Globalization in Photonics Research and Development

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***Abstract*—A brief account of photonics research activities in the selected countries in the Middle East and Africa is presented in this article. Though not comprehensive, we hope to provide a glimpse of the research landscape in the region, and the collaboration and connection with each other and the international partners.**

***Index Terms*—Photonics, globalization.**

I. Introduction

THE field of photonics has found its footprint globally, and new discoveries are often driven by multinational or interconnected teams across different regions, be it established or emerging. Seminal research from a single entity or geographical region can usher in worldwide impact when nurtured and conducted collaboratively or concertedly. As new researchers and discoveries are emerging in the Middle East and North Africa (MENA) and the surrounding region, it is timely that the progress in the region was discussed at the Symposium on Globalization in Photonics Research & Development held during the IEEE Photonics Society conference on November 15, 2022 [1]. A recent Feature Issue on Optics in Africa also captured the fundamental and applied research topics in the region to showcase the historical development of key research fields, covering the advances in lasers to present-day progress in photonic materials [2], [3]. Further, the aspects of quantum and optical communication technologies are guest-edited by researchers from countries in the Global South, including Cameroon and Morocco in Journal of Optics by IOP [4].

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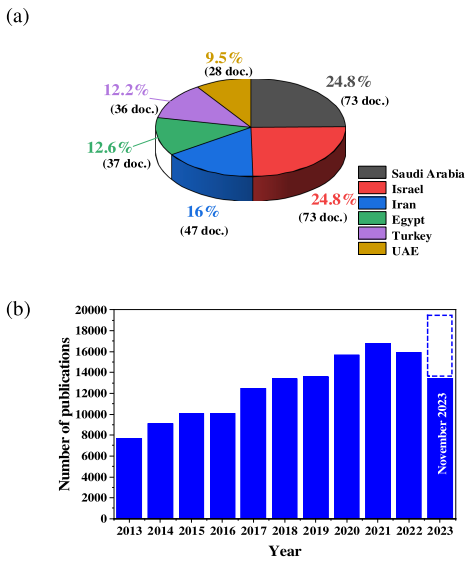

Fig. 1. (a) Percentage (number of documents, doc., for the year 2023) of publications of the six major countries in the MENA region in photonics research using only the "photonics" keyword search. **Source**: Web of science, November 2023. (b) Number of publications (i.e., articles, conferences, and patents) in photonics-related research over the last ten years plus. **Source**: Google Scholar. Keywords: Photonics, optics, optoelectronics, semiconductor, quantum optics.

Herein, we shed light on the flourishing photonics research of selected countries in the Africa–Arab-peninsular region and highlighted the collaborative effort and synergy among various research groups across different countries in the region and internationally. To the best of our knowledge, the 6 major countries contributing to photonics publications in the MENA region and the representative highly cited papers in 2023 are Saudi Arabia, Israel [5], [6], Egypt, Turkey [7], [8], [9], Iran [10], [11], [12], and United Arab Emirates (see Fig. 1(a)), while the total number of publications in photonics, optics, optoelectronics, semiconductor and quantum optics increases to over 10,000 in recent years (see Fig. 1(b)). The field of research covers optical communication, display and lighting, imaging and beam shaping, optical fiber sensing, optics, quantum technology, semiconductor devices and compound semiconductor epitaxy, et cetera, which are relevant to global photonics research. Furthermore, the emphasis on research translation and commercialization, arising from the maturity of university incubation or significant funding

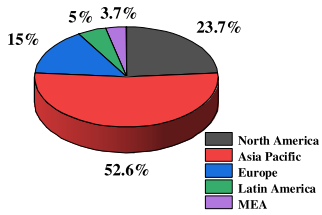

Fig. 2. Photonics market revenue share of the Middle East and Africa (MEA) region in 2022 (%). The global photonics market size accounted for USD 0.77 trillion in 2022. **Source**: Precedence Research [14].

from government agencies or companies, is gaining momentum in the region. Therefore, efforts in orchestrating photonics research networks or even forming a consortium to solve issues of national or regional priorities will usher in a vibrant photonics ecosystem with a trajectory toward sustainable development. This is expected to eventually translate into photonics-driven economic growth for a country, a region, or even worldwide [13]. In this respect, it is noted the photonics market-revenue share for the Middle East and Africa (MEA) is 3.7% of USD 0.77 trillion, in comparison to other regions of North America, Asia Pacific, Europe and Latin America (see Fig. 2). The article will also provide a glimpse into the research topics conducted in the individual section, which are of global interest.

II. Egypt

The photonics research scene in Egypt has been actively led by several prominent researchers. A leading scientist in the field is Professor Salah Obayya who is a Professor of Photonics and Director of the *Center for Photonics and Smart Materials (CPSM)* at *Zewail City of Science and Technology* [15] [https://www.zewailcity.edu.eg/]. The institution was named after Professor Ahmed Hassan Zewail, a chemist who was awarded the Nobel Prize in Chemistry in 1999. Embracing the challenge of 21st century, in which complex nanophotonics structures and devices are required, his significant findings in modern computational modeling, which numerically deal with very large linear, nonlinear or coupled partial differential equations, are relevant to designing a plethora of photonics components. These include photonic devices for optical communications, plasmonics, metamaterials, energy harvesting, optical biosensors, etc. [16], [17], [18].

Professor Hossam M. H. Shalaby is a distinguished Egyptian scientist and professor in the field of photonics. In *Alexandria University* [https://alexu.edu.eg/], he contributed significantly to the field of fiber optics, communication (including optical code-division multiple access) and photonics (including optical sensors) [19], [20], [21], [22]. His team recently investigated into silicon-on-insulator (SOI) for developing integrated photonics devices aiming to achieve mode-division multiplexing (MDM) and polarization division multiplexing (PDM) [23].

Professor Moustafa Hussein Aly is another renowned Egyptian scientist and professor in the field of photonics. He is currently the President Consultant for Alamein Branch and for Training Affairs at the *Arab Academy for Science, Technology and Maritime Transport (AASTMT)*, where he is also a Professor of Optical Communications in the Department of Electronics and Communications Engineering. His research focus encompasses optical fibers [24], [25], optical fiber communications [26], free-space optical communications [27] and optical sensors [28]. The regional institutes of AASTMT research into various relevant fields, across the Arab countries, and collaborate with international partners. [https://aast.edu/en/index.php].

Cutting-edge technology related to photonics was developed by Si-Ware, which is a fabless semiconductor company [https://www.si-ware.com/], developing an innovative MEMS Fourier-transform infrared spectrometer [29] for material analysis applications in agriculture, food and medicine. Continuous monitoring of air purification [30], predicting forage nutritive value [31], malaria parasite detection and quantification [32] as well as chemical fertilizers content prediction [33] are enabled with the photonics innovation. Si-Ware won the prestigious Prism Award in 2014 from the International Society for Optics and Photonics (SPIE) [34].

III. Tunisia

Tunisia has been steadily working to advance its presence in the field of photonics. In the following, we will highlight the principal research groups and their main contributions in this domain.

Professor Mourad Zghal and his team at the *University of Carthage's Telecommunications College (Sup'Com)* have made significant contributions to the study of nonlinear effects in optical fibers, with a particular focus on their applicability in telecommunications, sensing, and spectroscopy applications [https://www.carthage.edu/]. Their research has revolved around the supercontinuum generation (SCG) and stimulated Brillouin scattering (SBS) phenomena within specialty fibers, including photonic crystal fibers (PCFs) [35], [36] and chalcogenide fibers [37]. By harnessing advanced numerical tools to model and simulate these complex optical processes, much valuable insights were gained on the behavior of specialty fibers and the mechanisms behind the SCG and the SBS. Furthermore, through collaboration with South African scientists, the team has involved in space division multiplexing (SDM), especially within the regime of free space optics (FSO), using structured light [38]. In addition, the team performed the Mux and De-Mux of over 100 spatial modes using holographic approach [39].

Another group, led by Professor Habib Fathallah, within the *Faculty of Science of Bizerte (FSB)* of *University of Carthage* [http://www.fsb.rnu.tn/], in collaboration with Electronics and Microelectronics Laboratory [*University of Monastir*, http://emlab-fsm.tn], has contributed to the field of SDM with an emphasis on the design and numerical investigation of novel specialty fibers (e.g., fibers with new refractive index profiles) to effectively transmit orbital angular momentum (OAM) modes [40], [41]. This includes the design and the assessment of novel few-mode fibers (FMFs), multicore fibers (MCFs) [42], and PCFs, handling robust OAM modes to meet the demands of next-generation optical communication systems. Moreover, the group, in collaboration with King Saud University (KSU) has

involved in the design of novel fibers for SBS, particularly for temperature and strain sensing applications [43]. There are also other contributions in the field of millimeter waves (MMW) and semiconductor optical amplifiers (SOA) [44].

Furthermore, there are other areas that expand upon Tunisia's engagement in photonics research. Among these is the contribution made by Professor Rabah Attia and his research group at the SERCOM Laboratory, *Tunisia Polytechnic School* [https://ept.tn/sercom]. Their focus included work in photonic crystal components [45], the development of electro-optic modulators tailored for advanced optical communication systems, and in optical code division multiple access (OCDMA) [46].

One of the pioneers in the field of optics and photonics in Tunisia is Professor Zohra Ben Lakhdar [47], the founder of the Atomic Molecular Spectroscopy and Applications (LSAMA) at the *University of Tunis El Manar* [http://www.utm.rnu.tn]. The team has conducted experiments and developed sophisticated models, primarily focusing on the realm of infrared spectroscopy, including application-oriented research related to pollution detection and medicine [48]. Moreover, within the National School of Engineers of Tunis [http://www.enit.rnu.tn], Professor Houria Rezig has been conducting valuable research in optical code division multiple access (CDMA) [49], [50].

The creation of the *African Laser Centre (ALC)* [https://africanlasercenter.org], often referred to as a "virtual center of excellence" is dedicated to the promotion of optics research across the whole African continent. The platform contributed to facilitating student exchanges within Africa, while strengthening the research and educational landscape in photonics.

IV. South Africa

Photonics in South Africa is a relatively small field, but there are nevertheless several internationally recognized groups. Here we will mention the work being done by researchers at the major institutions, to the best of our knowledge.

University of the Witwatersrand (Wits University), Johannesburg: Within the School of Physics at *Wits University*, the Structured Light Laboratory, led by the esteemed Andrew Forbes, is world renowned for the study of structured light. [https://structured-light.org/] Recognised internationally, Forbes specialises in shaping laser light into high-order modes and delves deeply into quantum and non-linear photonics [51], [52], [53], [54], [55]. Additionally, members of his laboratory, such as Angela Dudley and Isaac Nape contributed significantly with their work in structured light [56] and quantum photonics [57], [52], respectively. *Wits University* also houses the *Wits OC Lab*, situated in the School of Electrical and Information Engineering. Mitchell Cox founded this laboratory in collaboration with Ling Cheng [https://www.wits.ac.za/oclab]. Cox's primary focus is structured light in turbulence and the use of machine learning to model the effects of turbulence on laser beams [58], [59], with research looking into low-cost free-space optical communications [60]. Ling Cheng's expertise lies in digital communications and hybrid systems that combine visible light with power line communication [61], [62]. The *Wits University* Optica/SPIE student chapter actively promotes optics, photonics, and STEM education across South Africa.

National Metrology Institute of South Africa (NMISA): Filippus S. Roux (Stef Roux), a member of NMISA, explores the theoretical intricacies of light behaviour, especially under the influence of atmospheric turbulence [63]. His work frequently intersects with experimental collaborations, one such being the study on characterising quantum channels with non-separable states of classical light [38], [64], [65], [66] [https://www.nmisa.org/].

University of KwaZulu-Natal: The Quantum Information Group, led by Thomas Konrad, operates under the School of Chemistry and Physics. Their research spans across quantum communication, teleportation, and quantum information processing [67], [68], [69]. Yaseera Ismail further the experimental facet of this domain, focusing on quantum key distribution and machine learning integration [70], [71]. [https://scp.ukzn.ac.za/thomas-konrad/].

Stellenbosch University: Francesco Pertuccione from Stellenbosch University, who is also affiliated with the National Institute for Theoretical and Computational Sciences (NITheCS), delves into open quantum systems and quantum information processing [72]. The Stellenbosch Laser Research Institute at the same university hosts researchers interested in microscopy, ultrafast spectroscopy, optical trapping, ion trapping and quantum nanophotonics [73], [74] [http://www.sun.ac.za/english/faculty/science/physics/lri] Prominent researchers here include Erich Rohwer, Pieter Neethling, Gurthwin Bosman, Christine Steenkamp, and Mark Tame. The university also boasts a robust Optica/SPIE student chapter, renowned for its outreach efforts, reaching over 1,200 primary and high school students in 2023.

University of Johannesburg: Under the leadership of Heidi Abrahamse, experimental works related to multicomponent drug delivery systems for photodynamic therapy and photobiomodulation for stem cell therapy are underway [75], [76]. There is also a research group at the university focussed on fibre optic sensors under the leadership of Michael Grobler [77].

Nelson Mandela University: The Centre for Broadband Communication, presently under the guidance of David Waswa (previously Tim Gibbon), delves into optical sensing and applications pertinent to South Africa, such as the Square Kilometer Array project [78]. [https://broadband.mandela.ac.za/]

National Laser Centre at the CSIR: The Council for Scientific and Industrial Research hosts the National Laser Centre (NLC), which conducts research and development in various laser and photonics-based fields. Darryl Naidoo is a research group leader at the NLC, focusing on kilowatt laser beam shaping and control, as well as laser systems development [64]. Nokwazi Mphuthi is a senior researcher with a keen interest in structured light [79].

Others: The Biophysics Research Group at the *University of Pretoria*, steered by Professor Tjaart Kruger, predominantly focuses on the nuances of photosynthetic light harvesting and regulation [80], [81], [82], [83], [84]. Kessie Govender's Quantum Physics Research Group at the *Cape Peninsula University of Technology (CPUT)* investigates atomic physics and cold atoms, with in-house capabilities to design and build their own quantum devices such as single-photon detectors [85].

V. Saudi Arabia

The photonics research in Saudi Arabia has been actively funded, for example, from *King Abdulaziz City for Science and Technology (KACST)* and *King Abdullah City for Atomic and Renewable Energy (K.A.CARE)*. In an effort to align all research efforts to the Kingdom's Vision 2030, RDIA (Research, Development and Innovation Authority) has been recently established to foster a thriving and sustainable national RDI ecosystem to create high-value jobs in science and technology. The four pillars of RDIA focus are Health and Wellness, Sustainable Environment and Supply of Essential Needs, Energy and Industrial Leadership and Economies of the Future. The universities in Saudi Arabia have been active in photonics research areas which aligned well with many of the identified priority areas.

Previously, in promoting Saudi Arabia's research consortium, *KACST* [https://kacst.gov.sa] funded the *Technology Innovation Center on RF and Photonics (TIC-RFTONICS)* for research toward e-society [https://rftonics.ksu.edu.sa]. This is part of the initiatives of National Science, Technology and Innovation Plan (NSTIP) with the goal of forming KACST's research centers within Saudi Arabia's universities. The TIC formation aims at increasing the research translation and commercialization effort as a basis toward diversifying the economy in the country. The center was co-founded by prominent figures of *King Saud University (KSU)*, Professor Saleh A. Alshebeili and Professor Habib Fathallah, and started its activities since October 2012. The TIC-RFTONICS in KSU produces both wireless and lightwave prototypes, while delivering significant research findings in both RF and optical wireless communications [43], [44], [86], [87], [88]. Through the TIC-RFTONICS, the collaboration among Saudi Arabia's universities were further fostered across KSU-KFUPM-KAUST [89], [90] in collaboration with other prominent communication scientist, such as Professor Mohamed-Slim Alouini [91], [https://cemse.kaust.edu.sa/ctl].

In the field of laser-based solid-state lighting and applications in terrestrial/underwater optical communication, Professor Boon S. Ooi led the *KACST's Technology Innovation Center on Solid-State Lighting (TIC-SSL) at KAUST* and the *TIC-SSL* at participating universities forming a research consortium from 2013-2021. The TIC-SSL combines *KAUST* partnership with *KACST*, *KFUPM (King Fahd University of Petroleum and Minerals)*, *Effat University* (an all-female-students university) and *King Abdulaziz University*, as well as international collaborators from *UCSB (University of California, Santa Barbara)* [https://ssleec.ucsb.edu/]. The *TIC-SSL* led numerous innovative research on laser-/superluminescent-diodes and semiconductor gain media [92] for white-light generation, wavelength conversion [93] and optical communication. Other prominent scientists, in the development of down-conversion halide-perovskites and related nanomaterials as well as the studies of these materials using ultrafast laser spectroscopy and four-dimensional electron imaging, included Professor Osman Bakr and Professor Omar F. Mohammed [https://funl.kaust.edu.sa/people/detail/osman-bakr-phd], [https://femto.kaust.edu.sa/]. *KFUPM-KAUST* collaboration has been fruitful in the development of self-injection locked laser and tunable lasers in the visible wavelengths. [94], [95], [96], [97] Professor Mohammad A. AlSunaidi, and later Professor Mohammed Zahed Mustafa Khan, led the cross-institution collaboration through the *KACST's TIC-SSL at KFUPM*. [https://faculty.kfupm.edu.sa/EE/msunaidi/], [https://faculty.kfupm.edu.sa/EE/zahedmk/].

At *KFUPM*, Professor Hussain Ali Jamid [98] [https://faculty.kfupm.edu.sa/EE/hajamed/], Professor Mohammad A. Alsunaidi [99] and Professor Husain M. Masoudi [100] [https://faculty.kfupm.edu.sa/EE/husainm/] led the early development of the field of Photonics in Saudi Arabia. In addition, Professor Khurram Karim Qureishi's research involved all-optical logic gates and optical fiber sensing and technology operating in the C- and L-bands [https://faculty.kfupm.edu.sa/EE/kqureshi/].

At *King Abdullah University of Science and Technology (KAUST)*, the synergy of interdisciplinary research and significant funding sources, including that derived from its endowment, has ushered in flourishing photonics research. Professor Boon S. Ooi led the *Photonics Laboratory* [https://cemse.kaust.edu.sa/photonics] and KAUST spin-off company, *AK-SENS* [https://ak-sens.com/] to address areas of economic importance related to the oil and gas industry (downhole photonics) [101], dates production [102], [103], and quantum communication security [104]. In collaboration with *Saudi Aramco*, *Ministry of Environment, Water and Agriculture (MEWA)*, *NEOM* [https://www.neom.com/], and *Royal Commission for AlUla (RCU)* [https://www.rcu.gov.sa/en/], the team implemented practical distributed fiber sensing and machine learning in oil production monitoring [101] or in early detection of red-palm weevil infestation for smart farming and precision agriculture [103]. Furthermore, to address the need for Red Sea marine life and environmental monitoring, photonics research has been conducted, which included underwater optical wireless communication [105], [106], underwater energy transfer by light [107] and optical fiber monitoring network [108]. The research on underwater photonics was also highlighted twice by Nature Photonics in 2015 and 2023, and thus demonstrating the team's persistent effort in addressing the technological challenges in underwater photonics [109], [110]. The team also collaborated with Professor Carlos M. Duarte, a world leading marine ecologist at KAUST, to utilize photonics technology in the ocean for red sea coral reef protection and environment protection [111], [https://www.kaust.edu.sa/en/study/faculty/carlos-duarte].

KACST and *KAUST* have also invested heavily in semiconductor epitaxy growth equipment to fuel research based on molecular beam epitaxy (MBE) and metal-organic vapor phase epitaxy (MOVPE) [112] semiconductor growth technique. *KACST-KAUST* have collaborated on group-III nitride light-emitters on various heterogeneous substrates using MBE (led by *TIC-SSL* co-principal-investigator, Tien Khee Ng [https://cemse.kaust.edu.sa/photonics/people/person/tien-khee-ng]), especially in addressing the research gaps in the ultraviolet regime and the "green gap" [113], [114], [115]. *KACST-KAUST-UCSB* also conducted joint-research in MOCVD grown semipolar lasers [116] under the *TIC-SSL* funding framework.

In *KAUST*, the semiconductor epitaxy effort is championed by Professor Kazuhiro Ohkawa and Professor Xiaohang Li.

In full-color display LED integration and optical communication, Professor Kazuhiro Ohkawa's ECO Devices Laboratory [https://cemse.kaust.edu.sa/ecodevices] has collaborated internationally. The team realized InGaN-based red LED [117], [118] and optical communication based on the device [119]. Subsequently, the team demonstrated the first all-InGaN-based RGB micro-LEDs and at high pixel density, which is significant for immersive visual experiences requiring ultra-high brightness and definition [112]. It is also noted that Professor Ohkawa has demonstrated the first 740-nm InGaN-based red LEDs in 2012 [120]. Related to photonics research, Professor Xiaohang Li's Advanced Semiconductor Laboratory [https://cemse.kaust.edu.sa/semiconductor] focused on the formation of ultrawide bandgap semiconductor for ultraviolet optoelectronic devices, notably in group-III-nitrides and group-III-oxides deep ultraviolet light-emitters [121], boron-containing nitrides [122], and Ga_2O_3 membrane [123]. The team has also reported significant work in semiconductor heterostructures design and deep-ultraviolet photodetectors [124], [125].

The Integrated Photonics Lab, led by Professor Yating Wan, further focuses on advanced integration of on-chip light sources for short-reach communication links by optimizing GaAs-based quantum-dots (QD) gain material epitaxy-growth, refining multilayer photonic integrated circuit (PIC) integration methods, and innovating in silicon photonic topological and dispersion engineering [126], [127], [128], [https://cemse.kaust.edu.sa/ipl]. The team has forged strong alliances with esteemed global entities, such as Intel, UCSB, and SZIQA (Shenzhen International Quantum Academy, [https://siqse.sustech.edu.cn/].

Cross-disciplinary and advanced photonics related research are thriving in *KAUST*, such as the following. Professor Qiaoqiang Gan's Sustainability and Photonic Energy Research (SuPER) Laboratory [https://super.kaust.edu.sa/], among other topics, research into sustainable water and cooling solutions by harvesting solar energy, and introduces radiative cooling technologies to achieve record-breaking thermal photonic architectures that require no electricity consumption [129], [130], [131]. Another advanced photonics related research is conducted by Professor Andrea Fratalocchi who delves in applied complexity [https://cemse.kaust.edu.sa/primalight], from basic research to sustainable technologies that tackle the contemporary problems of global interest, ranging from energy harvesting to clean water production, design of smart materials, biomedical applications, information security, artificial intelligence, and global warming [132], [133], [134]. Professsor Carlo Liberale's research applies photonics in bio-science, including the use of infrared and Raman micro-spectroscopy techniques and multi-photon processes in the studies of bio-molecules, as well as high-resolution 3D printing to produce complex optical systems [135], [136], [137], [https://vibralab.kaust.edu.sa/].

VI. United Arab Emirates

In line with the UAE's vision to become a leader in advanced technology, the *Advanced Technology Research Council (ATRC)* is defining Abu Dhabi's research strategy across academia and industry. By consolidating and facilitating efficient investment funding, driving policy and regulation for agile decision-making, the *ATRC* is reinforcing the existing R&D ecosystem to establish Abu Dhabi and the wider UAE as a global hub for innovation [https://www.atrc.ae].

The *ATRC*, overseeing the nation's shift toward a knowledge-based economy, comprises three core pillars: (i) *ASPIRE*, driving the technology program management and business development, (ii) *Technology Innovation Institute (TII)* as a leading global scientific research institute and the applied research arm [https://www.tii.ae], and (iii) *VentureOne* as the start-up incubator and commercialization arm bridging the gap between research pursuits and commercial engagements.

In this context, photonics, with its ever-expanding range of applications and groundbreaking innovations often endorsed by Nobel Prize laureates [138], stands as a pivotal element in the UAE's transition to an innovation-driven knowledge economy. It serves as the cornerstone for shaping and enhancing various existing and future technologies, applications, and capabilities that facilitate the rapid evolution of the country into a digital-first economy.

At *TII*, the *Directed Energy Research Center (DERC)*, led by the Chief Researcher, Dr. Chaouki Kasmi, emerges as a global center of excellence in photonics in the *UAE* [139]. An achievement resulting from the incremental efforts of the *Advanced Photonics Research (APR)* Department, led by the Scientific Director, Dr. Steevy J. Cordette [140]. The *APR*'s team made significant contribution to integrated photonics, particularly in the study of Efficient Frequency Comb Generation [141] and the development of narrow linewidth lasers with micro-ring resonators [142], addressing the need for stable integrated Lasers featuring linear frequency sweeps and necessary power for various applications [143].

TII is also actively advancing its efforts in photonics through its *Quantum Research Center (QRC)*, within the Quantum Sensing Department, led by the Senior Scientific Director, Dr. Rene Reimann, on levitated nanoparticle using optical twister [144], [145], and the Quantum Communications department, led by the Senior Scientific Director, Dr. James Grieve, on entangled single photon sources and quantum key distribution (QKD) [146], [147].

Notably, the academic research conducted at *Khalifa University* [https://www.ku.ac.ae], has significantly contributed to the study of THz generation and spectroscopy [148] by Professor Mauro Pereira and his team, as well as to field of Silicon Photonics and Micro/Nanofabrication process done by Professor Jaime Viegas's research group [149], [150].

Similarly, *New York University of Abu Dhabi (NYU)*, has made significant contribution through the research group of Professor Mahmoud Rasras, which address the current limitation of communication bandwidth with a focus on low-temperature germanium photodetectors integration on CMOS compatible platform (above 64 Gb/s) [151], [152], [153], [https://nyuad.nyu.edu/en/research/faculty-labs-and-projects/photonics-research-lab.html].

Research ongoing at the *UAE University* contributes greatly in the study of the optical soliton and nonlinear optics physics

within the laboratory of Professor Usama Al Khawaja [154], [155], [https://www.uaeu.ac.ae].

A complementary emphasis in developing Photonics Research within the ecosystem involves the establishment of a robust local community closely intertwined with academia, not only to enhance educational landscape in photonics for the future generation of researcher but also to foster collaboration for research of excellence addressing both local and global challenges head-on.

VII. Conclusion

The photonics research in the Africa–Arab-peninsula region is indeed dynamic, and collaborative effort within the region and with international partners kept the research landscape vibrant. It is anticipated that further research exchanges and funding support driven by government will foster greater success in advancing research frontiers as well as in seeding research translation and commercialization.

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