IfM MANAGEMENT TECHNOLOGY POLICY

UNIVERSITY OF CAMBRIDGE

briefing

50 Years of working at The Speed of Light

2010 marks the 50th anniversary of the invention of the Laser (Light Amplification by Stimulated Emission of Radiation). The science has evolved from a series of curious instruments conceived and produced by a handful of scientists, to one of the most important scientific inventions of all time. Research into the laser has led to seven Nobel prizes and the output from the research now touches every aspect of our lives from the production of magazines to the cooling of atoms, and the welding of automobiles to the destruction of missiles. This briefing by the IfM's Centre for Industrial Photonics describes the origins of laser technology and its future implications.

Background

It has been half a century since the first working laser was created, but the technology can trace its roots back to the 19th Century through the work of Faraday, in electromagnetic experiments and Heinrich Hertz on the production of electromagnetic waves. However, most histories of the laser begin with the emergence of Quantum Physics in the early 20th Century. Max Planck and later, Albert Einstein in 1917 developed new theories on the behaviour of light, defining simple laws as to the way individual photons and electrons operated.

These theories sparked a wave of research activity into its practical applications. The early 1950s saw the development of a groundbreaking Ammonia Maser "Microwave Amplification by Stimulated Emission of Radiation" . A patent was submitted for an optical Maser in 1958, while just 12 months later the first paper and patent submission which contained a description of and potential use of the "LASER" was submitted.

In 1960, Theodore Maiman of Hughes Aircraft Company produced the first experimental system. A flash-lamp pumped ruby laser that delivered pulsed outputs milliseconds in duration.

Theodore Maiman: produced first laser

The next five years saw a plethora of laser-related scientific and engineering breakthroughs. This short period of intense research laid the foundations for the revolutionary applications that were to follow in the fields of communications, medicine, metrology, entertainment and laser based manufacturing technologies.

Changing the world

The laser had long been a popular staple of science fiction and film and by the early 1960s technologists were beginning to make ambitious predictions for their use.

These predictions, seemingly outlandish at the time, included laser-based weapons, anti-missile systems and laser-based communications. But all of these have since been realised in one form or another. In fact developments in laser technology in the 1960s have led to several innovations:

- As early as 1961 lasers were being used in eye surgery
- Frustrated with sound quality from vinyl records, in 1965 James T. Russell, a senior scientist at the Pacific Northwest Laboratory, invented the technology that would lead to the compact disc player.
- The same year, Charles K. Kao and George Hockham, proposed the concept of fiber optic communications whilst working at the STL Labs, Harlow, UK. Kao shared the 2009 Nobel Prize in Physics for his for groundbreaking achievements. A team from Corning Glass demonstrated the first successful fiber optic communications in 1970.
- The consumer product bar–code format and scanner as we know it today was developed by IBM in 1973,
- Compact disc players, DVD players, laser printers and bar-code scanners now represent the most widespread laser applications on the planet.

Revolutionary tools

By the late 1960s engineers had started processing materials with lasers. They were already predicting great things in terms of the ability to apply these precise beams of energy in the structuring, joining, and trimming of materials. They were mainly concerned with machining, micro-welding, drilling, and electronic applications such as circuit patterning. Pulsed Ruby and CO2 lasers were employed in these applications and several companies quickly established themselves as laser system suppliers. Despite the flurry of application reports, these early systems were really not capable of making much impact on the industrial scene.

The electronics industry was still in its infancy and had yet to become a large volume user of laser systems. For real impact, high-power, industrially rugged systems were needed.

In 1966, Whilst working at The Welding Institute, Cambridge, UK, Peter Houldcroft was thinking about how he could develop a faster way of cutting thin sheet metals, a request made by the then Rover Company Research Station; they were trimming sheet

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metal pressings using a plasma torch, which was too slow and needed to be improved. In 1967, Houldcroft became aware of a "high power" (800W) CO2 laser being developed at the SER Laboratories, Harlow, UK. It was a potential solution to the cutting problem he had considered a year earlier.

He proposed a simple coaxial arrangement of a laser beam passing through an oxygen jet in order to "cut" the metal, it was an instant success and the first laser cut was recorded at SER Labs in 1967. A consortium was quickly established to develop an industrial laser-cutting machine. Engineers at the TWI went on to develop the first industrial fast axial flow CO2 laser. This technology was licensed by many companies around the world and enabled the development of laser based machine systems for cutting and welding; delivering high power laser applications that would soon become the dominant industrial laser revenue generator.

The further development of high power Nd:YAG lasers in mid 1970s enabled industry to establish applications such as pulsed welding of medical devices and hole drilling of aerospace components, essential for the manufacture of high efficiency jet engines and latterly hair removal.

Once the primary laser systems had been invented, significant industrial activity followed. Fine tuning of laser designs and greater levels of innovation in system technologies increased the take-up of industrial laser applications and firmly established the laser an important wealth generator. Excimer lasers enabled new lithographic technologies that would maintain Moore's law with ever decreasing line-widths, allowing the digital revolution to take a firm hold and provide consumers with an astonishing array of gadgetry. Semiconductor laser diodes and the associated fiber optic technologies would lay the technical foundations of the internet, and in doing so, changed the habits of a generation, and enabled the creation of new business models with the advent of the dotcom revolution.

A Step change in Performance

By the end of the last century the industrial laser had developed to deliver a wide range of processes such as machine cutting, and welding, with process resolutions from centimetres down to the nanoscale.

Systems were becoming semi-automated and benefited from control architectures that offered friendly graphical user interfaces. Increased efficiencies were developed, meaning lasers were able to target specific energy levels of a material and enable greater levels of power conversion with minimal heat loss. This lead to higher quality beams, enabling better precision and high levels of stability.

At the turn of the millennium, it was difficult to see the next major advance. Ultrafast lasers were making waves in research labs, but offered no real chance of industrial engagement, powers were low and systems were highly complex.

In another laser arena, that of fiber optic communications, the end of the 1990s saw a major global downturn. The global optical communications market was saturated, demand was low and companies that were riding the crest of the dotcom boom were now desperately finding ways of staying alive.

The world had warehouses full of fibre optics, fiber amplifiers, and pump diodes. These were technologies that were tested and designed not to fail for an average of around 25 years. Companies that were once feeding the communications industries turned their attention to the industrial laser markets. The arrival of the fiber laser meant more power, quality, efficiency, simplicity and lifetimes that were akin to those demanded by the communications industries.

Ten years have passed since this quiet revolution; fiber lasers have now displaced other low power lasers. Application specialists have jumped on these new laser capabilities to re-define the laser materials processing landscape. High-speed remote cutting, fine cutting and welding are now readily available, and offer industries a real chance to smash current productivity records. A 1 micron Yb single mode fiber source can deliver remote cutting of 100 10mm diameter holes in under 2.5 s when cutting 200 micron thick foil.

Future applications

Now the military are exploring the potential of the laser. Due to high beam quality, high power, and high efficiency now obtainable from lasers, the development of tactical laser weapons are now a reality. Lasers are now being applied in air-to-ground, ground-to-air, and air-to-air formats. Boeing announced its Laser Avenger mobile laser system in 2009. It is interesting to note that the US Army have used the "Zeus" by Sparta Inc, a Hummer Mounted fiber laser, for mine clearance operations in Afghanistan since 2003. The development of laser technologies is continuing apace, what is clear is that these potential applications will require even greater levels of engineering innovations and an army of engineers with the skills and knowledge to transform these ideas into reality.

For more information

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