TECHNICAL INFORMATION

PATENT PENDING

# XENON FLASH LAMPS

HAMAMATSU

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This technical information is the one having made it to understand a basic characteristics of the xenon flash lamp. The characteristics of the lamp might be unwarrantable because of the measurement condition of data.

# 1. Xenon Flash Lamp

The xenon flash lamp is widely used as a spectroscopic analysis light source, camera flash lamp, stroboscope light source, high-speed shutter camera lamp, and for many other applications because it produces instant high-power white light. It also provides a high-intensity continuous spectrum from the UV through the visible to the infrared range, and outstanding features such as small size, low heat build-up and easy handling. However, conventional lamps lack arc stability, which precluded their use as light sources for precision photometry.
HAMAMATSU embarked on the development of lamps with outstanding arc stability in addition to the excellent characteristics of the xenon flash lamp, and has now achieved xenon flash lamps with far better arc stability than conventional lamps. The super-quiet xenon lamps possess such outstanding characteristics as an arc stability five times higher and a service life 10 times longer than those of conventional lamps.
Examples of their main applications are listed below. They can be also used in various other fields.

## ● Industrial Applications

- **Stroboscope Light Source**
- **High-Speed Camera Light Source**
- **Photomask Light Source**
- **Color Analyzer**
- **Specimen Scanner Light Source**

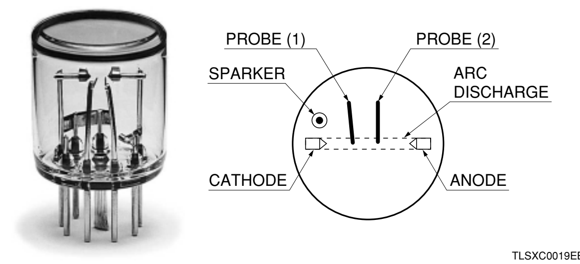
## ● Medical and Analytical Applications

- **Blood Gas Analysis**
- **Clinical Chemistry Analysis**
- **Fluorescence Analysis**
- **Atmospherics Analysis**
- **Water Pollution Analysis**
- **HPLC**

# 2. Construction

Figure 1 shows the external view and construction of a xenon flash lamp. The lamp comprizes an anode, cathode, trigger probes and sparker housed in a cylindrical glass bulb in which high purity xenon gas is sealed.

**Figure 1 External View and Construction (L2189)**




## 2-1 Trigger Probe

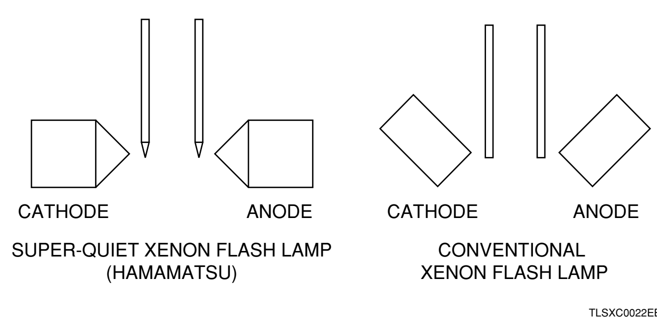
The trigger probes are electrodes used for preliminary discharge, which stabilize and facilitate the main discharge of the xenon flash lamp. The electrode is needle-shaped so that the electric field can be concentrated at the end. The number of probes depends on the arc size.

| Arc Size | Number of Probes |
|---|---|
| 8 mm | 5 |
| 3 mm | 2 |
| 1.5 mm | 1 |

## 2-2 Anode and Cathode

The xenon flash lamp uses a high-performance BI electrode (barium impregnated electrode), which has proven successful in super-quiet xenon lamps (DC type), as the anode and cathode. It features a high electron emissivity, low operating temperature, and high resistance to ion impact. The electrodes are formed in a conical shape to gather the electric field at its tip and to stabilize discharge. The HQ xenon flash lamp using general purpose electrodes (press impregnated type) possesses the same features.

**Figure 2 Electrode Shapes**



## 2-3 Sparker

The sparker electrode is employed to ensure stabilization of the xenon flash lamp discharge. This electrode is connected in series through a trigger transformer and capacitor to facilitate discharge. When a trigger voltage is applied, the sparker begins to discharge and UV light is emitted first. This UV light causes each electrode to emitt photoelectrons, which then ionize the xenon gas. As a result, the discharge between the trigger probes and the arc discharge between the main electrodes are stabilized.

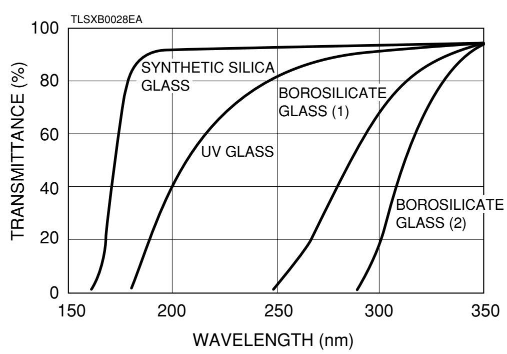
## 2-4 Bulb (Window Material)

The HAMAMATSU xenon flash lamp is a compact head-on type. Four kinds of window materials are available, depending on the wavelength used. Bulb diameters are 22 mm, 26 mm and 28 mm (SQ type) and 20 mm (HQ type).

**Table 1 Bulb Characteristics**

| Window Material | Wavelength (nm) | Applicable Type | Application |
|---|---|---|---|
| Borosilicate Glass (2) | 280~ | HQ type | Visible light for stroboscope light source, etc. |
| Borosilicate Glass (1) | 240~ | SQ, HQ type | |
| UV Glass | 185~ | SQ, HQ type | Liquid chromatography, spectrometers, fluorospectrophotometers, and other applications that use UV light. |
| Synthetic Silica | 160~ | SQ type | |

**Figure 3 Transmittance of Window Materials**




## 2-5 Stem

Three types of glass stems are used according to the bulb diameter.

<Types>

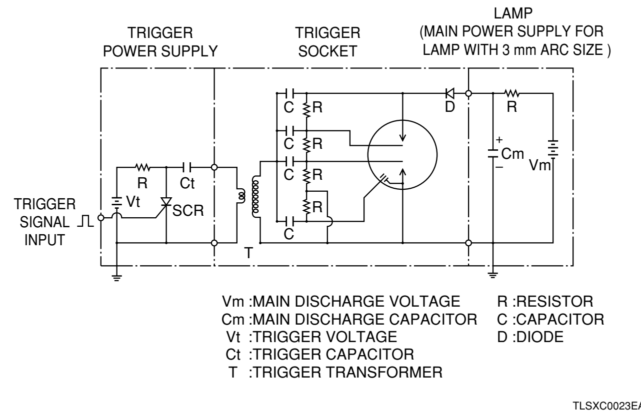
Bulb Diameter $\phi$20 mm, $\phi$22 mm ........... 9-pin Miniature type
Bulb Diameter $\phi$26 mm ............................. 8-pin Miniature type
Bulb Diameter $\phi$28 mm ............................. 12-pin Miniature type

# 3. Operation

## 3-1 Xenon Flash Lamp Discharge Operation

The prescribed voltage is applied between the anode and cathode, then a spike voltage is applied to the sparker and trigger probes to operate the xenon flash lamp. The power supply circuit, shown in Figure 4, is used to facilitate the above operation.

**Figure 4 Power Supply Circuit**




## 3-2 Flash of Xenon Flash Lamp

When a trigger signal is input while the prescribed voltage is being applied between the anode and cathode, the thyristor (SCR) in the trigger power supply section is activated and the charge stored in the trigger capacitor (Ct) is input to the trigger transformer (T), causing the transformer to generate a high-voltage pulse. This pulse is then input to the sparker, trigger probes and anode inside the lamp. At this time, the sparker is discharged first, then a discharge is produced between the cathode and the probe (1). Consequently, discharges are produced sequentially between the probes to form the preliminary discharge. Immediately after this, the main discharge between the anode and cathode occurs along the preliminary discharge path, and finally an arc is discharged. The lamp current, arc intensity and flash duration depend on the main discharge capacitor (Cm), main discharge voltage (Vm) and cable inductance (L) between the lamp and main discharge capacitor. This relationship generally conforms to the following equations.

$$\text{Mean Lamp Current (I rms)} = \frac{CmVm}{\sqrt{t\,1/3\,/f}}$$

$$\text{Peak Lamp Current (I pk)} = Vm\sqrt{Cm/L} = \frac{\pi CmVm}{t\,1/3}$$

$$L \cdots\cdots\cdots 0.4 \text{ to } 0.6\ \mu H$$

$$t\,1/3 = \pi\sqrt{LCm} = \text{Current 1/3 pulse width}$$

## 3-3 Trigger Signal and Flash of lamp

The xenon flash lamp flashes when the trigger signal is input. The following process occurs after the trigger signal is input until lamp flashing is completed.

<Discharge Process>

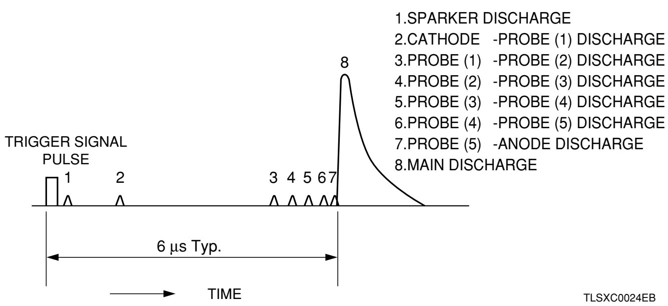
Sparker Discharge → UV Light → Cathode → Probe (1) → Probe (n) → Anode → Cathode

├──── Preliminary Discharge ────┼ Main Discharge ┤

(Trigger Input) Arc Discharge

Although a trigger pulse voltage is applied to each electrode at the same time as a trigger signal is input, the main discharge takes place after a certain delay following the input of the trigger signal. This delay varies depending on the arc size, sealed gas pressure, shape and other factors, but the delay characteristic depends largely on the main discharge voltage applied. The lower the voltage, the longer the delay. In the case of lamps with an arc size of 8 mm, the lamp flashes approx. 6 µs after the input of the trigger signal, if the applied voltage is 1 kV.

**Figure 5 Operation of Flash Lamp (With 8 mm Arc Size)**




# 4. Characteristics

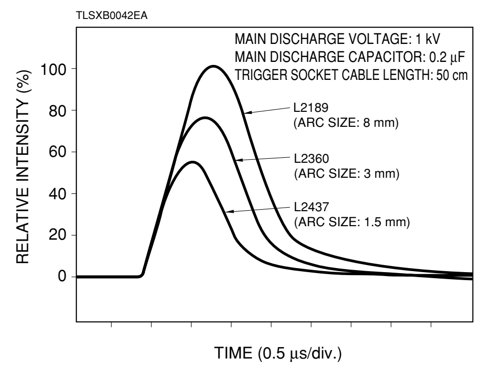
## 4-1 Flash Pulse Waveform

The flash pulse waveform of the xenon flash lamp is determined by the arc size, the applied voltage, the main discharge capacitor, and the cable inductance between the main discharge capacitor and the lamp.

### (1) Flash pulse waveforms at different arc sizes

Figure 6 shows the flash pulse waveform of xenon flash lamps with arc size of 8 mm, 3 mm and 1.5 mm. The smaller the arc size the shorter the flash duration, and the longer the arc size the longer the flash duration.

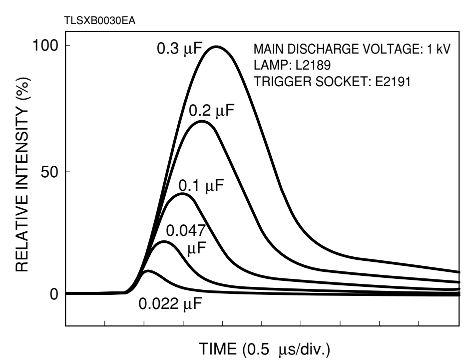
**Figure 6 Flash Pulse Waveforms at Different Arc Sizes**




### (2) Flash pulse waveforms at different main discharge capacitors

Figure 7 shows the flash pulse waveform at different main discharge capacitors. The larger the main discharge capacitor, the higher the light output.

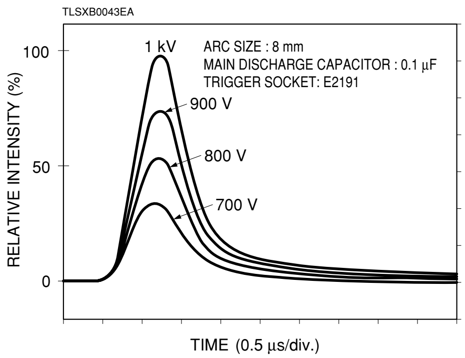
**Figure 7 Flash Pulse Waveform at Different Main Discharge Capacitors**



**(3) Flash pulse waveforms at different main discharge voltages**

When the discharge voltage is changed, only the pulse height changes. The pulse width does not change.

**Figure 8 Flash Pulse Waveforms at Different Main Discharge Voltages**




**(4) Flash pulse waveforms at different cable inductances**

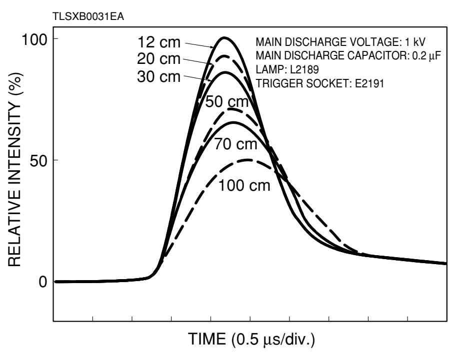
Changing the inductance (trigger socket cable length) between the main discharge capacitor and the lamp changes the flash pulse waveform.

The xenon flash lamp was designed for the usage with the trigger socket has 50 cm cable length as standard.

Once cut the cable less than 50 cm, it should be out of guarantee because makes higher lamp current and shorten the life time.

Just for information, the longer cable than 50 cm makes lower trigger energy and possible mis-ignition.

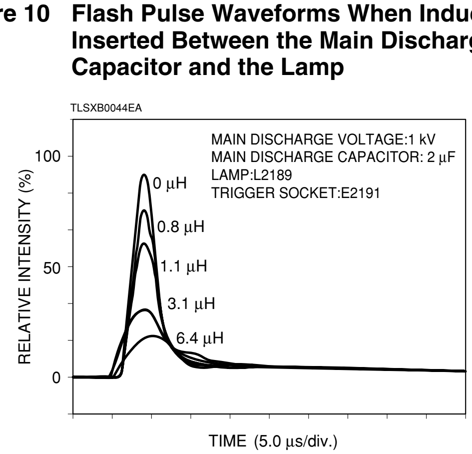
**Figure 9 Flash Pulse Waveforms at Different Trigger Socket Cable Lengths**




* Guaranteed with 50 cm cable.

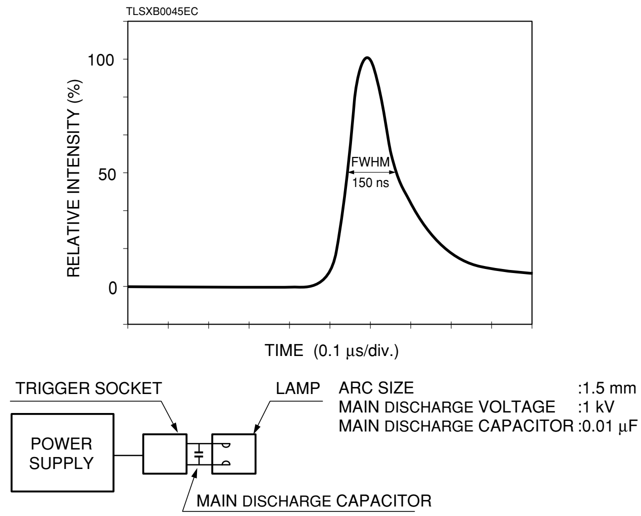
Figure 10 shows the flash pulse waveforms obtained when an inductance is connected between the main discharge capacitor and lamp with a 2 µF main discharge capacitor.

**Figure 10 Flash Pulse Waveforms When Inductance is Inserted Between the Main Discharge Capacitor and the Lamp**




To shorten the flash duration, the inductance must be reduced as much as possible. This can be done either by shortening the cable between the lamp and main discharge capacitor or by connecting the main discharge capacitor directly to the lamp. Figure 11 shows the flash pulse waveform obtained when a 0.01 µF main discharge capacitor is connected directly to the lamp using the socket adaptor. The waveform has a short FWHM 150 ns.

**Figure 11 Flash Pulse Waveform Obtained When 0.01 µF Main Discharge Capacitor Is Connected Directly to the Lamp**

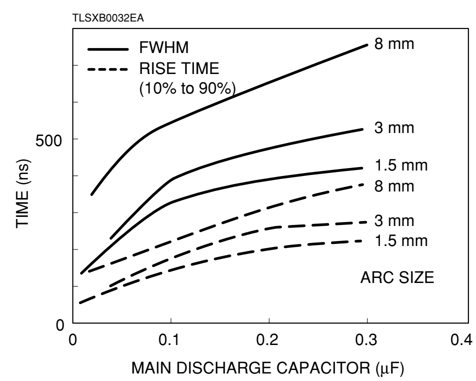



(NOTE) The main discharge capacitor is not built into the power supply.

**(5) Rise Time and FWHM**

Figure 12 shows changes in the rise time (10% to 90%) and FWHM the flash pulse waveform obtained when the main discharge capacitor is connected directly to the lamp.

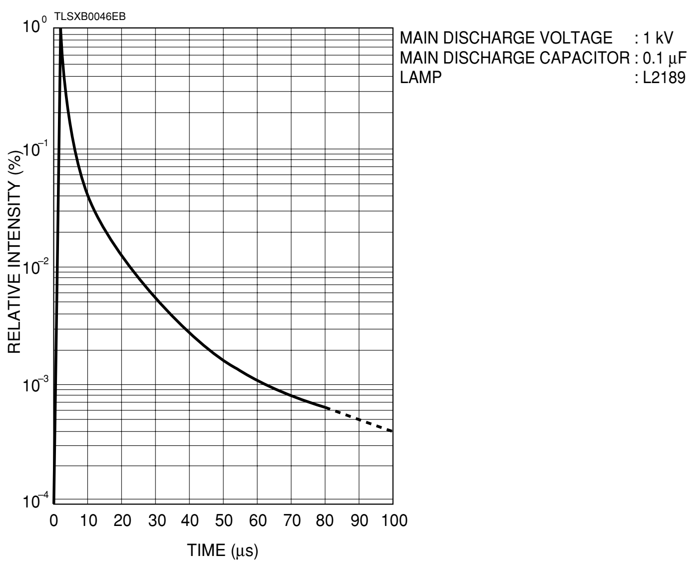
**Figure 12 Changes in Flash Duration**



**(6) Flash duration and recovery time**

The xenon flash lamp emits light as a result of ionization of the xenon gas contained in the bulb. It takes approximately 80 µs before the lamp is extinguished. Figure 13 shows time series change from flash to ion extinction. The ion extinction time is longer than the flash duration, and is approximately 400 µs according to experimental data.

**Figure 13 Flash Pulse Fall Time**




## 4-2 Delay Time and Jitter Time

As explained in section 3-3, the main discharge of the lamp occurs a little while after the trigger signal is input. The time until the main discharge occurs is called the "delay time". Fluctuation in the delay time is called "jitter". (See Figure 14.)

In the actual circuit, the delay time is several micro seconds, though it differs depending on the components making up the trigger power supply section (response time of photocoupler and thyristor etc.), as well as the lamp preliminary ionization time and main discharge voltage. The main discharge timing and trigger discharge generated during the preliminary discharge especially influence the delay time, and sometimes produce poor measured results. This problem occurs due to the unstable preliminary discharge characteristic of the sparker etc., causing either degradation of synchronization with the input signal or jitter. To solve this problem, certain methods are used; for instance, the measuring circuit is so designed that it receives the input signal at the time the lamp flashes to open the gate of the A/D converter. HAMAMATSU offers xenon flash lamps with minimized jitter characteristic. The delay time and jitter characteristics are shown in Table 2.

**Figure 14 Delay Time and Jitter Time (Arc size: 8 mm)**

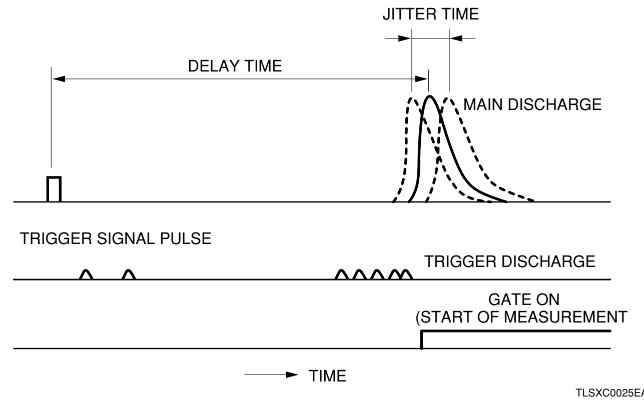



**Table 2 Delay Time and Jitter At Different Main Discharge Voltages (Typ.)**

Lamp: L2437

| Main Discharge Voltage (Vdc) | Diode Connected in Main Discharge Circuit | |
|---|---|---|
| | Delay time (µs) | Jitter (ns) |
| 1 kV | 2.0 | 100 |
| 900 V | 2.2 | 200 |
| 800 V | 2.4 | 400 |
| 700 V | 2.5 | 500 |

The delay time characteristics measured with different trigger capacitors and main discharge voltages are shown in Figures 15-1 and 15-2. The delay time remains virtually unchanged even when the trigger capacitor value is changed, but shortens as the main discharge voltage increases.

**Figure 15-1 Flash Pulse Waveform for 0.047 µF Trigger Capacitor**

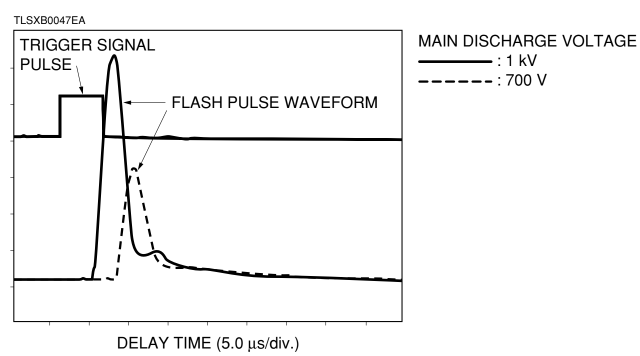
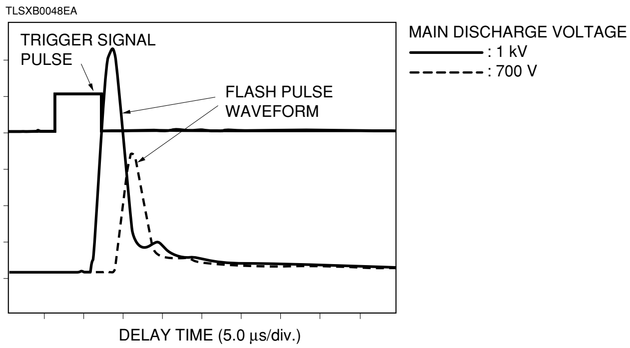


Figure 15-2 Flash Pulse Waveform for 0.1 μF Trigger Capacitor




## 4-3 Discharge Current, Voltage and Light Output

Standard operation using a 0.1 μF main discharge capacitor and 1 kV main discharge voltage causes a discharge current of approximately 400 A or higher to flow momentarily in the xenon flash lamp. Figure 16-1 shows this condition. In the actual circuit, a diode is used at the anode side to improve the discharge current waveform. The waveform differs depending on whether a diode is connected in series at the main discharge side. Fig. 16-2 shows the waveform observed when a diode is used. Unlike the ringing waveform observed when no diode is used, the waveform is improved when a diode is used. HAMAMATSU offers a trigger socket with a built-in diode as a standard type.

**Figure 16-1 Main Discharge Current Waveform**

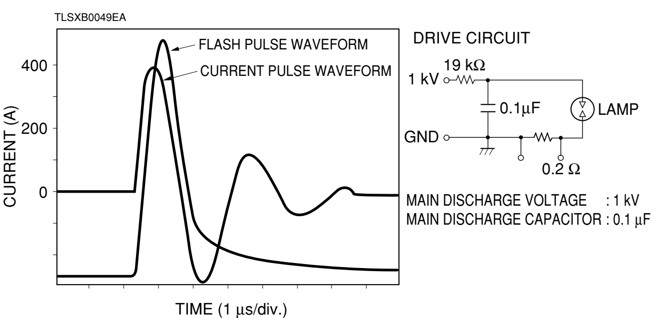



**Figure 16-2 Main Discharge Current Waveform (Diode Connected)**

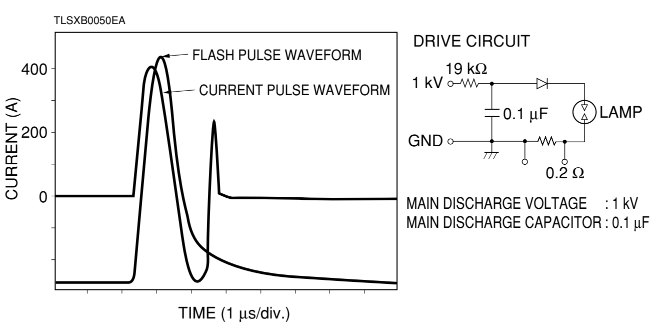
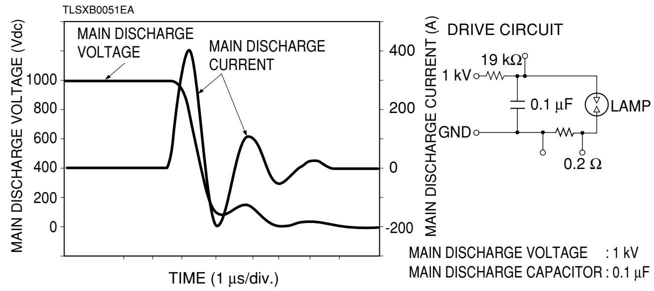


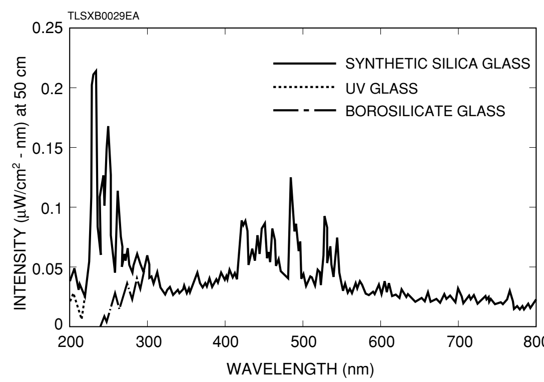

**Figure 17 Main Discharge Voltage and Current Waveforms**




## 4-4 Spectral Distribution

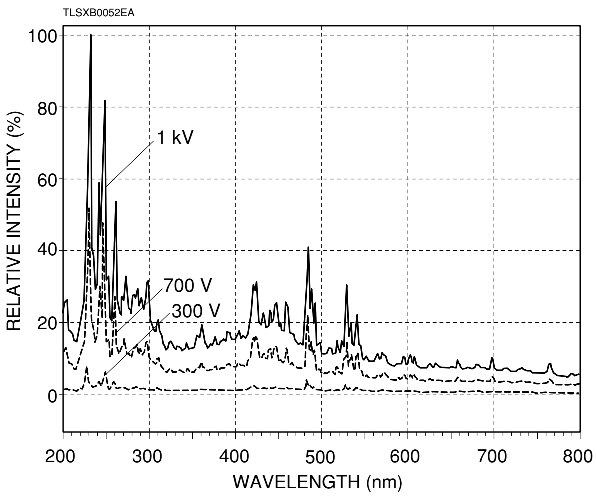
Although the spectral distribution of xenon flash lamps ranges continuously from the ultraviolet through the visible to the infrared, the bright-line spectrum is higher than that of continuous mode lamps. This is because the sealed gas pressure is about 1/10 or less than that of continuous mode lamps. The spectral distribution varies according to the input energy and other factors, as well as the sealed-in xenon gas pressure. It also differs with the transmittance of the window material. Figure 18 shows the spectral distribution for standard operating conditions.

**Figure 18 Spectral Distribution**




The light output in the ultraviolet range also tends to increase as the main discharge voltage is increased. Figure 19 shows the spectral distribution with a constant discharge capacitor (0.1 μF) and the main discharge voltage varied.

**Figure 19 Spectral Distribution at Different Main Discharge Voltages**




MAIN DISCHARGE CAPACITOR:0.1 µF

| INPUT ENERGY | MAIN DISCHARGE VOLTAGE |
|---|---|
| 0.05J | 1 kV |
| 0.024J | 700 V |
| 0.0045J | 300 V |

The spectral distribution of xenon flash lamps depends largely on the current density of the lamp. The intensity in the infrared range increases when the current is low, whilst the intensity in the ultraviolet range increases when the current is high. The lamp current and main discharge voltage (charge voltage) have the following relationship:

**<Mean lamp current>**

$$I\,rms = \frac{CmVm}{\sqrt{t\,1/3\,/f}} = CmVm\sqrt{\frac{f}{t\,1/3}}$$

**<Peak lamp current>**

$$I\,pk = Vm\sqrt{Cm/L} = \frac{\pi CmVm}{t\,1/3}$$

**Cm: Main discharge capacitor**
**Vm: Main discharge voltage**
**1/f : Rate**
**$t\,1/3 = \pi\sqrt{LCm}$ = Current 1/3 pulse width**
**$L = \frac{1}{\pi^2 f^2 Cm}$ ......Circuit inductance**

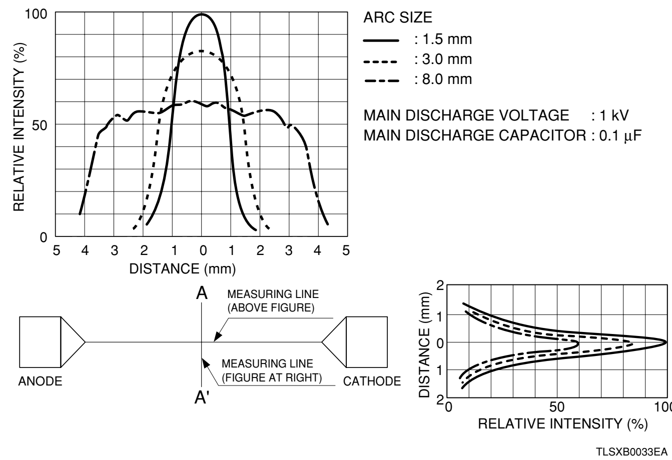
As can be seen from the above equations, the peak current and main discharge voltage are proportional.

## 4-5 Intensity Distribution and Stability

### (1) Intensity distribution

The light intensity of xenon flash lamps differs depending on the arc size. Figure 20 shows the intensity distribution at different arc sizes. The smaller the arc size the higher the intensity. Lamps with large arc size produce higher total emission.

**Figure 20 Intensity Distribution at Different Arc Sizes**




The arc stability of xenon flash lamps differs with the position of the arc. The lamp intensity is highest at the center. This also applies to the intensity stability; the closer to the center, the more stable the light output. (See Figure 21.)
In spectrographic analysis applications where highly stable light is required, it is recommended that only the light at the center be used if an optical system which uses a convex lens and concave mirror to converge and pass the arc through a fiber, slit or aperture is used. (See Figure 22.)

**Figure 21　Intensity Stability**

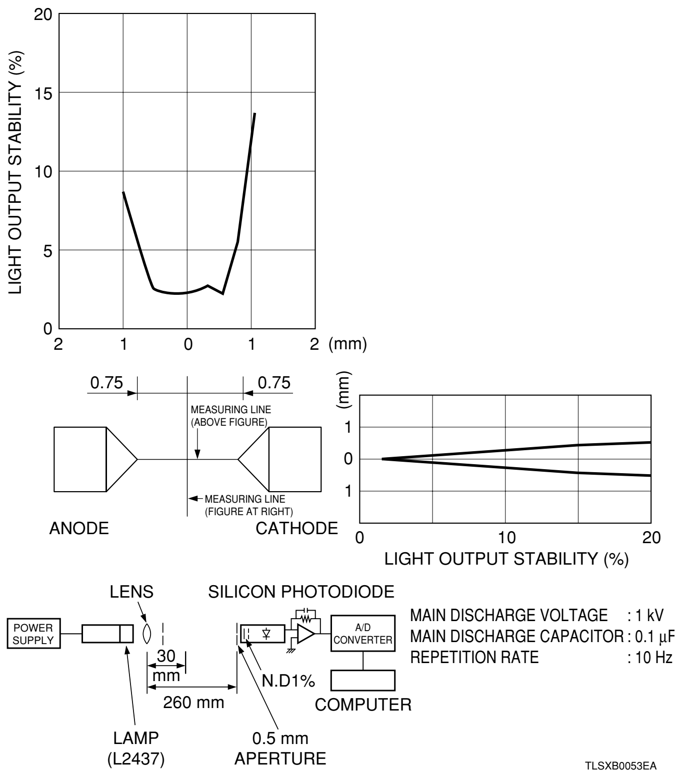
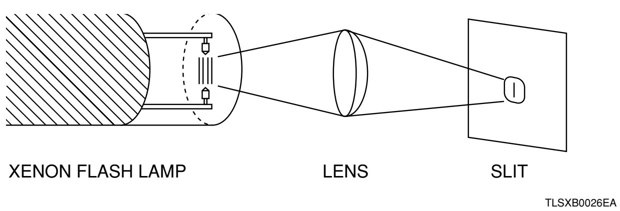



**Figure 22　Arc Input Example**




## 4-6　Light Flux Distribution

Figures 23-1 and 23-2 show the light flux distribution of a xenon flash lamp from two different directions. The light within 45 degrees from the flash point is effective.

**Figure 23-1　Light Flux Distribution (1)**

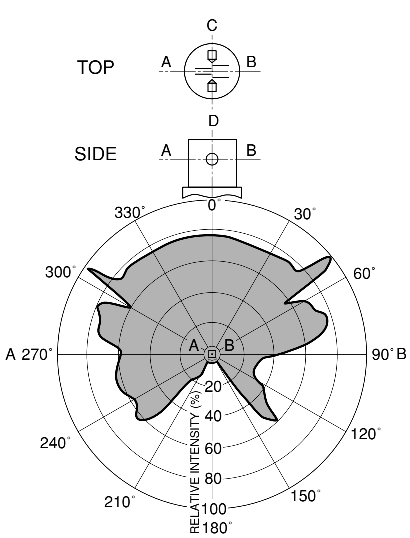
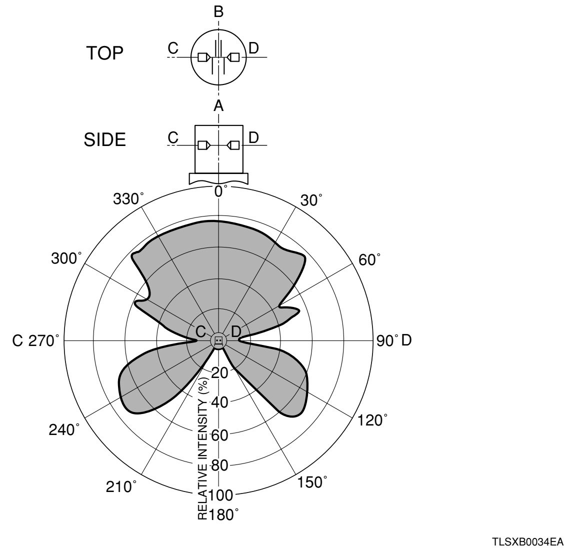



**Figure 23-2　Light Flux Distribution (2)**




## 4-7　Input Energy and Light Output

The light output of xenon flash lamps is proportional to the input energy.

| | |
|---|---|
| **Input energy E (J) =1/2CmVm²** | **Vm: Main discharge voltage (V)** |
| | **Cm: Main discharge capacitor (F)** |

To obtain highly stable pulse light, HAMAMATSU specifies the input energy as follows.

| | |
|---|---|
| $\phi$26 mm, $\phi$28 mm. series | 15 W (0.05 - 0.15 J/flash) |
| $\phi$20 mm, $\phi$22 mm. series | 10 W (0.05 - 0.1 J/flash) |

❇ When the main discharge voltage is set to 1 kV, the main discharge capacitor of 0.3 µF is required to produce an input energy of 0.15 joule (J)/flash and 0.2 µF to produce 0.1 joule (J)/flash.

Figures 24-1 and 24-2 show the relationship between the mean current and the peak current with main discharge capacitor varied.

**Figure 24-1　Mean Current (I rms)**

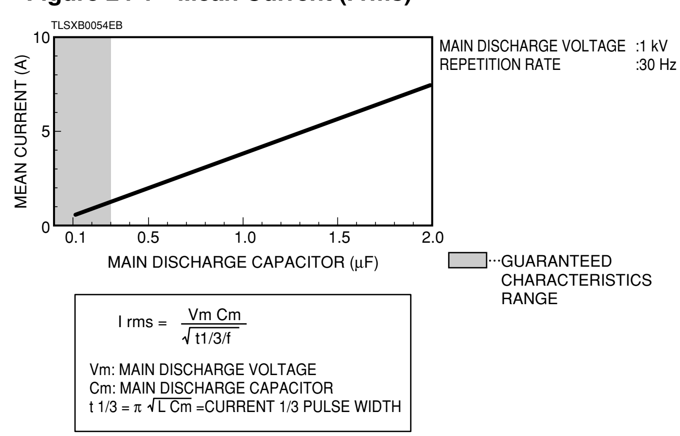
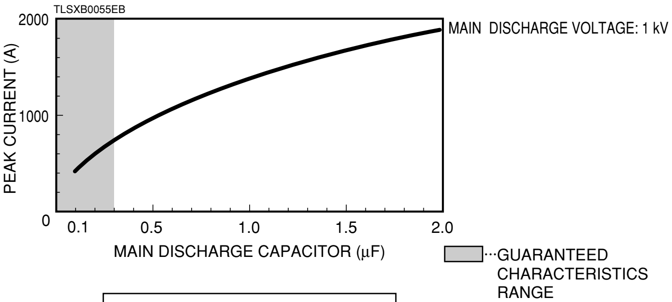


**Figure 24-2 Peak Current (I pk)**



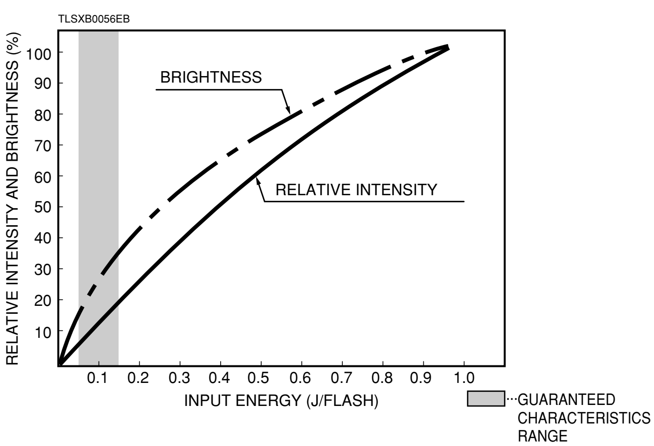

$$I\ pk = Vm\sqrt{Cm/L} = \frac{\pi VmCm}{t1/3}$$

Vm: MAIN DISCHARGE VOLTAGE
Cm: MAIN DISCHARGE CAPACITOR
L : INDUCTANCE

$$L = \frac{1}{\pi^2 f^2 Cm} = 0.5\ \mu H$$

The relationship between the relative light output and light flux with the input energy varied is shown in Figure 25. This shows that the relative light output is almost proportional to the input energy.

**Figure 25 Relationship Between Input Energy, Relative Light Output and Light Flux**




## 4-8 Light Output Stability

### (1) Measurement by sample-and-hold method

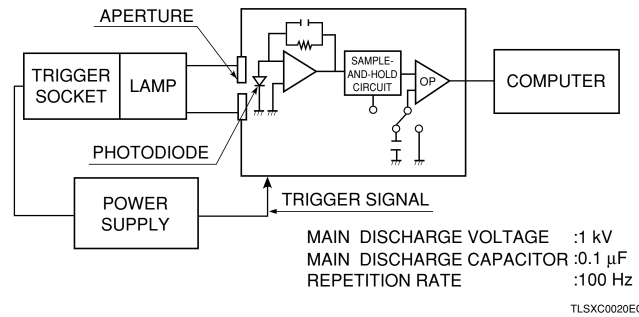
The stability of xenon flash lamps is expressed as the fluctuation of the intensity of each flash. For measurement of the stability, the sample-and-hold method is used so that evaluation is made almost in real time. Pulse light produced each time the lamp flashes enters a photodiode, and the optical current is integrated by an operational amplifier. The integrated value is then measured as the DC value using a sample-and-hold circuit.

During data processing, the value obtained by subtracting the minimum light volume from the maximum light volume of the light output is divided by the mean light output, then the result is multiplied by 100 to display it as a percentage (%). This is used as the stability.

**Light output stability (%) = {(maximum light volume − minimum light volume)/mean light output} × 100**

With this method, the typical light output stability of an ordinary xenon flash lamp is 3% at 100 Hz operation.

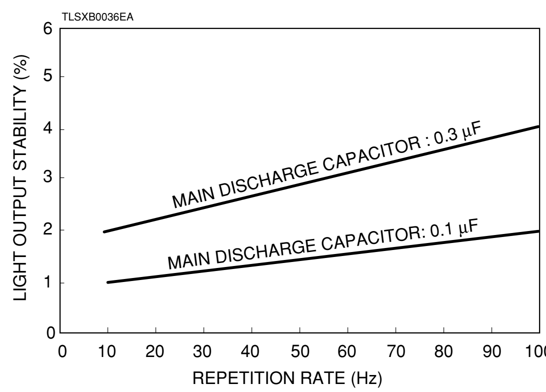
**Figure 26 Block Diagram of Sample-and-Hold Measuring Circuit**




### (2) Light output stability versus repetition rate

The lower the repetition cycle, the higher the light output stability of xenon flash lamps. Figure 27 shows the light output at different repetition rates.

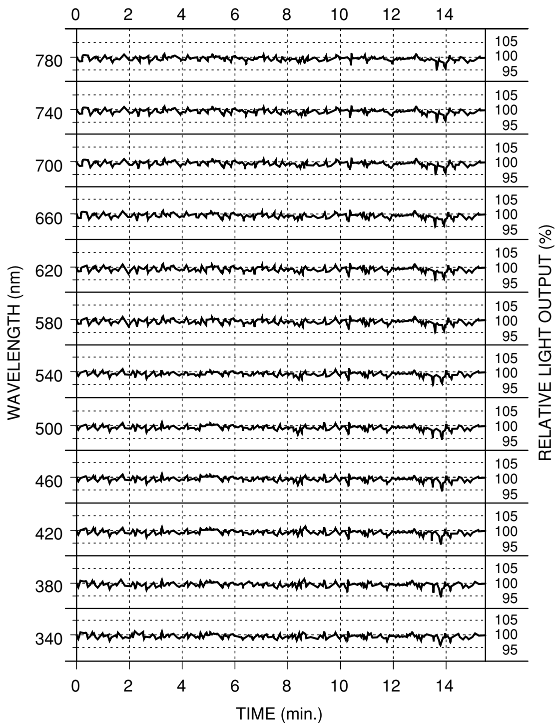
**Figure 27 Fluctuation of Flash Output**

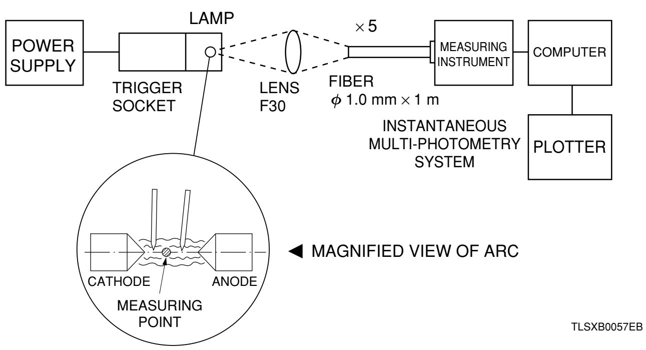



### (3) Brightness stability versus wavelength

The brightness stability for different wavelengths is shown in Figure 28. When the stability is studied by wavelength, the light of the high brightness part tends to be almost the same for each flash. This feature allows measurement to be carried out with a high Signal to Noise ratio, analyzing the differences between the two wavelengths, with one wavelength serving as the reference signal and the other wavelength as the sample signal.

**Figure 28 Brightness Stability for Different Wavelengths**

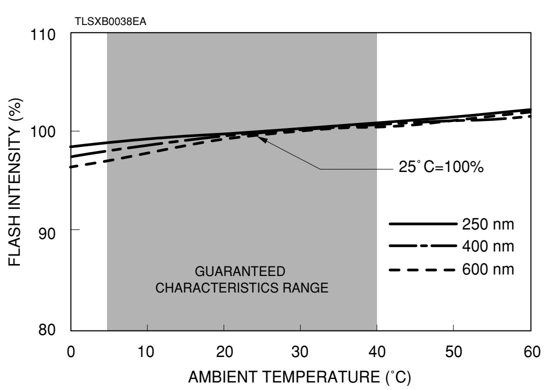



## (4) Flash intensity and ambient temperature

The flash intensity of xenon flash lamps changes with the ambient temperature because flash efficiency varies with the sealed gas pressure. Figure 29 shows this relationship. To stabilize the flash intensity, it is therefore necessary to minimize fluctuation of ambient temperature.

**Figure 29 Flash Intensity and Ambient Temperature**

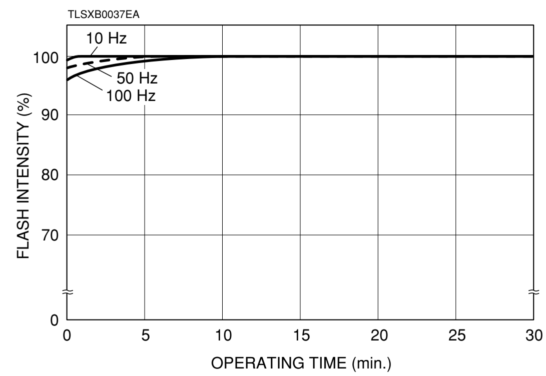



## (5) Flash intensity at initial operation Time

Xenon flash lamps flash immediately after the power is turned on, but approximately 10 minutes (at 100 Hz) are required to reach peak flash intensity if they are operated continuously. This is because the gas pressure inside the bulb increases together with the increase in the temperature of the gas. Figure 30 shows this condition. From the figure, it can be seen that the higher the repetition cycle the longer it takes to reach the peak flash intensity. However, xenon flash lamps reach the peak flash intensity faster than other discharge tubes due to less heat build-up in the bulb.

As long as lamps are used in the burst mode (where flash duration is short) even if the repetition cycle is high, the flash intensity will not be unduly influenced by the temperature during the initial operating time.

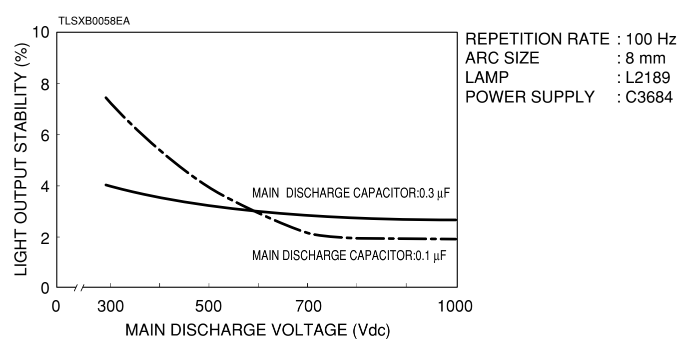
**Figure 30 Flash Intensity at Initial Operating Time**




## (6) Main discharge voltage and light output stability

The stability of the light output of xenon flash lamps differs with the operating voltage. Figure 31 shows the relationship between the main discharge voltage and light output stability. From the figure, it can be seen that the stability fluctuates considerably when the main discharge voltage is 700 V or below. Therefore, the lamps should be used within the recommended operating voltage range of 700 V to 1 kV.

**Figure 31 Main Discharge Voltage and Light Output Stability**




## 7) Trigger voltage and light output stability

The light output stability of xenon flash lamps depends on the trigger discharge stability. It is therefore important to set the trigger discharge to the optimum level. The trigger discharge is unstable if the trigger energy is too high, but flashability drops if it is too low. With a HAMAMATSU power supply, the trigger socket input energy is set as shown in Table 3.

To utilize the high stability of xenon flash lamps, they must be designed with trigger energy taken into account.

**Table 3 Power Supply Trigger Output and Output Energy**

| Type No. | Output Capacitor | Trigger Output Voltage | Trigger Capacitor | Output Energy |
|---|---|---|---|---|
| C5398 | 5 W | 140 V dc | 0.22 µF | $2.1 \times 10^{-3}$ J |
| C5728 | 10 W | | | |
| C3684 | 15 W | | | |
| C6096 | 60 W | 180 V dc | 0.22 µF | $3.6 \times 10^{-3}$ J |

## 4-9 Points to be Considered in Light Output Stabilization

When using xenon flash lamps for precision photometry, the following points should be taken into consideration.

**(1) Power supply and trigger socket**

<Main power supply>

Since the main discharge voltage fluctuation affects the light output, a stable DC power supply should be used. For frequent flashing, the extinction time of remaining ions (approximately 400 µs) and the safety of the main discharge capacitor recharging time should be taken into account during the design of the system, so that flashing is repeated at intervals of approximately 600 µs. (See page 4.)

<Trigger power supply>

For stable operation, set the trigger energy to be value at Table 3 as described in section 4-8-(7).

<Trigger socket>

Always use a trigger socket suitable for the lamp.

**(2) Measuring optical system**

Use the center of the brightest arc, since more stable pulse light can be obtained. (See section 4-5.)

When using a xenon flash lamp as a light source for precision photometry, it is recommended that it is positioned face up or to the side.

**(3) Signal processing system**

Because of its operating principle, the light output of xenon flash lamps is not as strong as that of continuous mode lamps. Therefore, the averaging method, which averages several flashes and uses the result as data, can be used to obtain a stable signal. This averaging method differs depending on the operating conditions and how the method is used. Averaging of five to ten flashes is recommended.

# 5. Life

The life of xenon flash lamps is expressed by the total number of flashes the lamp will emit, and it is greatly influenced by the input energy (lamp current) per flash. The input energy (E) is determined by the main discharge voltage (Vm) and the main discharge capacitor (Cm), and is expressed by the equation $E=CmVm^2 \cdot 1/2$. HAMAMATSU xenon flash lamps can produce more than $1 \times 10^9$ flashes under standard operating conditions (main discharge voltage: 1 kV, main discharge capacitor: 0.1 µF, repetition rate: 50 Hz). The lamp's service life is defined as the time when the relative intensity at whole spectrum drops below 50% of its initial level or the output fluctuation exceeds the allowable range (specified in figure 34 and 49 of the catalog).

## 5-1 Life and Wavelength

**(1) Intensity maintenance rate**

Figures 32-1 and 32-2 show the relationship between the intensity and operating time under standard operating conditions (main discharge voltage: 1 kV, main discharge capacitor: 0.1 µF, repetition rate: 100 Hz). From the figures, it can be seen that the intensity maintenance rate in the visible and near infrared ranges tends to be lower than that in the UV range.

**Figure 32-1 Life (SQ Type)**

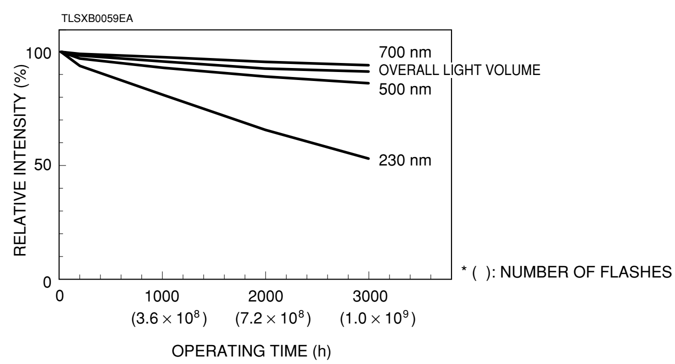



**Figure 32-2 Life (HQ Type)**

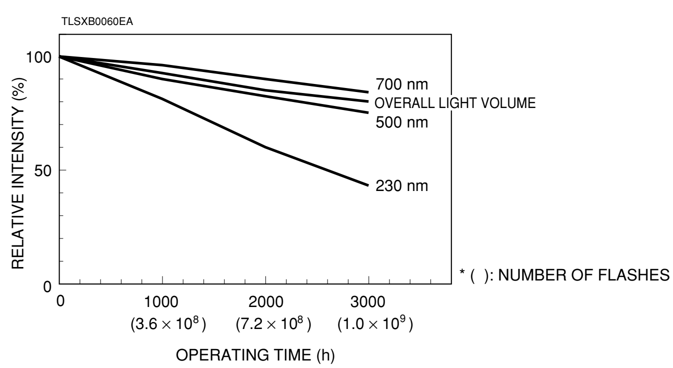
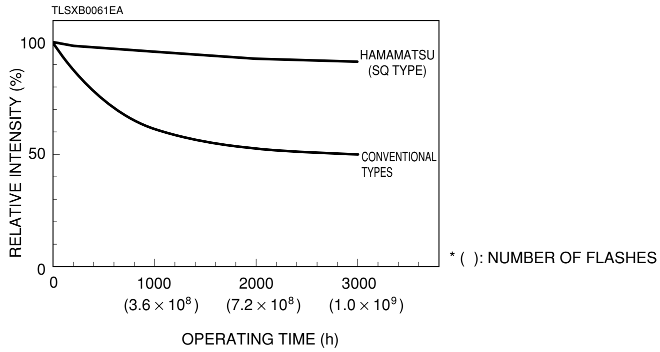


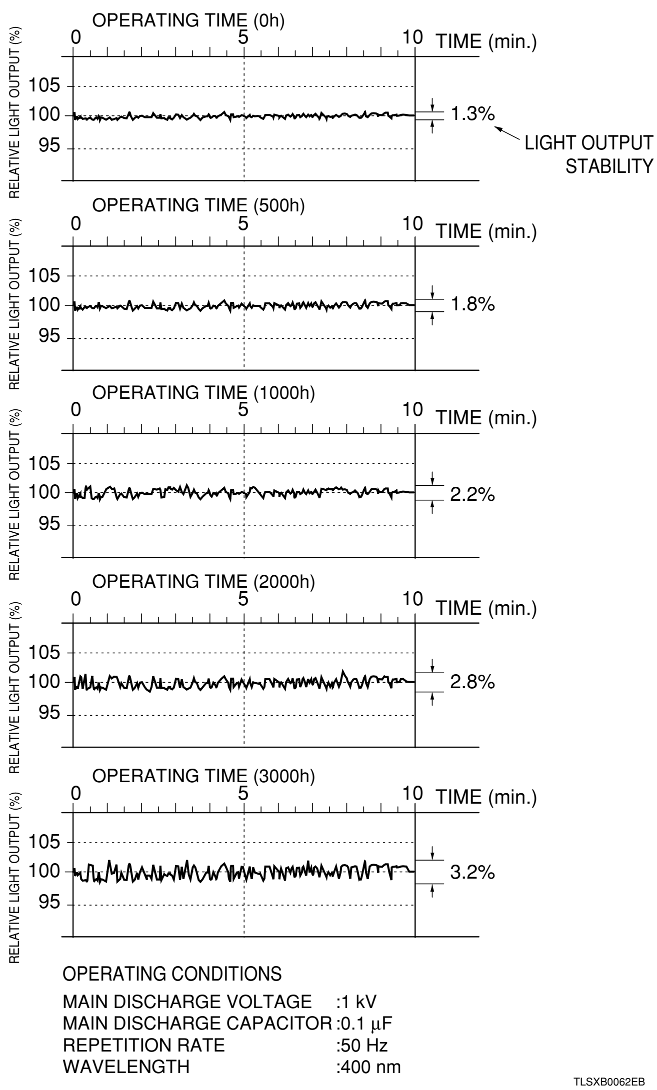
**Figure 32-3 Comparison of Life (Overall Light Volume)**




### (2) Stability and operating time

The light amount of the arc of xenon flash lamps changes within a certain fluctuation range per flash. Figure 33 shows the light current output at a series of times. The light current output is obtained as the light amount of each flash enters a silicon photodiode, and is then sample-hold. (See Figure 26.)

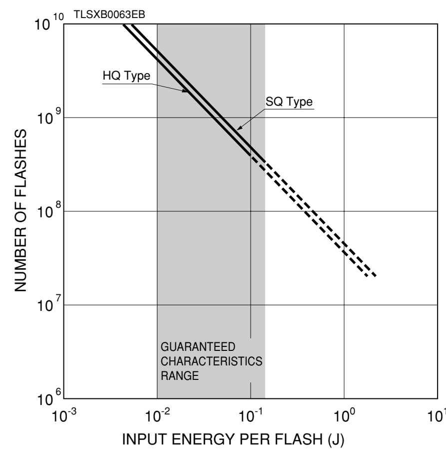
**Figure 33 Light Output Stability and Operating Time**




## 5-2 Input Energy and Life

The life of xenon flash lamps is influenced by the input energy. Figure 34 shows the relationship between input energy and the number of flashes.

**Figure 34 Life - Number of Flashes and Input Energy Per Flash**




**The guaranteed performance range of an HQ type is 0.01 to 0.1J.**

## 6. Induction Noise

Xenon flash lamps require a high trigger voltage of 5 to 7 kVp for every flash with the waveform shown in Figure 35. Additionally, during the main discharge, there is an instantaneous flow of current of several hundreds amperes which generates electromagnetic noise. Thus, it is necessary to provide shielding against this noise when using these lamps as a light source for precision measuring instruments. Noise is generated by the lamp itself, the trigger socket, cable and power supply; therefore, the following points should be taken into consideration:

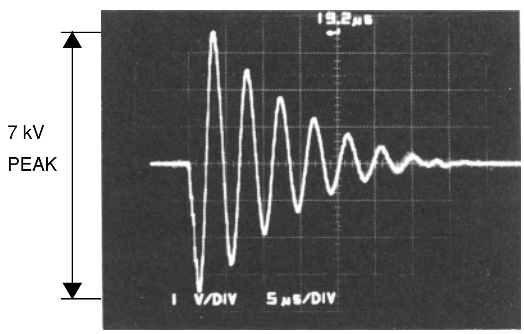
(1) The lamp and trigger socket should be placed in a metal shield box.

(2) The trigger socket should have a shielded cable.

(3) The case of the power supply should be grounded.

❇ The E2608 shield box applicable only to the 26 mm diameter type trigger socket is available from HAMAMATSU.

**Figure 35 Trigger Waveform**



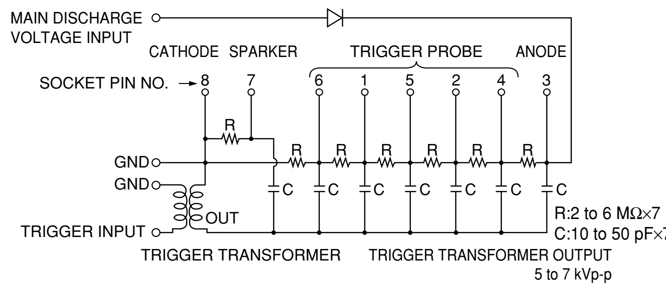

A probe with 1000:1 attenuation is used.

## 7. Trigger Sockets

### 7-1 Trigger Socket Configuration

A trigger socket (sold separately) is required to operate a xenon flash lamp. The trigger socket is made up of a high voltage generation transformer (trigger transformer), voltage-dividing resistors, bypass capacitors, and diodes.

**Figure 36 Trigger Socket (E2191 series)**




### 7-2 Operation of Trigger Socket

When a pulse voltage of 100 to 300 V (less than 2.8 mJ) is applied to the primary side of the trigger transformer, a high voltage pulse of 5 to 7 kV is generated at the secondary side. This generated pulse voltage is then applied to the sparker and each trigger probe electrode through bypass capacitors, generating the preliminary discharge. The main discharge is then generated between the cathode and anode to which the prescribed voltage has been applied. The appropriate voltage-dividing resistors and bypass capacitors are used in the trigger socket so that the lamp operates stably. The diode at the main discharge side is used to cause the current to flow in only one direction as well as to prevent the trigger energy from leaking at the main discharge capacitor (Cm), thereby permitting stable operation even at low voltages.

## 8. Xenon Flash Lamp Power Supply

The power supply consists of a main power supply section and a trigger power supply section. The same power supply can be used for high-power xenon flash lamps with a built-in reflector (described later).

### 8-1 Main Power Supply Section

The main power supply section supplies energy to the lamp. Since the arc intensity is almost proportional to the input energy, a highly stable DC power supply and high-quality main discharge capacitor are necessary.

| | |
|---|---|
| **INPUT ENERGY** | **$E(J)=CmVm^2 \cdot 1/2$** |
| | **Cm: MAIN DISCHARGE CAPACITOR (F)** |
| | **Vm: MAIN DISCHARGE VOLTAGE (Vdc)** |

### 8-2 Trigger Power Supply Section

In order for a xenon flash lamp to operate stably, the preliminary discharge must also be constant. The trigger power supply section is provided to produce constant preliminary discharge, and consists of a power supply, supplying power to the trigger transformer, and a control circuit consisting of a thyristor (SCR) as a switching element and a trigger capacitor to supply the trigger energy, and other parts. When a trigger signal is input to the gate of the thyristor, the charge stored in the trigger capacitor is discharged as the trigger energy to the primary side of the trigger transformer.

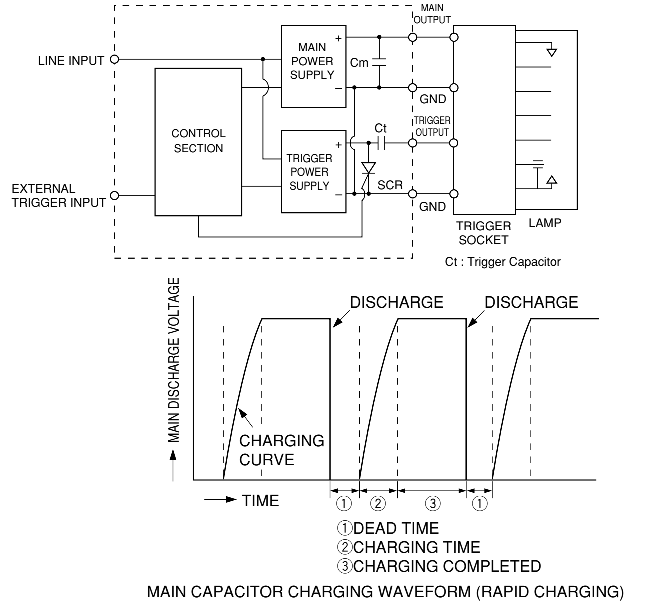
### 8-3 Power Supply Design Precautions

After a xenon flash lamp is lit, residual ions remain present for a certain length of time. The time taken for these residual ions to disappear (recovery time) is different depending on the pressure of the gas sealed in the lamp, the applied voltage, and the arc size. Among HAMAMATSU xenon flash lamps, the type which has an arc size of 1.5 mm has the shortest recovery time of approximately 400 µs (when the main discharge voltage is 1 kV). Therefore, the power supply must be so designed that the effect of these residual ions is avoided. This is necessary because if the main discharge capacitor is charged by the main discharge power supply at a speed higher than the recovery time, the lamp will flash continuously whether the trigger is input or not, resulting in unstable operation.
Typical power supply configurations for xenon flash lamps are described below.

**(1) Rapid-charging power supply (Hamamatsu circuit system)**

Figure 37 shows the basic circuit of a rapid-charging power supply. This power supply charges the main discharge capacitor (C) quickly and at a constant current. Once the lamp lights up, the charging circuit is forcibly isolated, and after a certain time (dead time) elapses the main capacitor is re-charged, then the lamp flashes. The circuit is complex, but unlike the CR charging power supply, no current limiting series resistor is required. As a result, power loss is reduced and the lamp can be operated at high repetition rate.

**Figure 37 Rapid-charging Power Supply Circuit**

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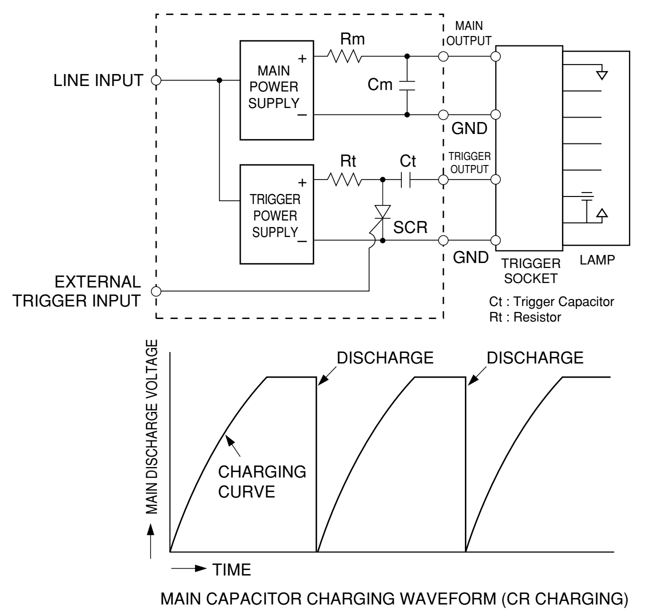
**(2) CR charging power supply**

Figure 38 shows the CR charging power supply circuit. This power supply charges the main discharge capacitor (Cm) from a high voltage DC power supply through a current limiting series resistor (Rm). The main capacitor is charged for a certain time, which is determined by the CR time constant, after which the lamp is flashed.
The circuit is simple, but the lamp cannot be operated at a high repetition rate due to high resistance loss.
With this circuit, the charging characteristics of the resistor and main capacitor must be taken into account and the CR time constant must be adjusted so that the residual ions have no effect.

**Figure 38 CR Charging Power Supply Circuit**

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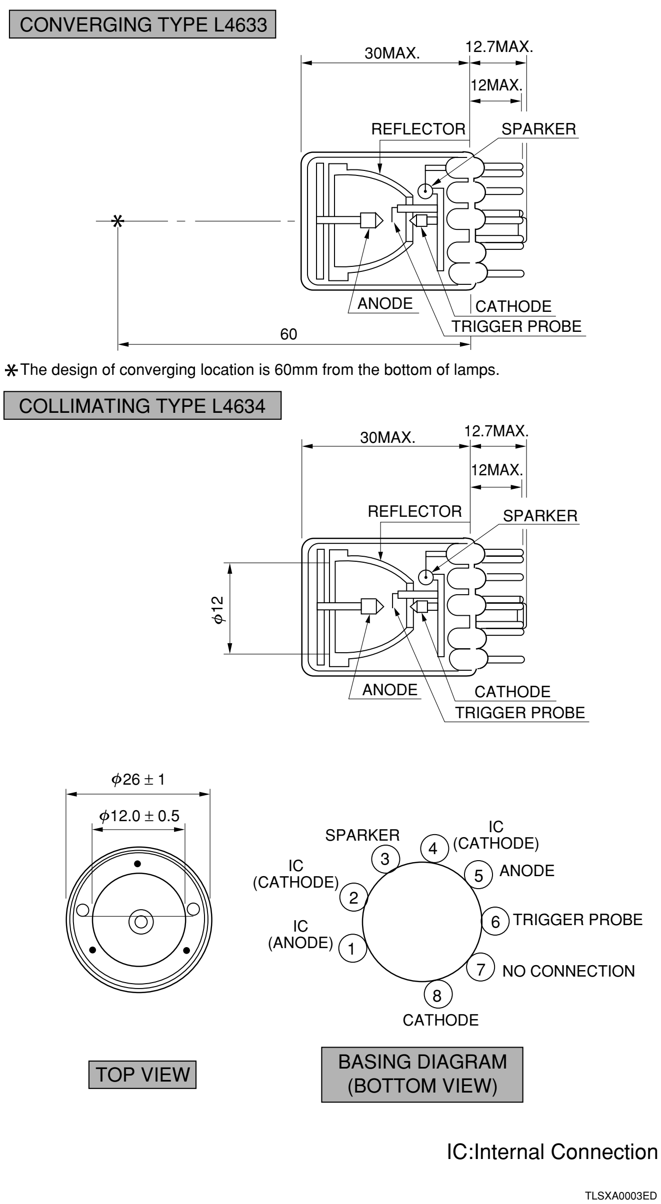
# 9. High-Power Xenon Flash Lamp With Built-in Reflector

The high-power xenon flash lamp is equipped with a reflector, so that a light output of about four times higher than that of regular xenon flash lamps is obtained. This high-power xenon flash lamp produces a high-intensity continuous spectrum throughout the near UV and visible to the infrared range, and features a compact size, low heat build-up, and easy handling. Two types of lamps are available: converging type (L4633) and collimating type (L4634).

## 9-1 Construction of Xenon Flash Lamps with Built-in Reflector (L4633 and L4634)

The high-power xenon flash lamp consists of an anode, cathode, trigger probes, sparker, and small reflector in a glass bulb in which pure xenon gas is sealed.

**Figure 39 External Dimensions and Construction (Unit: mm)**

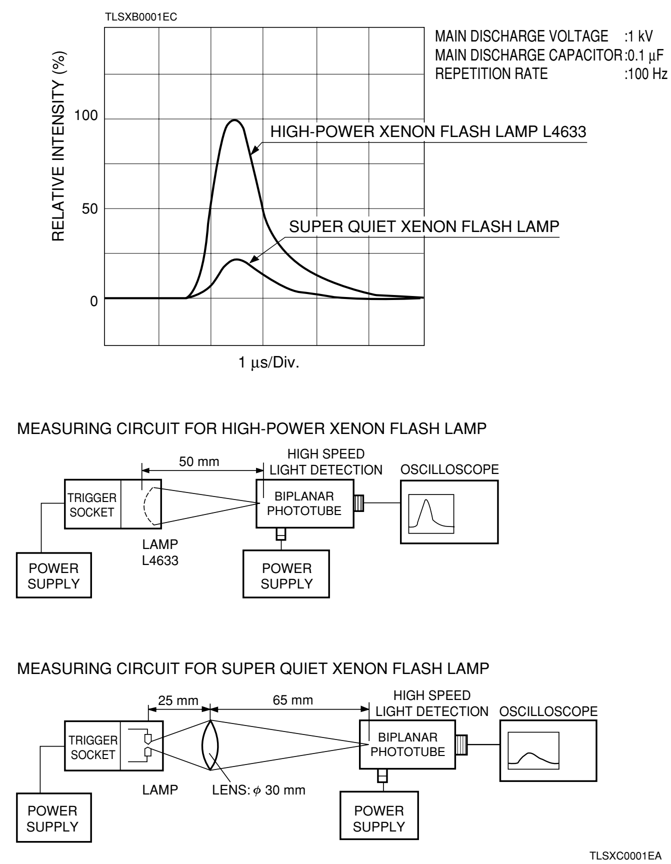



## 9-2 Characteristics of Xenon Flash Lamp with Built-in Reflector

### 9-2-1 Output Intensity Comparison

Figure 40 shows a comparison of the output intensity (pulse height) of the converging type L4633 and xenon flash lamp (arc size: 1.5 mm) and their measuring methods. As can be seen from the figure, the output of the converging type is about four times higher than that of the xenon flash lamp.

**Figure 40 High-Power Xenon Flash Lamp Flash Pulse Waveform**




### 9-2-2 Spectral Distribution

Figures 41-1 and 41-2 show the spectral distribution of the converging type (L4633) and collimating type (L4634).

From the standpoint of the built-in reflector design, the spectrum is measured at the converging point (theoretically 60 mm from the end of the lamp stem) for the converging type (L4633), and at 50 cm from the end of the lamp stem for the collimating type (L4634), using instantaneous multi photometry.

**Figure 41-1 Spectrum of Converging Type L4633**

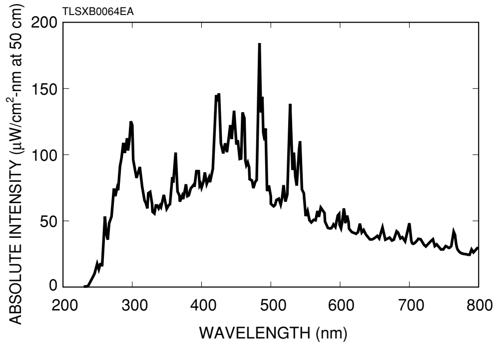
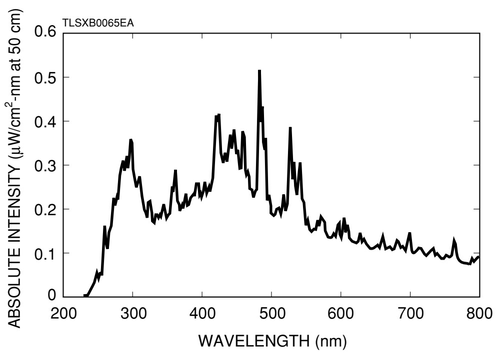


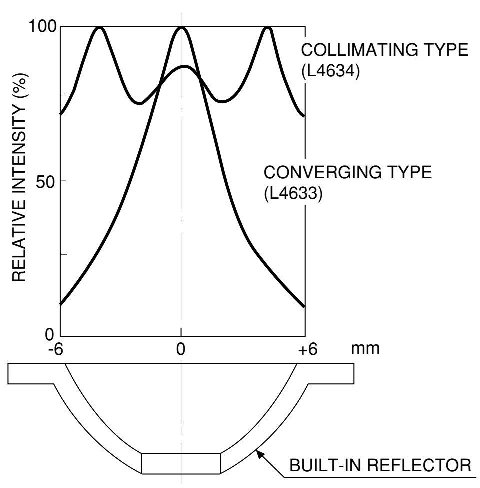

**Figure 41-2 Spectrum of Collimating Type L4634**



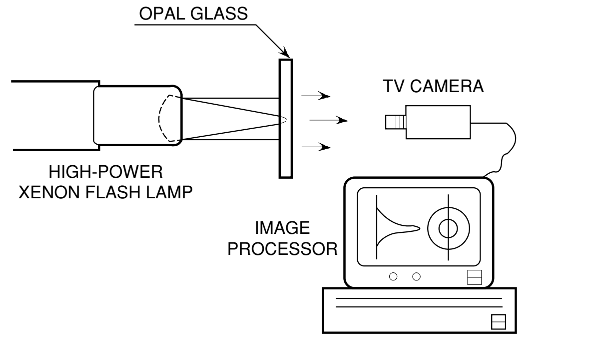

## 9-2-3 Light Flux Distribution

Figure 42 shows the light flux distribution of the output light of both converging type L4633 and collimating type L4634. The following method is used to remove optical system error from the light flux distribution measurement. The light flux distribution of the converging type L4633 is measured with a TV measuring system in which an opal glass plate is placed at the converging point of the reflector. The light flux distribution of the collimating type L4634 is measured by placing an opal glass plate at 10 mm away from the face plate.

**Figure 42 Light Flux Distribution of Converging Type L4633 and Collimating Type L4634**




**Converging Type L4633 and Collimating Type L4634 Measurement Method**

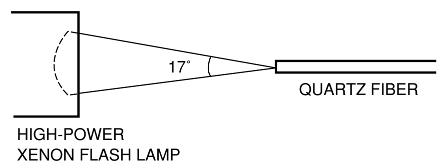


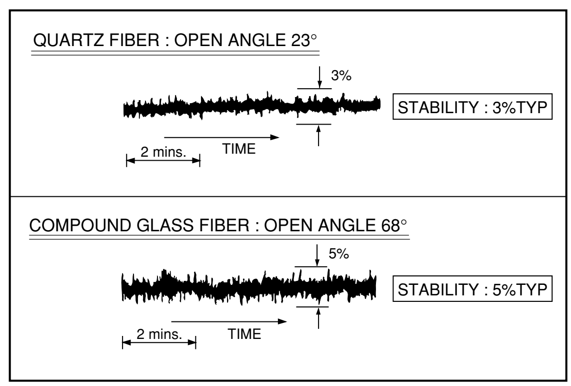

## 9-2-4 Input from Converging Type L4633 to Quartz Fiber

### (1) Fiber input stability

Figure 43 shows a comparison of output light stability between a quartz fiber and a compound glass fiber.
The output light stability differs depending on the kind (open angle) of the optical fiber used. This is because the closer the center of the lamp arc, the more stable the output light, and the smaller the open angle, the more stable the output light.

**Figure 43 Fiber Output Light Stability**




MAIN DISCHARGE VOLTAGE : 1 kV
MAIN DISCHARGE CAPACITOR : 0.1 µF
REPETITION RATE : 100 Hz

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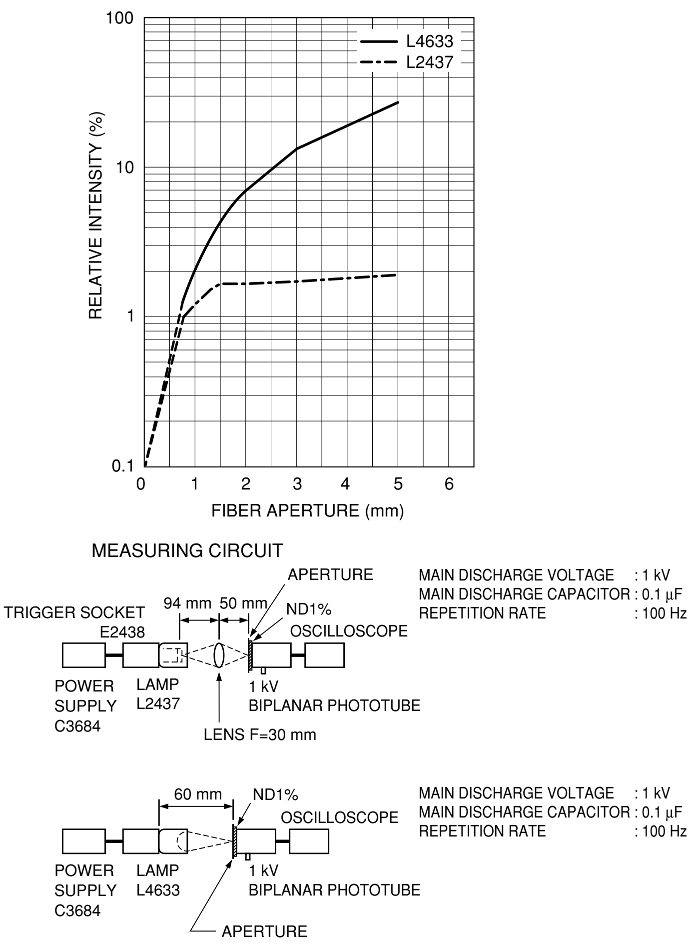
The converging type L4633 is designed so that the light converges at a position 60 mm from the bottom of the lamp bulb at the front. In this case, as the solid angle of the L4633 is 17 degrees, the light can be input to a quartz fiber (open angle: 23 degrees) effectively.

**(2) Fiber aperture diameter and light output**

Figure 44 shows a comparison of the intensity of the light input to an optical fiber, between the converging type L4633 and xenon flash lamp L2437 (arc size: 1.5 mm).
The intensity of arc image produced at the aperture by converging the light from the xenon flash lamp L2437 is compared with the intensity of the light sent from the converging lamp directly to the aperture, at different aperture diameters.
When the aperture diameter is 0.8 mm or below, there is almost no difference in light output between the two types, but the light output of the converging type L4633 increases as the aperture diameter increases. The characteristics of the converging type L4633 become noticeable when the fiber diameter is 3 mm or greater. This is because the lamp is not an ideal point light source.

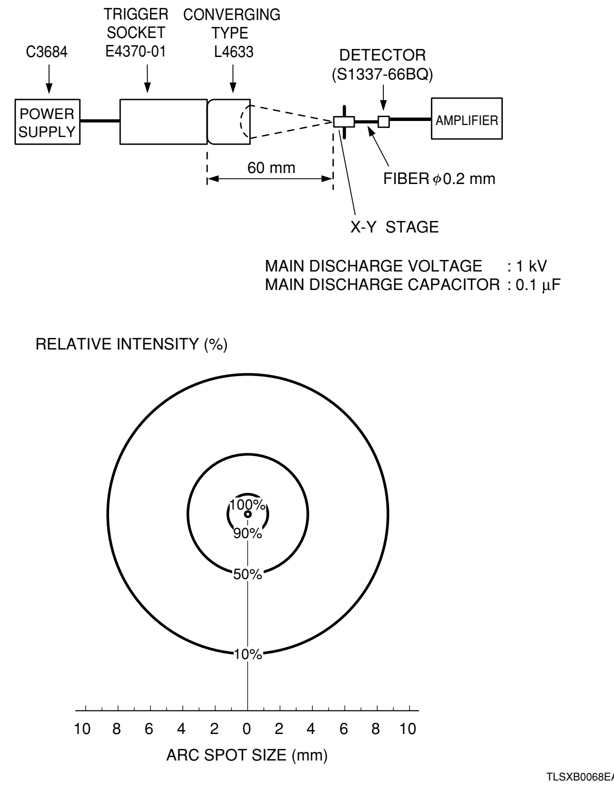
**Figure 44 Converging Characteristics of Xenon Flash Lamp**




## 9-2-5 Brightness Distribution of Converged Arc Spot (Converging Type L4633)

Figure 45 shows the relative intensity distribution of the arc spot of the converging type L4633. The effective intensity (90%) is produced within 2.2 mm dia. arc spot.

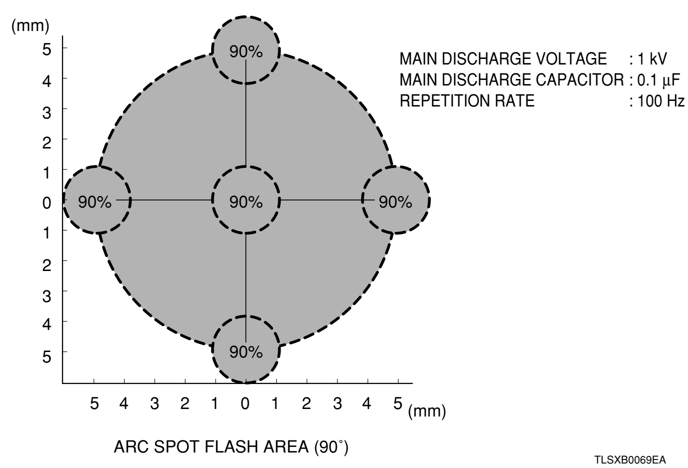
**Figure 45 Relative Intensity Distribution of Arc Spot of Converging Type L4633**




## 9-2-6 Position Deviation of Arc Spot of Converging Type L4633

Figure 46 shows position deviation of arc spot (90% relative intensity) of the converging type L4633. This deviation is caused by the reflector accuracy and lamp assembly accuracy. To obtain the maximum lamp intensity, its position should be adjusted to within +/-5 mm in the X and Y directions.

**Figure 46**




This position deviation means variation in the focus position of each lamp, not the deviation of each flash with the same lamp.

## 9-3 Life of High-Power Xenon Flash Lamp with Built-in Reflector

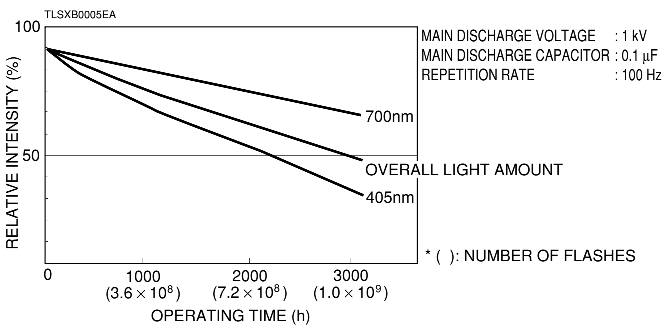
Xenon flash lamps with built-in reflector can produce more than $5 \times 10^8$ flashes under standard operating conditions (main discharge voltage: 1 kV, main discharge capacitor: 0.1 µF, repetition rate: 100 Hz). The lamp's life is defined as the time at which the relative intensity at whole spectrum drops below 50% of its initial level or the output fluctuation exceeds the allowable range (specified in page 9 of the catalog).

### 9-3-1 Life and Wavelength

**(1) Intensity maintenance rate of high-power xenon flash lamp with built-in reflector**

The life of the high-power xenon flash lamp with a reflector differs depending on the wavelength. The intensity maintenance rate in the visible and infrared ranges tends to be lower than that in the near UV range.

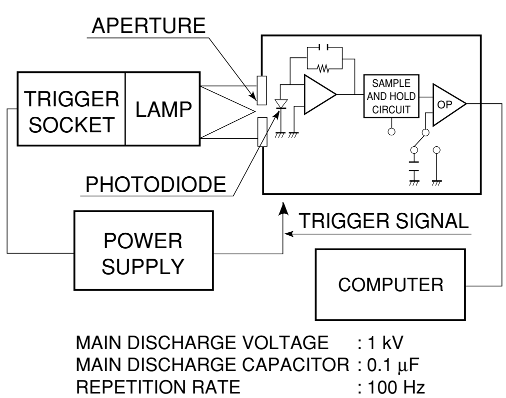
**Figure 47 Life of High-Power Xenon Flash Lamp**




**(2) Stability and operating time**

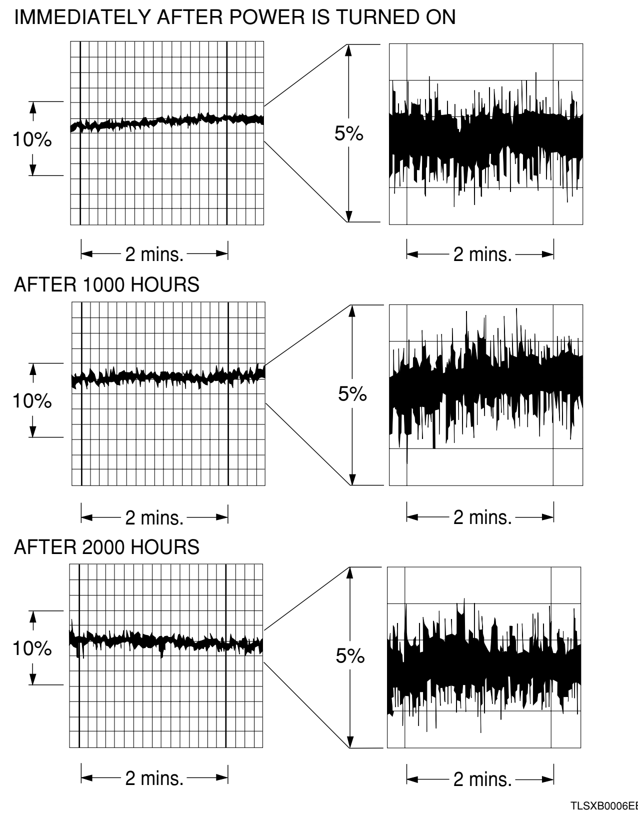
Figure 48-2 shows a comparison of light output stability measured immediately after the power is turned on, after 1000 hours have elapsed and after 2000 hours have elapsed. As can be seen from the figures, there is no noticeable change in the light output stability.

**Figure 48-1 Measuring Circuit (Sample-and-Hold Method)**




In this measurement, the light from the lamp is directed into a silicon photodiode, and the light amount is integrated for each flash. The output is then sent to the sample-and-hold circuit, where it is converted to DC data and then recorded by a computer.

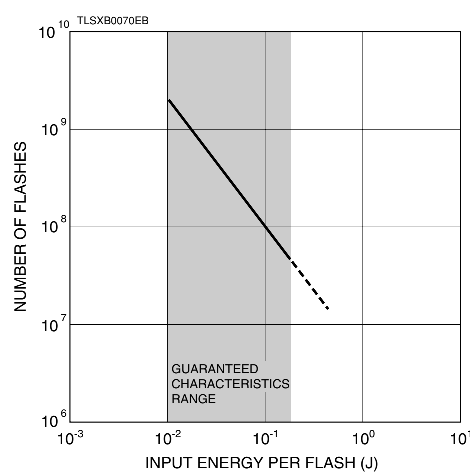
**Figure 48-2 Light Output Stability and Operating**




### 9-3-2 Input Energy and Life

Figure 49 shows the relationship between input energy per flash and the number of flashes (life time).
The life of xenon flash lamps is influenced by the input energy.

**Figure 49 Life-Number of Flashes and Input Energy per Flash**



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HAMAMATSU

**HAMAMATSU PHOTONICS K.K., Electron Tube Division**
314-5, Shimokanzo, Iwata City, Shizuoka Pref., 438-0193, Japan
Telephone: (81)539/62-5248, Fax: (81)539/62-2205
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360 Foothill Road, P.O. BOX 6910,
Bridgewater, N.J. 08807-0910, U.S.A.
Telephone: (1)908-231-0960, Fax: (1)908-231-1218
E-mail: usa@hamamatsu.com

*Western U.S.A. Office:*
Suite 110, 2875 Moorpark Avenue
San Jose, CA 95128, U.S.A.
Telephone: (1)408-261-2022, Fax: (1)408-261-2522
E-mail: usa@hamamatsu.com

*United Kingdom:*
**HAMAMATSU PHOTONICS UK LIMITED**
Main Office
2 Howard Court, 10 Tewin Road Welwyn Garden City
Hertfordshire AL7 1BW, United Kingdom
Telephone: 44-(0)1707-294888, Fax: 44-(0)1707-325777
E-mail: info@hamamatsu.co.uk

*South Africa Office:*
PO Box 1112, Buccleuch 2066,
Johannesburg, South Africa
Telephone/Fax: (27)11-802-5505

*France, Portugal, Belgiun, Switzerland, Spain:*
**HAMAMATSU PHOTONICS FRANCE S.A.R.L.**
8, Rue du Saule Trapu, Parc du Moulin de Massy,
91882 Massy Cedex, France
Telephone: (33)1 69 53 71 00
Fax: (33)1 69 53 71 10
E-mail: infos@hamamatsu.fr

*Swiss Office:*
Richtersmattweg 6a
CH-3054 Schüpfen, Switzerland
Telephone: (41)31/879 70 70,
Fax: (41)31/879 18 74
E-mail: swiss@hamamatsu.ch

*Belgian Office:*
7, Rue du Bosquet
B-1348 Louvain-La-Neuve, Belgium
Telephone: (32)10 45 63 34
Fax: (32)10 45 63 67
E-mail: epirson@hamamatsu.com

*Spanish Office:*
Centro de Empresas de Nuevas Tecnologies
Parque Tecnologico del Valles
08290 CERDANYOLA, (Barcelona) Spain
Telephone: (34)93 582 44 30
Fax: (34)93 582 44 31
E-mail: spain@hamamatsu.com

*Germany, Denmark, Netherland, Poland:*
**HAMAMATSU PHOTONICS DEUTSCHLAND GmbH**
Arzbergerstr. 10,
D-82211 Herrsching am Ammersee, Germany
Telephone: (49)8152-375-0, Fax: (49)8152-2658
E-mail: info@hamamatsu.de

*Danish Office:*
Skyttehusgade 36, 1tv. DK-7100 Vejle, Denmark
Telephone: (45)4346/6333, Fax: (45)4346/6350
E-mail: lkoldbaek@hamamatsu.de

*Netherlands Office:*
PO Box 50.075, 1305 AB Almere The Netherland
Telephone: (31)36-5382123, Fax: (31)36-5382124
E-mail: info@hamamatsu.nl

*Poland Office:*
02-525 Warsaw, 8 St. A. Boboli Str., Poland
Telephone: (48)22-660-8340, Fax: (48)22-660-8352
E-mail: jbaszak@hamamatsu.de

*North Europe and CIS:*
**HAMAMATSU PHOTONICS NORDEN AB**
Smidesvägen 12
SE-171 41 Solna, Sweden
Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01
E-mail: info@hamamatsu.se

*Russian Office:*
Riverside Towers
Kosmodamianskaya nab. 52/1, 14th floor
RU-113054 Moscow, Russia
Telephone/Fax: (7)095 411 51 54
E-mail: info@hamamatsu.ru

*Italy:*
**HAMAMATSU PHOTONICS ITALIA S.R.L.**
Strada della Moia, 1/E
20020 Arese, (Milano), Italy
Telephone: (39)02-935 81 733, Fax: (39)02-935 81 741
E-mail: info@hamamatsu.it

*Rome Office:*
Viale Cesare Pavese, 435, 00144 Roma, Italy
Telephone: (39)06-50513454, Fax: (39)06-50513460
E-mail: inforoma@hamamatsu.it

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