Has optics finally found its rightful place in physics curriculum in universities of Eastern Africa?

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ABSTRACT

For a long time, optics has been the "neglected child" in physics university curriculum in Kenya and indeed in East Africa as a whole! But due to emerging applications of laser technology and photonics, some physics departments have started developing undergraduate and postgraduate programmes in optics, lasers and photonics. What are the challenges and chances of success?

Key words: Higher education, curriculum, optics, photonics, laser technology, physics, East Africa

1. INTRODUCTION

In an inspirational article" Promoting Physics and Development in Africa" published back in 2004 in Physics Today, the late Professor Edmund Zingu, one the most prominent scholars physicists on the African continent, wrote: "to excel in physics research in Africa is to conquer Mount Everest without the aid of additional oxygen"[1]. Although the article was mainly concerned with physics research and industrial dissemination of the findings, the atmosphere was then not better in the class-room: frustrated lecturers, depressed students who learned with apathy in ill-equipped laboratories and were not sure of getting a job after graduating.

This was almost15 years ago. Many things have changed since. In 2017, in East Africa, some of the national economies are rated among the fast-growing in the world and as a regional block, the East African Community with a total population of over 150 million people is regarded as the most attractive for foreign investment regions on the continent. As the late Professor Zingu pointed out the most important role of government in the socio-economic development of a nation is to ensure that peace and political stability prevail and at least for the core of East Africa, Kenya, Uganda and Tanzania, this has been the case for the last 13 years, after the publication of the above mentioned article in 2004.

The education sector too has undergone a kind of revolution mainly due to the ICT and Internet deployment. The prevailing political stability has enabled the emergence of a middle class with stable income, capable of investing in education not only at personal or household level, but also capable of investing in setting up and running private universities. Education is a booming business. This has put an end to the government monopoly in higher education. For example in Kenya, in 2008 there were only 6 public universities with a total enrollment of 95,863 students and 11 private universities with a total enrollment of 21,132 students[2]. In 2017, Kenya has 24 public and 32 private universities with a cumulative enrollment of 769,000 students in 2015[3]. The whole region (Burundi, Kenya, Rwanda, Tanzania, Uganda) boasts 103 private and 50 public universities with a total student population of over 1,200,000 students [4,5,6].

However, physics education has not enjoyed this exponential growth : its enrollment has remained low and the teaching-learning conditions inadequate. Traditionally, in East Africa, optics has not enjoyed the same honours as pure theoretical courses such classical mechanics, quantum mechanics, statistical physics in the physics university curriculum. For example in a typical BSc. in Physics curriculum, there are only three units in optics for the Bachelor of Science in Physics: Waves and

14th Conference on Education and Training in Optics and Photonics: ETOP 2017, edited by Xu Liu, Xi-Cheng Zhang, Proc. of SPIE Vol. 10452, 104522H · © 2017 ICO, IEEE, OSA, SPIE
CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2269796

Optics (1st year), Physical Optics (3rd year) and Quantum Electronics (4th year). The first unit is core and the two others are elective but the three theoretical units Classical Mechanics, Quantum Mechanics and Statistical Physics are core. The teaching is organized in such a way that all practical work is done in separate units Practical Physics I (3rd year) and Practical Physics II (4th year) and these units are elective [7]. This means that a student may graduate after four years of study in physics without having seen or touched a lens or a prism, let alone a microscope or a spectroscope. This is just an example on how optics is a "neglected child" in the B.Sc in Physics family.

All over the world, optics and photonics are considered to be on the heart of the second global industrial revolution [8]and they are enabling technologies for socio-economic growth[9]. Lasers have become an integral part of manufacturing, communications, energy research, medicine and dozens of other fields [10]. For this to happen, the academia and industry in developed countries have joined hands to capitalize on the majestic scientific breakthroughs that took place all along the 20th century in optics and photonics to make this technology the heart and the engine of a "new society" of today and the near future [11].

In the year 2011, according to the 2011 OSA-SPIE Global Directory of Programs in Optics and Photonics globally there were 307 universities with programs in optics and photonics; 144 were in USA and Canada, 94 in Europe, 45 in Asia, 14 in Latin America, 10 in Australia and unfortunately none in Africa. The total global undergraduate enrollment was 27,762 students, among them 8,890 in USA (32%) and 5,537 (20%) in China [12].

One understands that it would be again one missed opportunity for Africa to bridge the scientific and technological gap if it does not embrace and develop optics and photonics technology. Indeed, we are witnessing the effect of information and communication technology and Internet in bridging the digital divide between Africa and the rest of the world [13]. Therefore, there are expectations that optics and photonics can help to bridge the technological gap in the same way. It is also clear that there cannot be progress in that direction if universities do not build capacity in this crucial area by introducing training programmes at undergraduate and postgraduate levels to jump start the process, because it is the role and duty of universities and academia to prepare the necessary workforce the society and the nation require, not only for the present labor market but also for the needs of tomorrow. After all, Africa is lucky in some sense: they do not have to invent the wheel but only to adapt it to the rough riding conditions.

With this in mind, two universities, namely Multimedia University of Kenya, located in Nairobi and Dedan Kimathi University with headquarters in Nyeri, Central Kenya, through their few staff with background in optics and photonics resolved to launch programmes in Applied Optics and Photonics, a Bachelor of Science degree and a Master of Science in Industrial Laser Technology and Photonics degree, respectively. As one of the initiators of this endeavour, we would like to share the motivations, the expectations and challenges with the ETOP community from which we expect support and advice.

2. CURRICULUM FOR THE DEGREE OF BACHELOR OF SCIENCE IN APPLIED OPTICS AND LASERS

2.1. Motivation

The motivation behind this curriculum is to give the students enough knowledge and skills so that they are able to take advantage of any opportunity in the optics, lasers and photonics sector or in any application area such as medicine, manufacturing, communications…, but at the same time to give them a strong background in physics and mathematics so that they are able to successfully compete with other physics majors in research or academics or even change career. We have considered that it would still premature for logistical reasons, to introduce specializations and electives at this stage instead we wanted to provide to all the students a scope in optics and photonics as broad as possible. Interested and excelling students are invited to continue research and postgraduate studies in order to build capacity in human resources for the university. We count on collaboration with other institutions, nationally and internationally that have more expertise and capabilities.

2.2 The name of the University and the host Department

Name of the host University: Multimedia University of Kenya, Nairobi, Kenya
Name of the Department: Department of Physics
Number of core Optics/Photonics students currently enrolled in the programme: 25

2.3. The goal of the programme

The goal of the programme is to produce graduates equipped with up-to-date knowledge and skills for planning, management, application, teaching and research in lasers, fibre optics, optical and electro-optical systems used in communications, industrial manufacturing environments and conduct independent research in the same fields

2,4. The expected learning outcomes of the programme

1. Apply acquired knowledge to set up and perform laboratory experiments in optics and lasers
2. Apply laser safety management skills in the laboratory and in industrial environment as well implement industrial safety standard and guidelines
3. Demonstrate competence in the application of laser systems used as an instrument and as part of a lager industrial system in areas including production, testing, maintenance, research and development
4. Demonstrate professional skills in the application of electronic, electro-optic, acousto-optic systems, sensors and controls used in laser systems
5. Conduct research in applied optics and lasers using a variety of lasers sources
6. Participate in the general implementation of sustainable scientific and technological development in teaching, research , industry and innovation

2.5. Core optics/Photonics related courses

The core optics/photonics courses are given in Table 1.

Table 1. Core optics/photonics related courses

Year of study	Courses	Total
1	Geometrical Optics I, Laser Safety and Management	2
2	Optical Fiber I, Laser Physics I, Geometrical Optical II, Natural optical Phenomena, Optical Fiber II, Optical System Design, Laser Interferometry, Optical Photography, Mathematical Methods for Optics I	9
3	Laser Physics II, Optical System Performance, Fiber Communications I, Optical Polarization, Laser Material Processing, Laser Physics III	6
4	Mathematical Methods for Optics II, Optical Holography, Laser Metrology, Fiber Optics Communications II, Diffraction and Imaging, Laser Physics IV, Laser-Biological Interactions, Nonlinear Optics, Holographic Applications	9
	Total	26

The remaining courses are University common courses (3), Faculty common courses (3), mathematics courses (7), physics courses (12), chemistry (2) and ICT (3) [14]

3. CURRICULUM OF THE DEGREE OF MASTER OF SCIENCE IN INDUSTRIAL LASER TECHNOLOGY AND PHOTONICS

3.1. Name of the University and host Department

Name of the University: Dedan Kimathi University of Technology
Name of the Department: Department of Mathematics and Physical Sciences

3.2. The goal of the programme

The degree of Master of Science in Industrial Laser Technology and Photonics is designed to develop multidisciplinary professionals and scientists, who have up-to-date knowledge in laser fundamentals, technical and professional skills in application areas such laser industrial material processing, optical-fibre based technology, industrial spectroscopy and related fields

3.3. The expected learning outcomes of the programme

By the end of this programme depending of area of specialization, the graduate should be able to:

1. Apply acquired knowledge and skills to develop, set and implement basic and advanced laboratory experiments in laser technology and photonics
2. Plan, procure, install, test and maintain laser equipment integrated in larger industrial systems and ensure their safe and effective use
3. Test the performance of optical fibre components and deploy them in a communications network or sensor system
4. Install, calibrate, test and run laser spectroscopy equipment in industrial and research laboratory settings
5. Show leadership in effective dissemination of knowledge and skills in laser-based science and technology through mentorship, training of young scientists and technologists and the public at large and through entrepreneurship in laser-based innovations.

3.4. **Core and specialization optics/photonics courses**

Core and specialization optics/photonics related are given in Tables 2-5

Table 2. Core optics/photonics courses offered in the programme:

Year of study	Courses	Total
1	Applied Optics, Laser Physics, Photonic Devices and Systems, Practical Industrial Lasers, Optical Fibre Communications, Laser Materials Processing and Workshop, Graduate Seminar I	7
2	Optimization Techniques of Laser Processes, Graduate Seminar II	2
Total		9

Table 3. Specialization courses: Industrial Laser Materials Processing

Year of study	Specialization: Industrial Laser Materials Processing	Total
1	None	0
2	Industrial Laser Systems and Applications, Microprocessing and Advanced Industrial Laser Techniques, Industrial Laser Systems and Applications Lab	3
	Project	1
Total		4

Table 4. Specialization courses: Optical Fibre Applications

Year of study	Specialization: Optical Fibre Applications	Total
1	None	0
2	Optical Communications Networks, Optical Fibre Sensors and Applications, Optical Fibre Technology Lab	3
	Project	1
Total		4

Table 5. Specialization courses: Laser Spectroscopy Techniques

Year of study	Specialization: Laser Spectroscopy Techniques	Total
1	None	
2	Fundamentals and Techniques of Laser Spectroscopy, Advances in Laser Spectroscopy, Laser Spectroscopy Techniques Lab	3
	Project	1
Total		4

Other courses are: Productivity Management, Research Methods in first year of study [15]

3.5. Profile of the programme

This programme is multidisciplinary. It is meant to provide the engineering graduate mainly mechanical and mechatronic the necessary laser fundamentals they lack when they use a laser as a tool in materials processing and manufacturing. It provides physics majors with understanding and skills in laser manufacturing and related engineering skills such CNC. It wants also to expand applications of fiber optics of a communications engineering graduate to sensing and instrumentation as optical fibre sensors are playing a bigger and bigger role in structure health monitoring, instrumentation , precision machinery, biophotonics… To chemistry graduate, laser spectroscopy offers additional advanced tools and it broadens the scope of spectroscopic techniques. To put students with such diverse backgrounds on an equal footing, we propose basic common courses: Applied Optics, Laser Physics and Photonics Devices and Systems.

3.6. **Teaching and research equipment now available**

As Prof. Zingu pointed out his article, laboratory equipment in teaching and research laboratories remain one of the main issues in universities in Africa. Dedan Kimathi University of Technology has been lucky to be awarded a LASFEST, AIP-

OSA-SPIE-IEEE Photonics grant back in 2010 and some equipment has been purchased. LaserFest was organized to celebrate the 50th anniversary of the Laser during the year 2010. The University is still grateful for that generous donation. In addition they got a research grant from the NCST, the National Council for Science and Technology, a Government of Kenya agency that funds scientific research. From the two grants the equipment available at the Department is as presented in Table 6.

Table 6. Equipment available for the programme at the Department

SN	Item	Quant	Observations
1.	Red diode laser Module	1	Useful in experiments on geometrical optics
2.	IR diode laser module, λ=785 nm	1	Useful for investigation of characteristics of diode lasers
3.	He-Ne laser	2	Useful in most of physical optics experiments, including interference , diffraction and polarization
4.	Tektronix Digital Double Trace Oscilloscope	1	50 MHz
5.	Digital Function Generator	1	Up to 20 MHz
6.	Photodiode Amplifier	2	Can function as optical power meter, 0-40 kHz
7.	Lens kits	1	25 mm 24 lenses
8.	Optical table	1	Home made
9.	DPSSL kit	1	Froe teaching, research and testing: Experiments on diode laser pumping, frequency doubling…
10.	Optomechanics kits	1	Bases and post holder essentials kit
			Posts and accessories essentials kit
			Optical mount essentials kit
11.	Stereo Zoom Microscope Digital Video System	1	For common imaging applications and high-resolution microscopic inspection
12.	General Purpose Thermal Sensor	1	For industrial laser high-power measurements

3.7. Challenges

3.7.1. Equipment

The above-listed equipment is hardly adequate for the initial phase of the project (experiments in Applied Optics, Laser Physics and Photonic Devices and Systems), however we hope we can upgrade for more advanced experiments. Equipment for optical fibre experiments and research and for spectroscopy as well must be acquired. We consider this will be done progressively. The toughest challenge has been the purchase of an industrial high-power laser because financial and logistical constraints. We hope to get a grant from the newly formed NRF, National Research Fund to purchase such equipment if the hurdles due to public procurement procedures are overcome

3.7.2 Teaching and supervising staff

The most problematic and long-term challenge is experienced in the human resource department, because, as we pointed out, there are few academic staff with specialization in optics, lasers and photonics. Therefore we plan to mobilize on a part-time basis all the available manpower scattered all over in different universities first locally, then regionally. We count much on international cooperation, especially with universities in South Africa where research and implementation of laser technology is quite advanced and scientific organizations such AIP, OSA, SPIE, IEEE Photonics and the ETOP community for the success of this project.

4. CASE STUDY OF CAREER OPPORTUNITIES IN LASER MATERIALS PROCESSING IN EAST AFRICA: AUTOMOTIVE MANUFACTURING INDUSTRY

The success of any academic technological programme is gauged by the professional success of its graduates on the labor market and the impact of the technology on the socio-economical development of a region or a country. Laser materials processing in East African region is still at its infancy stage and its growth will depend on the pace of industrialization of the economy. One of the sectors where the graduates of the programmes in optics and lasers could have good career opportunities is the emerging but fast growing automotive manufacturing industry.

Frost & Sullivan sees automotive manufacturing as one of the key future industries in Africa[16]. Despite African economic growth slowing down due to low oil and commodities prices, the automotive market is forecast to grow between 3 and 3.7 in 2017, East Africa retaining its position as the fastest growing economically region on the continent[17,18] .While Africa's automobile market is still underdeveloped, Deloitte recognizes the potential of the automobile industry in Africa and foresees room for growth across the automotive value chain including vehicles sales, after sales, vehicle assembly and production. Deloitte regards the continent as the final frontier for the global automotive industry. This is as per capita income levels continue to rise, financial markets develop and cars become more accessible for a greater share of the population[19]. The automotive manufacturing and assembly in Africa is driven by South Africa, Nigeria and Kenya. The expanding transport corridor projects such Lamu Port Southern- Soudan Ethiopia Transport Corridor (LAPSSET) are expected to reveal greater logistics opportunities and increase the demand for commercial vehicles in East Africa significantly over the next 5 years[16]. The Kenyan government has identified the automotive and auto parts industry as a major economic driver in the Kenya National Industrialisation Policy Framework released in 2010. In July 2015 the Ministry of Industrialisation proposed policy measures in the Policy Framework for Motor Vehicle Assembly in Kenya to complement the National Industrialisation Policy Framework. The policy was expected to be implemented in 2016 with the aim of promoting new investments in the country's automotive industry and for Kenya to become a globally competitive vehicle manufacture. In 2015 Kenya assembled 9,295 vehicles most of which were heavy commercial vehicles (HCVs). The assembly of motor vehicles grew by 31.4% from 2013 to 2014 and vehicle assembly figures are forecasted to almost double between 2013 and 2019[19] .

The expansion of automotive manufacturing and assembly in Kenya and in the region is a great opportunity for deployment of high-power laser technology as the automotive industry is the first user of laser technology for materials processing globally. For example, Volkswagen began production at its Kenyan facility, at Thika just outside Nairobi, in January this year, 40 years after it closed its original Kenyan plant. The new factory receives part assembled Polos and Vivos from Volkswagen South Africa's (VWSA) Uitenhage assembly plant in the Eastern Cape for final assembly. It will handle 1,000 cars this year, increasing over time to 5,000 units. The company has plans to open a similar assembly plant in Rwanda[20]. The re-entry of Volkswagen in the East African car manufacturing scene might trigger the deployment of high-power lasers as the company is a heavy user of industrial lasers with more than 800 high-power laser systems installed at its assembly plants worldwide back in 2006 [21]. Such eventuality would be a good job and career opportunity for laser technology graduates and would enhance the local intellectual content of the automotive manufacturing industry, because other players in the ground, such General Motors would follow suit.

This is about the career opportunities in automotive industry only. The deployment of large industrial projects such as the Standard Gauge Railway (SGR) and LAPSSET, present other opportunities for laser materials processing in repair and maintenance of equipment.

This is just one example of emerging wide spectrum of opportunities in optics, laser technology and photonics applications that include communications, medicine, sensing, surveying… research and academic careers.

CONCLUSION

Optics and photonics are the heart and engine of the second global industrial revolution and Africa cannot afford to miss another opportunity of catching up with the rest of the world. Universities in East Africa have initiated academic programmes for training the much needed manpower in optics and photonics despite limited financial and human resources. The success of these projects depends on how they will be able to mobilize the available resources locally and regionally in collaboration with the global photonics community.

Acknowledgement

We thank Prof. Liu Xu, the management of Zhejiang University, the organizing committee of the 14th International Conference on Education and Training in Optics and Photonics (ETOP 2017) for the kind invitation to present this paper. We also thank the management of Multimedia University of Kenya and Dedan Kimathi University of Technology for their continuous logistic support.

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