Laser video projector for large-area display is composed of a white laser (Kr-Ar laser), acousto-optic modulators (AOM) and a beam scanning part. Red, green, and blue light beams are separated by dichroic mirrors from the white laser. After modulating laser beams according to video image signals, laser beams are recombined again by dichroic mirrors. The scanning part is composed of a galvanometer and a polygon scan mirror. Optical system of this projector is designed such that the long collimating distance keeps. To prevent the image on the screen from joggling in the horizontal direction, image joggling correction circuit is used. In this study, 4 × 3 m² of video image can be obtained at the throw distance of 10 m.

Introduction

Current projectors based upon cathode ray tubes (CRTs) types or LCD light valve types have greatly advanced but still need some technical improvements for large-area display. Practical CRT projectors today have limited power input and poor resolution. LCD projectors also have poor resolution and low brightness according to increasing screen size. Researches on the laser projection for large-area display are therefore being continued because laser has inherently possibility of obtaining an excellent brightness, contrast ratio and natural color.

In this study, a laser video projector is presented for large-area display. Our laser video projector is simpler than any other laser projection systems, because the usual systems use multiple light sources to get the red, green and blue colors. Only one light source in this laser video projector makes operation and maintenance easy comparing to the other laser projectors.

Laser video projection

A laser projection display creates an image by writing directly onto the projection screen with a laser beam. The laser light is diffused by the screen, making the real image visible to the viewer. Laser displays possess several inherently high-quality aspects: the fully saturated colors, the high-resolution capability of a focused laser beam, and the high luminance and contrast capability of lasers. The color gamut of a laser display depends on the wavelengths of the lasers used in the system. The color gamut of laser displays is typically larger than that of the other display types because the colors are fully saturated, lying on the outside of the chromaticity diagram. So it has excellent ability to express the natural color.

This laser video projector is mainly composed of two parts. One is optic part, the other is signal processing part. Optic part is composed of a light source, laser beam separating part, modulators, laser beam recombinating part, scanning part, and optical lenses. Signal processing part is composed of a NTSC decoder, sync signal separating circuit, image joggling correction circuit, and AOM drives. Figure 1 is a schematic diagram of the basic layout of the laser video projector using a white laser.

Figure 1. Schematic diagram of the laser video projector
Optics

It is mainly composed of a white laser for light source, acousto-optic modulators for modulating laser beams, and the laser beam scanning part which is composed of a galvanometer and a polygon scan mirror. Dichroic mirrors are used for separating the white laser beam to red, green, blue light beams and recombining the modulated red, green, blue light beams to one light beam which makes beam scanning easy. Figure 2 shows a schematic diagram of the optic part using a white laser.

![Optic part diagram](image)

Figure 2. Optic part

White laser (Kr-Ar laser)

White light source is a Krypton-Argon laser. The laser is lasing in the multi modes from 450nm to 700nm, so three color laser beams are mixed. The main wavelengths of red, green, blue beams are 647nm, 515nm, 488nm, respectively. Taking into account the main wavelengths, optical components for laser video projector are selected. The laser has beam diameter of 2.0mm and beam divergence of 1.4mrad. The maximum output power of the laser is 4W and the output power ratio of blue, green, red light beams is 1:0.78:0.74.

Modulator

Collimated and focused laser beams are modulated at acousto-optic modulators (AOM) according to the video signals. Laser beam modulation is implemented by varying the amplitude of the AOM drive signals, which in turn varies the amplitude of the light passed to the first-order. Acousto-optic modulator (AOM) consists of TeO2 crystal which is attached LN(LiNbO3) transducer, and laser beam goes through the TeO2 crystal. As for using high power laser, TeO2 crystal's surface needs high damage threshold. In our development for the crystal polishing and the optical coating, the damage threshold level is acquired over 40W/mm². We made an anti-reflective coating on TeO2 crystal with YF3 film. The coating has over 95% transmittance in the range of 400 ~ 700nm visible light. The modulation efficiency of the AOM is over 80% and it is possible to process up to 5MHz video signal with very low distortion.

Color separation and recombination

White light passing through the collimating lens is separated by dichroic mirrors to red, green, blue light. The first dichroic mirror for separating blue light from the white light has 99% reflectance in the blue region (440 ~ 490nm) and 90% transmittance in the green and red region (510 ~ 685nm). The second dichroic mirror for separating green light has 99% reflectance in the green region (510 ~ 585nm) and 90% transmittance in the red region (600 ~ 685nm). Red light passing through the second dichroic mirror is reflected by a high reflection mirror to the acousto-optic modulator.

The modulated red, green, blue light beams are recombined again by dichroic mirrors and a high reflection mirror. Then the recombined beam is projected by the beam scanning part. The third dichroic mirror for recombining green light with red light is the same mirror as the second dichroic mirror for separating green light. The fourth dichroic mirror for recombining blue light with green, red light has 90% transmittance in the blue region (440 ~ 490nm), 99% reflectance in the green and red region (510 ~ 685nm). All dichroic mirrors are designed to obtain the best performance for the s-polarized beam with the 45° incident angle.

The output power ratio of separated blue, green, red light beams is 1:0.65:0.56, and the output power ratio would be changed when laser beams are recombined again by dichroic mirrors. RGB color balance is tuned by adjusting the amplification ratio of AOM drives taking into account the eye sensitivity to colors.

Scanning

Recombined laser beam is vertically scanned by a galvanometer and horizontally scanned by a polygon scan mirror. Galvanometer is running at a 60Hz rate. Polygon scan mirror has 24 facets and is rotating at the speed of 39,375rpm. The polygon scan mirror is synchronized by the horizontal sync signal separated from the composite NTSC video signals. Therefore the scan rate is 15.75kHz in coinciding with NTSC video signal format which has 525 scanning lines and
video images of 30 frames per second.
Between a galvanometer and a polygon scan mirror, relay lenses are inserted for which vertically scanned beam is focused onto the polygon scan mirror facet.

Collimating and focusing
In order to acquire the best performance of the AOM, laser beam must have adequate beam waist diameter and collimated beam, when passing through the AOM. Laser beam has some divergence, so collimating lens is inserted in front of the laser to make sure of the parallel beam. Focusing lenses are inserted for adequate beam waist diameter. Using long focal length lenses, the beam is focused and collimated at the AOM itself. It makes sure that the AOM is located within the Rayleigh range, for high modulation efficiency of the AOM.

In this projector, infinite focusing system is applied, so it can make high-resolution image at any projection distances. That is, divergence angle of the projecting laser beam is controlled by adjusting the lenses that are inserted at the rear part of the AOM. Actually infinite focusing keeps within the Rayleigh range (collimating distance) of the laser beam. The divergence angle of this projecting laser beam is adjusted to 0.8 mrad.

Signal processing
Signal processing part is composed of a NTSC decoder, sync signal separating circuit, image joggling correction circuit and AOM drives. Figure 3 shows the schematic diagram of the signal processing part.

Any composite color video signals from TV, VCR, LDP, etc. are separated to RGB signals and composite sync signals by the NTSC decoder. These separated color signals are modulated and amplified by AOM drives. Composite sync signals are separated to horizontal sync signal (H; 15.75 kHz) and vertical sync signal (V; 60 Hz) by the sync signal separating circuit. The horizontal sync signal is divided by three at the sync signal divider and then used to clock for driving the polygon scan mirror. The vertical sync signal is integrated to ramp signal at the integrator for driving the galvanometer. If only using these circuits mentioned, image joggling will happen due to the scanner speed jitter of the polygon scan mirror. It therefore needs correction circuits in order to prevent from the image joggling.

Image joggling correction
Even if the polygon scan mirror is synchronized by the horizontal sync signal, it's impossible to make the facet to facet phase of the polygon scan mirror synchronize without any compensation. For that reason, display image is usually joggling. To overcome this problem, image joggling correction circuit is employed and photo diode detection system is used for monitoring the position of each facet. Extra laser beam (one of the zero order transmitted laser beam from the AOM) is steered into the facet and the reflected beam is monitored by the photo diode.

Image joggling correction circuit is composed of a A/D converter, memory (FIFO), D/A converter, control signal circuit, PLL (phase loop lock) circuit, oscillator and clock divider. To the image joggling circuit, RGB signals, horizontal sync signal (H;), photo diode signal and reference clock are provided. The horizontal sync signal (H;) is given to the PLL circuit for generating sampling frequency. Timing signal of the control signal circuit is also generated by the horizontal sync signal (H;) for memory. Reference clock is generated by the oscillator and in-phased by the clock divider with H; triggering, then given to the control signal circuit. When the horizontal sync signal (H;) is given from the PLL circuit to the A/D converter, RGB analog signals (image data) for one line scanning time (1H) are converted to digital signals, and then stored to the memory (FIFO). Photo diode signal is used as a start point of the scan line. On the basis of this start point, RGB digital signals stored in the memory are sent to the D/A converter and restored to analog signals. After that, these RGB signals are modulated and amplified by AOM drives. The facet-to-facet phase error is eliminated and the image on the screen is not joggling.

Performance
Figure 4 shows the image by the laser video projector.
The size of image, $2.0 \times 1.5 \text{ m}^2$ is obtained at the throw distance of 5 m using 2W white light. The size of image is controlled by the projection distance. As the projection distance is increased, the size of image is also increased. Accordingly, $4 \times 3 \text{ m}^2$ of video image can be obtained at the distance of 10 m using 4W white light with the same brightness of Figure 4.

![Image](image.jpg)

**Figure 4.** Image acquired by the laser video projector

*This figure is reproduced in color on page 1132.*

Maximum efficiency of this laser video projector is 50% at peak white. From 4W white light, laser power of 2W is projected to the screen. In this case, maximum brightness can be obtained over 1,500 lumens at peak white. In case of water-cooled gas lasers, kilowatts of input power is required to obtain watts of optical output power. The white laser used this laser video projector needs 16kW of input power for 4W laser output. But, if semiconductor diode lasers were used instead, the electrical power consumption would be greatly reduced.

**Conclusion**

Laser video projector using a white laser (Kr-Ar laser) is developed and demonstrated successfully. The merit of a laser video projector is that it can make large-area display with high-brightness and high-resolution. It has excellent ability to express the natural color in accordance with the wavelength selection. Laser video projector is expected to the outdoor advertising medium or large-area laser TV. In the future, if the blue-green semiconductor diode laser is developed and then used to the laser video projector, laser video projector is highlighted as a new media in the type of laser TV.

**References**