Toy box supplies parts for teacher's light table

Optics is developing rapidly as a means to put other sciences to work, **John Bell** writes. Teachers are starved of funds and some have learned to raid the toy cupboard to build optical demonstrations for their students.

Europe's optics community knows that light sources, optical components and detectors represent an enabling technology that sets other sciences to work in countless applications. It also knows that it must teach the possibilities of modern optics to colleagues in hundreds of other disciplines.

There is no all-purpose text or teaching method to catalyse non-specialists into thinking about optics, that much is clear from the recent Education and Training in Optics meeting in Delft. Each audience needs to hear a specific message relevant to its needs, sometimes delivered in an individual way.

The optics community needs to ask how many external audiences it can reach and what messages it should direct to them. There is no shortage of conferences and events serving any industry that you care to name, and there must be few major conference centres in Europe more than an hour or two away from an optics laboratory.

It is hardly a hardship for a specialist to give up a morning to present a paper about the possible applications of optics at a conference for the cosmetics industry, for example. The message could be as simple as: "A sensor based on optical fibres determines the size, velocity and path of powder particles in air or liquid in one measurement."

Perhaps chemists and production engineers in the cosmetics industry are well educated about the possibilities of laser anemometry. If not, then a few hours of effort is sufficient to make a cross-section of the industry aware of the existence of optical fibre sensors and at least one relevant application.

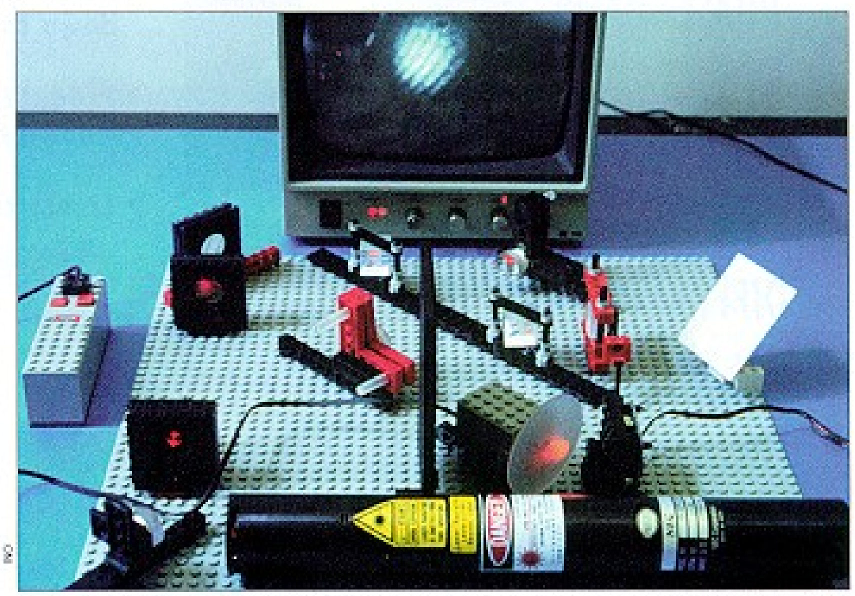
Most papers at the Delft event looked at more specific and accessible audiences in universities, companies and organizations than in industry at large. William Swift of the Welsh consultancy Swift Technical Services summed up the problem of presenting optics as an enabling technology when he said: "Optics should be a part of every engineer's education. This may be the ideal, but it is not practicable because most engineering courses are already heavily loaded or even overloaded."

No more money

He added that it was unlikely that teachers would receive extra money to solve the problem because courses are losing resources. "It might be possible to find enough time to present a couple of lectures giving typical examples of applications, just to provide a very basic introduction that will alert people to possibilities. This approach would not take up much time, it would not cost much and it would be significantly better than nothing."

Others are less pragmatic than Swift. Irena Veretenicoff and Hugo Thienpont of the Laboratory for Photonic Computing and Perception at the Free University of Brussels, for example. They think of optics as an exciting fundamental subject that is too often taught by teachers who are too conservative to keep up with changes in society.

Veretenicoff and Thienpont say that optics should be taught at all levels, to interest youngsters in science and engineering. Teaching through optics means that "natural and man-made wonders can be shown and seen and explained in simple terms", and it puts applications well within the reach of boys and girls who like science fiction.



Mach Zehnder patterns: the Lego interferometer produces fringes on the screen (right) and on the rotating ground-glass screen imaged by the camera and presented on the monitor.

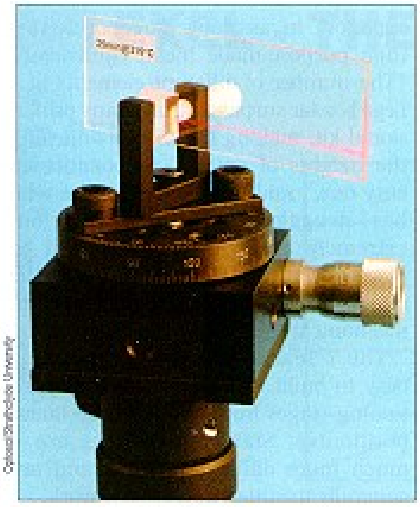
The Belgian university has experimented with multidisciplinary training for engineers since 1993, when changes in the law allowed universities to write their own curricula. Students share a common basic training, which incorporates optics, as well as specializing in a subdiscipline such as optoelectronics. "Photonics electrical engineers are recognized in Belgium and abroad. Most of our students have found jobs in their fields of study," they told the meeting.

Teaching aids

Even when teachers know who and what to teach, they need up-to-date demonstration equipment. If the equipment is not there, then educational objectives suffer or students never see key technical principles demonstrated.

Walter Johnstone told delegates that the Electronic and Electrical Engineering Department at Scotland's University of Strathclyde refused to limit demonstrations to the constraints of existing equipment. It teamed up with Glasgow company Optosci to produce aids to teach optoelectronics from first principles.

"The result is a series of kits containing the hardware and teaching manuals to investigate key technical issues hitherto excluded from the teaching laboratory by the high cost of equipment," said Johnstone. "Modular design means that some of the kits can be mixed and matched to provide customized experiments for particular needs."



Optosci/Strathclyde University

Purpose-built: apparatus to demonstrate prism coupling of light to an optical waveguide.

There are kits to teach the basics of light and optics, the properties of optical fibres, waveguiding, optical communications, network analysis, and erbium-doped amplifiers and fibres.

Italy's National Institute of Optics in Florence is looking at an even less expensive method of providing a light table and optomechanical components by basing them on Lego. Franco Quercioli told delegates that ABS Lego elements, with a few modifications and some non-standard parts machined from acrylic, will assemble into an optical bench capable of teaching interferometry.

Quercioli thinks that Lego shows the weaknesses of commercial mounts. "Low-cost, reduced weight and compact size are all desirable characteristics in a laboratory that has been set up for educational or research purposes," he said. "Commercial optomechanical components are still very far from such goals."

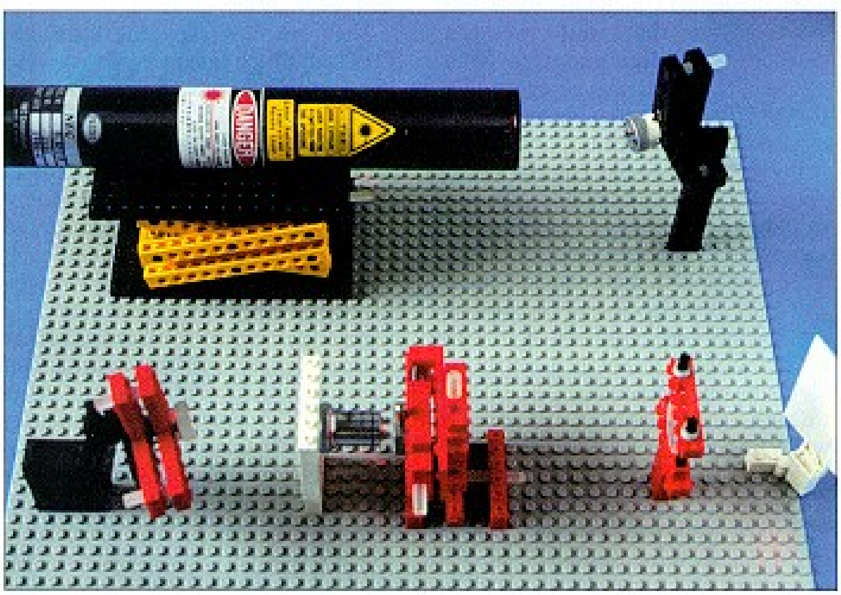
Lego parts are made to close tolerances so that "the force needed to separate elements reaches the remarkable figure of 1. 5 to 3 N for each stud-and-tube unit." The Florentines exploit these connective forces, mostly between standard components, to make holders, translation and rotation stages, *xyz* positioners and tilters, as well as posts, bases, rails and breadboards. These components assemble into optical instruments and systems such as microscopes and interferometers.

Standard Lego elements work best as static mountings, which are adjusted once and for all during the alignment of the optical bench. Standard screws, gears, rails and tracks, especially from the Lego Technic system, provide moving parts such as translators.

Most modified and non-standard parts are beams or axles, with cross-sections poorly suited to the precision guiding of moving stages. Modifications include rods to guide springs in the positioning stages, precision screws machined into standard holes for the fine control of moving parts, and threaded adapters to hold microscope objectives.

As every child knows, a drawback in building moving assemblies from Lego elements is that instability increases with size. Apparently size is not a serious problem with the Lego optical table if a component, such as a jack to support a 500 g HeNe laser, does not need regular adjustment and is supported by a standard baseplate.

Some components, such as lens or cube-splitter holders, are "far >>>



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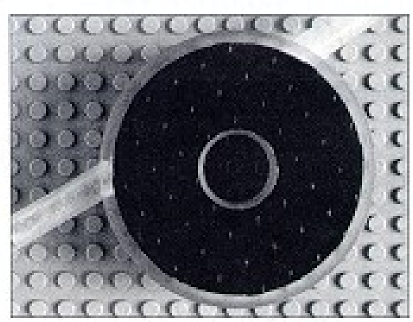
Beam expander: the three-axis stage positions a 50 µm pinhole (centre front). The other parts made of Lego elements hold mirrors, a filter and lenses, and support the 500 g laser.



Home-made rotator: discs cut from a baseplate sandwich an acrylic ring, screw and cam.

superior" in assembly and positioning than purpose-made metal equivalents. "The number of different elements in a Lego box far surpasses that of any professional kit, making the task of adjusting the heights of optical components an easy one," said Quercioli. "Anyone who has struggled with this trivial but extremely annoying problem will be pleased that it can be solved with little effort and no severe reduction in mechanical stability."

The researchers found it relatively easy to build two- and three-axis positioning stages from two or three linear positioners. Standard rotators are a much more difficult problem and are generally unsuited to precision work.

Their rotator is an acrylic ring, with an off-axis hole, sandwiched between circular pieces cut from a baseplate. A screw pushes a cam, glued to one piece, to provide small angular displacements while a spring provides loading.

They also recommend placing the baseplate, which secures the components, on a flat surface to prevent bending. In fact, most of the optical apparatus assembled from Lego elements performed experiments while resting on an office desk. Although the position of the studs on the baseplate tends to restrict the geometry of components, single-stud bricks allow components to rotate.

"It seems possible to integrate Lego and conventional optomechanical components of aluminium or steel," suggested Quercioli. "Some more research, working on the most promising mechanical configurations to devise some new elements, maybe trying different polymers, and Lego may soon appear on many optical benches."

The proposal would cut the cost of optomechanical components from pounds to pence. Lego in Denmark is intrigued by the suggestion, but a spokesman said that the company would not want to make custom components. "We would look positively at it if the Italians wanted to produce special elements in small quantities," he said. "If we have a good sales letter from them we will consider it."

Moving audiences

The most fortunate teachers of optics might appear to be those who work in companies and organizations such as hospitals. At least they know the capabilities of who they have to teach and what their students need to learn. In fact, hospitals often find it hard to assemble a class of mixed professionals in one place and they need highly specialized teaching aids.

Teachers at Swansea in South Wales devised a programme to provide healthcare staff – ranging from administrative, technical and scientific personnel to doctors, nurses and paramedics – with optical skills involving experimental and commercial equipment. The scheme had to solve three problems.

First, the range of staff demanded diverse levels of skills, in varying detail and with different priorities. That problem was solved by a pyramidal structure: all staff learn the basics, most are taught operational principles, some get to grips with service details and a few tackle theory. William Davies of the Swansea NHS Trust told delegates at Delft.

The other problems involved getting students who work shifts into the classroom at the same time and then assessing what they learn from lectures. "Much of the training has serious implications for the well-being of the patient," said Davies. "It is important to audit trainees' acquired skills."

Davies added that the NHS trust and Swansea Institute of Higher Education have tried to solve the problems with traditional tutorials – effective, expensive and needing good teachers – or with slide or video material – less expensive, especially with large groups of students, and generally less effective.

They are now exploring interactive CD-ROM, which is expensive to produce but captures a range of expertise and is cheap to replicate. The cost of equipment to play the discs is also falling rapidly.

There is another route to teach optics as an enabling technology to a diverse, willing audience of many non-specialists. It is the stream of ideas and application that tens of thousands of readers find in this magazine every month.

Organizations such as the European Optical Society and the International Commission for Optics could exploit our method to promote optics to industry. What would happen if such societies asked every major optics laboratory in Europe to mount just one lecture or seminar once a year to encourage optics where it is barely known? There is nothing like the promise of an optical solution to an intractable problem to arouse interest in technology transfer. •