ADAPTIVE OPTICS: ADDITIONAL ADVANCES AND APPLICATIONS

Graham Collins's Search and Discovery story "Making Stars to See Stars: DOD Adaptive Optics Work Is Declassified" (February, page 17) mentions only two of the three laser guide-star adaptive optics experiments sponsored by the Department of Defense. The third, sponsored by the Office of Naval Research and funded by the Innovative Science and Technology Directorate of the Strategic Defense Initiative Organization, was performed during 1989–90 by my research group in San Diego. We used an ultraviolet laser star at a distance of 8 km to compensate for the effects of turbulence at 353-nm wavelength over a 0.5-meter telescope. The turbulence was corrected using a deformable mirror composed of an array of 500 flat mirror segments, each controlled in piston, tip and tilt. Our tests consisted of comparing 3-msec images of the star Vega before and after correction. An average of several short exposures indicates that after adaptive correction, the full width at half-maximum of the star decreased by a factor of 4, from 2 arcsec to less than 0.5 arcsec. Thus there is further evidence that laser-star adaptive optics can substantially sharpen images, even in the ultraviolet, where the effects of turbulence are quite strong. We are now beginning experiments on a 1-meter telescope, aimed at achieving nearly diffraction-limited images at optical wavelengths using a commercial visible laser to project the artificial star.

In the section entitled "Synthetic constellations," Collins accurately points out that correcting large telescopes may require several laser stars. He implies that only one experiment has been performed: a proof of principle using two laser stars. In fact, last year we performed experiments for the Air Force using a lattice of 20 laser stars over a 1-meter telescope. These experiments showed that if the lattice has a special geometry, the wavefront distortion can be measured as if the light emanated from a single point, thus removing many of the complications that arise if one tries to keep track of the light from each star.

Manuscripts describing these experiments are being completed for publication. This should surely be an exciting period for ground-based astronomy as the DOD adaptive optics methods and technology are applied to astronomy in the near term. In the longer term, a challenge for the adaptive optics community is to innovatively extend the DOD research and technology to better fit the resources and needs of astronomers.

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The discussion of adaptive optics and synthetic "guide star" beacons was extremely interesting. In addition to the astronomy applications discussed, another emerging application for lasers with adaptive optics is now receiving considerable attention: the possibility of providing power in space using laser beams.[1] Lasers with high average power are beginning to become available. Using the technology of adaptive optics, such lasers can be used to produce nearly diffraction-limited illumination on space photovoltaic arrays. Lasers and photovoltaic arrays are a natural match: Solar cells can be twice as efficient under optimally chosen monochromatic light as under solar illumination.

Using ground-based lasers for power-beaming has several advantages over other space power systems, including the ability to power systems during the local eclipse period[2] and the possibility of high power density. Possible applications include providing eclipse power for satellites, power for electrically propelled space transfer vehicles and power for a Moon base during the 14-day-long lunar night. At the distance of geosynchronous orbit, an 800-nanometer laser with a 10-meter beam director would illuminate an 8-meter-diameter spot; at the Moon, the same laser would illuminate an 80-meter spot. As the technology becomes better understood, more applications are likely to become evident. This interesting topic has been made technologically possible by the advent of adaptive optics and is now under investigation by several researchers.[3]

References

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2. G. A. Landis, Acta Astronautica **25**, 229 (1991).
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Has Defense Research Held Science Back?

I read the news stories in the February Search and Discovery section with a mixture of pleasure and dismay. The reports describe the use of artificial guide stars for adaptive optics, and the discovery and further study of gamma-ray bursters. What wonderful, exciting stuff! The potential for future telescopes offered by adaptive optics is matched by the fascination of the puzzles presented by bursters, and I imagine that both subjects will make more appearances in PHYSICS TODAY.

But as exciting as these developments are, it is disturbing to realize that both subjects began behind the closed doors of the defense industry and were shared with the rest of the scientific community only after a decade or more. How much more might we know by now about adaptive optics or gamma-ray bursters if the early discoveries had been published in the open literature when they were made? Similarly, how much knowledge in other fields remains classified?

More important, how much talent and work have we wasted over the last few decades? The advances in physics and technology that were required to cancel atmospheric distortion and to observe transient gamma-ray events are no small achievements; there have clearly been some creative, brilliant minds at work here. How many more such minds are focusing their efforts on ever more accurate cruise missiles or command-and-control software, instead of (let's say) more efficient high-speed trains or better models of climate change? We have used the work of many of our best scientists to make stockpiles of weapons that now have little or no use. I hope that we can recover, intellectually and economically, from this squandered investment.

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US Nuclear Stockpile Safety: Review No. 2

Sidney Drell, in his November 1991 letter (page 9), writes that "last year we [the three-man House Armed Services Committee Panel on Nuclear Weapons Safety that he headed] did the first *(and only)* comprehensive review of the safety of the US nuclear stockpile since World War II and the subsequent buildup to more than 20 000 warheads" (emphasis added).

At the request of several members of the United States Senate and House of Representatives, I also prepared a technical report on the same subject, entitled "Report to Congress: Assessment of the Safety of US Nuclear Weapons and Related Nuclear Test Requirements" (UCRL-LR-107454, Lawrence Livermore National Laboratory, Livermore, California, July 1991). Drell knew that I was preparing such a report and was included among those to whom it was distributed.

My report deals with many, but not all, of the topics dealt with in his report. The converse is also true. In particular, my report discusses in some detail the question of how many nuclear explosive tests would be needed to implement different options under consideration for improving the safety of the US nuclear weapons stockpile, and how long it would take to complete them. His panel's report is silent concerning this politically important technical question.

Copies of my report are available from the National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield VA 22161.

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Physics Departments: Don't Chop the Shop

After years of watching physics departments being herded down the wrong path by forces they were unable to resist, I finally feel compelled to write. I refer to the virtual disappearance in the US of the open departmental physics machine shop. Before World War II and the advent of government research contracts for university research in physics, physics departments usually had very little money for *buying* things, but they had good university-supported facilities for *making* things. The open physics shop was just as much a part of physics education as the library. As far as I know, the Berkleley physics department is the last bastion of this arrangement in the US, and its members, such as myself, are bloody from the recurrent strife involved in defending it against administrators for whom a university-supported research facility (other than the library), existing outside the usual system where almost everything related to research is charged to a grant, is an anomaly foreign to their experience. My thesis is that everyone is out of step but us. My concern is, Can anything be done about it?

With an open shop, a physicist and his or her students who want to try something new can spend their time designing an apparatus, submitting it to the shop for fabrication, and testing the idea when the shop work is complete. Without the open shop, the physicist has to start by trying to get a grant—a procedure that we all know is long and arduous even if the idea is smashing. The short turnaround time that an open shop permits is especially important to the young assistant professor, who has to involve students and make his or her mark as a productive and innovative researcher within strict time constraints. (Our open shops at Berkeley have given us a real edge in recruiting gifted young experimentalists, by the way.)

And look at it from the other end. In the open shop the mechanicians are busy making *things*, not making *estimates* and keeping books. In the open shop, where orders pile up, the mechanicians' goals are to have the physicists and students satisfied and "off their backs" as soon as possible, a climate that stimulates their ingenuity to make things simpler and easier to fabricate. In the shop that depends on recharges for its existence, the goal (unconsciously, of course) can become one of stretching jobs out to increase revenues.

I understand that in Britain the university grants committees will not even consider funding a project unless the university supports adequate shop facilities independently of the grants. If that is so, our British cousins have been wiser than we.

What can be done? I think this is the sort of issue that the National Academy's Government–University–Industry Roundtable, which has been finding ways to improve the collective national research enterprise, ought to address. A start would be to have those institutions that substantially support research fabrication in their own shops receive automatic and generous credit for that support by the funding agencies when their projects are being evaluated for institutional cost-sharing. I submit that open shops make even more sense for universities than cost-sharing on expensive pieces of equipment. Open shops nurture the research enterprise across the board. And innovative homemade instruments are more apt to lead to scientific and technological advances than off-the-shelf ones.

Nor should one forget the importance of supporting open shops for physics courses. Creative teaching of lower-division courses and of experimental courses in the upper division requires good shop facilities that are freely available as a resource to the instructional staff.

I see no reason why faculty and administrators should be opposed on this question. Our libraries are supported in part by overhead monies derived as legitimate indirect costs of contract research. Why not shops as well?

Maybe other physics departments are fighting the good fight and still maintaining open shops. If so, we would like to hear from them. Solidarity forever! Maybe things can be turned around.

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Don't Omit Population from Energy Equation

In their article "US Energy Transition: Getting from Here to There" (July 1991, page 22), John H. Gibbons