Quick calculations: will the speed of light do?

The optical computer, which uses light beams instead of electrical impulses, is on its way.

Wires and small metal boxes seem to be everywhere: it looks like the aftermath of an accident between an electronics shop and a truck of spaghetti.

However, this bizarre device, built by scientists at the University of Colorado at Boulder, may be an important step towards a key technology of the next century: the optical computer.

Today's computers may seem extremely fast, but in fact most of them solve problems in a very inefficient way. The slowness occurs because they are simply tackling one part of the problem at a time.

A much better way would be to use "parallel processing" - that is, working on all the different bits of the problem at the same time.

Many scientists believe that tomorrow's supercomputers will be parallel processors. They also think that they will be based not on electrical pulses as with today's machines, but on beams of light.

Such an optical computer would have two main advantages over its electronic rivals.

First, pulses of light move quickly: in one second, a light beam can, theoretically, travel around the globe seven times; electrons flowing through electronic devices typically move far more slowly.

Second, light beams can be split up much more easily into parallel streams than a flow of electrons, which makes them a more natural choice for a truly powerful parallel processing computer. The resulting computing power could be used in such demanding problems as threedimensional image processing, for example, virtual reality games. The challenge, however, has been to convert the theoretical advantages into the "mechanics" of a working machine.

Now a team under Professors Vince Heuring and Harry Jordan at the University of Colorado's optoelectronic computing systems centre has succeeded in showing that an optical computer can indeed work.

The two have built a machine that stores and manipulates data just like an electronic computer, using rays of light instead.

To keep things relatively simple, the Colorado team decided to begin with an optical machine that solved problems one at a time, leaving the problems of building a full parallel machine until later when the study was more advanced. "We wanted to establish the principles of computing at the speed of light," says Professor Heuring, who has been working on the project since the mid-1980s. "We wanted to see whether we are able to understand the complexity of the system."

Complex it certainly is: the machine consists of five infra-red semiconductor lasers, 25 optical-fibre delay loops and 60 lithium niobate optical switches - costing £4,000 (about £2,700) each.

The result, Professor Heuring believes, is the single most complex optical system ever built. Just trying to ensure that all the light pulses get to the right places at the right time was a nightmare.

"Everything has to be totally synchronised all the time - it was just one technical hurdle after another," Professor Heuring says. "We are pleased that, even so, we saw all the problems from the word go."

The machine carries out simple calculations by first converting numbers into streams of infra-red light pulses about four metres long. These "bit streams" are then fired into the machine's maze of optical fibres. Then, following instructions from a clock ticking 50 million times a second, the streams are directed towards various optical "switches" for processing.

The result is an optical computer that solves problems using the light beams - although admittedly not very sophisticated problems. At present, the machine can carry out only basic arithmetic, and can hold 128 bytes of information in its memory. More complex calculators can do much better.

Yet the first electronic computers 40 years ago were just the same: room-size machines with thousands of wires and little memory. The Colorado team think that its breakthrough puts optical computing where those pioneers were with electronic computers in the 1950s. The Colorado team has also followed in the great tradition of the computer pioneers, who gave the early machines evocative names such as Ace or Maricle.

They call their machine a Stored Program Optical Computer, or Spec, in tribute to Mr Spock from Star Trek. Professors Heuring and Jordan are now working on the first practical optical computer: a record-sized disc, which will run about 400 times faster than Spec.

William Thompson