Publication-driven Research Experience for Undergraduates (REU) program in optics and photonics in the Philippines using circuit analogue-based research experiments

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Abstract: We summarize a unique publication-driven Research Experience for Undergraduates program in optics/photonics that uses electronic circuit analogue-based research to strengthen students' engagement in research. At present, we have published 4 journal and conference papers.

1. Introduction

Recently, we reported an unconventional, university and industry collaboration arrangement that taps practicing scientists (alumni of the Ateneo de Manila University (AdMU) but resides outside the Philippines) to mentor undergraduate students in research via online means and translates these mentoring activities into publication outputs [1]. We call this program "**P**ublication-driven **U**ndergraduate **R**esearch **E**xperience – **A**ssisted by online **T**echnologies and **O**verseas **M**entoring" (PURE-ATOM for short). The program has generated 16 publications in the last 3 years from research collaborations between undergraduate students and alumni [1].

An important operational objective of PURE-ATOM is to have *low-cost research structure* since it goes without saying that the private universities in the Philippines have generally limited resources. *In PURE-ATOM, we focus on modelling- and simulation-based research activities ONLY.* The reasons for this approach are (i) easier to start, (ii) cheaper to operate, (iii) maximizes students' programming skills and physical concepts, and (iv) the university has limited resources and facilities to conduct experimental research in optics and photonics.

Our original research topic is the *Special-Relativity-on-a-Photonic-Chip* [1] which is shown on the left side of Fig. 1a, and is indicated by the yellow-shaded region. It is an on-going research work where we "fuse" two distant studies, namely: (i) the traditional Special Relativity (SR) in Physics, and (ii) the fast-emerging technology called as Photonic Integrated Circuits (PICs). Previously, we reported "PICs-based building blocks" that mimic the behaviors of SR phenomena such as: (a) Relativistic Aberration of Light (RAL), (b) Einstein Velocity Addition (EVA), (c) Thomas Rotation Angle, (d) Relativistic Doppler Shifts, and (e) others [1]. For us, these topics remain in the modelling and simulation arena because the required equipment for the PIC experiments is still cost-prohibitive and fabrication is very expensive.

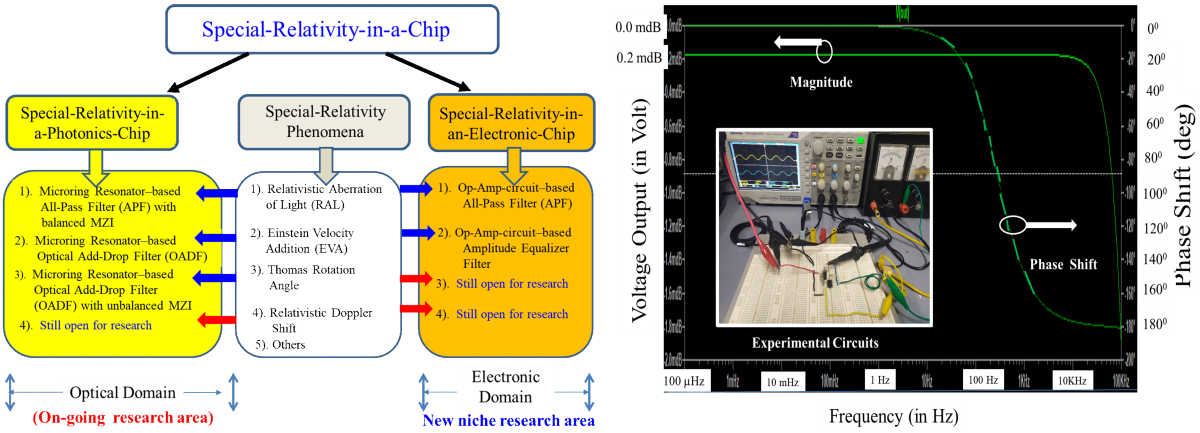

Fig. 1 depicts an (a) overview of our research area consisting of *Special-Relativity-on-a-Photonics-Chip*, and *Special-Relativity-on-an-Electronic-Chip*. Example of the electronic circuit analogues we developed for the phenomenon called Relativistic Aberration of Light (RAL) reported in [2] (b).

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2. New Challenge: Toward research topics with experiment

Lately, there is an increasing number of undergraduate students engaging in the PURE-ATOM program who prefer research with some form of experiment aside from the original simulation-focused research. The above challenge translates into two requirements namely, (i) finding publishable niche research topics that can address the call for experiment activities among students, and (ii) designing these experiments to be inexpensive. These niche research topics must also be unique and not yet fully developed to allow further research and potential publications.

3. New Niche Research Topic: Special-Relativity-on-a-Electronic-Chip

A *"not-so-obvious and probably a counter-intuitive solution at first glance"* is to use low-cost, readily available electronics technologies as an experimental platform rather than the obvious optics- or photonic-based technology. This creates a new niche research topic for us which we called the *Special Relativity-on-an-Electronic-Chip* (*SR-on-an-Echip*). It is shown in the right side of Fig. 1a. It involves mimicking the behaviors of the different phenomena of SR using the "analogous behaviors" of some specially designed electronic circuits. We look for "knowledge-connections" that are not yet known so that we can develop and experiment with them and eventually publish.

Clearly, this new research topic builds upon our earlier work and is the direct electronic counterparts of "*Special-Relativity-on-a-Photonic-Chip*". Thus, we leverage all theoretical learnings we gained from the above-mentioned research topic and our students use them as the foundation for unique electronic-based, experiment-focused research topic. By applying the established concept in electronic circuits onto SR, students built a strong "link" between (i) some of the phenomena and concepts in SR, with (ii) the amplitude, phase, and power responses of the electronic circuits. Note that the translations from optical to electronic analogues are not straightforward. An example of this electronic circuit analogue for RAL is given in Fig. 1b which we reported in [2].

Table 1 shows the generated 4 published journal and conference papers [2-5] based on these research topics.

		Journal Name	Title	Status	Ref
Journal Paper					
1		European Journal of Physics	Circuit analogue of relativistic aberration of light using low-cost, low-complexity operational amplifier-based all-pass filters (APFs)	Published Jan. 2021	2
International Conference					
2		ETOP - Education and Training in Optics & Photonics Conference	Publication-driven Research Experience for Undergraduate (REU) program in Optics/Photonics/Physics in the Philippines using electronic circuit analogue-based research experimentations	Submitted	3 (this paper)
Domestic Conference					
3		38th Annual Conference of Samahang Pisika ng Pilipinas (Philippines Physics Society)	Low-cost, low-complexity electronic analogue of the phenomenon known as Relativistic Aberration of Light using OP-AMP-based All-Pass filters circuits	Published Oct. 2020	4
4		National Academy of Science and Technology Philippines: Luzon Regional Scientific Meeting (RSM) on 11-12 May 2021	"Smartphone-as-a-Testbed-Laboratory: Alternative to the typical "brick-and-mortar" undergraduate physics/electronics laboratory in the time of Covid-19 pandemic"(Poster Presentation)	Published May 2021	5

A more detailed description of the REU program will be provided in the actual conference presentation.

4. Conclusion

We presented a niche, low-cost, experimental research topic for Research Experience for Undergraduate (REU) that lead to publications. It uses novel electronic circuit analogue with rich physics and photonics contents.

5. Acknowledgment

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