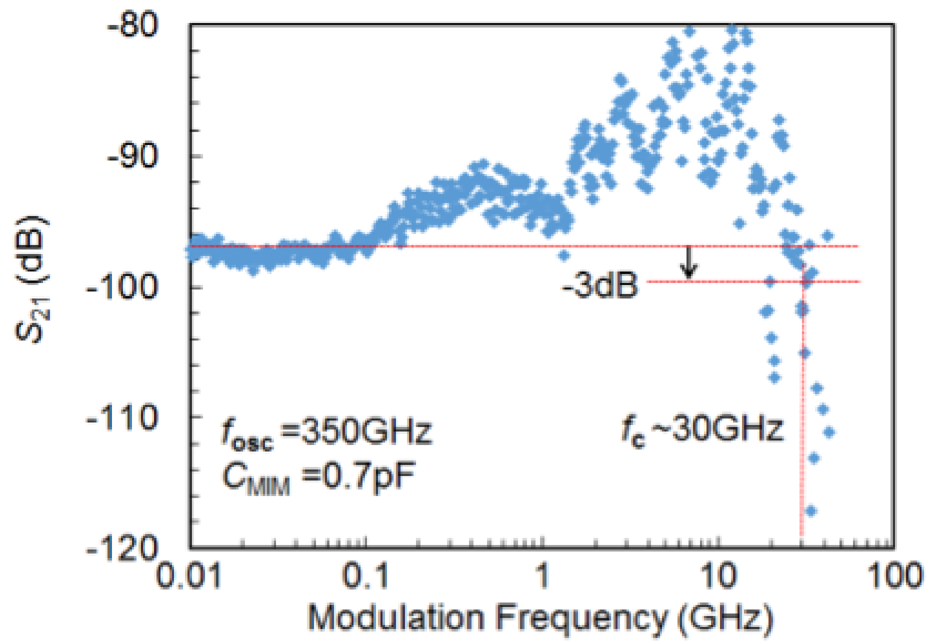




- All-electronic RTD
- Optoelectronic RTD-PD

RTD with up to 30 GHz modulation (2015)



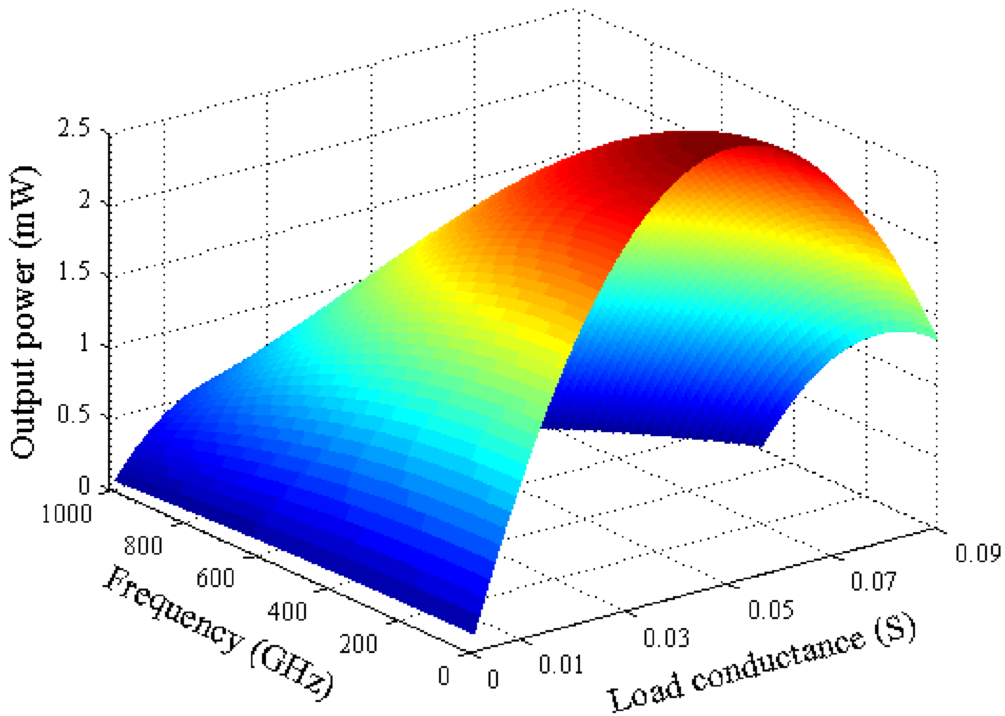


f_{OSC} = 350 GHz

Y. Ikeda, S. Kitagawa, K. Okada, S. Suzuki, M. Asada, "Direct intensity modulation of resonant-tunneling-diode terahertz oscillator up to ~30GHz"

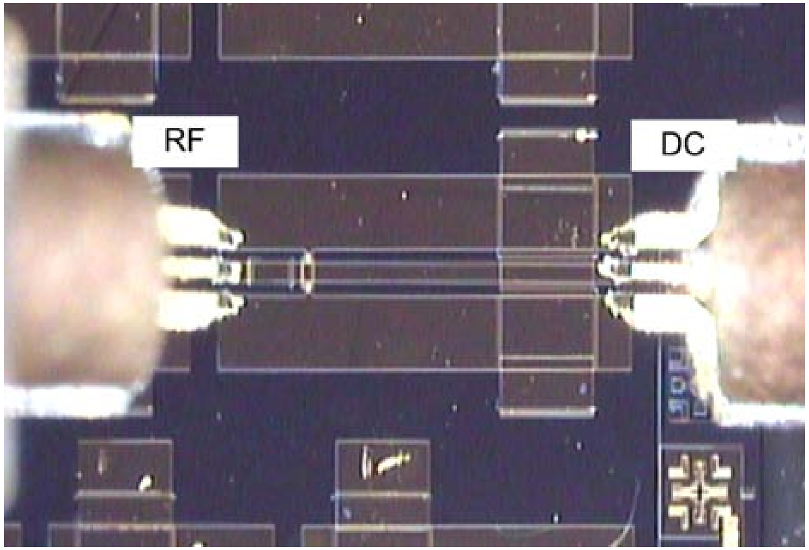
IEICE Electronics Express **12**, p. 20141161 (Jan-2015).

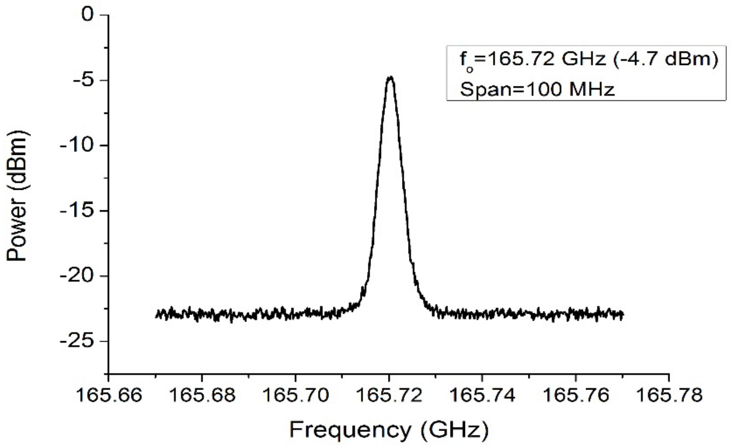
Potential of RTDs as THz Sources



Simulated output power of a single RTD device oscillator

RTD THz source chip



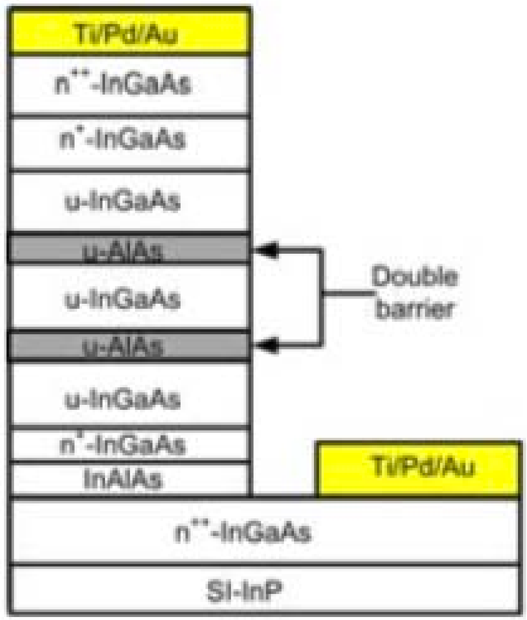


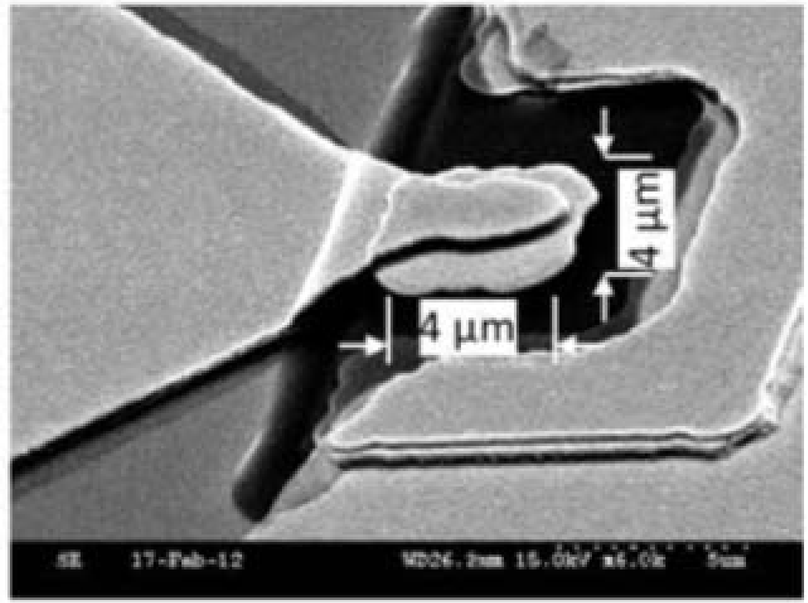
On-wafer characterisation of an RTD oscillator

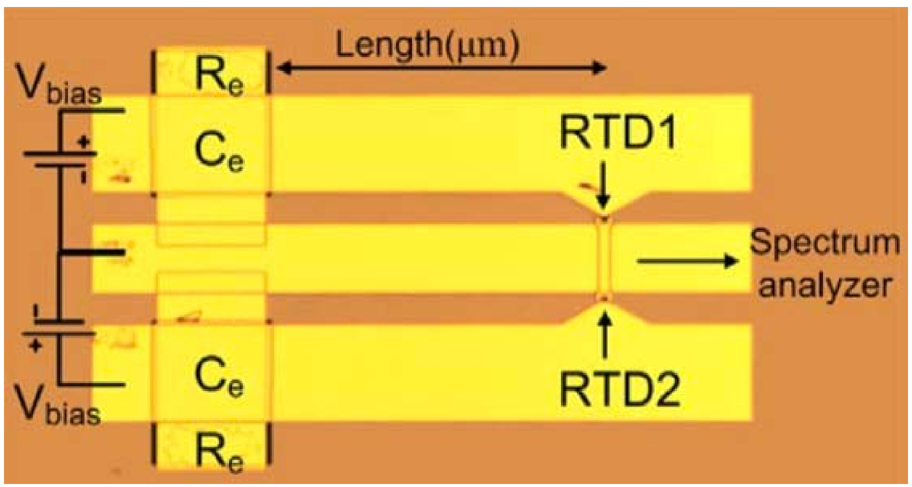
Measured spectrum of a fabricated 165 GHz RTD oscillator with record 0.35 mW output power

Details to be presented at IEEE Compound Semiconductor IC Symposium CSICS 2015; 11-14 Oct-2015; New Orleans, USA
J. Wang, E. Wasige et al., "High Performance Resonant Tunnelling Diode Oscillators for THz applications"

Example of developed electronic RTD





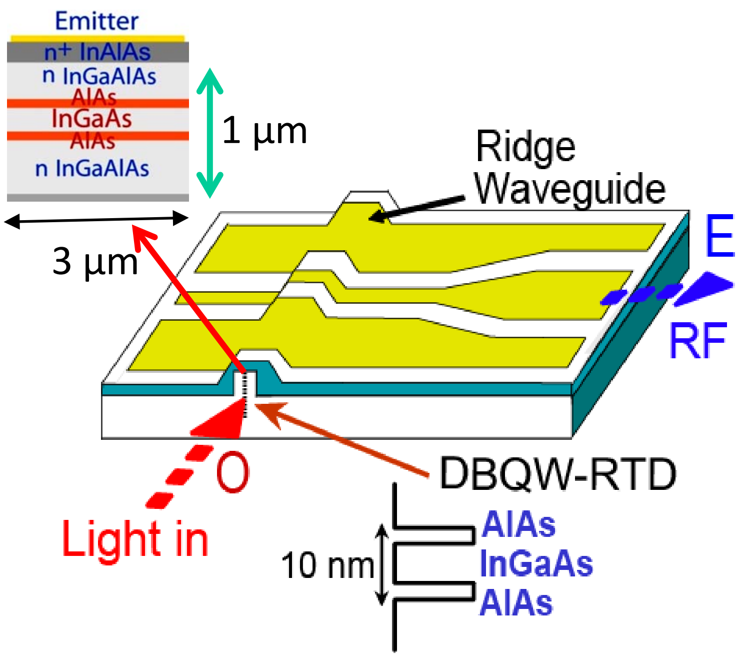


University of Glasgow

IQE SILICON COMPOUNDS

Monolithic integration

- RTDs can be made of III-V semiconductor materials
  - Typically employed in optoelectronic devices
- Allows for quasi-monolithic optoelectronic transceivers based on RTD-photodetectors and RTD-laser-modulators



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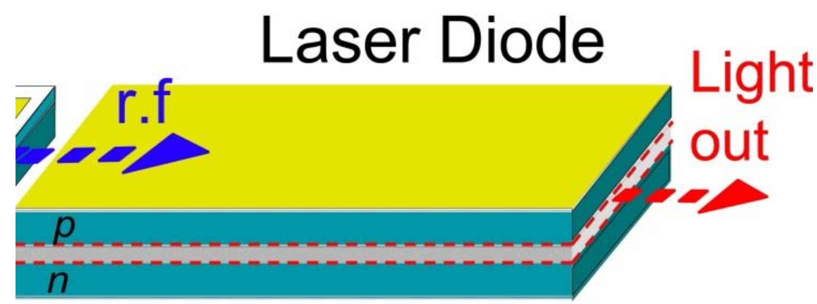
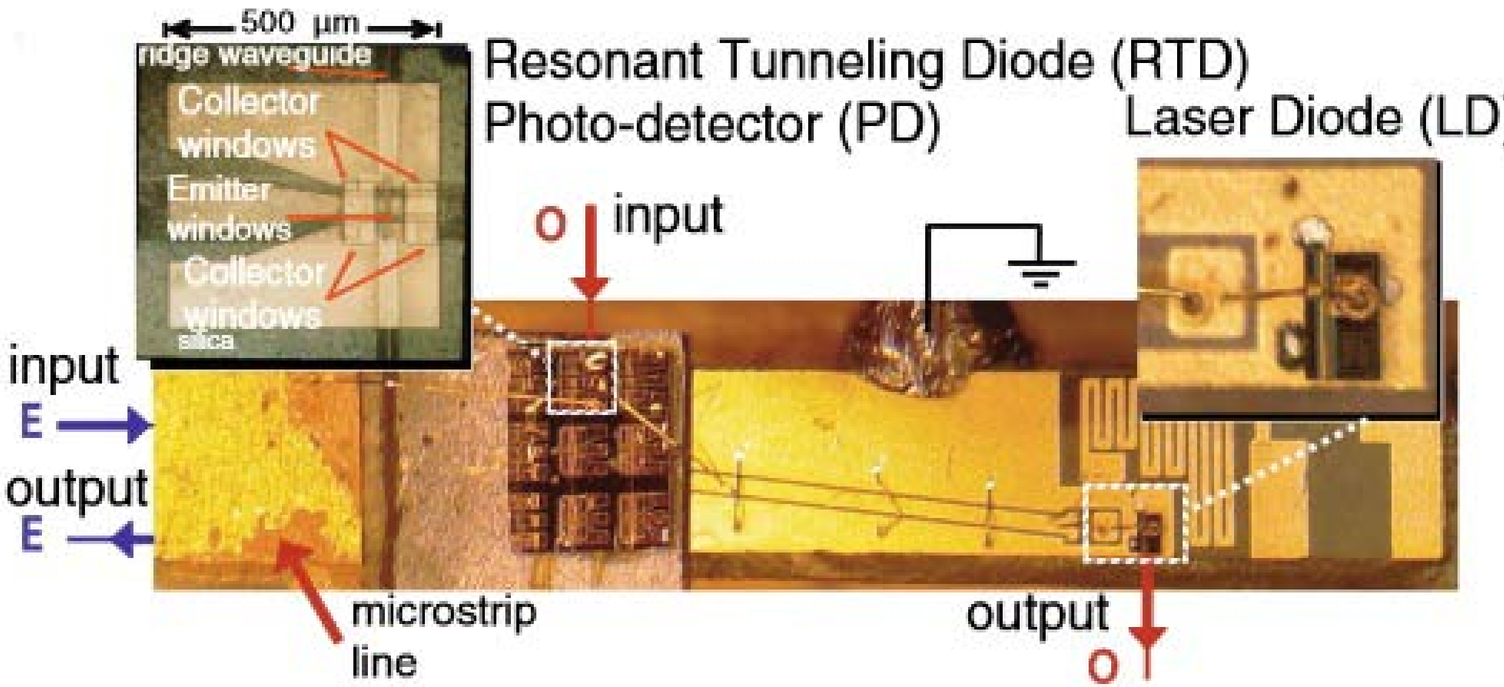


→ Simple, compact and low cost built-in direct laser modulation

Example of developed optoelectronic RTD



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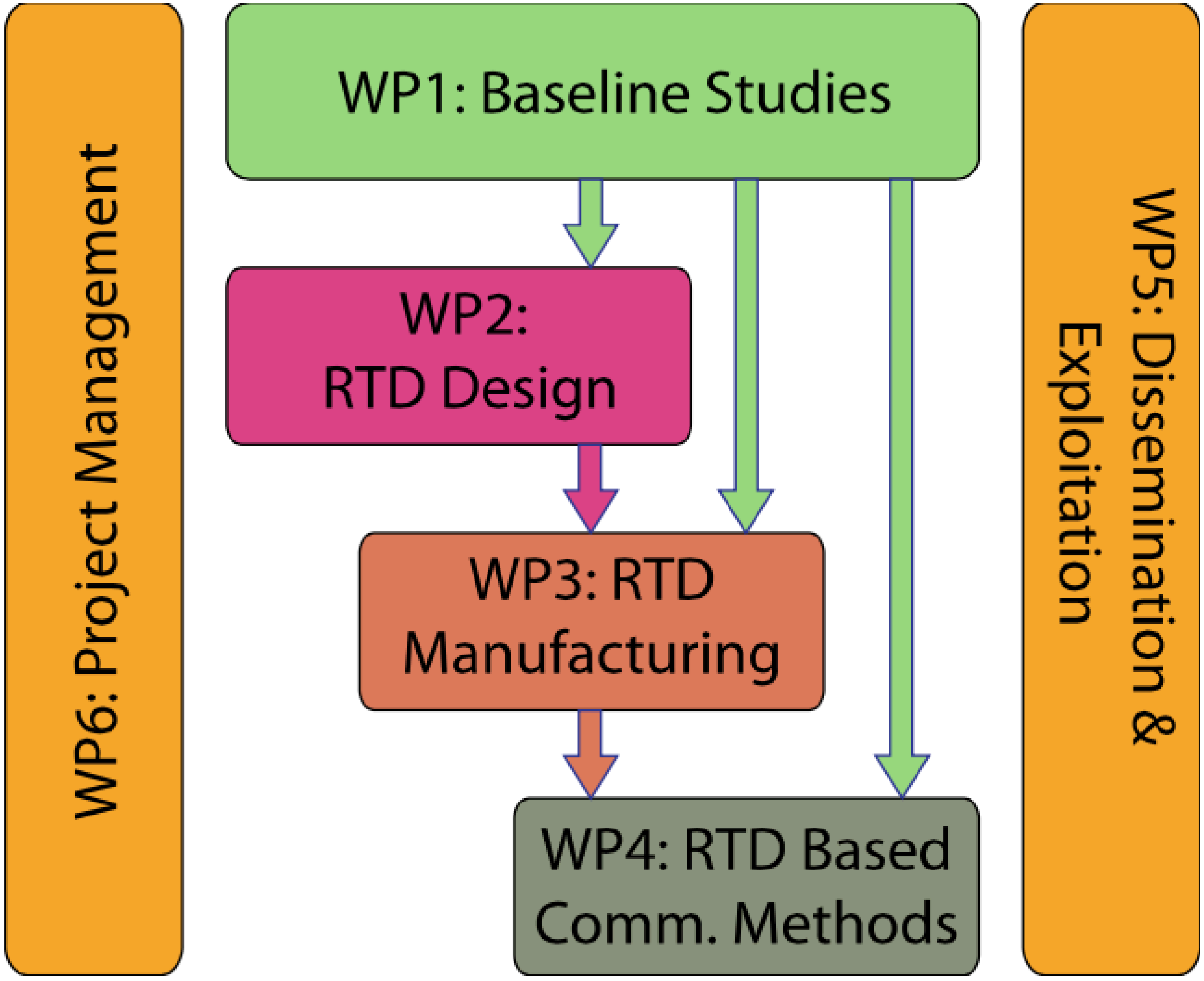
Compound Semiconductor Technologies

iBROW workplan



iBROW methodology

- Baseline studies to establish application scenarios
  - RTD technology options
  - Channel modelling & communications architectures
  - SWOT analysis
- Monolithic realisation of high power
  - 10 mW @ 90 GHz
  - 1 mW @ 300 GHz
  - Low phase noise sources
  - → Ultimately on a III-V on Si platform
- Monolithic realisation of high responsivity (>0.6 A/W) and high sensitivity RTD-photodiode detectors
- Hybrid integration of RTD-PD and laser diode optical–wireless interface and its characterisation
- Evaluation of wireless–wireless links and optical–wireless links
- Test bed demonstrator

Consortium organisation

Electronic RTD design

University of Glasgow

III-V on silicon

IQE Silicon Compounds

III-V lab

cea

Packaging

optocap

Communications

INESCTEC Technology & Science Associate Laboratory Portugal

Technische Universität Braunschweig

Optoelectronic RTD Design

University of Glasgow

UAlg Universidade do Algarve

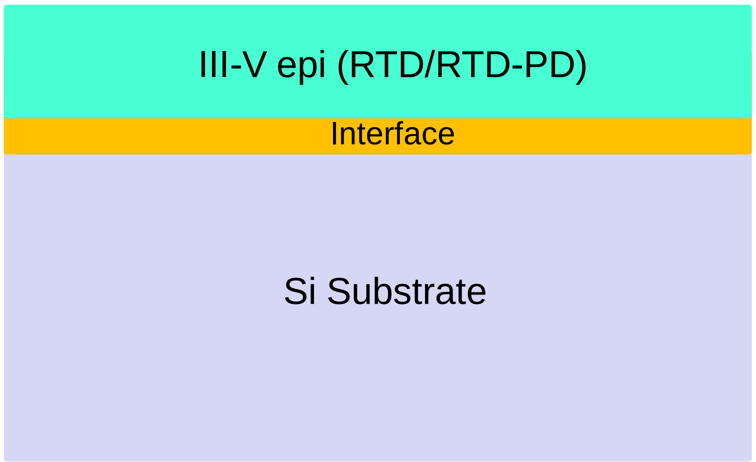
Compound Semiconductor Technologies

End-User

Alcatel·Lucent

How to achieve low cost?

III-V on silicon

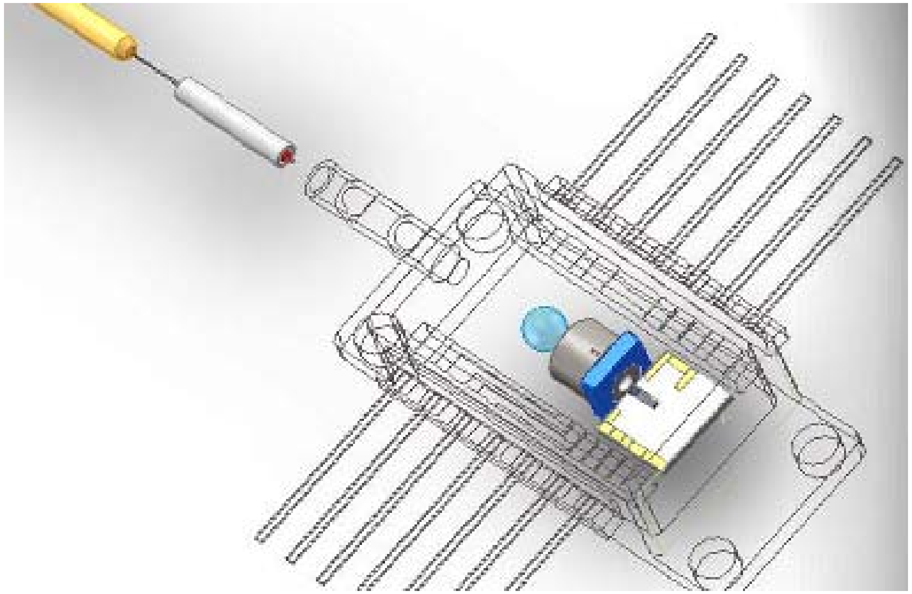


- **Direct growth** of III-V RTD layers on a Si substrate
- **Direct wafer bonding** between III-V & Si substrates
  - Potential for large diameter **≥200 mm wafers**
  - Integration with CMOS, etc.

III-V on silicon

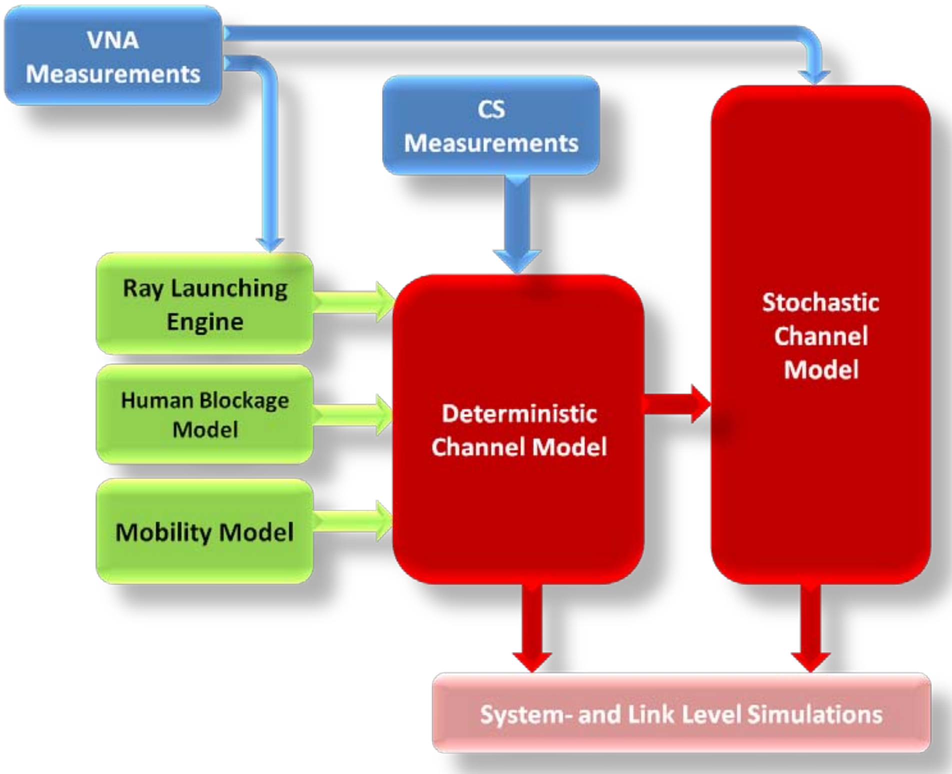
- Conventional hybrid approaches, such as wire-bonded or flip-chip multi-chip assemblies suffer from variability and relative placement restrictions
- **Direct hetero-epitaxial growth** of III-V on a GeOI/Si template
  - Exploit previous knowledge from the DARPA COSMOS programme
- **Direct wafer bonding**
  - Process the III-V surface to achieve bonding at room temperature
- Proved effective in solving mismatch problems
  - Lattice constant
  - Thermal expansion coefficient.

RTD Packaging



- **Thermal, mechanical and optical packaging design**
- Hermetic sealing
- Lensed fibre coupling

Communication methods



- **Channel modelling**

- **Test-bed for the demonstration of >10 Gbps wireless communications between several stand-alone prototype nodes at around 90 GHz and 300 GHz**

Project Summary

iBROW will achieve a novel RTD device technology:

- **on a III-V on Si platform**
- **operating at millimetre-wave and terahertz frequencies**
- **integrated with laser diodes and photo-detectors**

A simple technology that can be integrated into both ends of a wireless link

- **consumer portable devices**
- **fibre-optic supported base-stations.**