Laser Entertainment and Light Shows in Education

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ABSTRACT

Laser shows and beam effects have been a source of entertainment since its first public performance May 9, 1969, at Mills College in Oakland, California. Since 1997, the Photonics Center, NgeeAnn Polytechnic, Singapore, has been using laser shows as a teaching tool. Students are able to exhibit their creative skills and learn at the same time how lasers are used in the entertainment industry. Students will acquire a number of skills including handling three-phase power supply, operation of cooling system, and laser alignment. Students also acquire an appreciation of the arts, learning about shapes and contours as they develop graphics for the shows. After holography, laser show animation provides a combination of the arts and technology. This paper aims to briefly describe how a krypton-argon laser, galvanometer scanners, a polychromatic acousto-optic modulator and related electronics are put together to develop a laser projector. The paper also describes how students are trained to make their own laser animation and beam effects with music, and at the same time have an appreciation of the operation of a Class IV laser and the handling of optical components.

Keywords: Laser shows, PCAOM, laser animation, white-light Kr-Ar laser, vector-graphics.

1. BACKGROUND

NgeeAnn Polytechnic[1] is a tertiary institution in Singapore offering both business-related and technology-based diploma and advanced diploma programmes, ranging from engineering to business, maritime studies, biotechnology, mass communications, information technology, computing and e-commerce. In addition, the polytechnic also offers many short courses for working professionals. Students who gain entry at the age of 17, do a 3-year programme.

The Photonics Center[2] is one of the technology centers in the School of Engineering of NgeeAnn Polytechnic. It was established in 1995. The principal aim of the Photonics Center is to provide a broad-based and practice-oriented education and training in photonics and laser technology for our students and to promote Photonics and Laser Technology in Singapore.

Final-year students with electronics background but no photonics knowledge are taught the theory and applications of this technology. As such, the Photonics Center has been providing graduates with this additional skill since 1995 in preparation for this new technology that is beginning to emerge in Singapore.

As an effort to train our graduates to provide support in R&D in industry, our final-year project students do applied R&D projects. Today, the Photonics Center, NgeeAnn is a leader in training in this technology in Singapore. We have also developed expertise in holography, laser show animation, and fiber optic sensors.

In 1996, the Photonics Center acquired a system to develop laser shows. The original system was acquired from Holo-Spectra Inc.[3], USA. The software for the laser show design and animation used by the Photonics Center is developed by Pangolin Laser Systems Inc.[4], USA. The Photonics Center is probably the first tertiary institution to use laser show design and animation for teaching purposes.

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Seventh International Conference on Education and Training in Optics and Photonics,
Tuan-Kay Lim, Arthur H. Guenther, Editors, Proceedings of SPIE Vol. 4588 (2002)

2. LASER PROJECTION SYSTEM

The laser projection system in NgeeAnn comprises the following:

a) A 3.5W Class IV white Krypton-Argon laser.
b) Projection system comprises the galvanometer scanners and scanner amplifiers, which together move the beam fast enough to create graphics. It also contains a polychromatic acousto-optic modulator (PCAOM) that blanks or colors the laser beam.
c) A 3-phase power supply for the laser.
d) A water-cooling system for the laser.
e) A PC to house the QM32 board that makes running the laser show software possible. [Pangolin has since upgraded the QM32 board (ISA bus) to QM2000 (PCI bus)[5]]

3. SYSTEM OPERATION

The laser graphics and animation are created using two of Pangolin's software products: Lasershow Designer frame creation software and Showtime show creation software (which combines music with animation) respectively. The shows are uploaded to the projection system.

The white-light laser beam enters the polychromatic acousto-optic modulator (PCAOM). The PCAOM can be thought of as a computer-controlled electric prism. It splits the beam into two components: a beam with the desired colors and a "waste" beam. The desired beam exits the PCAOM, onto a 45-degree bounce mirror, hits the X-axis scanner mirror, and bounces up onto the Y-axis scanner mirror that aims it at the projection surface. The waste beam contains all the undesired colors. The waste beam exits the PCAOM at a slightly different angle, so it can be dumped onto a black surface.

4. ANIMATION: THE PROCESS[6]

Like the cel animation techniques used in creating cartoon characters, the laser animation process typically begins with a hand-drawn image or character. From there, however, it rapidly departs from the cartoon analogy; for unlike cartoons, where light is passed through an image to be focused on a screen, laser images are drawn using a precisely directed, rapidly moving laser beam.

Because laser beams are so parallel, when they strike a surface, the reflection back to one's eyes appears only as a bright dot of light. Laser images are "drawn" by guiding the laser beam (and thus this very bright dot) along the path of the original drawing. This type of image display is referred to as "vector graphics".

In order to steer the laser beam along a path, that path's information needs to be defined as a series of horizontal and vertical coordinates. This is accomplished through a process called "digitizing". Lasershow Designer™ frame creation software allows us to digitize images with the aid of a mouse or digitizing tablet.

To create the final laser image, these X and Y signals are simultaneously output as voltages to devices called scanners. Essentially, each scanner has a mirror mounted on a shaft which can rotate to precise angles based on the input voltage it receives. The scanners are mounted in such a fashion that the laser beam reflects off first one and then the other, one of them oscillating along the horizontal axis, with the other in charge of the vertical. Working together, the two devices can precisely steer the laser beam to any point on the chosen screen's surface. Thus, with the right directions, the original image is re-traced in laser light.

After having been hand drawn and, all that now remains is to output all those coordinates from all those frames, one frame at a time. Again, just as with cartoon animation, the illusion of movement is dependent upon small changes in each frame.

Along with the XY coordinates, for example, intensity and color information must be defined and stored on a point by point basis. As the laser beam is tracing out, there will be times when a line needs to end and begin again in a new position without any connecting line in between (and this is techniques is called blanking). There will be a need to change color from the brown hair of a lady to her cherry red lips. The Polychromatic Acousto-Optic Modulator makes

this all possible. A single laser beam consisting of many specific wavelengths of light enters the crystal of the PCAOM. Each specific wavelength is then individually either refracted out of the beam path leading to the scanners, or allowed to *continue* on the beam path at precisely controllable intensities. The technique involves the use of ultra-high frequency sound waves to compress the molecular structure of the crystal, thus changing its refractive index.

The end result of all this, however, is an extremely bright dot rapidly changing it's color as it follows the path of the original artwork

Without persistence of vision, we would merely see the moving dot. The eye and brain perceive the image being traced, and not merely the dot which traces it. Thus a single frame can be perceived, and many frames in a row can be sequenced to provide the illusion of motion, i.e., animation.

This phenomenon begins in the retina of the eye itself. The millions of rods and cones present there are transformers of information. As they are hit with the photons of light reflecting from our rapidly scanning laser beam, their light sensitive pigments are bleached, and an electro-chemical signal is generated which travels to the visual cortex. It is this signal which our brain translates into what we call vision. These light sensitive pigments, however, take *time* to recharge to an unbleached state, and during this time, a signal is still being generated, and propagated to the brain. The result: an image flashed on a screen will be retained briefly in your retina while the rods and cones recharge. As they recharge, the image perceived by your mind fades. Thus, a bright dot moving along a path leaves a trail of decreasing intensity behind it...though only in your mind.

5. LASER ANIMATION AS A TEACHING TOOL

5.1 Infusing Interest in Photonics

Nothing is more spectacular than a laser show. When the light goes off and the show comes on, the spectators are captivated from start to finish. Every year the Photonics Center offers to the final-year students the elective module, Photonics and Laser Technology. By fueling their interest with one or two laser shows, the Photonics Center has been able to draw more and more students from the Electronic & Computer Engineering Programme to sign up for this elective module. Students are able to see an example of an application of lasers and enjoy it at the same time. Last year, this elective module received the largest number applicants, 125 out of some 600 final-year students.

Fig.1 A delegation from Finland are shown the operation of the laser projection table.

Fig. 2 Children from NTUC Kindergarten enjoying a room filled with smoke and beam effects.

5.2 Developing Creativity Skills

During the vacation period, the Photonics Center recruits students from other disciplines, as part of their vacation training programme, to create laser animated shows for the Center. By so doing, we are able to a) add value to the education by providing them with a new skill in creating laser shows, b) sharpen their creativity skills, and c) provide them with the basic knowledge on the operation of a laser system.

Also, staff members of the Photonics Center continue to upgrade our design knowledge through periodic training from Charles Symons of Digital-Creations, Pte. Ltd., Malaysia. With over 10 years of experience in laser shows, Charles has been able to train us and our students in various useful techniques to create laser shows.

5.3 Understanding Beam Manipulation and the Modulation of Light

Students who cover the topic on Modulation of Light in the elective module are able to see one application as demonstrated by the PCAOM. The laser projection system is able to illustrate how the radio frequency signal pumped into the PCAOM is converted to ultra-high frequency sound waves. These waves in turn, change the refractive index of the crystal, thus causing it to act like a grating.

Students are also able to better appreciate how mirrors and beamsplitters can be used to manipulate the beam.

5.4 Providing Training in All Aspects of Engineering

Upon graduation, some of the students are recruited as temporary staff of the Photonics Centre. During this period, they are not only trained to create laser shows but also to maintain the equipment. As such, the student is transformed to a graphics artist (developing laser animation), an electrician (maintain the 3-phase equipment operating the laser), a plumber (overhauling the cooling system), and a laser technologist (maintaining the laser system).

6. CONCLUSION

The Photonics Center has been using laser shows since 1996 and we have found this to be an extremely useful tool to demonstrate on application of lasers. Students are also able to try out their creative skills, not only in laser animation, but also in beam effects. The next step will be to train the students to launch the beam through a fiber and have a laser show at a different location. This will take photonics a step further into understanding fiber coupling and other aspects of fiber optics.

ACKNOWLEDGEMENTS

The authors would like to thank the Yong Saw Soon (Technical Support Officer) and Geremy Sia Yii Luen (Technical Support Officer and former graduate) for their invaluable help and support in making the laser projection system portable. The authors would also like to thank Alton Linus Ng (graduate) for creating a large graphics library for the Center.

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