Final report on OTKA-PD 109288 postdoctoral project

Investigation of in-line and reflective semiconductor optical amplifiers for broadband optical access

(2013.09.01 - 2015.08.31)

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Short project and progress overview

Generally, the work performed followed the original work plan, including dissemination at conferences and in scientific journals, where the goals set for the 3 years have been achieved. As of yet, a total of 5 project-related international publications have been published [1-5]. During the project I have been working with 2 PhD student (research and modeling) and 6 regular BSc and MSc students (experimental setup and measurements) [6-8]. Regarding financing, total spending followed the planned budget.

Scientific results of the research

The overall goal is to produce new theoretical and practical results in semiconductor optical amplifier based colorless optical unit for wavelength division multiplexed optical access networks. The work was divided into the following main parts.

1. Literature overview
   The literature of the new generation passive optical network architectures was thoroughly reviewed. The limited modulation bandwidth of the Reflective Semiconductor Optical Amplifier (RSOA) and the solution methods were overviewed. The applied models of the RSOA were studied.
2. Experimental characterization of the devices
   The in-line and reflective semiconductor optical amplifiers were compared by measurements. The properties of (R)SOAs were characterized based on experimental results. A simplified test-bed was designed and constructed for the system measurement.
3. Modeling of the devices
   During the theoretical investigation and simulation work, the analysis demanded detailed device structural models based on the rate equations, which described the internal physical effects of the devices. It took into account the behaviour of the multisession devices, the chirp effect and the internal reflection. The models were integrated to the VPI Transmission Maker optical device and system simulation environment. It permitted of the system performance investigation by simulations.
4. Extension of the limited modulation bandwidth
   The modulation bandwidth limitation of the system was realized by experimental and simulation methods. A solution was proposed applying off-set optical filter. The method

applies optical filter for phase to amplitude conversion. Direct modulation of RSOA produces optical signals modulated both in amplitude and phase. The amplitude modulation is received by direct detection, but phase modulation part is eliminated by direct detection. The main idea, that phase modulation can be converted to amplitude modulation by using proper optical filter and it can be detected by direct method. The frequency response of the system is modified, and the modulation bandwidth is improved.

5. System simulation
   The suggested system was implemented in VPI optical simulation environment. It can determine the effects of optical filter type, optical filter slope and the off-set frequency. Based on the simulation results, application possibility of a multifunctional optical filter was investigated. The WDM system requires optical filter for multiplexing and demultiplexing. So if the optimal filter bandwidth and slope perform the WDM demultiplexing requirements, the device can be used for two functions. On the other hand, the combined chromatic dispersion and off-set filtering effect was investigated.
6. System measurement
   The simulation results were validated. Different types of the optical filters were characterized from the point of the phase to intensity conversion. The system was characterized by measured transfer function.

In the framework of the PD109288 research grant 5 international scientific manuscripts were published. All manuscripts are available online. The results achieved were presented on 3 international conferences as invited talks. 2 international journal papers were accepted and published. One more international journal paper is submitted and under review.

Other results

Besides the scientific results, one of the main goals of the project was the establishment of a young research team lead by Eszter Udvary. From the Budapest University of Technology and Economics 8 students (Gábor Fekete, Norbert Gábor, Zsolt Domján, Nóra Bokori, Ágoston Schranz, Balázs Matolcsy, Tamás Pető, Tamás Trásy) participated in the project. Gábor Fekete and Tamás Trásy were responsible for the simulation of the RSOA modulator. Norbert Gábor and Zsolt Domján took part in the measurements, they built the simplified test bed and experimentally compared the in-line and reflective devices. Nóra Bokori and Tamás Pető integrated the RSOA model to VPI Transmission maker simulation system. Balázs Matolcsy and Ágoston Schranz were working on the system related data. Two MSc students (Ágoston Schranz and Balázs Matolcsy) will join to the research group as PhD students in next year. In general, the project helped the formation of a new and young research group at the Budapest University of Technology and Economics.

On the other hand, the project opened the door to interconnect with international research groups working in optical access network domain. During the project a Marie-Curie Innovative Training Network established (FiWin5G, http://www.fiwin5g.eu) in Radio over Fibre optical access networks, where one foreign PhD student is supervised by Eszter Udvary. A bilateral research cooperation proposal is submitted with University of Ljubljana (TÉT_16-1-2016-0050). Based on the OTKA PD109288 project work, new collaboration is planed with the Institute of Communication, Pisa, Italy.

Publications

[1] Eszter Udvary: Investigation of Semiconductor Optical Amplifier Direct Modulation Bandwidth, INFOCOMMUNICATIONS JOURNAL VII: (1) pp. 22-27. (2015)

[2] Eszter Udvary: Off-set Filtering Effect in RSOA Based Optical Access Network, Radioengineering Journal, ISSN 1210-2512 (Print), ISSN 1805-9600 (Online), IF(2014): 0.796, vol 25/1 pp. 26-33. (2016)

[3] Eszter Udvary: Investigation of semiconductor optical amplifier direct modulation speed, 16th International Conference on Transparent Optical Networks, ICTON 2014. Graz, Austria, 2014.07.06-2014.07.10. Paper Mo.C2.5.

[4] Eszter Udvary: Enhancement of RSOA direct modulation speed with optimized optical filter, 17th International Conference on Transparent Optical Networks. Budapest, Hungary, 2015.07.06-2015.07.09. Paper Tu.C5.1.

[5] Eszter Udvary, Ágoston Schranz, Balázs Matolcsy: Dispersion and off-set filtering in RSOA based networks (Invited), 18th International Conference on Transparent Optical Networks (ICTON), Trento, Italy, 2016.07.10-2016.07.14. Paper Th.B2.2. 4 p.

Final student reports under the project:

[6] Norbert Gábor: Optikai összeköttetés megvalósítása reflektív SOA alkalmazásával (in Hungarian), BSc thesis, December 2014 (http://diplomaterv.vik.bme.hu/hu/Theses/Optikai-osszekottetes-megvalositasa-reflektiv)

[7] Domján Zsolt: Reflektív és In-line félvezető optikai erősítő vizsgálata (in Hungarian), MSc thesis, December 2015 (https://diplomaterv.vik.bme.hu/hu/Theses/Reflektiv-es-Inline-felvezeto-optikai-erosito)

[8] Bokori Nóra: RSOA modulációs sávszélességének vizsgálata (in Hungarian), MSc thesis, December 2016

Full publication list: https://vm.mtmt.hu//search/slist.php? AuthorID=10029697