Chapter

Biophotonics in Africa Powered by Light Technology Applied to Medical Work

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Abstract

Biophotonics technologies can be designed to provide unique, dynamic information about tissue structure and biochemical composition. Their impact spans from medical diagnostic and therapeutic devices to consumer-based wearable sensors. With advances in device miniaturization and high-performance biophotonics components, the line between conventional medical instruments and consumer devices is becoming increasingly blurred. Health care economic pressures are further accelerating this ambiguity by shifting clinical attention from expensive disease treatments to strategies for cost-effective disease management and prevention. This clinical research collaboration introduces emerging biophotonics technologies that are capable of characterizing brain tissue structure and biochemical composition spanning from micro to macroscopic regimes.

Keywords: biophotonics, Africa, health technology, light, point of care, medicine

1. Introduction

Biophotonics is a scientific field merging biology and photonics, with photonics being the science and technology of generation, manipulation, and detection of photons, quantum units of light. Research in biophotonics is focused on the development of innovative applications in clinical diagnosis of cancer and related therapies involving fluids, cells, and tissues using light-based tools to excite matter and to transfer information back to the biological operating system.

"Today, healthcare is moving from a treatment-oriented system to a diagnostic oriented one, the end-goal being companioned diagnostic, which is promising but still far away. All these issues have in common a strong need to study real-time evolution of complete living organisms, or part of them (tissues, organs, cells, proteins, DNA, etc.) [1]" and "Therefore, it's essential to develop technologies for quality and process control, as well as rapid microbiological methods suited to the entire production system," says Jacques Cochard, Founder of Tematys.

Global Health Care systems are currently focused on the creation of a well-structured coordination of research effort at global scale aiming to find and implement innovative solutions for sustainable biophotonics devices production and light use as a resource and therefore centered on the need of developing a long term and sustainable partnership in the biophotonics research area that will develop a set of actions devoted to deliver an implementation plan able to stir it and make it effective and operative in terms of sustainable solutions for Health Care systems dealing

with new challenges that arise from climate change non described potential epidemics leading to new avenues exploration in terms of scientific research to develop new tools for clinical practice to be applied at point of care in order to improve better clinical protocols outcomes both at low cost and patient patient-centered health care delivery policies.

Diagnosis security is globally recognized as one among the major challenges our society is facing in health care systems. Neurodegenerative diseases are a serious emerging problem in Africa that health care systems need to cope with but the strategies to this novel epidemic ecosystem is far from the optimal resources to ensure the control of epidemical dimension of the problem in Africa. This is particularly the case in rural areas, the most vulnerable regions, exposed to multiple challenges. At the same time, the health care system still plays a key role in improving the life quality in populations by providing support to local rural and urban ecosystems. In fact, health sectors are strategic in the whole African area in terms of future social development, of rural population and territorial development of population in Africa. While natural resources are under climate and population stress, clinical practice must cope with quality requirements imposed by patients and by their ever-changing health patterns. How to apply new diagnostic systems on the population and safeguard their biological machinery health for future quality of life is a great challenge in this area.

Given the scarcity of these biophotonic resources and the increasing neurodegenerative diseases in Africa's population, proper biophotonic research and market output is one of the most crucial issues for the sustainable future of African health care systems. In addition, the challenge of low-cost biophotonic diagnostic devices' scarcity is closely linked to the lack of biophotonic researches, as diseases epidemics in Africa human ecosystem has resulted in an overexploitation of nonscientific based clinical resources and the subsequent risk for population health safety.

This issue requires a more focused approach where the long-term impacts of health care management and biophotonics research use should be considered for ensuring sustainable health care on diseases epidemics provision without harmful effects on the population and the patients in particular. Cooperation in research and innovation is considered of particular importance in order to tackle the most pressing challenges of the biophotonics research area in particular through the development of innovative solutions and the promotion of their adoption for improving the efficiency and sustainability of low-cost biophotonics-based diagnostic devices' production and the safety of clinical practice to treat neurodegenerative diseases in Africa.

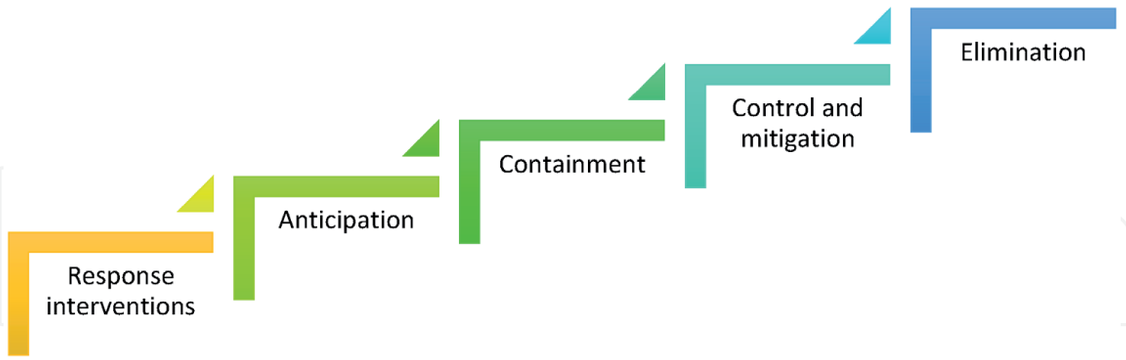
2. Africa health care solutions and epidemics overview

Africa is a continent with a complex ecosystem concerning biological entities and specific climate characteristics that enable systematic events of diseases epidemics over population leading to a process phase that we can describe in schematic phases according to World Health Organization monitoring epidemic events assessment identification from level emergence, localized transmission, amplification to reduced transmission being this one the last phase of the process in epidemics. World Health Organization proposal strategic planification to provide response in diseases epidemic events in Africa for the different previous identified phases of diseases epidemics process are first anticipation, containment, mitigation and last eradication.

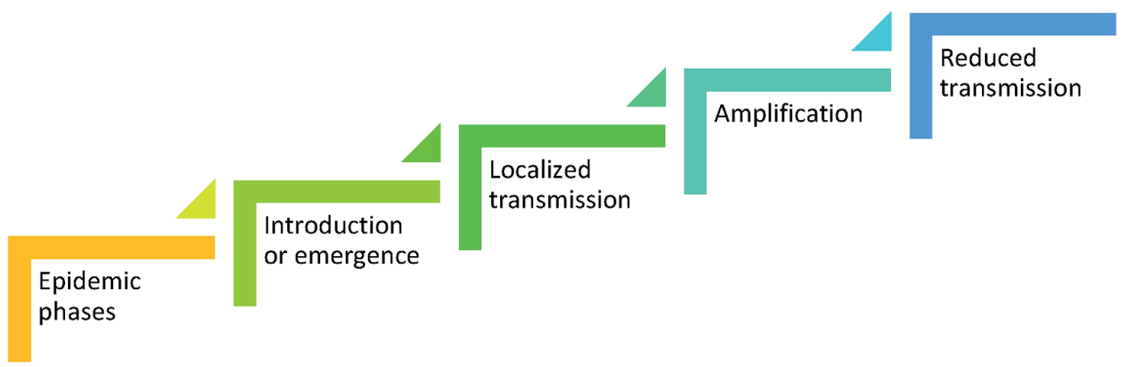
The standard approach based on emergency plan formula with similar parallel to the territory planning in terms of human demographics criteria often deliver poor cost-effective results as the target for the emergency plan is a group of individuals that are subject to different epigenetics that may present different results on

standard protocols applications as current world wide programs apply over African territories for epidemic treatment approach.

According to World Health Organization [2] the response interventions are



and epidemic phases are



African regions face several epidemic outbreaks that are still a severe threat to national health care systems, which are low-resource settings representing a risk to population health management in the long term.

In order to deal with this critical and systemic situation, African regions receive support from the United Nations World Health Organization and several other global players such as the Gates Foundation Programs, to provide health care solutions for managing epidemics in Africa.

One of the potential solutions for African Governments to accelerate effective response to the epidemics in African regions could be the acquisition of low-cost "top notch equipment," powered by biophotonics technology to enable further impact on the epidemic's detection and eradication.

In recent years, African regions have received significant scientific support concerning biophotonics tools applied to health care with focus on how to "develop cost-effective health care for underserved populations," according to Gerard L. Coté—Director, NSF-ERC on Precise Advanced Technologies and Health Systems for Underserved Populations (PATHS-UP) [3] project development to serve Health Care System on malaria diagnosis in Rwanda with photonics designed technology.

PATHS-UP
Precise Advanced Technologies and Health Systems for Underserved Populations

Image: Paths Up Project.

Another example of biophotonics technology applied to health care systems in Africa can be found in Nairobi, Kenya, developed by Prof. Katarina Svanberg [4], leading work in oncology with research work applied to medical lasers to accelerate biomedicine solutions in Africa, empowered by her academic work based at the Department of Oncology in Lund University. Prof. Katarina Shanberg [5] ignited biophotonics education in Senegal. Prof. Katarina Shanberg's group promoted doctor training and offered the medical community photonics-based fluorosensor instruments for trained doctors to perform further biophotonics treatment protocols in Dakar, Senegal, in collaborative work with Sheikh Anta Diop University.

Prof. Katarina Svanberg urges health care systems in Africa to promote the application of biophotonics -based clinical tools at point of care in remote rural areas where patients cannot access health care systems facilities in cities.

The scientific community in Africa is developing one of the firmest research communities dedicated to the exploration of biophotonics applications due to the lack of current medical conventional solutions in African regions, to serve the population suffering from African continent-specific epidemic contexts. This contextual situation is leading to a new generation of African students with academic training in physics and light-based sciences like optics, photonics, and biophotonics searching for solutions in order to accelerate production of light-based clinical instruments to serve African regions in terms of contributing toward health care; according to Zghal [6] "African countries definitely need better-prepared researchers and teachers in optics and photonics to pass on their skills to younger generations."

Africa region is a potential area at global scale that can deliver sustainable biophotonics research and clinical instruments development as Africa needs to accelerate practical low cost solutions to provide innovative Health Care systems with diagnosis and therapeutics for clinical work in African countries, collaborative work has been already ignited with education and training in Africa with the celebration of some events "organized by universities throughout Africa to provide education and training for advanced graduate students and post-doctoral faculty in optics, laser science and technology [7]." like the First African Summer School on Optics and Applications to Sustainable Development [8].

Image: SPIE CEO Eugene Arthurs (at center holding "are" sign) and participants of the Lighting up Africa with Lasers, Optics, and Fibers event in March. In Promoting Optics in Africa https://spie.org/news/spie-professional-magazine/2015-july/optics-in-africa?SSO=1

Africa dares to innovate with biophotonics scientific development in a low resources ecosystem to cope with constant critical epidemic problematics re-emergence that challenge current applied treatments that show less effective

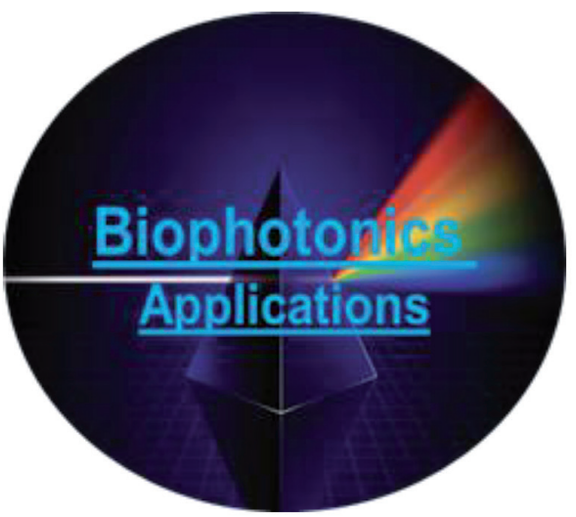
solution than biophotonics approach being the critical point for this structural problem in Africa the lack of scientific infrastructures and consolidated educational and training programs in the African Universities and a high level of dependence on educational skills leading to poor scientific results outcomes without external support from other scientific communities participating and contributing to a balanced educational and training environment that is crucial for Africa to mitigate epidemics with a knowledge based own scientific community inside the African territory to increase collaborative research work in the field in a systematic way by monitoring the factors driving to replication and mutation of epidemics outbreaks that requires multidisciplinary scientific and clinical research multidisciplinary approaches for consolidated results.

Investment on biophotonics education and research should be a priority for African Governments to advance with innovative solutions for health care systems "because epidemics are social problems as much as medical ones, we need to move beyond the traditional biomedical approaches to them." as World Health Organization suggests [9], for making progress in emerging health issues in Africa.

Biophotonics represents Africa pipeline focus in sustainable Health Care systems management towards effective results over efforts to eradicate debilitating epidemics in Africa leading to rapid cost-effective growth biophotonics health technology in Africa to deliver smart point of care diagnosis and therapeutic assessments for population health improvement with biophotonics applied to medical protocols. Biophotonics is consequently a significant and promising scientific resource to empower Health Care systems with light based clinical instruments in Africa.

3. Biophotonics for health tech delivery

Biophotonics [10] is the use of light-based technologies in biomedical sciences with a multidisciplinary approach involving the interaction of biology, physics, neuroscience, nanotechnology, and other related fields of scientific knowledge that can provide innovative solutions to products and services development, in this case applied to health care systems.



Biophotonics technologies can be designed to provide unique, dynamic information about clinical conditions. The use of biophotonics technology to develop medical diagnostic and therapeutic devices for clinical applications is a growing field of clinical research work worldwide. With advances in devices miniaturization and high-performance biophotonics components, the frontier between conventional

medical instruments and innovative light-based clinical application devices is becoming a challenge to doctors that are adapting their own professional skills and resources into a more effective operational clinical work with biophotonics tools.

This issue requires a more holistic approach where the long-term impacts of health care management and biophotonics research use should be jointly considered for ensuring sustainable health care on diseases provision without harmful effects on the population and the patients in particular. Cooperation in research and innovation is considered of particular importance in order to tackle the most pressing challenges in the field of biophotonics in particular through the development of innovative solutions and the promotion of their adoption for improving the efficiency and sustainability of low-cost biophotonics-based diagnostic devices' production and the safety of clinical practices to treat diseases at a global scale.

Biophotonics educational and scientific development practices and policies, through action and investigative research activities, are urgent to promote educational and scientific improvement, and clinical practice resulting in optimal development and high levels of achievement and accomplishments for biophotonics as a leading health technology resource that must be available in the market to health care providers in order to accelerate the development of health innovative products and services with biophotonics technology and related fields of knowledge to serve patients population at global scale because to health care systems, search for information is perhaps the most important problem to minimize the clinical assessment error. In addition, in health care systems, frequently, much time is lost in the search for correct information: this results in downtime and patient's mortality.

Biophotonics systems applied to health care offer the point of integration between the different health care systems and the health care provider operator himself, who performs operations and is the only one who can make decisions and take the actions needed in a very short time, thus reducing costs involved in health care assistance to patient with high quality, which requires smart solutions but simple and inexpensive to simplify clinical protocols at Point Of Care (POC) activities of the assembly operators, in order to reduce errors and increase health care systems' efficiency.

Main economic benefits of biophotonics applied to health

The main benefits for health care providers implementing biophotonics technology systems are:

a. increase in clinical performance because they can get the same health care services delivery at a much lower cost;

b. greater competitiveness in the market;

c. reduction in response times to patients;

d. simplification of clinical protocols activities by health care providers and decision-making processes.

The main end users of biophotonics technology applied to health care are health care provider companies, mainly hospitals, clinics, government NHCS, who often seek to invest in new technologies and improve their health care system services' processes, from older technological systems in departments to flexible and efficient services delivered at point of care with focus on ITC technologies integrations like e-health, telemedicine, and other clinical protocols.

This solution could be particularly attractive for health care providers operating in the market given the expected significant savings in terms of costs.

Time saving + cost and brain diagnosis time waste reduction + elimination of the dependence on other systems + simplification of activities → more efficiency → higher competitiveness

Biophotonics light-based devices for fast diagnosis and theragnostics of low cost and that are intuitive to use are particularly suitable for dynamic realities

a. seeking not too structured systems, flexible to point of care remote clinical needs and

b. wanting fast and simple systems to use and implement.

Rapid demographic, socioeconomic, and climate change factors are threatening the sustainable development of global societies where health care systems must be able to cope with increased demand for innovative diagnostic instruments' production in a scenario of non-invasive diagnostic devices' scarcity in the health care market.

- distributing to the various e-health workstations the ability to decide,
- simplifying and speeding up the decision-making activities in clinical protocols,
- streamlining the activities to be fulfilled by the health care systems elements/operators.

To perform the evaluation and analysis of biophotonics-based innovative solutions from the lab to the marketplace from a technical point of view, several stages of innovation are necessary during systems validation; therefore, technical feasibility studies must be focused on details such as:

- Redesign of the production system
- Device control test
- Detailed energy consumption analysis
- Study on the integration of devices with different production systems
- Control of the information flow
- Compliance with regulatory and safety requirements.

Once the technical feasibility studies are completed, several tests will be performed simulating real working conditions.

The solution will have to be further analyzed from a logistic and from an environmental point of view, to evaluate the clinical diagnosis impacts of the systems to be used.

Integrated systems for biophotonics clinical assessment already exist in the market, in particular, devices for point of care and low-cost applications to be used in smartphones applied to pathologies diagnosis that are able to integrate with

- e-health systems
- health care providers

- national governments' management of healthcare systems

Advantages of biophotonics applied to health care innovative solutions:

- Fewer indirect clinical structures
- Less clinical delivery time
- Ability to keep under control the health care system from all points of view with encrypted data collection but with a real-time action control system
- Monitoring of patient health status in direct time and reducing unnecessary clinical resources waste.

The rationale of the innovation with biophotonics approach health technology is the importance given to innovation which finds solutions that can reinforce competitiveness and better health care results for all the elements involved in the health care process with focus on patient centered clinical assessment for excellent clinical outcomes and patients benefits.

The current challenge for Biophotonics science applied to health care market is to be able to disrupt the medical applications conventional market with powerful clinical tools light based as "Biophotonics research is a field with a history of more than 50 years. Giants like Britton Chance were one of the first scientists to realize the potential of using light in medical applications. Until his death at the age of 96 he was a world leader in the field. He very early transformed theoretical science into useful biomedical applications" [5] for a sustainable diagnosis and theragnosis delivery with light based clinical tools to accelerate global health balance with Biophotonics powered by light technology for the benefit of Humanity. The missing link for sustainable democratic health care systems is technology enabled by biophotonics.

4. Research impact of biophotonics in Rwanda

Current stage of innovation development of BioAdd device has been studying the solution since 2016. Following the Technology Readiness Levels classification, the proposed business innovation project is positioned at TRL 3: technology demonstrated in relevant environment.

All the preceding TRLs (from 1 to 3) have been already tackled and successfully overcome during previous research works. In particular, three major milestones have marked the completed phase "from idea to application" enabling the project to enter the next step "from lab to market":

(M1) Preliminary study and research: this phase was conducted internally in VB lab, through the (human and material) resources of the company. The initial goal was to study how the internal production lines could be improved. Later, an exchange of views with some clients was conducted to verify their needs.

(M2) Construction of an experimental pilot room lab: an experimental system was built (experimental but currently functioning).

(M3) Experimentation successfully carried out on the small pilot room lab, in which some of the technologies here proposed have been tried, obtaining very good feedback from partner to VB Company: IBM Finland.

We can find BioAdd as a diagnosis advanced system applying biophotonics by observing the offered solution:

- Monitoring can take place anywhere and can be done by anyone
- Monitoring can be as frequent as needed with low-cost screening device and App
- Results compare to/beat those obtained by current oncological invasive lab protocols
- Results are available in minutes warning to doctor can be sent within minutes of a test Effectiveness of protocol can be monitored in real time
- Instant analysis and availability of related data improve speed and effectiveness of cancer treatments.

5. Conclusion

Biophotonics represents Africa pipeline focus in sustainable Health Care systems management towards effective results over efforts to eradicate debilitating epidemics in Africa leading to rapid cost-effective growth biophotonics health technology in Africa to deliver smart point of care diagnosis and therapeutic assessments for population health improvement with biophotonics applied to medical protocols. Biophotonics is consequently a significant and promising scientific resource to empower health care systems with light-based clinical instruments in Africa.

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Conflict of interest

The author declares no conflict of interest.

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References

[1] New technologies will expand the biophotonics market to $36B by 2017 "Biophotonics Market, Focus on Life Sciences & Health Applications" report from Yole Développement & Tematys. http://www.yole.fr/iso_upload/News/2013/PR_BIOPHOTONICS_YOLE%20DEVELOPPEMENT_April2013.pdf

[2] Managing epidemics: key facts about major deadly diseases World Health OrganizationISBN 978-92-4-156553-0 accessed online 05.10.2019 file:///C:/Users/a/Downloads/9789241565530-eng.pdf

[3] Health Systems for Underserved Populations (PATHS-UP). Available from: https://today.tamu.edu/2017/09/12/texas-am-system-to-lead-new-nsf-engineering-research-center/ [Accessed: 05 October 2019]

[4] Katarina Svanberg MD. Professor Lund University Department of Oncology. Available from: https://spie.org/membership/student-services/visiting-lecturers-program/lecturer-directory/svanberg-katarina [Accessed: 05 October 2019]

[5] Sterenborg HJCM, Bendsöe N, Svanberg K. Clinical Biophotonics. Journal of Biophotonics. 2011;**4**(10):665-666. https://doi.org/10.1002/jbio.201100510

[6] Promoting Optics in Africa Community leaders in Africa are increasing the visibility of optics and photonics. Available from: https://spie.org/news/spie-professional-magazine/2015-july/optics-in-africa [Accessed: 05 October 2019]

[7] Tunisia hosts first African Summer School on Optics and Applications to Sustainable Development. Available from: https://spie.org/about-spie/press-room/press-releases/african-summer-school-11-5-2013 [Accessed: 05 October 2019]

[8] First African Summer School on Optics and Applications to Sustainable Development. Available from: https://www.osa.org/en-us/meetings/global_calendar/events/2013/first_african_summer_school_on_optics_and_applicat/ [Accessed: 05 October 2019]

[9] Managing Epidemics Part I. Key Facts about Major Deadly Diseases. Available from: file:///C:/Users/a/Downloads/9789241565530-eng.pdf [Accessed: 05 October 2019]

[10] Make Light Work for Medicine. Available from: https://ec.europa.eu/digital-single-market/node/65248 [Accessed: 05 October 2019]