Active Photonic Circuits and Biophotonics at Monash University, Australia

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Abstract - We outline the research and development taking place at Monash University, Melbourne, Australia, in the fields of active photonic circuit design and simulation, and biophotonics.

I. INTRODUCTION

Monash University is located 12 miles South-East of Melbourne city centre, at the centre of the high-tech industry belt of Victoria. As a recent initiative to build on the strengths of Monash’s Engineering Faculty, which include antennas, IPv6, optical systems, microfluidics, nano-materials, physiology, new staff have been recruited in the areas of bio-photonics, photonic simulation and modeling, wireless modeling (MIMO and OFDM) and antenna design.

This paper outlines recent research in the areas of Active Photonic Circuits and Biophotonics, which is undertaken by the Advanced Computing and Simulation Laboratory (AXL), in the Department of Electrical and Computer Systems Engineering. This research calls on the unique mix of commercial and academic R&D experience of AXL’s staff.

II. ACTIVE PHOTONIC CIRCuits

Active Photonic Circuits [1] use combinations of active semiconductor devices and passive elements to provide novel functionality, for applications such as high-speed demultiplexing (Fig.1), optical packet switching, microwave photonics, optical ranging and optical instrumentation. The active element is usually a semiconductor optical amplifier, as SOAs:

- Have high optical gains (>20 dB)
- Have high nonlinearity, particularly though interactions via the carrier reservoir
- Can be switched using their injection current
- Indicate their saturation state via their contact voltages
- Are easily integrated with waveguides to form multi-section lasers incorporating active, passive, modulating and filtering regions.
- Are small, allowing compact integration.

Researchers at Monash University have a long history of development of active photonic circuits, particularly in using computer simulation to design and verify novel circuit concepts [2]. Arthur Lowery has researched active devices since 1983. His university work has encompassed SOAs, mode-locked lasers, laser simulation, optical gates

and packet switches, wavelength converters and transmultiplexers, optical radar, SOA detectors. The main theme has been developing novel topologies and optimizing their performance using time-domain simulations (Fig.2). Malin Premaratne has worked on fiber-Bragg-grating stabilized laser design, optical amplifier dynamics, optical amplifier topologies and performance, optical delay discriminators, and optical rangers. He also has a wide experience of network modeling, configuration and optimization.

The global simulation company, VPIsystems, was co-founded by Arthur Lowery, who now leads simulation research at Monash University as part of the Advanced Computing and Simulation Laboratory (AXL). Arthur’s pioneering work on time-domain modeling of semiconductor lasers (the ’Transmission Line Laser Model’ [3]) became the basis for VPI’s first product OPALS (Opto-electronic, Photonic and Advanced Laser Simulator). OPALS provided a library of photonic models (transmitters, fibers, filters, gratings, receivers and instrumentation) which could be interconnected using the LabVIEW graphical programming language [4]. Under Lowery’s direction as CTO of VPIsystems, OPALS became VPlComponentMaker™Active Photonics (Fig.3), which is used by many commercial components manufacturers and research labs to design novel lasers and optical signal processing systems, such as fiber Bragg-grating stabilized lasers, wavelength converters, semiconductor optical amplifiers and wavelength converters. The time-domain algorithms themselves have been adopted by many groups, because of their ability to incorporate nonlinear effects inside the laser cavity, and also longitudinal inhomogeneities, which cause many types of modal instability that can be used for clock generation and clock recovery. Free simulations illustrating this work can be downloaded from www.vpiphotonics.com/VPIplayer.
Application: Tunable and Fixed Lasers

- Grating-controlled Fabry-Perot
- Fiber Bragg Grating/External Cavity
- Distributed Feedback
- DBR-FP Tunable
- Gain-coupled DFB
- Complex Coupled DFB
- DBR/Phase Section/Fabry-Perot Tunable
- Multi-Section Gain-Coupled

Application: SOA Signal Processing

- Switch (or Gate)
- Reflective Modulator
- Amplifier/Detector/Gate
- Detector/Amplifier

Applications: SOA Wavelength Converters

- Cross-Phase Modulation
- Sagnac Loop
- Four-Wave Mixing
- Integrated DFB-SOA Cross-Gain Modulation

Fig. 2. Common topologies of active photonic circuits.

Fig. 3. VPIComponentMaker™ Active Photonics encapsulates TLLM algorithms to allow new topologies to be created rapidly (www.vpiphotonics.com)
Currently, Arthur and Malin are researching into novel topologies for active photonic circuits, and semi-analytical models for these topologies. Recent work has developed a compact design for an optical pulse delay discriminator [5], which produces a voltage proportional to the timing difference of two optical pulse trains impinging on an SOA. This can be used as part of an optical phase locked loop (for clock recovery and clock frequency multiplication or division). This device can also form a compact laser ranger (Fig. 4), as the SOA simultaneously amplifies the transmitted and received pulses, as well as detecting their relative timings. These simulations are backed up with new semi-analytical treatments for the sensitivity and noise characteristics.

Fig. 4. SOA-based ranging system 6.

The applications of photonic circuits are also of great interest, and recent work by the group has included:
- Split-step spline methods for efficient modeling of nonlinear optical pulse propagation in fibers [7]
- Simulation of microwave photonic circuits such as optical serrodyne comb generators and microwave distribution systems [8]
- Optimisation of wavelength converters using red-shifting and an optical filter [9]
- The performance of Semiconductor Optical Amplifiers and optical detectors.

III. BIO-PHOTONICS

We are developing models and algorithms to describe the interactions of photons with living tissue [9], in conjunction with an experimental program across departments, faculties and external institutions. Our aim is to develop new methods of non-invasive sensing of the concentrations and flows of key blood components. In Reference [9], we removed an inconsistency in commonly-used models of photon propagation within tissue with varying refractive index. This will enable more accurate tomography and non-invasive blood component identification.

IV. CONCLUSIONS

We have presented an overview of the work at the Advanced Computing and Simulation Laboratory, Monash University. We welcome discussions on possible collaborations within Australa and overseas. We also encourage PhD and Masters candidates to apply to us at the address given on page 1.

REFERENCES


http://www.opticsexpress.org/abstract.cfm?URI=OPEX-13-10-3647