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Innovative ultra-BROadband ubiquitous Wireless communications through terahertz transceivers

iBROW

Deliverable D5.24
Dissemination kit

Technical Coordinator: Edward Wasige
Organisation: University of Glasgow
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Leader in charge of deliverable: Bruce Napier
Vivid Components

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Dissemination level		
PU	***Public***	***X***
PP	***Restricted to other programme participants (including the Commission Services)***	
RE	***Restricted to a group specified by the consortium (including the Commission Services)***	
CO	***Confidential, only for members of the consortium (including the Commission Services)***	

Contents

Change register

Version	Date	Author	Organisation	Changes
A_DRAFT_SUB	29-Jun-2018	Bruce Napier	Vivid Components	Draft version ahead of review to be updated with final dissemination material
A	03-Oct-2018	Bruce Napier	Vivid Components	Final newsletter info; typos, formatting

Reviewed by Edward Wasige UGLA A_DRAFT_SUB 29-Jun-2018

1. Statement of independence

The work described in this document is genuinely a result of efforts pertaining to the iBROW project: any external source is properly referenced.

Confirmation by Authors: Bruce Napier Vivid

2. Abbreviations

FP	Fabry Perot
Gbps	Gigabits per second
InP	Indium Phosphide
LD	Laser Diode
MIMO	Multiple Input Multiple Output
MMIC	Monolithic Microwave Integrated Circuit
mm-wave	Millimetre-Wave
MOVPE	Metal-Organic Vapour-Phase Epitaxy
OFDM	Orthogonal Frequency Division Multiplexing
OOK	On Off Keying
PIC	Photonic Integrated Circuit
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RIN	Relative Intensity Noise
RTD	Resonant Tunnelling Diode
RTD-LD	Resonant Tunnelling Diode integrated with a Laser Diode
RTD-PD	Resonant Tunnelling Diode Photodetector
RTD-PD-LD	Resonant Tunnelling Diode Photodetector integrated with a Laser Diode
SBD	Schottky Barrier Diode
Si	Silicon
SNR	Signal to Noise Ratio
TDD	Threading Dislocation Density
TOSA	Transmitter Optical Sub-Assembly

3. Executive summary

The iBROW project finished at the end of Jun-2018. Over the last 42 months the project has had a major impact on the development of RTD technology and demonstrated the potential for mm-wave and THz communications, as well as imaging and sensing applications based on RTDs.

The key advances include:

- Improved RTD devices
  - New state-of-the-art in RTD power and efficiency for e-RTDs and RTD-PDs
  - RTDs successfully demonstrated from direct epitaxial growth on silicon substrate
  - First ever RTDs from direct silicon wafer bonding and improved bonding process developed
- New developments in the application of RTDs in wireless networks
  - RTDs used to drive LDs and RTD-PDs used as photo-detectors at GHz frequencies
  - Improved understanding of electronic/photonic interfaces and clear suggestions for improved future designs
- Practical implementation of RTDs for commercial systems
  - 10 Gbps RTD-LDs packaged and designs completed for RTD-PD packaged devices
  - Ground-breaking simulation and experimental channel modelling to improve understanding of the application of THz communications
  - Important steps towards application of massive MIMO
- Direct application of RTDs in wireless communications systems
  - First ever transmission using RTD-PDs with advanced modulation formats (QPSK, 16-QAM and OFDM)
  - Demonstration of RTD synchronisation using injection locking mode
  - New state-of-the-art achieved for W-band (84 GHz) and J-band (300 GHz) transmission
    - 15 Gbps over 50 cm with correctable BER using e-RTDs (84 GHz)
    - 1.5 Gbps over 20 m HD video transmission using e-RTDs (300 GHz)
    - 16 Gbps over 30 cm with correctable BER using e-RTDs (300 GHz)
  - First ever DVB-T audio/video transmission using RTD-PDs (10 GHz).

This document outlines the material available in the public domain.

More information may be found at the project website: www.ibrow-project.eu

For further information, please contact: Bruce Napier bruce@vividcomponents.co.uk

4. Information on iBROW

The iBROW website has lots of information on the project: www.ibrow-project.eu

Main contact point is: Dr. Bruce Napier; Vivid Components
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The website includes presentations and leaflets along with other background material, including the following items.

4.1. Newsletters

There were six project newsletters issued during the project, which may all be downloaded:

http://ibrow-project.eu/results/newsletters/

- Newsletter #6 D5.22 (Sep-2018)
  - Improved RTD devices
    - First ever RTDs from direct silicon wafer bonding
    - New state-of-the-art in RTD power & efficiency for e-RTDs and RTD-PDs
    - RTDs demonstrated from direct epitaxial growth on silicon substrate
  - Direct application of RTDs in wireless communications systems
    - New state-of-the-art W- (84 GHz) and J-band (300 GHz) transmission
    - First transmission using RTD-PDs with advanced modulation formats
    - First ever DVB-T audio/video transmission using RTD-PDs (10 GHz)
  - Practical implementation of RTDs for commercial systems
    - Improved dynamic measurement of laser diodes for driving RTDs
    - 10 Gbps RTD-LDs packaged and designs for RTD-PD packaged devices
    - Ground-breaking simulation (p. 2) and experimental channel modelling

- Newsletter #5 D5.17 (Feb-2018)
  - iBROW final workshop (Glasgow , UK; 23-24 Apr-2018)
  - An update on RTD and RTD-PD development work at UGLA
  - CST investigations into laser dynamics measurement techniques
  - fotonIC - Fibre Coupled PIC Platform: edge coupled fibre alignment from OPC

- Newsletter #4 D5.13 (Dec-2016)
  - iBROW at European Microwave Week (London; Oct-2016)
  - III-V on Si wafer bonding for RTD processing from CEA-LETI
  - First reported RTDs on direct growth silicon wafers from IQE
  - Integrated antenna design and simulation from INESC TEC
  - iBROW input to standards for wireless communications led by TU Braunschweig

- Newsletter #3 D5.10 (Sep-2016)
  - iBROW at European Microwave Week (Oct-2016)
  - Modelling of RTDs (University of Algarve)
  - Packaging high speed RTD and laser devices (Optocap)
  - Reducing thread dislocation density (IQE)
  - III-V on Si wafer bonding for RTD processing (CEA-LETI & III-V Lab)

- Newsletter #2 D5.9 (Feb-2016)
  - Heterogeneous integration in the context of iBROW
  - Laser characterisation and development work at CST
  - Laser measurement and simulation at INESC TEC

- Newsletter #1 D5.6 (Sep-2015)
  - An overview of RTD technology
  - News of record-breaking RTDs from University of Glasgow
  - THz standards work from TU Braunschweig
  - A preview of the ALT 2015 conference (07-11 Sep-2015; Faro, Portugal)

4.2. Project videos

An introductory video giving an overview of the project (Dec-2015) and an update video presenting some of the key project results (Jan-2018) were produced by Vivid Components. These are available from the project website:

http://ibrow-project.eu/results/

The videos are also hosted on YouTube with the following direct links:

https://www.youtube.com/watch?v=ACZgfA5THgE Intro (Dec-2015)

https://www.youtube.com/watch?v=s-HkoSTMyt4 Update (Jan-2018)

4.3. Publications and conferences

The project contributed six journal papers (with five others under review at the time of writing) and over thirty conference papers and posters. (This is expected to rise to forty by the end of 2018 as the final project results are presented. This included a workshop on iBROW at European Microwave Week 2016 (London; Oct-2016) and a dedicated session at AOP 2017 (Faro; May 2017). The project concluded with a workshop in Glasgow at which the project results were presented to a large expert audience, including invited papers from some of the leading researchers from across the world.

Details may be found on the website: http://ibrow-project.eu/results/publications/

4.4. Other background material

A range of further material is available from the project website:

- Project presentation
- Plan for use and dissemination of results
- Project conclusions promotional leaflet
- Other white papers and technical documents

4.5. Public project report

This document gives a summary of the project objectives and context and details of the S&T progress. It includes more technical details not covered in the final newsletter as well as contacts for further information on each topical area.