Changes and challenges: Physics in India

To go from having islands of excellence to being a major world player in science, India must solve such problems as a dearth of teachers and a divide between research and teaching.

> In the old days we had no money but we had people. Today, we have the money but not the people.
>
> *Obaid Siddiqi*
> *Bangalore, India*

Over the past century, India has produced stars in physics and astronomy. Think Satyendra Nath Bose and Nobel Prize winner C. V. Raman. In 1945 nuclear physicist Homi Bhabha established the internationally respected Tata Institute of Fundamental Research (TIFR) in Mumbai. After India gained independence from Great Britain, Jawaharlal Nehru, the first prime minister, emphasized science and technology for his country's future.

Today the country has pockets of scientific excellence. The economy is growing at 8% or more a year, and the government is eager to invest in science—although it still puts only around 1% of gross domestic product into research and development, low compared with about 1.8% in China and 2–3% in developed countries.

Still, India's aim of becoming a global leader in science is a tall order. Chief among the challenges are training teachers, providing infrastructure for a ballooning population of students, and attracting a higher fraction of those students to physics and other sciences. The good thing, former TIFR director Sabyasachi Bhattacharya says, is that "there is a great churning of ideas. The complacency among the people who make policy decisions is gone."

Collaborations and facilities

A surge of big projects is perhaps the most visible sign of scientific growth in India. Participation in CERN for two decades "has played a key role in glamorizing science and technology in India," says Archana Sharma, who works on the compact muon spectrometer experiment at the lab's Large Hadron Collider. In recent years India has broken out of the mold of providing mostly software and services and has contributed such hardware as magnets to the LHC and other experiments. The country is a member of or is considering joining a slew of international projects. They include the test fusion reactor ITER and the Facility for Anti-Proton and Ion Research, under construction in France and Germany, respectively, and projects at earlier stages such as the Thirty Meter Telescope and the Square Kilometre Array.

Excitement is building about the prospect of India's hosting a leg of Advanced LIGO, the upgrade to the US-based Laser Interferometer Gravitational-Wave Observatory. After it became clear that Australia would not come up with the funds to be a LIGO site (see PHYSICS TODAY, December 2010, page 31), IndIGO, a consortium of 11 Indian institutions involved in gravitational-wave experiments and LIGO data analysis, sprang into action to bring the experiment to India. The group's LIGO-India proposal squeaked onto the list of megaprojects under consideration for the country's next five-year budget plan, which begins in April 2012. So far the project has gotten a good reception, according to people who presented the case for it, and they are now working on a detailed proposal. "It's gratifying that we are being considered," says IndIGO spokesman Tarun Souradeep of the Inter-University Centre for Astronomy and Astrophysics in Pune. "We could be entering the field in good time, not when it has already blossomed."

Among large home-grown physics projects, India counts the Giant Metrewave Radio Telescope near Pune, with 30 steerable 45-meter dishes; the Major Atmospheric Cherenkov Experiment, a 21-meter cosmic-ray telescope under construction in the Himalayas; the lunar probe *Chandrayaan*, which flew in 2008–09; *Astrosat*, India's first science satellite, a multiwavelength mission set for launch late next year; a petawatt laser planned for Hyderabad; and the India-based Neutrino Observatory (see PHYSICS TODAY, October 2008, page 28). Digging for INO's three caverns is scheduled to start next year and data-taking four years later, says project spokesman Naba Mondal of the TIFR. "Our aim is to become on a par with the best underground labs in the world."

On a smaller scale, individual labs and institutions increasingly can afford such homemade and off-the-shelf instruments as high-power lasers, optical and atomic traps, atomic force microscopes, and accelerators. "It would be wrong to understate the role played by the development of good quality experimental laboratories and facilities within the country that has given us the collective confidence to take on bolder responsibilities in international projects," says the TIFR's Deepak Mathur. A member of a three-

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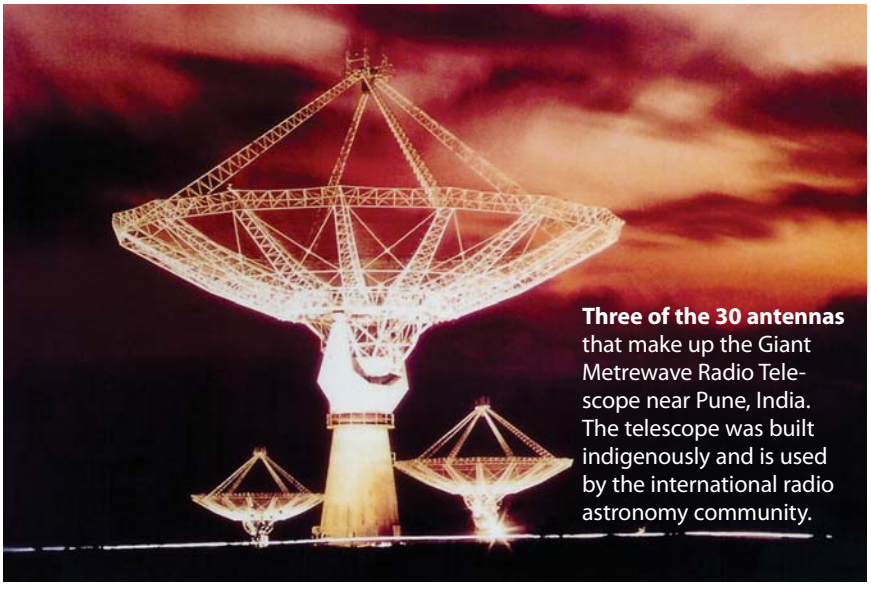
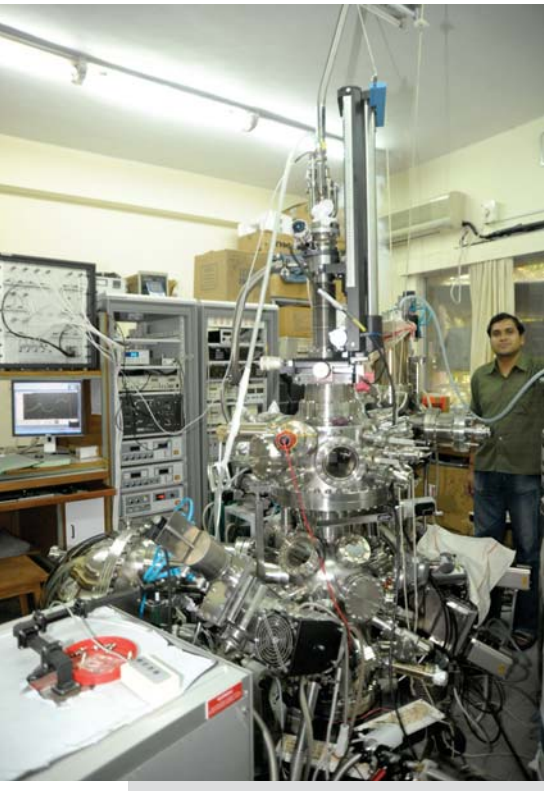


Three of the 30 antennas that make up the Giant Metrewave Radio Telescope near Pune, India. The telescope was built indigenously and is used by the international radio astronomy community.



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With India's economy flush, labs are becoming more sophisticated. Built in 2004 for about $4 million, this spin- and angle-resolved electron spectrometer at the Tata Institute of Fundamental Research in Mumbai has an energy resolution of 1.2 meV and angular resolution of 100 millidegrees. It is used for photoemission studies in condensed-matter physics.

year-old photonics initiative involving a handful of institutions, Mathur says, "We use lasers to modify materials. For example, making optical waveguides within a bulk material." Initiatives like that, he says, "have enabled people like me to set up collaborations. This was missing in small science." Tabletop experiments "have a lot more impact in terms of training people than the large, high-profile experiments," says Bhattacharya, a condensed-matter physicist.

Suboptimal conditions

Training people is perhaps the most daunting hurdle facing both the manning of large scientific projects and the meeting of higher-education needs in India. "Human resources to feed [big science] projects is a bit of a chicken-and-egg problem. To attract talent you need such exciting projects. But you cannot begin them without people," says M. V. N. Murthy, a physicist at the Institute of Mathematical Sciences in Chennai. With so many new projects, he adds, "our success depends on how we handle this issue" of training people. B. S. Sathyaprakash of the UK's Cardiff University says of LIGO-India, whose scientific potential he has evaluated, "I am not worried about the money. The site is no big deal. But finding a strong leader and a team of experimenters will be a challenge."

Sheer numbers give hope that upcoming generations may produce more scientists: The Indian government has set a goal of increasing undergraduate attendance from one in nine to one in three in the next 10 years. It has also begun to implement policies to give Indians from disadvantaged communities access to education. "There has to be equitable growth before tangible benefits start manifesting themselves," says Mathur. "This is the challenge right now—how to make the benefits of growth reach out to the millions who are presently totally left out." But to accommodate the anticipated growth in enrollments, says Bhattacharya, "India needs to create 8 to 10 universities per month." That, of course, is impossible.

New institutions are opening. For example, the Indian Institute of Technology (IIT) system—for which undergraduate admission is more competitive than for Harvard University or MIT—is in the process of more than doubling its campuses from 7 to 16. The first several of a new system of universities called the Indian Institutes of Science Education and Research (IISERs) have started up in the past five years. As part of the reform of higher education, the IISERs combine research and teaching, which in India have been mostly separate. Resistance to change comes from both sides, says Mathur: "University faculty are used to not having to fight for funding. We in the national institutes have got used to not having to deal with teaching inquiring minds." But the separation has led, he says, "to both parties working in suboptimal conditions."

Attracting students

For at least two decades, India's best students have tended to go into information technology, finance, management, or engineering, where they earn 2 to 10 times more than in academia. And in fields like physics, theorists outnumber experimenters, largely because of the historical lack of funding. But Surajit Sen, a statistical physicist at the University of Buffalo who moved to the US in 1983, says, "Because the IT and finance sectors have been going bust, many of the good students may now

RUDRA PRATAP

A state-of-the-art nanofabrication center and other labs related to nanophotonics, MEMs and NEMs, biosensors, neuroelectronics, gas sensors, and more are housed in the Indian Institute of Science's Centre for Nano Science and Engineering in Bangalore. The center opened in 2010.

head to hard sciences. [India's] science student body may have seen its lows."

A host of initiatives by the central and local governments and by individual institutions are springing up to attract people to the sciences. In 2007 the government introduced INSPIRE (Innovation in Science Pursuit for Inspired Research); the program awards 10 000 scholarships a year at the bachelor's and master's degree levels. "The students who did best were from small towns and semirural areas," says Mathur. "That was an eye-opener. There is a lot of untapped talent." For the five-year period that is winding down, INSPIRE had roughly $400 million available; its future grants will also aim at primary- and secondary-school students.

At the TIFR, a PhD program trains students in theoretical and experimental neutrino physics with the aim of preparing them to work at INO; so far, 19 students are enrolled in the three-year-old program. A few years ago the institute started taking graduate students at an earlier stage to catch them before they left for programs in other countries. But, says Bhattacharya, such initiatives make only a tiny difference.

Mass education

The sciences are "expanding very fast, so we are forced to be less choosy" about hiring, says Obaid Siddiqi, a neurobiologist at the TIFR National Centre for Biological Sciences in Bangalore. "It's true for all fields." The paradox, he says, is that there are "fewer really good people and plenty of places for them, and many people who are just average but they don't easily get jobs." As an example, due in great part to the IIT expansion, some 2500 faculty positions sit vacant at the system's campuses across the country.

A medley of approaches is being discussed to tackle the dearth of teachers and the need for more colleges and universities. The government hiked faculty salaries to lessen the discrepancy between academic and industrial or managerial positions. New government fellowships pay salaries for the tenure-track period, and other perks are being offered to make academic careers attractive.

Some US institutions are interested in opening branches in India—a popular practice in the Middle East and China. But often, says P. Balaram, a chemist and director of the Indian Institute of Science in Bangalore, foreign institutions "are really interested in recruiting students. A collaborative solution will emerge only if there is something in it for both sides."

Among the ideas for coping with the student population swelling faster than infrastructure are the use of the internet to reach more students and the recruitment of expats for permanent or short-term stints. "The bottom line is that going back [to India] is a great deal" for access to money and equipment, says the University of Buffalo's Sen. "But who is there to talk to? And what is the atmosphere?" There are the elite schools, he says, "but the state universities are a shambles, and that is where the need is." He adds that he would be "more than happy" to spend a month every summer there, but no set-up is in place to take advantage of such offers.

"Even if everyone returned, it would not be enough," says Bhattacharya. On the bright side, he says, in the past few months "the problem is finally being articulated in the national discourse." It's impossible to generalize about India, he says, but "what's on the up and up is funding. And what's on the down and down is people. And that is very hard to explain for a country that has a population of 1.2 billion." **Toni Feder**

Germany's high-tech success due to (gasp!) government

Could the German model of applied research be emulated as the US struggles to retain what remains of its manufacturing sector?

Germany has emerged from the great recession as one of the world's strongest economies, in large part because of successful government–industry targeting of applied research. In the US, such combinations are generally seen as undesirable interference in free markets or as picking winners and losers. The contrasting models were discussed at a Washington, DC, panel sponsored by the German embassy and the DC-based Information Technology and Innovation Foundation (ITIF) on 18 October.

"Germany has figured out something over the last decade about how to succeed in a worldwide economy that we haven't [done]," said ITIF president Robert Atkinson. "The simple message [to US policymakers] is [to] support applied research cooperation between industry and government."

Germany's gross domestic product (GDP) has grown at an annualized