Advance Program

Infrared Sensors

Monday, 17 July 2006

Krieghoff

08.45 - 10.30

Session J-PLE: JOINT PLENARY SESSION
Session Chairs: Alexandre Pauchard, *id Quantique, Carouge/Geneva, Switzerland*
Siddharth Ramachandran, *OFS Laboratories, Somerset, NJ, USA*

08.45 - 09.00 **Introduction**

J-PLE1 09.00 - 09.45

Quantum Communication in Standard Optical Fibers, N. Gisin, *University of Geneva, Geneva, Switzerland*

BIO: Professor Nicolas Gisin is the director of the<http://www.gap-optique.unige.ch/> Group of Applied Physics of the University of Geneva. He leads a group of about 24 researchers exploring the foundations of quantum mechanics. Prior to joining the University of Geneva, he has held various industrial positions in companies developing both hardware and software. In 1994, he was among the founders of Gap Optique SA, a spin-off developing test and measurement equipment for the optical fiber communication industry. The company was acquired in 1995 by EXFO Electro-optical Engineering of Quebec, Canada.

Prof. Gisin is the author of more than 100 publications in prestigious journals such as Nature and Science, and is cited as an inventor on more than 20 patents. Prof. Gisin holds a PhD in Physics and a Master in Mathematics from the University of Geneva. He has spent one year at the University of Rochester, USA, in a post-doctoral position. He has received a Doctor Honoris Causa degree from the Swiss Federal Institute of Technology in Lausanne.

ABSTRACT: Quantum cryptography, quantum teleportation and experiments on entanglement will be reviewed with special emphasize on the state of the art and the challenges of the 5-10 next years.

J-PLE2 09.45 - 10.30

Future Fun with Fantastic Fibers, W. H. Knox, *University of Rochester, Rochester, NY, USA*

BIO: Wayne H. Knox obtained BS (1979) and PhD degrees (1983) at The Institute of Optics, University of Rochester in Rochester, NY. He went to Bell Labs in Holmdel NJ in 1984 and worked as a Postdoctoral Fellow, was promoted to Member of Technical Staff in 1985 and to Distinguished Member of Technical Staff in 1990. In 1997, he was promoted to Director of the Advanced Photonics Research Department where he was responsible for forward-looking research in a number of areas related to advanced technologies in telecommunications in long-haul, access and Metro networks. He is a Fellow of the Optical Society of America and a Fellow and Life member of the American Physical Society, in 1990 won the National Academy of Sciences W.O. Baker Award for Initiatives in Re and biomedical optics. He was elected to a 2002-2005 term as Director-at-large on the OSA Board of Directors, search. In 1999 he won the Richtmyer Award for Physics teaching from the American Association of Physics Teachers. He has authored over 150 publications and 39 patents, and has chaired many international professional society meetings such as Ultrafast Phenomena, CLEO, Quantum Optoelectronics, Ultrafast Electronics and Optoelectronics, the OSA Annual Meeting, and Nonlinear Optics. He has served on OSA and APS Fellows committees, and was Chair of the 2002 Tyndall Award Committee. In April 2001 he returned to The Institute of Optics as Director and Professor of Optics where he currently carries out a research program in ultrafast science and technology, nonlinear fiber optics and served on the Finance Committee. He serves on several Scientific Advisory Boards. He was appointed to the Board of Directors of the Rochester Regional Photonics Cluster in 2002. In 2004, he won the University of Rochester's Robert B. Goergen award for undergraduate teaching.

ABSTRACT: The great variety of specialty fibers that has become available has already had a significant impact on fiber lasers, amplifiers, and nonlinear devices. In this talk, we review and speculate about some exciting future possibilities.

10.30 – 11.00 **COFFEE BREAK**

REMAINDER OF PROGRAM TO BE HELD IN FORTIN-LEDUC

11.00 - 12.15

Session MD1: PHOTON COUNTING APD ARRAYS
Session Chair: Joe C. Campbell, *University of Virginia, Charlottesville, VA, USA*

MD1.1 11.00 - 11.30 (Invited)
Geiger-Mode Avalanche Photodiodes for Laser Communications and Laser Radar, B. F. Aull, J. C. Aversa, E. A. Dauler, J. P. Donnelly, E. K. Duerr, J. P. Frechette, J. E. Funk, S. H. Groves, P. I. Hopman, K. E. Jensen, Z.-L. L. Liau, J. M. Mahan, L. J. Mahoney, K. McIntosh, A. Napoleone, D. C. Oakley, E. J. Ouellette, D. C. Shaver, G. M. Smith, S. Verghese and C. J. Vineis*, MIT Lincoln Laboratory, Lexington, MA, USA*

Arrays of photon-counting avalanche photodiodes (APDs) enable laser-communications and laser-radar receivers with unprecedented sensitivity at 1.06-μm wavelength. Near room temperature, the best detectors have: 50% photon detection efficiency, 30-kHz dark count rate, and a 1-μs reset time to avoid after-pulsing. Arrays with 64 elements were fabricated in the InGaAsP/InP materials system and were bump-bonded to a custom CMOS integrated circuit (IC) with a novel nonblocking architecture to continuously report both time-of-arrival for incoming photons as well as their spatial location on the array. Larger arrays with 1024 elements were mated to custom read-out ICs that report time and location data at lower duty cycles (typically 1-5%) and are appropriate for pulsed laser-radar systems.

MD1.2 11.30 - 12.00 (Invited)

3D LADAR Detectors, M. D. Jack*, Raytheon Vision Systems, Goleta, CA, USA*

ABSTRACT NOT AVAILABLE

MD1.3 12.00 - 12.15

4x4 Individually Addressable InGaAs APD Arrays Optimized for Photon Counting Applications, Y. Gu, *University of Maryland Baltimore County, Baltimore, MD, USA*, X. Wu, *Adtech Optics, City of Industry, CA, USA*, S. Wu, F.-S. Choau*, University of Maryland Baltimore County, Baltimore, MD, USA*, F. Yan, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, P. Shu, *Adtech Optics, City of Industry, CA, USA*, and M. A, Krainak, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*

InGaAs APDs with improved photon counting characteristics were designed and fabricated and their performance improvements were observed. Following the results, a 4x4 individually addressable APD array was designed, fabricated, and results are reported.

12.15 – 13.30 LUNCH BREAK

13.30 - 15.00

Session MD2: APDS AND PHOTON COUNTING DETECTORS
Session Chair: Michael A. Krainak, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*

MD2.1 13.30 - 14.00 (Invited)

Recent Advances in Avalanche Photodiodes, J. C. Campbell*, University of Virginia, Charlottesville, VA, USA*

This paper will review recent advances in avalanche photodiodes. Topics to be covered include novel structures designed to achieve low excess noise, high-speed waveguide devices, and simulation tools.

MD2.2 14.00 - 14.30 (Invited)

Avalanche Diodes and Circuits for Infrared Photon Counting and Timing: Retrospect and Prospect, S. Cova, F. Zappa, A. Tosi and M. Ghioni*, Politecnico di Milano, Milano, Italy*

The evolution of Single-Photon Avalanche Diodes (SPAD) and associated avalanche-quenching circuits for extending beyond 1 micron wavelength the spectral range of photon counting and timing is reviewed and the prospect of further progress is discussed.

MD2.3 14.30 - 15.00 (Invited)

Superconducting Nanowire Single Photon Detectors, A. J. Kerman, B. S. Robinson, R. J. Barron, D. O. Caplan, M. L. Stevens, J. J. Carney, S. A. Hamilton, W. E. Keicher*, MIT Lincoln Laboratory, Lexington, MA, USA*, E. A. Dauler, J. K. W. Yang, K. M. Rosfjord, V. Anant, and K. K. Berggren, *Massachusetts Institute of Technology, Cambridge, MA, USA*

We present our ongoing work on superconducting NbN-nanowire photodetectors, which deliver both high speed (<30 ps timing resolution) and high detection efficiency (>50% at 1550 nm), proming access to new regimes inultrafast photon counting applications.

15.00 – 15.30 COFFEE BREAK

15.30 - 17.00

Session MD3: JOINT SESSION ON SINGLE PHOTON DETECTORS FOR QKD
Session Chair: Mark A. Itzler, *Princeton Lightwave, Cranbury, NJ, USA*

MD3.1 15.30 - 16.00 (Invited)

Photon Counting Detectors for Quantum Key Distribution, G. S. Buller*, Heriot-Watt University, Edinburgh, Scotland, UK*

Advances in semiconductor single photon avalanche diode detectors have enabled expanding application areas in the near-infrared. This presentation will discuss their performance, potential and their use in applications such as quantum key distribution.

MD3.2 16.00 - 16.15

A High-Performance Single Photon Avalanche Detector for Telecom Wavelengths, M. Liu, X. Bai, C. Hu, X. Guo, J. C. Campbell, *University of Virginia, Charlottesville, VA, USA*, Z. Pan and M. M. Tashima, *JDS Uniphase Corporation, Milptitas, CA, USA*

An $In_{0.53}Ga_{0.47}As/InP$ avalanche photodiode with high performance (dark count rate=12kHz and single photon detection efficiency=45% at 1.3μm, 200K) is reported. The low dark count rate was attributed to the good crystalline quality of the device.

MD3.3 16.15 - 16.30

Afterpulsing in InGaAs/InP Single Photon Avalanche Photodetectors, R. Ben-Michael, M. A. Itzler, B. Nyman and M. Entwistle, *Princeton Lightwave, Cranbury, NJ, USA*

The effect of short gating pulses on afterpulsing in a single photon avalanche photodetector (SPAD) is characterized and discussed. Afterpulsing for short (~1 ns) and long (>20 ns) gating pulses is presented for the same SPAD structure, and the dependence of afterpulsing on detector bias is also reported.

MD3.4 16.30 - 17.00 (Invited)

Optical and Near-Infrared Photon detection with Superconducting Transition-Edge Sensors, S. W. Nam, A. Lita, *National Institute of Standards and Technology, Boulder, CO, USA*, D. Rosenberg, *Los Alamos National Laboratory, Los Alamos, NM, USA*, and A. J. Miller, *National Institute of Standards and Technology, Boulder, CO, USA*

There is increasing interest in using high-performance cryogenic optical photon detectors in a variety of applications in quantum information science and technology. These applications require detectors that have extremely low dark count rates, high photon count rates, high quantum efficiency, and moderate energy resolution or photon number resolution for near-infrared and optical photons. In this paper, we describe the operation, fabrication, and performance of superconducting transition-edge sensors designed for quantum optics and information applications.

18.30 – 20.00 **WELCOME RECEPTION – BOURDUAS**

Tuesday, 18 July 2006

09.00 - 10.00

Session TuD1: QUANTUM WELL INFRARED PHOTODETECTORS
Session Chair: TBD

TuD1.1 09.00 - 09.30 (Invited)

Quantum Well Infrared Photodetectors – Recent Advances at NRC, H. C. Liu, *National Research Council, Ottawa, ON, Canada*

We review recent advances on quantum well infrared photodetectors (QWIP) at the National Research Council. These include the demonstration of QWIP-LED pixelless imaging, the development of THz, ultrafast, and two-photon QWIPs.

TuD1.2 09.30 - 10.00 (Invited)

Noise Modelling in Quantum IR Detectors, A. Carbone, *Politecnico di Torino, Torino, Italy*

Many properties of Quantum We detectors are, at a given extent, deduced from those of bulk semiconductors. The standa nt fluctuations in quantum IR detectors. We discuss the limits of the g-r noise approach fo

CANCELLED

10.00 – 10.30 **COFFEE BREAK**

10.30 - 12.00

Session TuD2: QUANTUM WELL SUPERLATTICE PHOTODETECTORS
Session Chair: Michael Flatte, *University of Iowa, Iowa City, IA, USA*

TuD2.1 10.30 - 11.00 (Invited)

First Demonstration of 10 microns FPAs in InAs/GaSb Superlattices, M. Razeghi, Y. Wei, P.-Y. Delaunay, R. Mcclintock, B. M. Nguyen, E. Michel, A. Hood, D. Hoffman, K. Mi, *Northwestern University, Evanston, IL, USA* and M. Z. Tidrow, *Missile Defense Agency, Washington, DC, USA*

We report the most recent progress on demonstrating the first of its kind focal plane arrays with cutoff wavelength of 10 microns using InAs/GaSb superlattices. Device performance and CV characterization results will also be discussed.

TuD2.2 11.00 - 11.30 (Invited)

Progress on MBE Grown Type-II Superlattice Photodiodes, C. J. Hill, J. V. Li, J. M. Mumolo and S. D. Gunapala, *Jet Propulsion Laboratory, Pasadena, CA, USA*

We report on the status of type-II superlattice diodes fabricated at the Jet Propulsion Laboratory. These diodes are designed for detection of radiation in the mid and long wavelength regions of the infrared spectrum.

TuD2.3 11.30 - 11.45

Mid Infrared InP-based Photodiodes Operating At/Near Room Temperature, R. Sidhu, *Advanced Micro Devices, Inc., Austin, TX, USA* and A. L. Holmes, *University of Texas at Austin, Austin, TX, USA*

In this talk, our work on InP-based mid-infrared photodiodes, using type-II superlattice absorption regions, is discussed. Room temperature results include a specific detectivity (D*) of 3.8×10^9 cm-$Hz^{½}$/W for pin devices and multiplication gains above 20 for avalanche photodiodes.

TuD2.4 11.45 - 12.00

A Novel Type-II Infrared Single Photon Detector, O. G. Memis, S. C. Kong, A. Katsnelson, P. A. Behr and H. Mohseni, *Northwestern University, Evanston, IL, USA*

A novel infrared single photon detector for wavelengths above 1 mm is presented. It incorporates novel carrier focalization and nanoinjection. A finite element method based simulation is implemented to model and verify predicted superior performance.

12.00 – 13.30 LUNCH BREAK

13.30 - 15.00

Session TuD3: QUANTUM DOT PHOTODETECTORS
Session Chair: John P. David, *University of Sheffield, Sheffield, South Yorkshire, UK*

TuD3.1 13.30 - 14.00 (Invited)

Quantum Dot Infrared Photodetectors, P. Bhattacharya and X.-H. Su, *University of Michigan, Ann Arbor, MI, USA*

Quantum dot infrared photodetectors have emerged as viable devices capable of normal incidence operation over wide wavelength range at high temperatures. The latest results in the development of these devices will be presented and discussed.

TuD3.2 14.00 - 14.30 (Invited)

Infrared Focal Plane Arrays Based on Quantum Dots and Strain Layer Superlattices, S. Krishna, *University of New Mexico, Albuquerque, NM, USA*

We are presently investigating two material systems for infrared detectors. They are intersubband transitions in quantum dots in a well (DWELL) detectors and spatially indirect transitions in Type-II strain layer superlattices. The performance of single pixel and 320x256 focal plane arrays based on these systems will be reviewed.

TuD3.3 14.30 - 15.00 (Invited)

Algorithmic Tunabilty of Quantum-Dot Infrared Detectors, M. M. Hayat, U. Sakoglu, Z. Wang, B. Paskaleva, J. Tyo and S. Krishna, *University of New Mexico, Albuquerque, NM, USA*

Quantum-dot infrared detectors (QDIPs) with dot-in-a-well structures have been known to exhibit spectral responses whose peak wavelengths can be shifted continuously as a function of the applied bias voltage. Photocurrents corresponding to different bias voltages can therefore be viewed as outputs of spectrally overlapping bands. In this work, signal-processing strategies are presented that exploit such spectral diversity offered by QDIPs to yield spectral-tuning capability and general algorithms for feature extraction and image classification for QDIP-based infrared sensors.

15.00 – 15.30 COFFEE BREAK

15.30 - 17.00

Session TuD4: DETECTORS FOR IR IMAGING ARRAYS
Session Chair: Michael D. Jack, *Raytheon Vision Systems, Goleta, CA, USA*

TuD4.1 15.30 - 16.00 (Invited)

The HgCdTe Electron Avalanche Photodiode, J. Beck, C.-F. Wan, M. A. Kinch, J. E. Robinson, P. P. Mitra, R. Scritchfield, *DRS Infrared Technologies, Dallas, TX, USA*, F. Ma, *University of Texas at Austin, Austin, TX, USA* and J. C. Campbell, *University of Virginia, Charlottesville, VA, USA*

Electron injection avalanche photodiodes in SWIR to LWIR HgCdTe show properties indicative of a single ionizing carrier gain process ($\alpha_h/\alpha_e=0$). The result is an electron avalanche photodiode with rather unique characteristics including near noiseless gain.

TuD4.2 16.00 - 16.30 (Invited)

Large Format HgCdTe Arrays for the James Webb Space Telescope, B. Mott, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, T. Boeker, *ESTEC, Noordwijk, The Netherlands*, C. Cabelli, *Rockwell Scientific Company, Camarillo, CA, USA*, G. De Marchi, *ESTEC, Noordwijk, The Netherlands*, P. Ferruit, *CRAL – Observatoire de Lyon, Saint Genis Laval, France*, J. D. Garnett, *Rockwell Scientific Company, Camarillo, CA, USA*, R. J. Hill, *Science Systems & Applications, Inc., Lanham, MD, USA*, M. Loose, *Rockwell Scientific Company, Camarillo, CA, USA*, B. J. Rauscher, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, M. W. Regan, *Space Telescope Science Institute, Baltimore, MD, USA*, A. Waczynski, *Global Science & Technologies, Inc., Greenbelt, MD, USA*, Y. Wen, *Science Systems & Applications, Inc., Lanham, MD, USA*, S. Wong, M. Zandian, *Rockwell Scientific Company, Camarillo, CA, USA*, D. Alexander, C. K. Brambora, R. Derro, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, C. Dunn, T. Ellis, *ITT Space Systems Division, LLC, Rochester, NY, USA*, M. B. Garrison, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, B. Howe, *ITT Space Systems Division, LLC, Rochester, NY, USA*, P. Jakobsen, *ESTEC, Noordwijk, The Netherlands*, T. E. Johnson, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, M. Jurado, G. Lee, *ITT Space*

Systems Division, LLC, Rochester, NY, USA, S. S. Manthripragada, J. M. Marsh, C. Marshall, R. J. Martineau, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, J. Nieznanski, *ITT Space Systems Division, LLC, Rochester, NY, USA*, W. D. Roher, *Northrop Grumman Technical Services, Lanham, MD, USA*, K. B. Shakoorzadeh, M. T. Smith, *NASA Goddard Space Flight Center, Greenbelt, MD, USA*, P. Strada, *ESTEC, Noordwijk, The Netherlands*, P. Wallis, *ITT Space Systems Division, LLC, Rochester, NY, USA*, W. Xia-Serafino, *Global Science & Technologies, Inc., Greenbelt, MD, USA*, and J. R. York, *ITT Space Systems Division, LLC, Rochester, NY, USA*

The Near-Infrared Spectrograph (NIRSpec) is the James Webb Space Telescope's primary near-infrared spectrograph. NASA is providing the focal plane array and electronics. The focal plane array comprises two closely-butted 5 micron cutoff Rockwell HAWAII-2RG arrays.

TuD4.3 16.30 - 17.00 (Invited)

InGaAs Imaging Arrays, M. J. Cohen, M. Ettenberg, and J. C. Dries*, Sensors Unlimited/Goodrich Corporation, Princeton, NJ, USA*

The status of indium gallium arsenide focal plane array technology will be summarized and applications described. Include will be PIN photodiode arrays for low light level imaging and avalanche photodiode arrays for flash laser radar and range gated imaging.

Wednesday, 19 July 2006

09.00 - 10.15

Session WD1: NOVEL PHOTODETECTOR STRUCTURES
Session Chair: Silvano Donati, *University of Pavia, Pavia, Italy*

WD1.1 09.00 - 09.30 (Invited)

Photodetectors for the 2-5μm Spectral Range based on III-V Heterojunctions, A. Krier and W. Suleiman*, Lancaster University, Lancaster, UK*

The design, fabrication and characterization of heterojunction photodiodes for room temperature operation in the mid-infrared (2-5 μm) spectral range is described. Devices appropriate for methane and carbon monoxide detection have been developed and studied.

WD1.2 09.30 - 09.45

Interdigitated Photodoide Fabricated on High Quality Ge on Si with Thin SiGe Buffer Layers, Z. Huang, S. K. Banerjee*, University of Texas at Austin, Austin, TX, USA*, J. Oh*, Sematech, Austin, TX, USA* and J. C. Campbell*, University of Virginia, Charlottesville, VA, USA*

An interdigitated Ge-on-Si photodetector has been fabricated, and achieved 73% quantum efficiency at 1.3μm. The internal quantum efficiency is close to unity due to the high quality Ge film grown with thin SiGe buffer layers.

WD1.3 09.45 - 10.00

Modeling Hot Electron in single Quantum Well P-i-N Photodiodes, H. Z. Fardi and G. Alaghband*, University of Colorado at Denver & Health Sciences, Denver, CO, USA*

Hot electron effect in a single quantum well AlGaAs/GaAs PiN photodiode is investigated by solving the energy balance equations. Simulation results show hot carriers influence I-V characteristics in QW photodiodes with long energy relaxation lifetimes.

WD1.4 10.00 - 10.15

Recent Developments in Infrared Phosphors, R. P. Rao*, Authentix, Inc., Douglassville, PA, USA*

Up-converting as well as optically stimulable phosphors are being used as infrared detectors in various applications. Recent developments related to nano-phosphor materials and their role in security and other potential applications are presented in this paper.

10.15 – 10.30 COFFEE BREAK

10.30 - 12.00

Session WD2: INGAAS PHOTODETECTORS
Session Chair: Rengarajan Sudharsanan, *SpectroLab, Sylmar, CA, USA*

WD2.1 10.30 - 11.00 (Invited)

High Performance Photodiodes for Demanding Applications, B. Dion, C. Ledoux, P. Lepage*, CMC Electronics, Montreal, QC, Canada*, and N. Bertone, *OEC, Montreal, QC, Canada*

Demanding applications like laser range finding, proximity fuses, laser designation, smart munitions and laser warning systems all have the following in common: detecting short pulses of light; ability to operate in harsh environments over a wide temperature range; and requirement for large dynamic range. In this paper, we will examine how to design modules and package photodiodes for these applications. In particular, we will focus on InGaAs APDs for laser range finding and InGaAs PIN arrays for laser-warning modules.

WD2.2 11.00 - 11.30 (Invited)

High-Power Photodiodes, K. J. Williams, D. A. Tulchinsky, J. B. Boos, D. Park, and P. G. Goetz*, US Naval Research Laboratory, Washington, DC, USA*

Recent progress in high current photodiodes now makes it possible to linearly detect over 250 mA at frequencies into X Band. This paper will discuss the recent improvements that have lead to this dramatic improvement.

WD2.3 11.30 - 11.45

An InGaAs/InP Photodiode with 600mW RF Output Power, N. Duan, N. Li, *University of Texas at Austin, Austin, TX, USA* and J. C. Campbell, *University of Virginia, Charlottesville, VA, USA*

We report an InGaAs/InP charge compensated uni-traveling-carrier photodiode with thick depletion region with RF output power of 600mW at 2GHz.

WD2.4 11.45 - 12.00

Design of Very Low Dark Current SWIR PIN Arrays, J. C. Boisvert, T. D. Isshiki, R. Sudharsanan, P. Yuan and P. McDonald, *SpectroLab, Sylmar, CA, USA*

We report on the design of very low dark current InGaAs PIN arrays for photon counting imaging applications at room temperature. Both material and device designs are considered and presented.

END OF PROGRAM