



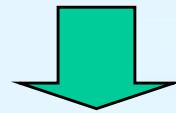
# **Mechanism of audible sound generation during flash lamp operation**

Ushio Inc. R&D center

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## Features :

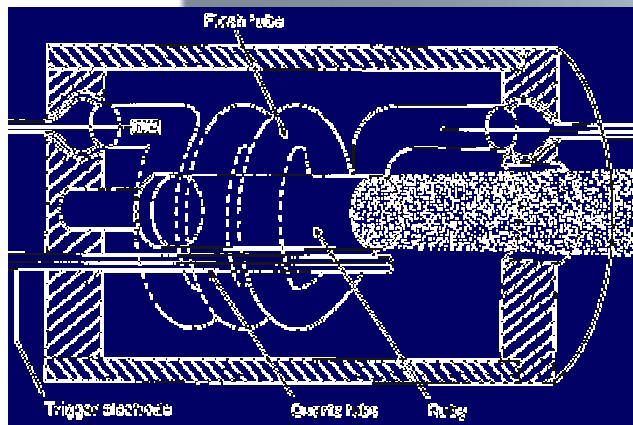
- Pulsed light source
- High peak power
- Good color rendering properties



For industrial applications...

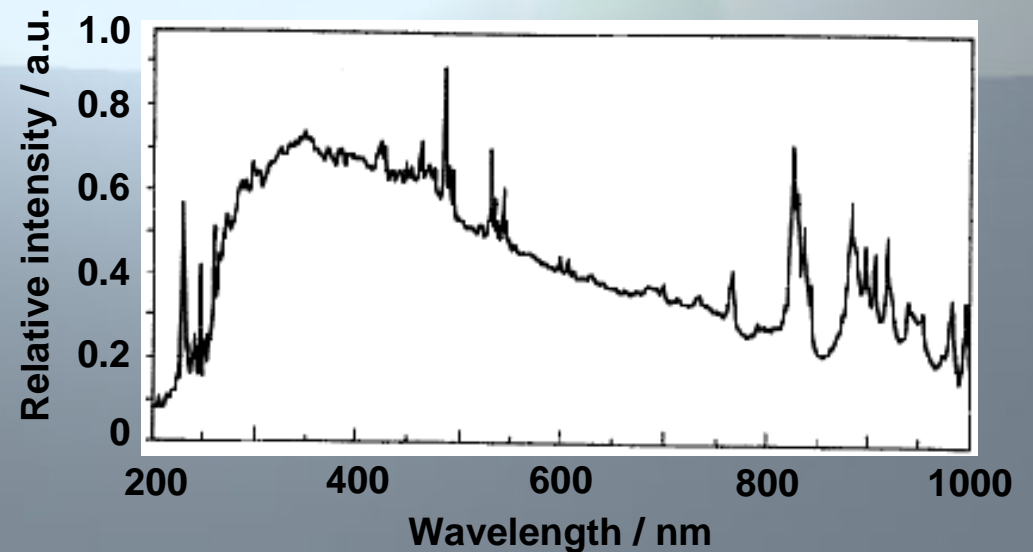
## 1. High peak power

Solid-state laser pumping



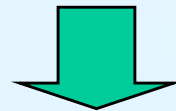
## 2. Very short period irradiation

(Radiates from the UV to the IR light ! )



## Features :

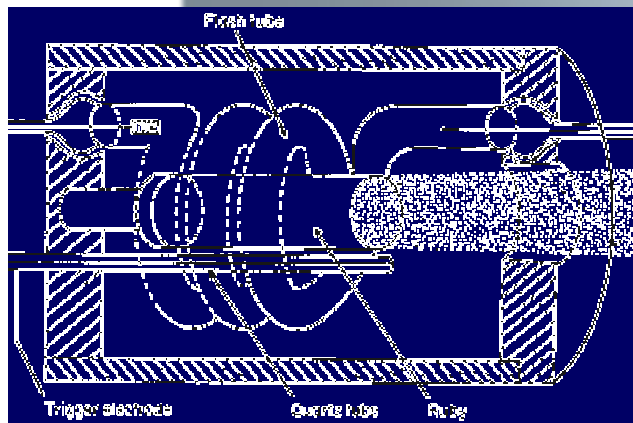
- Pulsed light source
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For industrial applications...

## 1. High peak power

Solid-state laser pumping

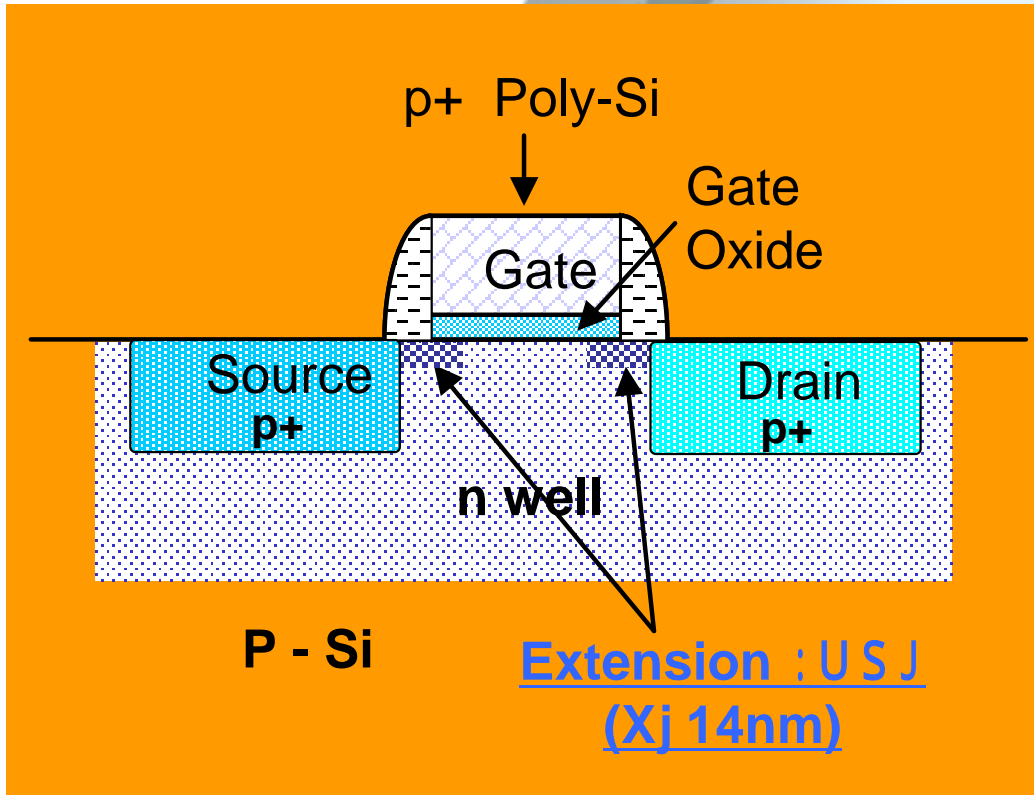


## 2. Very short period irradiation

(Radiates from the UV to the IR light ! )

- Strobes (Camera)
- Cure of adhesive agent (DVD)
- Toner fixing (Copy machine)
- Thermal treatment of MOSFET

## Activation process of an implanted Si wafer



**Schematic cross sectional view of P- MOS**



**FLA machine for 12 inch wafer**  
(Courtesy of Dainippon Screen MFG.,Co.,Ltd)

## Xe flash lamp

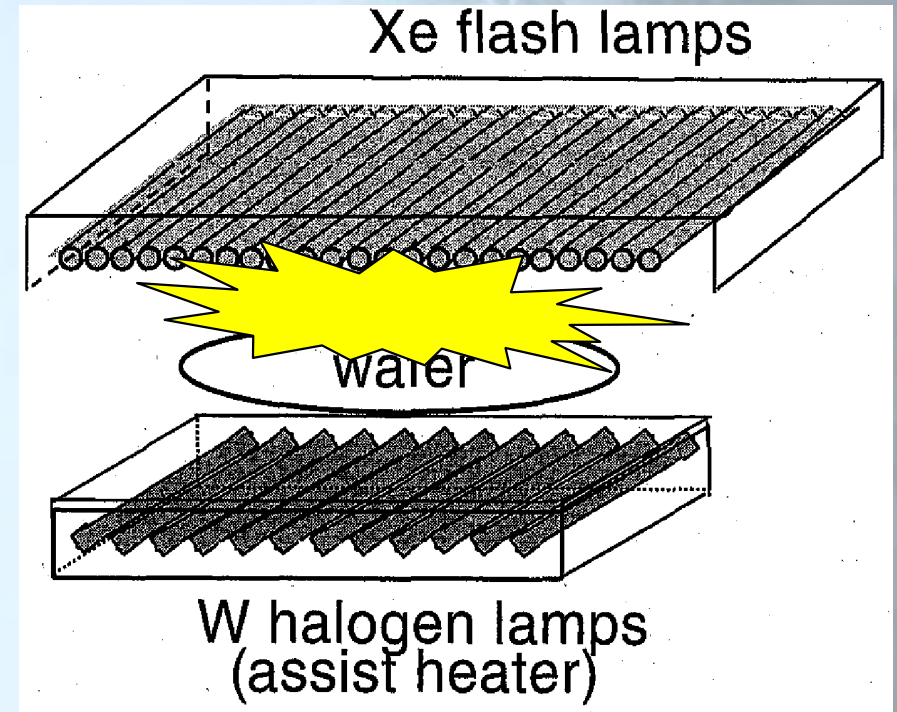
USJ formation

: FLA (flash lamp annealing)

Pulse width 1 ms

Energy density on a wafer surface

$25 \text{ J/cm}^2$



When flash lamp is operated,  
significant audible sound is generated

the sound generation mechanism

has NOT been clarified

**Purpose : To clarify the mechanism  
of the sound generation**

# USHIO Models of the sound generation

## 1. Mechanical vibration of the flash lamp tube

An object will vibrate and become a sound source, if it is rubbed or struck.

## 2. Due to the light radiated from the lamp

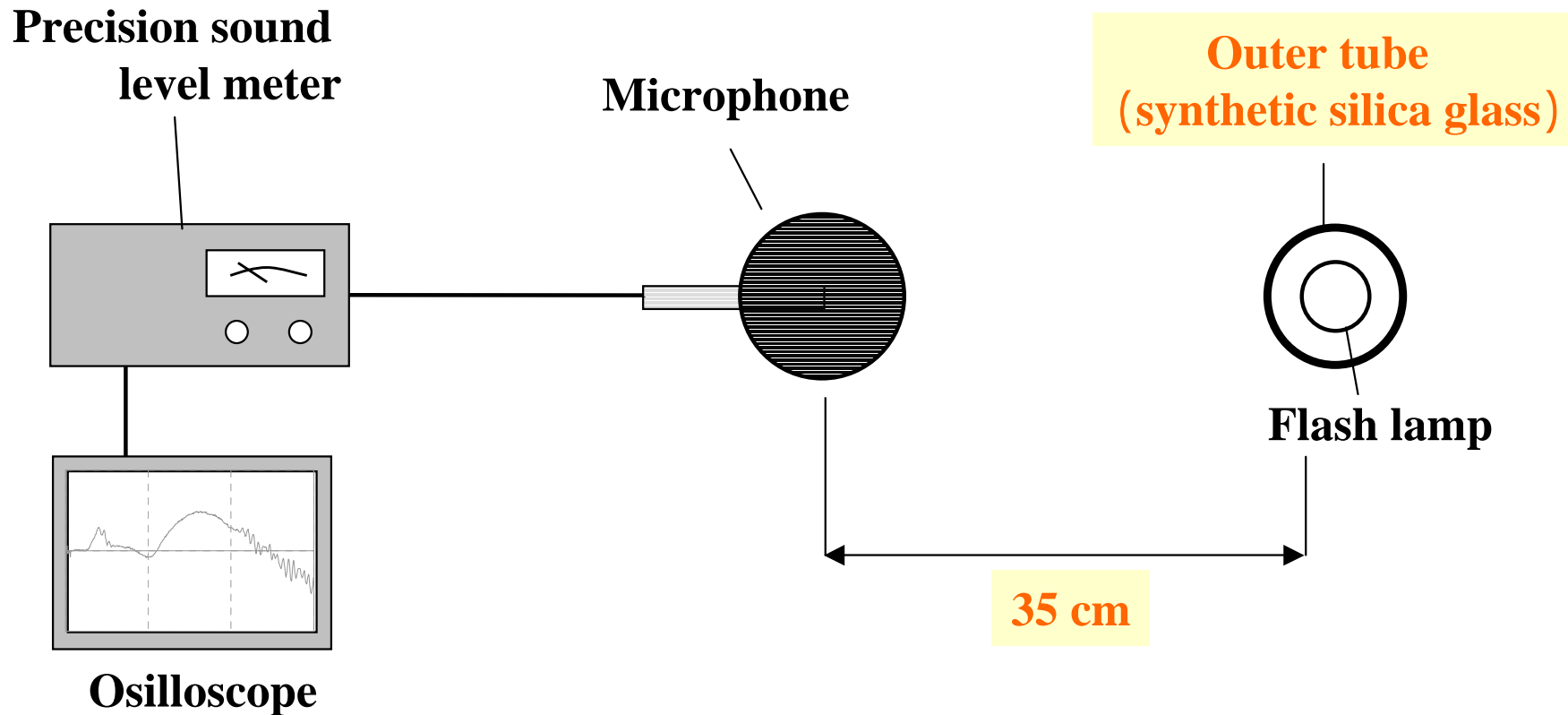
Test experiment : Selection of tube materials

- VUV lamp

- O<sub>3</sub> free lamp (UFQ-75002, Ushio Inc.)

Two types of the lamps, The intensities of the sound differ.

# USHIO Experimental set up 1



**Role of outer tube : divide the model 1 and 2**

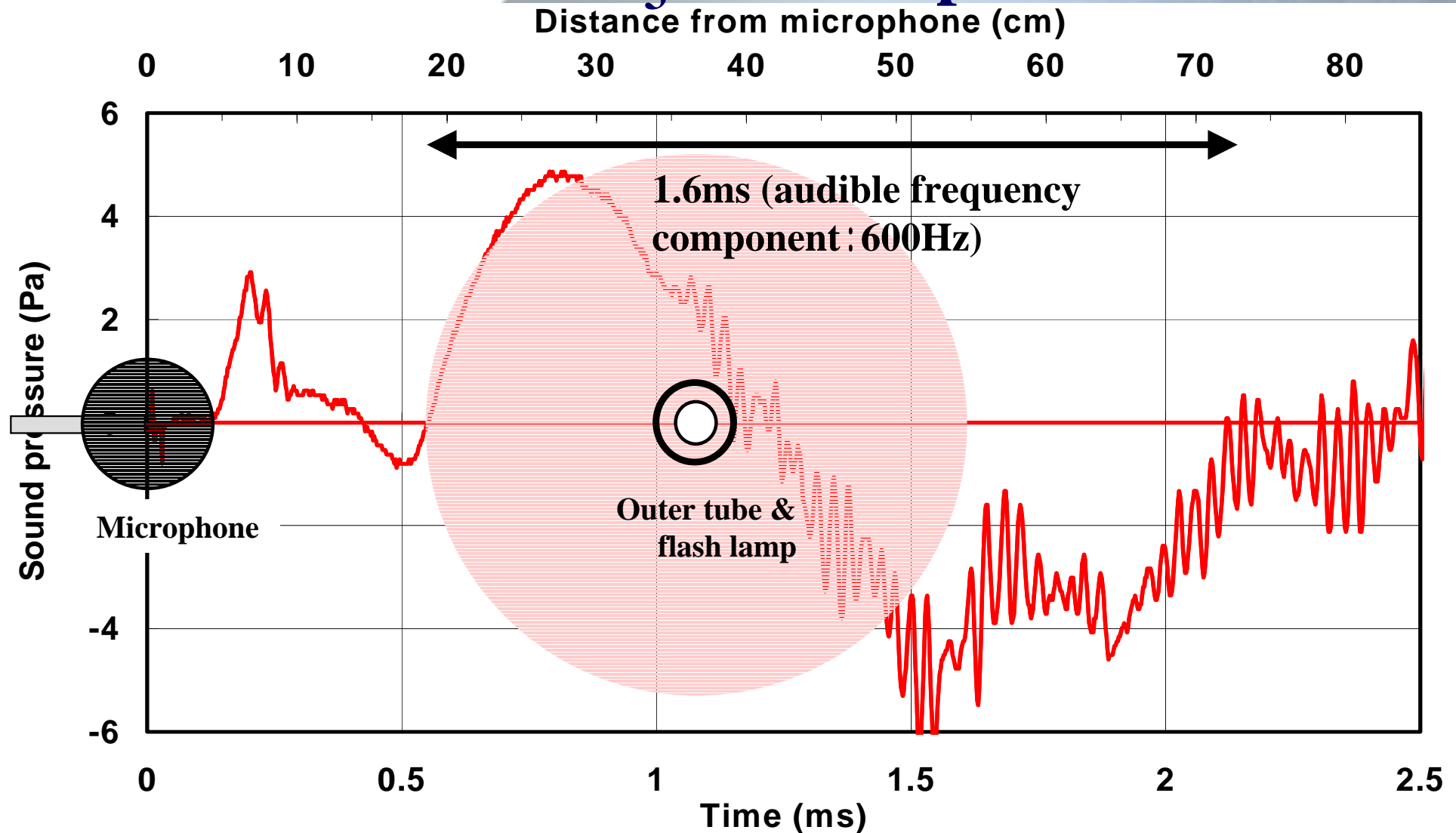
**The sound by vibration of the tube**

**reduced**

**The sound due to the light**

**not reduced**

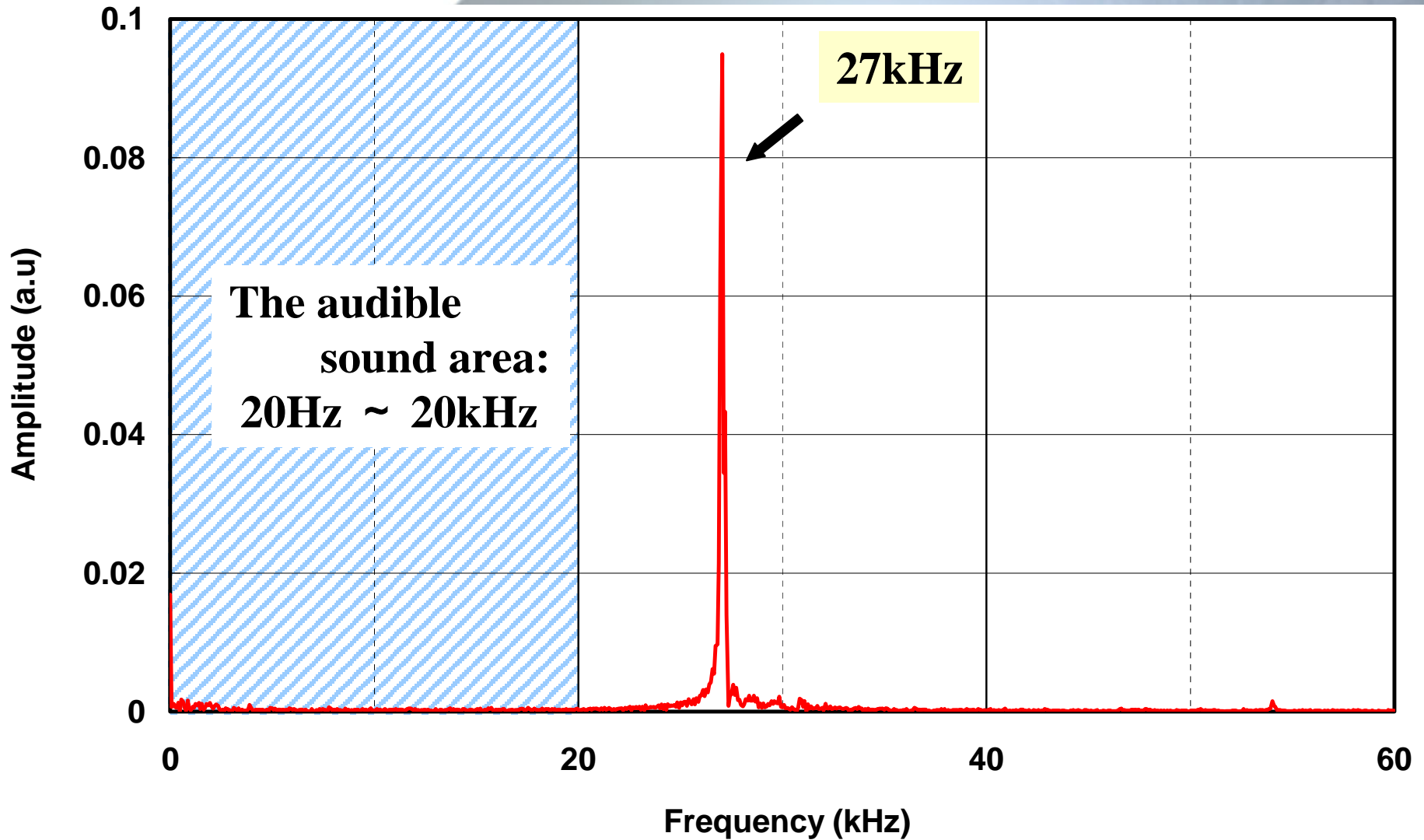
# Sound pressure waveform of O<sub>3</sub> free lamp



- The audible frequency component, originated from light
- The high frequency component : vibration of the tube

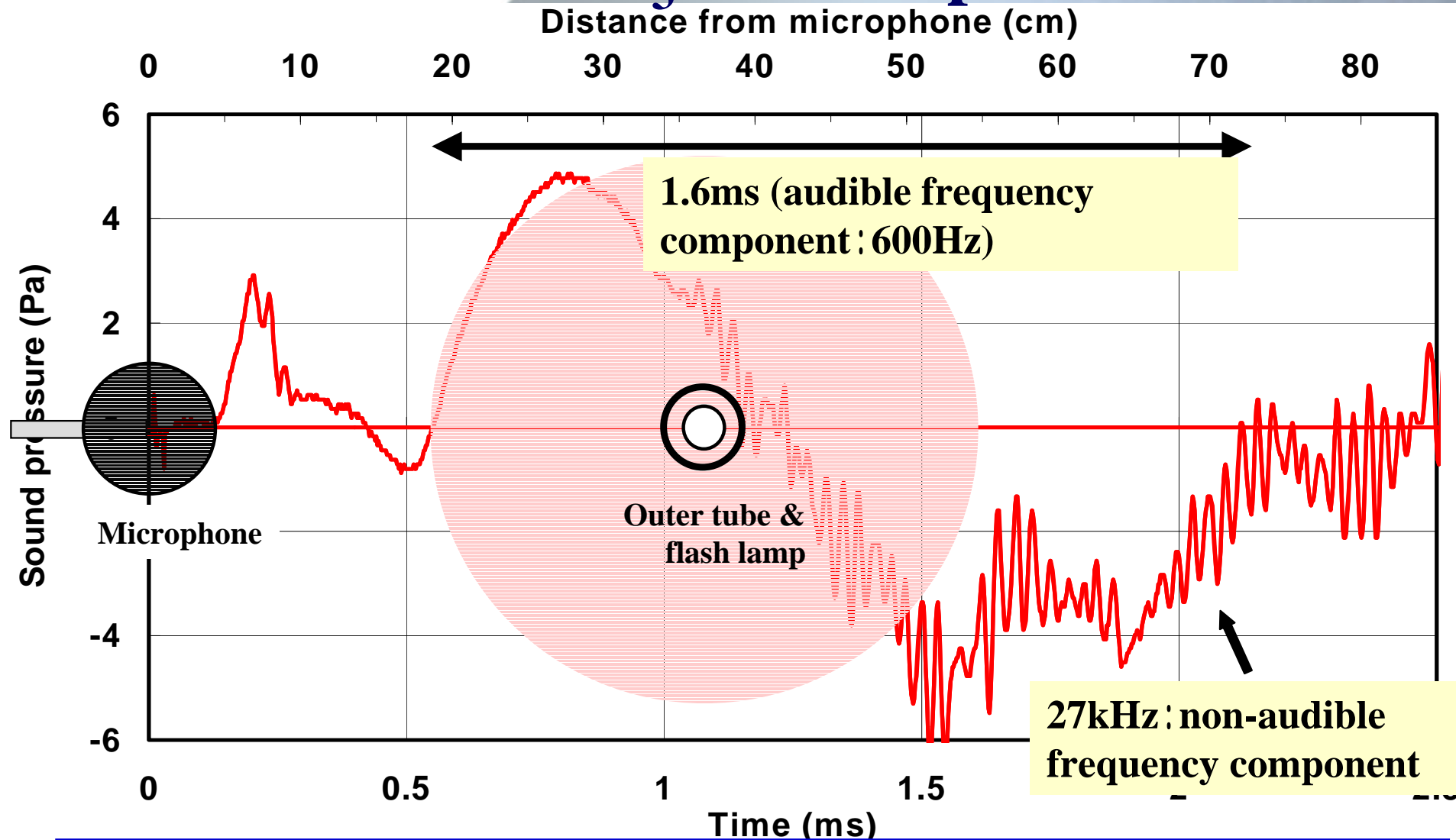


# Frequency analysis of the O<sub>3</sub> free lamp waveform (without outer tube)



**Mechanical vibration of tube**  
: The sound of 27 kHz cannot be heard.

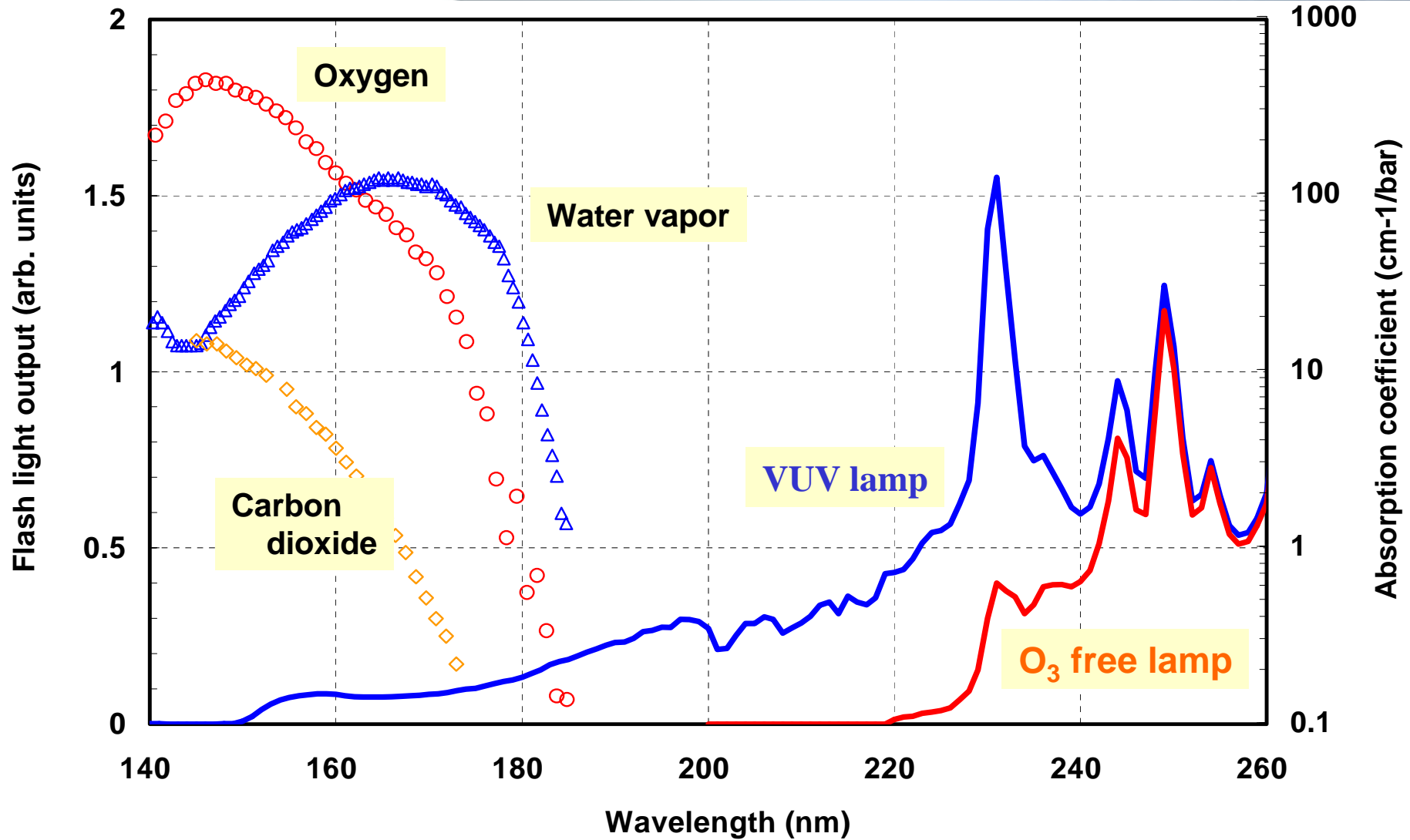
# Sound pressure waveform of O<sub>3</sub> free lamp



**The audible sound accompanied by flash lamp operation is from light, not from vibration.**

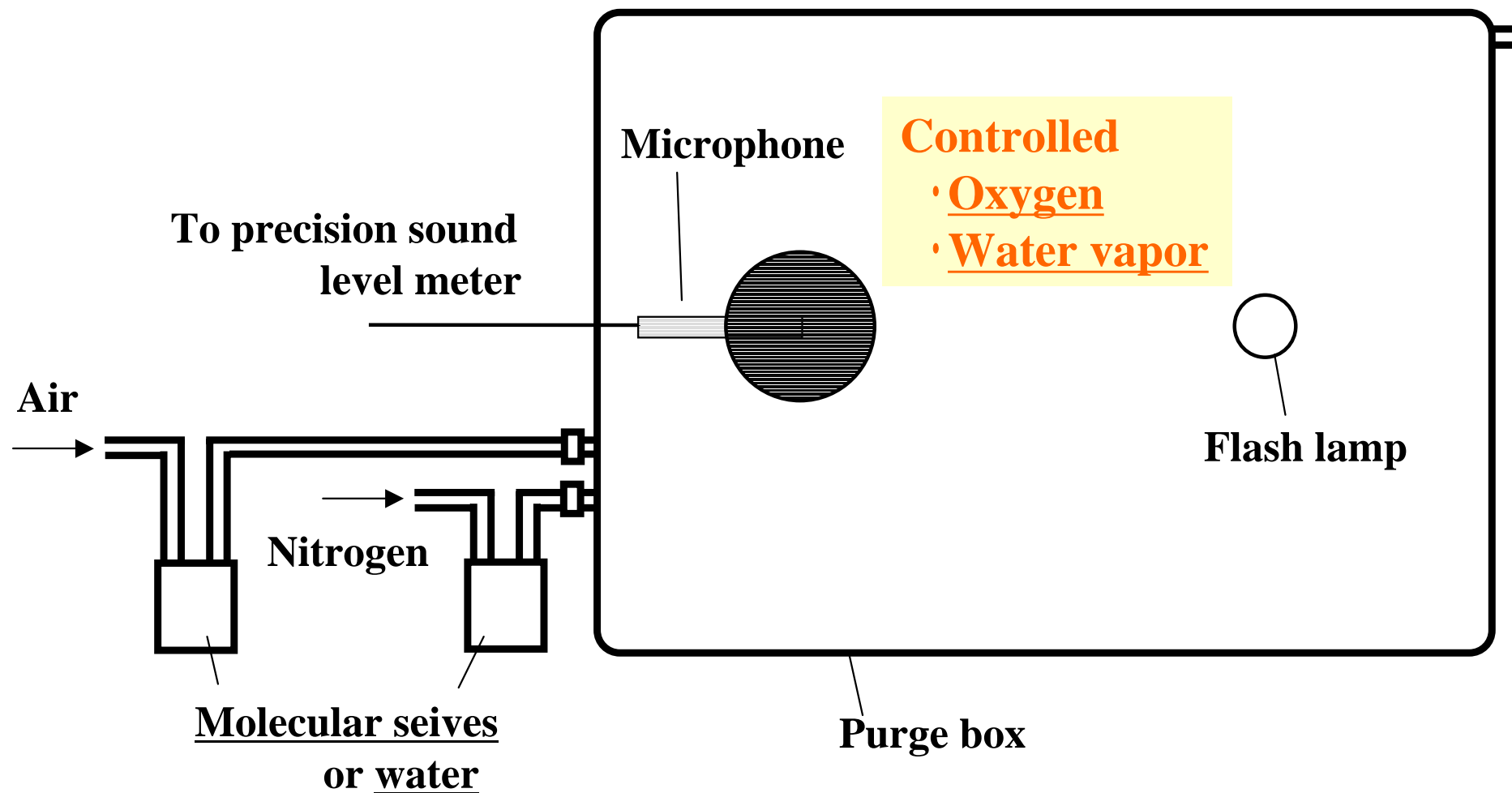


# Emission spectra of operated lamps in VUV-UV regions



**Hypothesis : Oxygen and water vapor may be  
the cause of the sound generation**

# USHIO Experimental set up 2



**Oxygen concentration : Controlled by adjusting air and nitrogen flow**  
**Water vapor pressure : Controlled by molecular sieves or water**

# The dependence of maximum sound pressure on the oxygen concentration

	Oxygen concentration (vol %)	
	20.5	→ 0.06
VUV lamp	100	→ 13
O <sub>3</sub> free lamp	0.62	→ 0.62

The water vapor pressure was kept at 500Pa

- VUV lamp: noticeably reduced at low oxygen concentration
- O<sub>3</sub> free lamp: NOT depended on the oxygen concentration

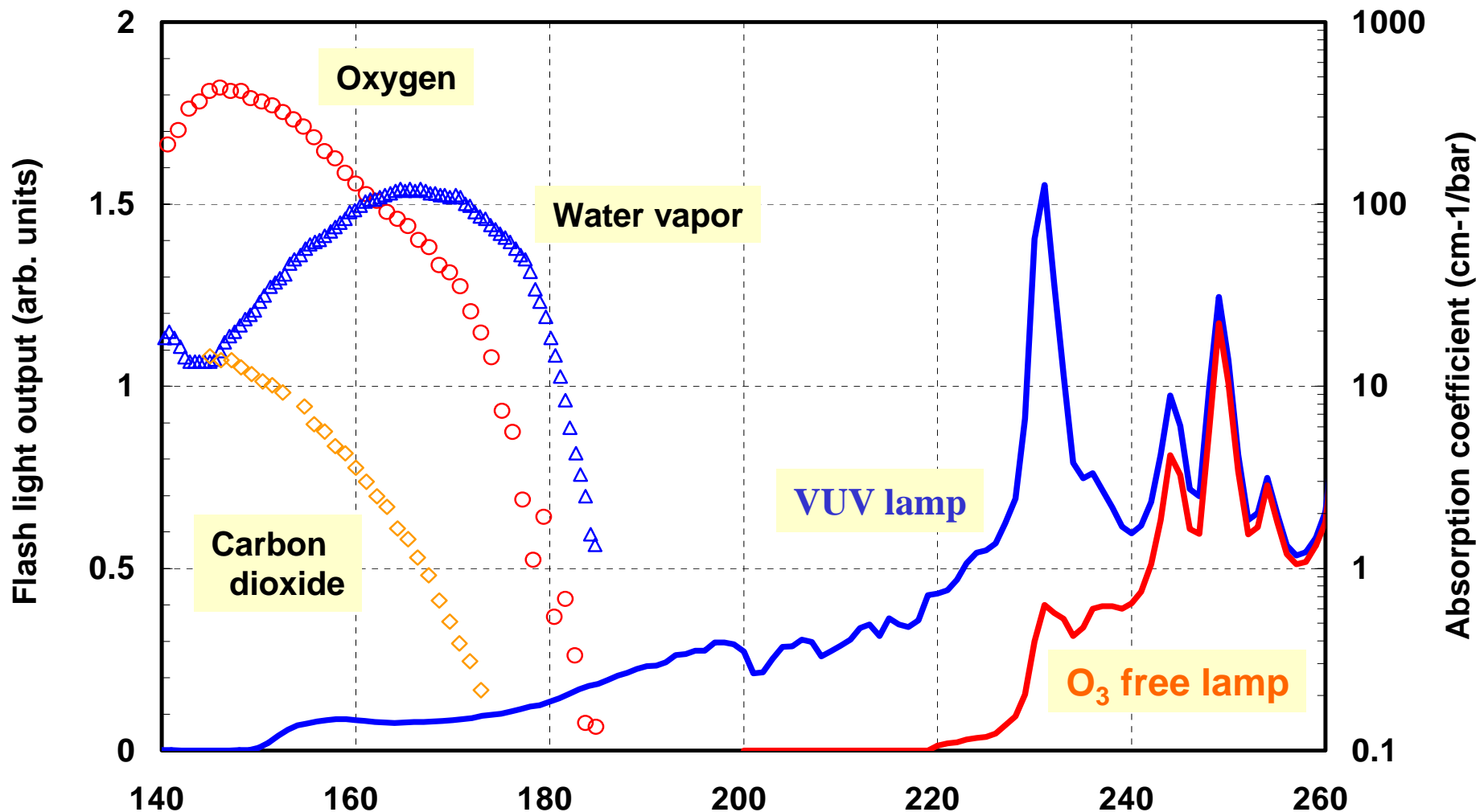
# The dependence of maximum sound pressure on the water vapor pressure

	Water vapor pressure (Pa)	
	2400	→ 500
VUV lamp	100	→ 13
O <sub>3</sub> free lamp	0.88	→ 0.62

The oxygen concentration was kept at 0.06 vol %

- VUV lamp: noticeably reduced  
at low water vapor pressure
- O<sub>3</sub> free lamp: tended to be reduced

# The absorption coefficient of atmospheric main constituents and the spectral distribution of the lamps



- VUV lamp : be influenced by oxygen and water vapor
- O<sub>3</sub> free lamp : be influenced only by water vapor

We studied the mechanism of the audible sound generation accompanied by flash lamp operation.

As result, we clarified as follows;

- The audible sound originated from the light which was radiated from the lamp.
- Oxygen and water vapor absorb VUV light, water vapor absorbs IR light and heating occurs. Consequently air rapidly expands and the audible sound is generated.