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Optics in Africa

Part 2: Realizing the Promise

OPN talked with a number of African researchers about the prospects for advancing optical and photonic science on a diverse and changing continent.

Stewart Wills

Last May, OPN profiled six scientists from African countries about some intriguing optical and photonic research on the continent ("Optics in Africa: Six Stories, OPN, May 2021, p. 44). The researchers—at various career stages and from different countries—all had contributed papers to a 2020 joint feature issue of JOSA A and JOSA B, "Optics in Africa." The issue showcased work on topics ranging from free-space and fiber communications to structured light to quantum optics (opg.optica.org/josaa/virtual_issue.cfm?vid=476).

Africa is, of course, a diverse continent comprising 54 different countries. Can anything general really be said about "African science" and its challenges and opportunities? To investigate the question, OPN revisited some of the interviews and conversations behind its May 2021 feature, as well as seeking the perspectives of a few additional scientists attempting to advance physics generally, and optics and photonics in particular, across the continent.

Much of what follows dwells on the sub-Saharan African countries, which account for more than 80% of the continent's burgeoning population. The picture that emerges, while anecdotal and incomplete, suggests the enormous promise for African optics and photonics—and some of what needs to happen to realize it.

K. Chernush/Getty Images

Optics Papers with African Authors
2018-2019

	Papers	Population
WORLD	58,657 / 100%	7,800,000,000 / 100%
AFRICAN COUNTRIES:		1,338,826,604 / 17.2%
Egypt	501 / 0.85%	102,334,404 / 1.31%
South Africa	352 / 0.60%	59,308,690 / 0.76%
Algeria	274 / 0.47%	43,851,044 / 0.56%
Tunisia	181 / 0.31%	11,818,619 / 0.15%
Morocco	114 / 0.19%	36,910,560 / 0.47%
Nigeria	74 / 0.13%	206,139,589 / 2.64%
Cameroon	47 / 0.08%	26,545,863 / 0.34%
Benin	22 / 0.04%	12,123,200 / 0.16%
Sudan + South Sudan	19 / 0.03%	55,042,985 / 0.71%
Kenya	15 / 0.03%	53,771,296 / 0.69%
Ethiopia	13 / 0.02%	114,963,588 / 1.47%
Ghana	10 / 0.02%	31,072,940 / 0.40%
Other countries (41)	54 / 0.09%	584,943,826 / 7.50%

Data sources: Publication data—Web of Science (Clarivate Analytics) totals of papers with the subject category "Optics" including authors with affiliations in the countries shown (analysis run 30 April 2021). Population data—United Nations estimates, 2019.

Untapped potential

Evidence of Africa's potential in science and engineering is easy to find. A key strength lies in the continent's vast human resources. With nearly 1.34 billion persons, Africa accounts for more than 17% of the world's population, and at current growth rates is expected to host one quarter of the world's people by 2050. It's also the youngest population on the planet, with more than 60% of Africa's people below the age of 25. On its face, that adds up—given adequate educational and institutional support—to a significant talent pool for a cohort of young scientists to drive future research in Africa.

Yet at present, the African continent considerably lags the rest of the world in scientific research opportunities and output. The 2021 UNESCO Science Report, "The Race Against Time for Smarter Development," notes that no African country spends more than 1% of its GDP on research and development. (In sub-Saharan African countries, the average share is just 0.51%.) That puts the continent well behind other areas such as North America (which spent 2.73% of its GDP on R&D in 2018), East and Southeast Asia (2.13%) and Europe (1.78%). It also largely means that African countries currently must depend on foreign knowledge and technology to advance their economies.

For optics and photonics, meanwhile, publication data from the Web of Science (Clarivate Analytics) reveal that, in the two years before the pandemic (2018 and 2019), researchers in African countries were listed as authors on less than 2.6% of the articles published worldwide with the subject code "optics." Further, of the optics papers including African authors during that period, nearly 88% of the representation came from just five countries—Egypt, South Africa, Algeria, Tunisia and Morocco—that together account for only 19% of the continent's population.

Institutional shortcomings

Clearly Africa, and sub-Saharan Africa in particular, faces many challenges that have contributed to science's uphill climb—the legacy of centuries of colonialism; persistently high, albeit declining, poverty rates; uneven educational systems; a lack of basic infrastructure in areas such as broadband internet; a still predominantly rural population heavily dependent on agriculture. Yet the African researchers that OPN spoke with tended to stress that the challenges for African science are not solely a matter of money or capacity. Instead, these sources suggest, many problems stem from poorly developed or nonexistent national scientific institutions to set priorities and channel available funding.

"The main issue with scientific research in Africa is not the lack of intellectual resources," says Alain Dikandé, a physicist on the faculty of the University of Buea in Cameroon, and a co-editor of the 2020 JOSA A/B feature issue on optics in Africa. "Our countries need strong institutions that will favor good governance and promote intellectual activities."

"Africa is in principle not poor," according to Optica Fellow Andrew Forbes, a professor at the University of the Witwatersrand, South Africa, and also a co-editor of the JOSA A/B feature. "The money is not well allocated or well used," because of a "lack of formality in the system." Forbes points out, for example, that many African governments lack a ministry of science or dedicated funding body analogous to the US National Science Foundation (though he adds that his home country, South Africa, has both).

"That makes it extremely difficult, when there are no annual calls, no central body you can go to," he says. "It means that African researchers are knocking on the doors of people with their ideas. And of course, after a while, people get sick of listening to an endless stream of ideas, without expert panels to sift the good from the bad."

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Africa is a diverse continent comprising 54 different countries. Can anything general really be said about "African science" and its challenges and opportunities?

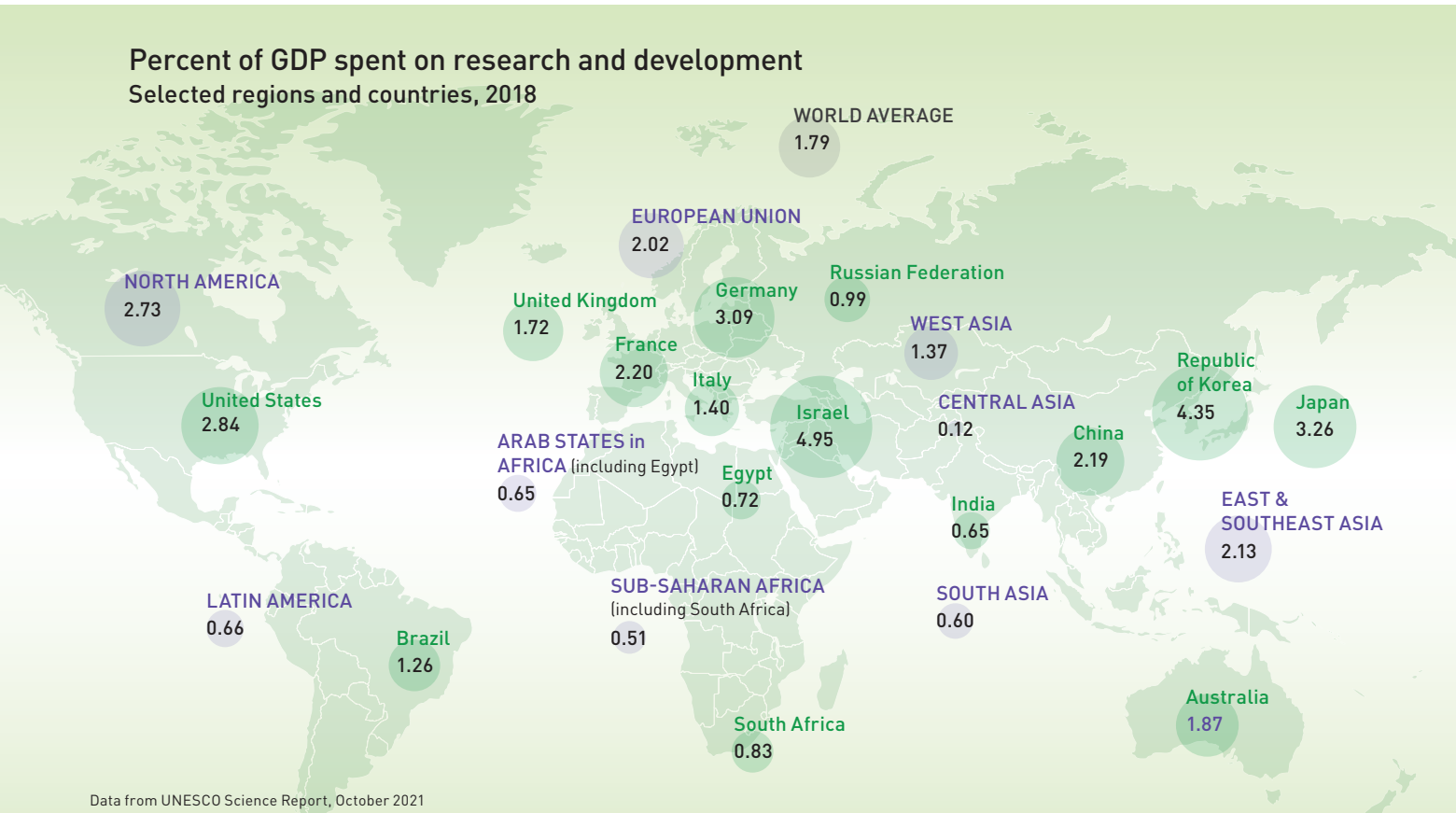
Even in countries where there is a nominal government structure around science, reliable government and institutional commitment can lag. Dikandé notes that in his country, there is "a whole ministry devoted to scientific research," the Ministry of Scientific Research and Innovation. Yet, he maintains, "there is unfortunately no institutional support for scientific research in Cameroon … In my opinion, the problem resides in a lack of interest in science. Governments in Africa don't believe in their researchers." Instead, he and others suggest, support for academic science in most sub-Saharan African countries focuses heavily on teaching—admittedly a vital component—rather than on doing original science.

Differing levels of government support help explain, to first order, the fact that so much of African optics and photonics research output concentrates in just a few countries. In addition to South Africa, "the North African countries have always done well," according to Forbes. "They have formal structures; they have calls for proposals. And they also complain about lack of funds—but they do find them."

Losing talent

Building strong scientific institutions would seem essential to take advantage of Africa's much-discussed young population and its human potential for scientific and economic development. That's because, at present, a lack of home-grown opportunities makes it difficult to keep the most talented young science graduates on the continent. Numerous sources allude to an "African science diaspora," the result of temporary (and sometimes permanent) migration both within and beyond the continent in search of better facilities and prospects.

"Africa's most important wealth today is its human capital and particularly its youth," says Dikandé. "Unfortunately, they are unemployed, though educated and sometimes well trained, and these are consequences of



Data from UNESCO Science Report, October 2021

Another challenge: Political unrest

Beyond other issues, scientists in some sub-Saharan African countries face uncertainty and fear over their personal safety owing to civil conflicts, often between governments and separatist groups, that are a bitter legacy of colonialism. Alain Dikandé's country, Cameroon, has experienced years of conflict and civil war between the majority Francophone (French-speaking) government and an Anglophone (English-speaking) separatist minority concentrated in the country's northwestern and southwestern regions. He says such conflicts can particularly impact working conditions for scientists in these countries.

Dikande notes that scientists and their families are "usually one of the privileged targets" of separatist rebels, and that "protecting ourselves without the help of the government is another challenge." Dikandé and his family have been personally touched by the crisis multiple times, including two incidents where he was kidnapped by separatist militia members and required to pay a large ransom for his release.

"I think that the scientific community, and particularly scientists from developed countries," says Dikandé, "need to know that wars that their governments are sponsoring in the Third World, impact the working conditions of scientists in the Third World."

bad governance. It is not surprising that they will … seek a better life overseas." Forbes adds, "In many African countries, [people] don't see that there's any future in science—or they see that the future in science is to *leave* the country."

Those that choose to stay, especially in many sub-Saharan countries, can find their work's horizons circumscribed by limited home-government investment in basic infrastructure.

Four years ago, Dismas Choge, an early-career researcher from Kenya, wrapped up his Ph.D. in the lab of Wan-Guo Liang at the Chinese Academy of Sciences, and returned to his home country for a faculty position at the University of Eldoret, 350 km northwest of Nairobi. Settling into the new job, he found that the changes in his work went well beyond a new mailing address. For one, his experience in China had blended theoretical study and experiments in a well-equipped lab, probing a cutting-edge material for integrated photonics, lithium niobate. His return to Kenya meant that his work would henceforward mainly be not in the lab but on the computer, doing the theory—a consequence of a lack of scientific infrastructure and experimental equipment in the country.

Choge, one of the African scientists profiled in the May 2021 OPN feature, also noted that, for physics in particular, "we really have a limited human capacity … especially the women's enrollment is really low," despite recent government efforts to boost the number of secondary-school science teachers. "The national government agenda seems to focus on other areas, like food security," Choge told OPN last year. "The focus on science, and on physics, is a little bit low."

The experience reported by Choge seems to be common among many young scientists. "That is absolutely true," says Dikandé. "When you return home with a Ph.D. in experimental physics, for instance, and cannot get support from your country to set up a research lab in your field … you have no choice but to switch to theory or numerical simulations."

International partnerships

Some research groups have responded to limited government involvement by seeking international partners who can help them establish centers of laboratory research excellence on African soil. Paul Buah-Bassuah, a professor at the University of Cape Coast, Ghana, described for OPN last year the long process of building his institution's Laser and Fiber Optics Center—leveraging assistance from the International Center for Theoretical Physics (ICTP) in Trieste, Italy, to overcome initial skepticism and make the case with the government and the university for a laser laboratory in Ghana.

Buah-Bassuah also cited help, especially in the area of diode lasers, from Lund University in Sweden and the participation of figures from a number of other countries. The Ghana lab has since emerged as one of a number of centers of excellence in optics and photonics in sub-Saharan Africa, with a focus on applying laser-induced fluorescence to problems relevant to Africa in health, environment and agriculture.

ICTP in particular—which was founded in 1964 by the Pakistani Nobel laureate Abdus Salam specifically for "advancing scientific expertise in the developing world"—was cited as playing an important role by a number of the senior scientists OPN spoke with. Ahmadou Wagué, who spent many years on the faculty of the University of Dakar, Senegal, acknowledges the support of ICTP and other partners in efforts to build interest and capacity in optical and photonic science in a variety of African countries through the African Laser, Atomic, Molecular and Optical Sciences (LAM) Network (lamoptinet.org), which Wagué founded in Senegal in 1991.

Wagué also stresses the contributions of a number of other partners,

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including programs at Upsalla University and Lund University, Sweden; international societies such as the International Commission for Optics, SPIE and Optica; the International Union for Pure and Applied Physics; and some universities and country governments. Even so, he says, the process of building laboratories on the continent has been slow and piecemeal, given that government and external partners tend to allocate only a small share of their support specifically for lab equipment. "This is why, every year, we buy, step by step, the equipment that we need. Step by step."

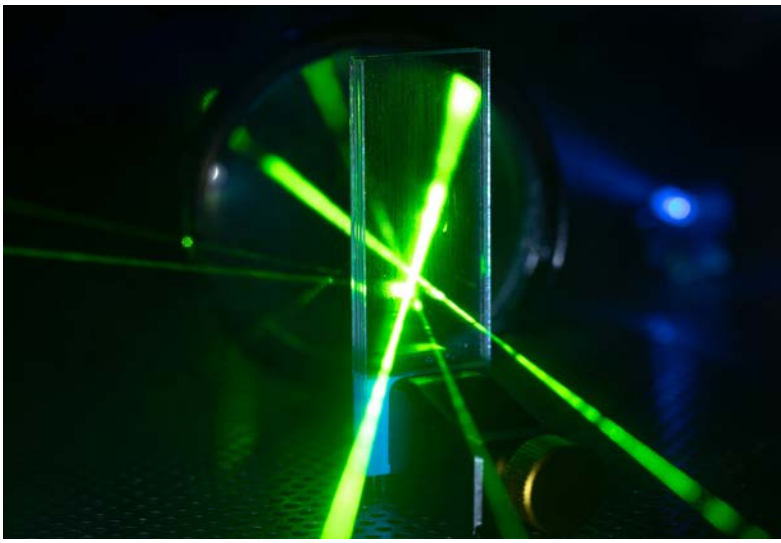
Scientists earlier in their careers also see connections with overseas labs as one part of a strategy to advance optics and photonics research in Africa. Choge continues to collaborate with the China lab in which he did his doctoral work, and also is actively seeking partnerships with researchers in the United Kingdom and other countries. And another scientist interviewed by OPN last year, Tesfay Gebremariam with the University in Arba Minch, Ethiopia, stressed the activities of his university in establishing "bilateral teaching and research arrangements" with institutions both within and outside of Ethiopia.

Alain Dikandé—while acknowledging the importance of international support in his own career—does note that there's a limit to what can be expected. "Even international organizations such as UNESCO," he observes, "traditionally fund only research in agriculture—assuming that 'Africans are hungry,' and feeding the population should be the priority."

"You cannot expect … a government that does not believe in science to spend financial resources on scientific equipment," says Dikandé. "On the other hand, you cannot force a donor to fund research in areas that are of no interest to [them]."

Forging alliances

The fickle nature of overseas funding underscores the importance of African countries taking their scientific destinies into their own hands. Dismas Choge believes that, in addition to the potential of the continent's large and youthful population, the slowly proceeding economic integration of the African continent "can really be an opportunity to convince the African governments to fund or to invest in science and technology, and also engineering, for the advancement of their economies."



One effort to advance laser science across the continent, the African Laser Center, has evolved differently from the original plan owing to inadequate funding commitments from countries other than South Africa.

Laser image from Getty Images

Some of the scientists OPN spoke with see continued promise in forging alliances among scientists in different African countries. Wagué, the founder of the LAM Network—who also serves as the president of the African Physical Society, and who has participated in efforts to create an African Optics and Photonics Society—believes that, by facilitating meetings, discussion and scientific exchange among African scientists, the network has helped catalyze the development of optical research not only in his home country of Senegal, but in other countries such as Ghana, Tunisia, Cameroon, Kenya, Sudan and Morocco.

Another cross-African project—which also illustrates the underlying challenges in such efforts—is the African Laser Center (ALC). Established in 2003, the center was envisioned, according to Forbes, as a way to build on some of the relative success of South Africa in optics and photonics and "launch it across the continent."

But while South Africa made a large initial investment, Forbes and Wagué say that other countries,

Mid-frequency radio dishes in Africa that form part of the Square Kilometer Array (SKA), an effort to build the world's largest radio telescope. The SKA is one of several big-science projects that some believe will create new scientific opportunities in on the continent.
SKA Observatory (CC-BY-3.0)

which had pledged to follow up with their own funding of US$20 million each year through the New Partnership for Africa's Development (NEPAD), have failed to come through with those commitments. As a result, the ALC—while it is, according to Forbes, "working very effectively" bringing students from other parts of the continent into South Africa for training—remains a distinctly South African rather than pan-African initiative. "The sad part," says Forbes, "is the opportunity lost."

Still another possible vehicle for pan-African scientific support is the African Union (AU)—a continental union of African member states, analogous to the European Union, that was formed in 1999 as a successor to the earlier Organization of African Unity. Forbes says that the AU "could have a role, if we could get them to accept the importance of science"—which he does not believe thus far has been the case. "As a researcher, I don't feel or see its impact at all." Paul Buah-Bassuah adds that he is "looking forward to when the AU can honor its promise of trying to [devote] a lot of money for scientific research … One thing I've learned from my experience is if the government is able to honor its promise of trying to get 1% of its GDP for science, Africans have the capability to perform."

Big-science efforts

A few big-science initiatives are also afoot in Africa that could play into its scientific future—and create new opportunities to nurture and retain scientific talent. One such project is the Square Kilometer Array (SKA), involving a consortium of European, North American, Australian, South African and Asian organizations. The SKA effort aims to build the world's largest radio telescope, with a total collecting area of approximately 1 km^2, through a global network of distributed radio dishes, connectivity, hardware and software.

Tim Gibbon, who directs Center for Broadband Communications at Nelson Mandela University, South Africa, has put his students—drawn from both South Africa and other African countries—to work on the problem of synchronizing clock signals across the optical-fiber networks that will link up the SKA facilities. Such projects, he suggests, can create lasting opportunities for developing both optical science and industry applications that can benefit the wider society. "It's important to work on these big, big projects that inspire people, that really push the frontiers of the technology," he told OPN in an interview last year, "because in the future that's actually going to be in our homes."

Equally ambitious in its own way is the African Lightsource (AfLS)—an attempt to create the first synchrotron light source on the African continent. Africa is now the only continent (other than Antarctica) that lacks such a light source; that absence, in the view of the facility's proponents, contributes to the African scientific diaspora, since researchers in need of such a site's capabilities must leave the continent to find them.

Efforts to build a synchrotron source in Africa go back more than two decades. The current project, according to the chair of its executive committee, Simon Connell, a physicist at the University of Johannesburg, South Africa, would have an initial price tag of US$1 billion (to cover hardware, building and staffing), and an annual cost of US$100 million for ongoing operation. "I don't think that's a big ask for Africa," Connell maintains. (According to the International Monetary Fund, the current total GDP of African countries exceeds US$2.9 trillion.) And, while the synchrotron itself would necessarily be in a single country, he says AfLS is envisioned as a pan-African initiative, with a variety of regionally distributed supporting labs and infrastructure.

The project still has far to go to convince African governments to support it. AfLS is currently trying to make that case, and is actively seeking letters of intent from the community for a conceptual design review. But Connell and others believe that the light source, if

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realized, could prove a potent attractor to keep talented young scientists in Africa—and to bring back some who have left. Connell points to the experience in Brazil, where he says building and staffing a synchrotron facility fostered a professional cadre of young scientists of the highest caliber. With the African Lightsource, he believes, something similar could happen in Africa. "If the African governments say, this is what Africa wants," says Connell, "then young people are going to step up."

Toward positive change

This short feature, focusing on the experiences and perspectives of a number of active researchers particularly in sub-Saharan Africa, can provide only a very selective view of the many forces shaping optics and photonics across a diverse continent. One common theme that does clearly emerge, however, is that the future of optical science and research in Africa will depend on building strong scientific institutions, and on persuading African governments of science's importance as a long-term investment.

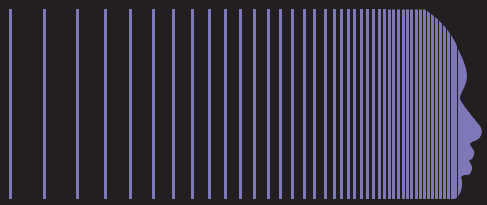
"We want to approach this issue [in Kenya] by looking at the success stories from other African countries—even apart from South Africa and North Africa—where science has really contributed to the well-being of the people," Dismas Choge told OPN. "And if we can … convince the government to [support] science research that is geared towards economic development—even if it will take a long time—[it will be] a big step for African young scientists."

Choge, Forbes and a number of other researchers OPN tapped for this feature also stressed the positive role that can be played by international, member-driven science organizations such as Optica and SPIE. Such organizations, they maintain, could help in advocating for improved science leadership and institutions on the African continent—and in making the case to governments that photonics can contribute to solving national problems.

And there's at least some evidence that the attitudes of African governments may indeed be shifting. One catalyst, oddly enough, could be COVID-19. While the pandemic has hit Africa hard, several of the sources for this feature believe that it may also have raised the consciousness of African national governments on the value of scientific research.

Connell, of the African Lightsource project, cites work on other continents in which high-energy beamlines have proved central in determining the structure of the SARS-CoV-2 virus, uncovering potential drug targets and assisting in vaccine development. "That point was not lost on African governments in these COVID times," he says. And he feels it is leading to "a reevaluation of the role of large-scale research infrastructures—especially ones that can deliver to industry, to innovation, to Africa's disease burden, to other very important aspects."

Paul Buah-Bassuah, of the University of Cape Coast in Ghana, also hopes that the pandemic could help tip the scale toward a greater government interest in science, both in Ghana and elsewhere on the continent. "Government has realized that science is one of the essential things to look at, out of the COVID-19 [experience]," he told OPN. "So funding of science, I hope, is going to change." OPN



Optica and African science

Optica offers significant discounts for scientists and engineers from the African continent, including discounted membership dues, reductions or waivers of author publishing charges, and free registration to Optica's meetings and events. Additionally, the society is launching the Amplify Black Voices in Optics campaign, including scholarships and waived article processing charges for Optica journals. Information on these programs can be found at optica.org/diversity.

Stewart Wills is the senior editor of *Optics & Photonics News*.