

# Mercury-free Nitrogen Fluorescent Lamps

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(Ehime Univ., \*Harison Toshiba Lighting)

2005 September 15 Light Sources Workshop at Ehime University



# Background d 1

**Environmental Friendly has become more important**

Europe : RoHS

Japan : Manufacturers' own standard

Environmentally non-friendly materials  
( Mercury, Lead, Heavy metals)

**LCD backlight ( CCFL ) . . . using Mercury**





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**LCD backlight ( CCFL ) . . . using ~~Mercury~~**

**As a substitute**

**Rare-Gas Flat-panel Fl, Half-Barrier Type FL**

**Rare-Gas Fl : independent of ambient temperature,  
fast start-up of luminous response**





# Background 2

However,

**Xenon FL** Efficacy is not enough high (except for our lamp).



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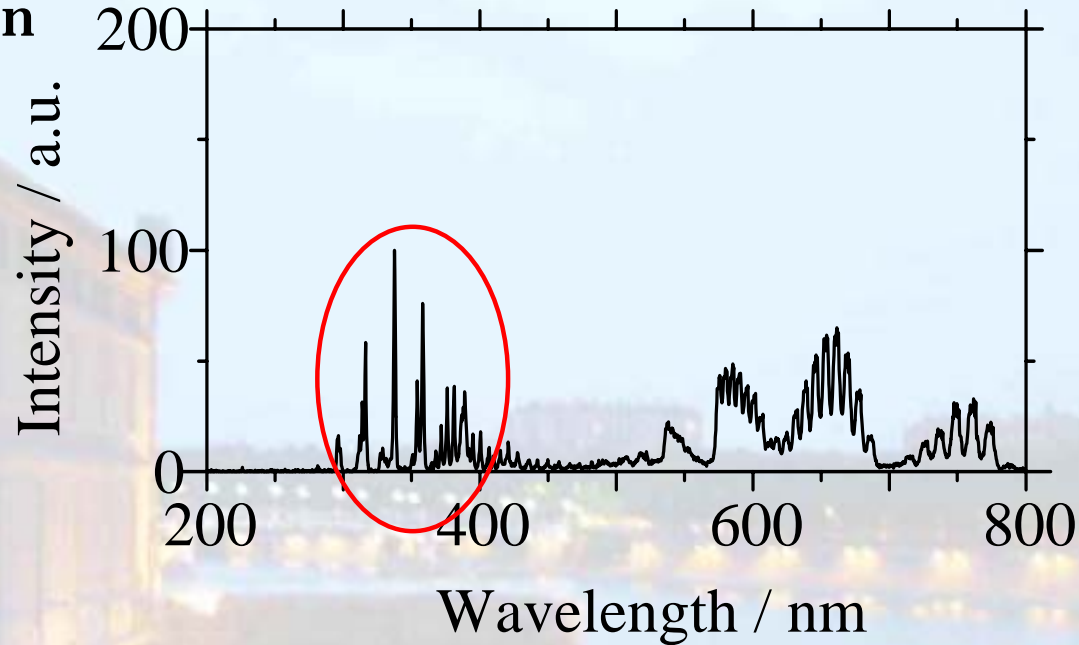
Prof Shigeo  
Fujita at Kyoto  
Univ.

**“Jinno, You must make a lamp which uses nitrogen near UV!  
That is your work.” in 1995**



# Background d 3

Spectra of Nitrogen  
Plasma

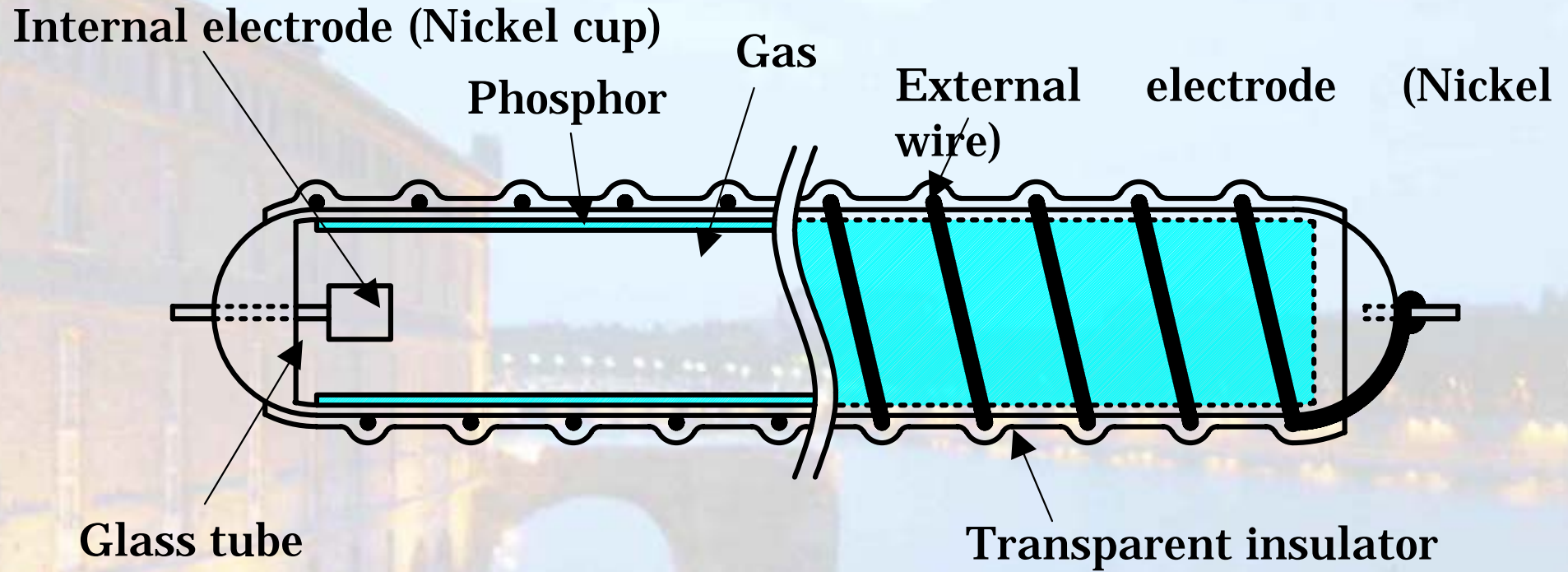


**Nitrogen Molecule ( $N_2$ ) generate near UV bands emission.  
(300 nm-400 nm)**

**Near UV brings smaller Stokes-loss**



# Lamp Configuration



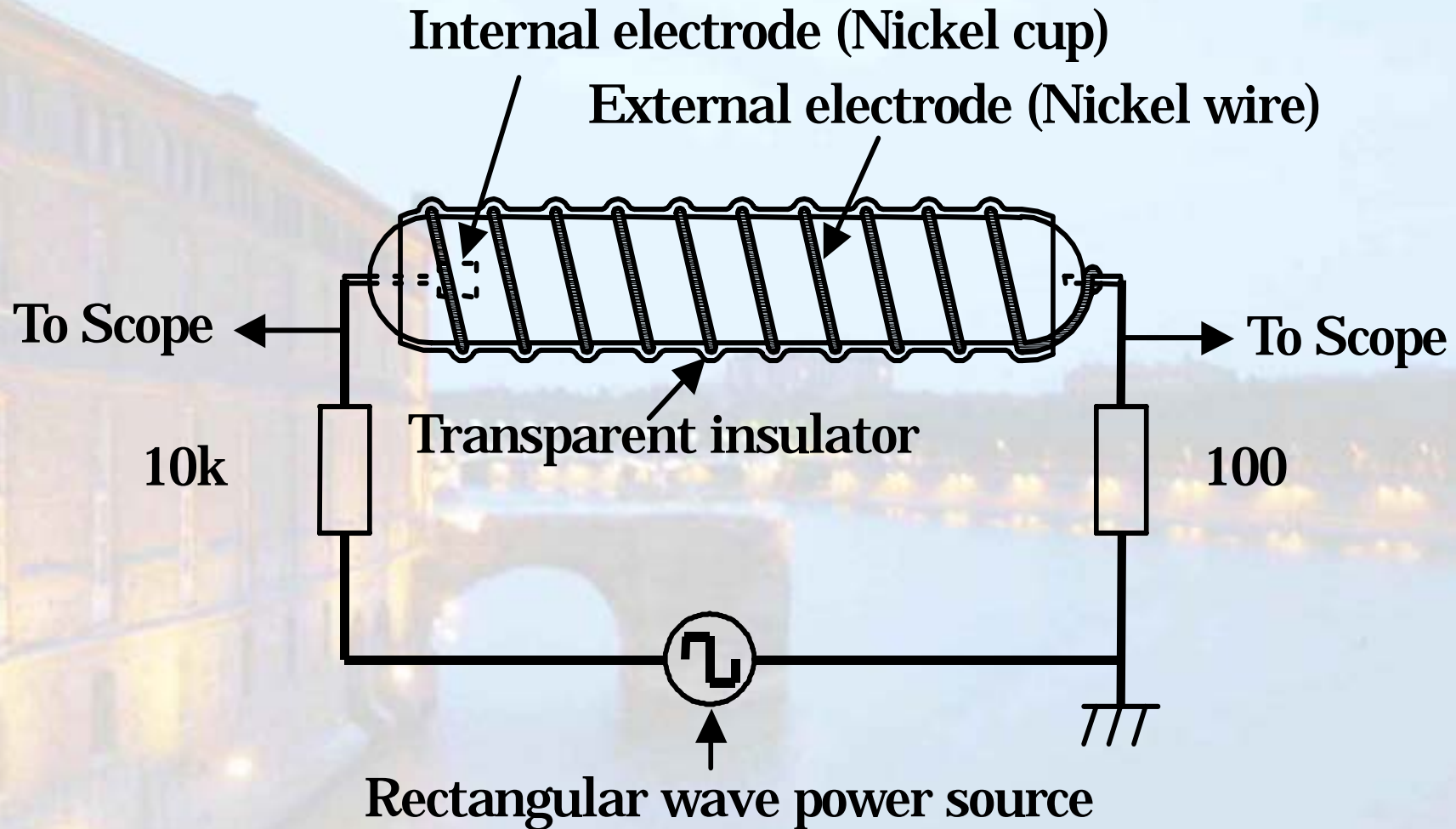
Diameter :  $\phi = 3.0\text{mm}$ , ( ID 2.4mm)  
Length : 200mm  
Phosphor: White (NP-107,220,360 )  
Ext. Electrode Diameter : 0.1mm  
Pitch : 5mm







# Operational Condition



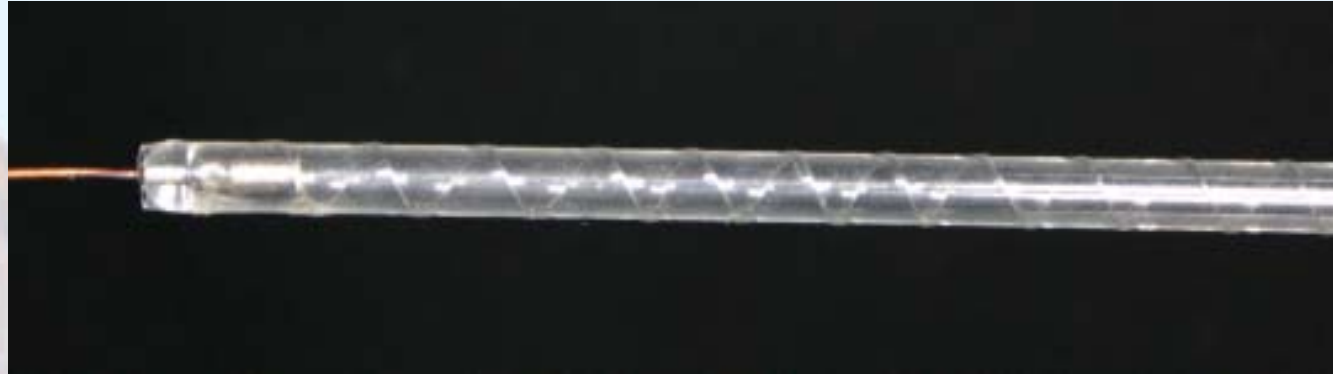
Frequency : 30 kHz ( Square wave)

Duty : 50%



# Nitrogen Lamp

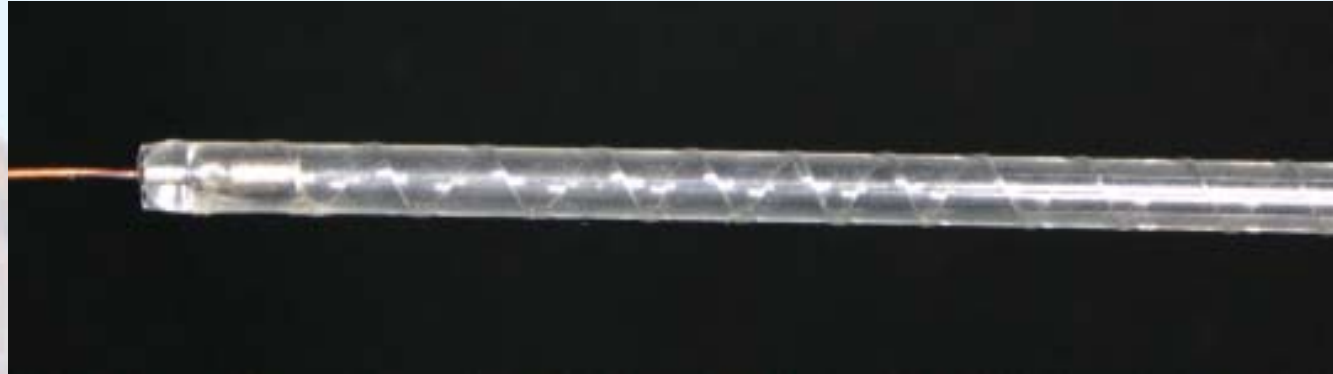
Non-operation





# Nitrogen Lamp

Non-operation



**N<sub>2</sub> only** 9.31 kPa,  
Discharge



**Commonsence**

Increase input power -> lamp is broken!  
**× Discharge does not expand**



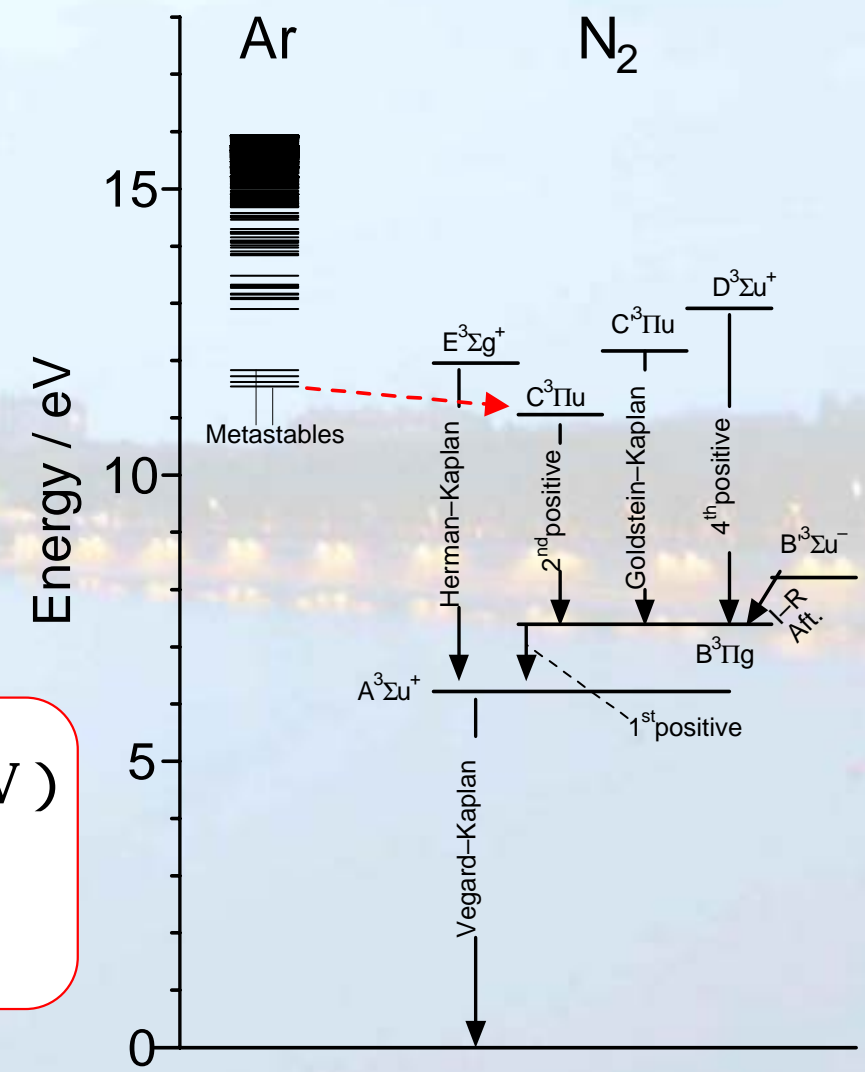
# Argon and Nitrogen

Ar-Hg FL uses Penning ionization , energy transfer from Ar to Hg.

Partial pressure of Hg is about 0.1 % or less.

Argon Metastable Level ( 11.5,11.7 eV )

Nitrogen  $C^3\Pi_u$  ( 11.052 eV )



Energy Diagram



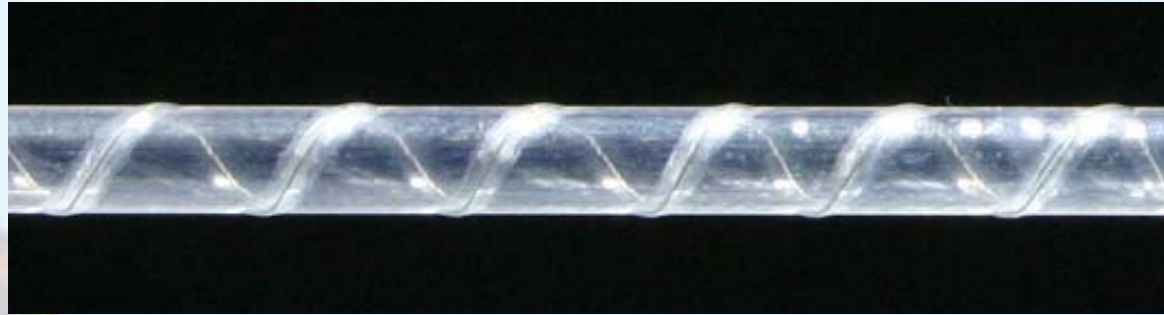
# Samples

<b>Gas pressure</b>	<b>4.67 kPa (35 Torr)</b>	<b>9.31 kPa (70 Torr)</b>	<b>13.3 kPa (100Torr)</b>
<b>Gas ratio</b>			
<b>Ar</b>	<b>A</b>	<b>B</b>	<b>C</b>
<b>Ar:N<sub>2</sub> = 99:1</b>	<b>D</b>	<b>E</b>	<b>F</b>
<b>Ar:N<sub>2</sub> = 95:5</b>	<b>G</b>	<b>H</b>	<b>-</b>



# Discharges ( w/o Phosphor )

Non-operation



Lamp



# Discharges ( w/o Phosphor )

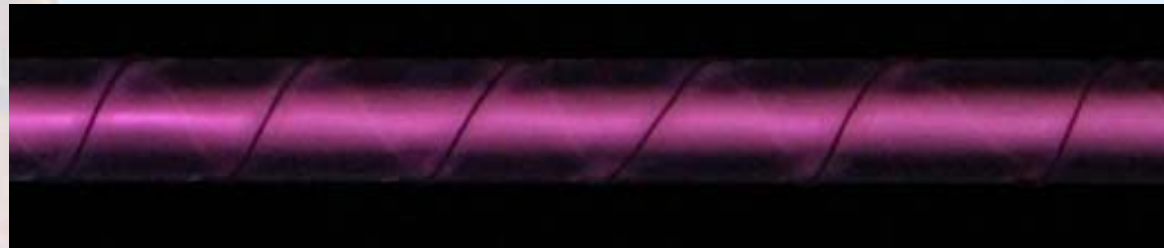
Non-operation



Lamp

Ar 100 % ( 9.31 kPa )

Dark Red  
Slightly thin Positive  
Column

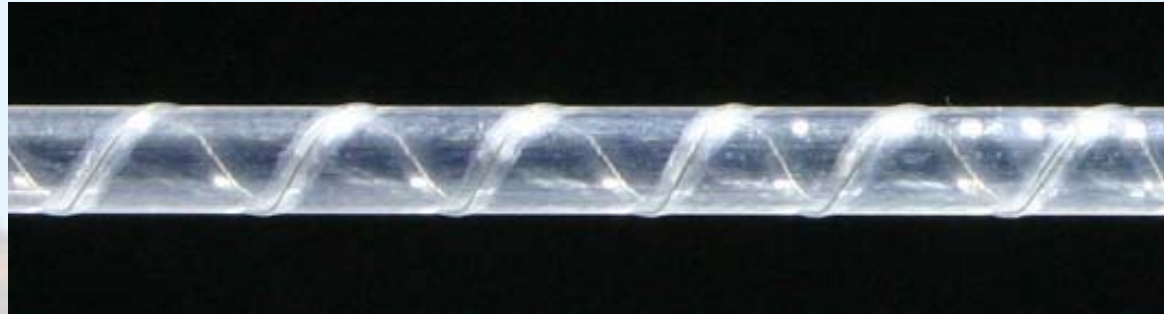


Lamp



# Discharges ( w/o Phosphor )

Non-operation



Lamp

Ar 100 % ( 9.31 kPa )

Dark Red  
Slightly thin Pos. Col.



Lamp

N<sub>2</sub> : 1 % ( 9.31 kPa )

Whity-Red  
**Thick Pos. Col.**



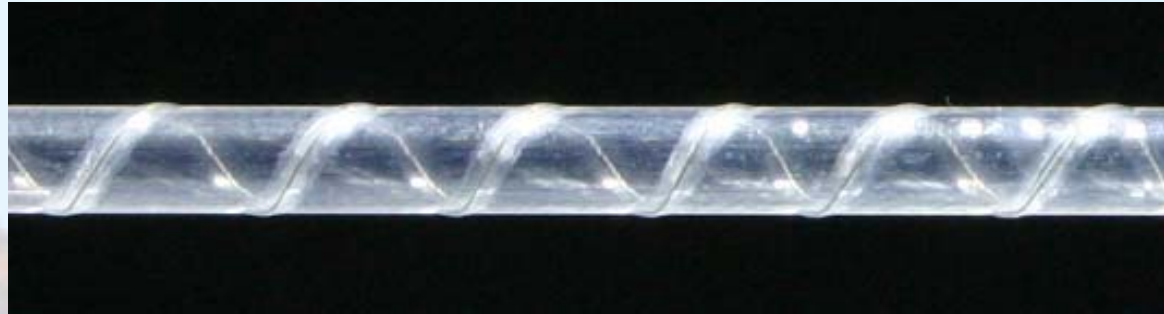
Lamp





# Discharges ( w/o Phosphor )

Non-operation



Lamp

Ar 100 % ( 9.31 kPa )

Dark Red  
Slightly thin Pos. Col.



Lamp

N<sub>2</sub> : 1 % ( 9.31 kPa )

Whity-Red  
**Thick Pos. Col.**



Lamp

N<sub>2</sub> : 5 % ( 9.31 kPa )

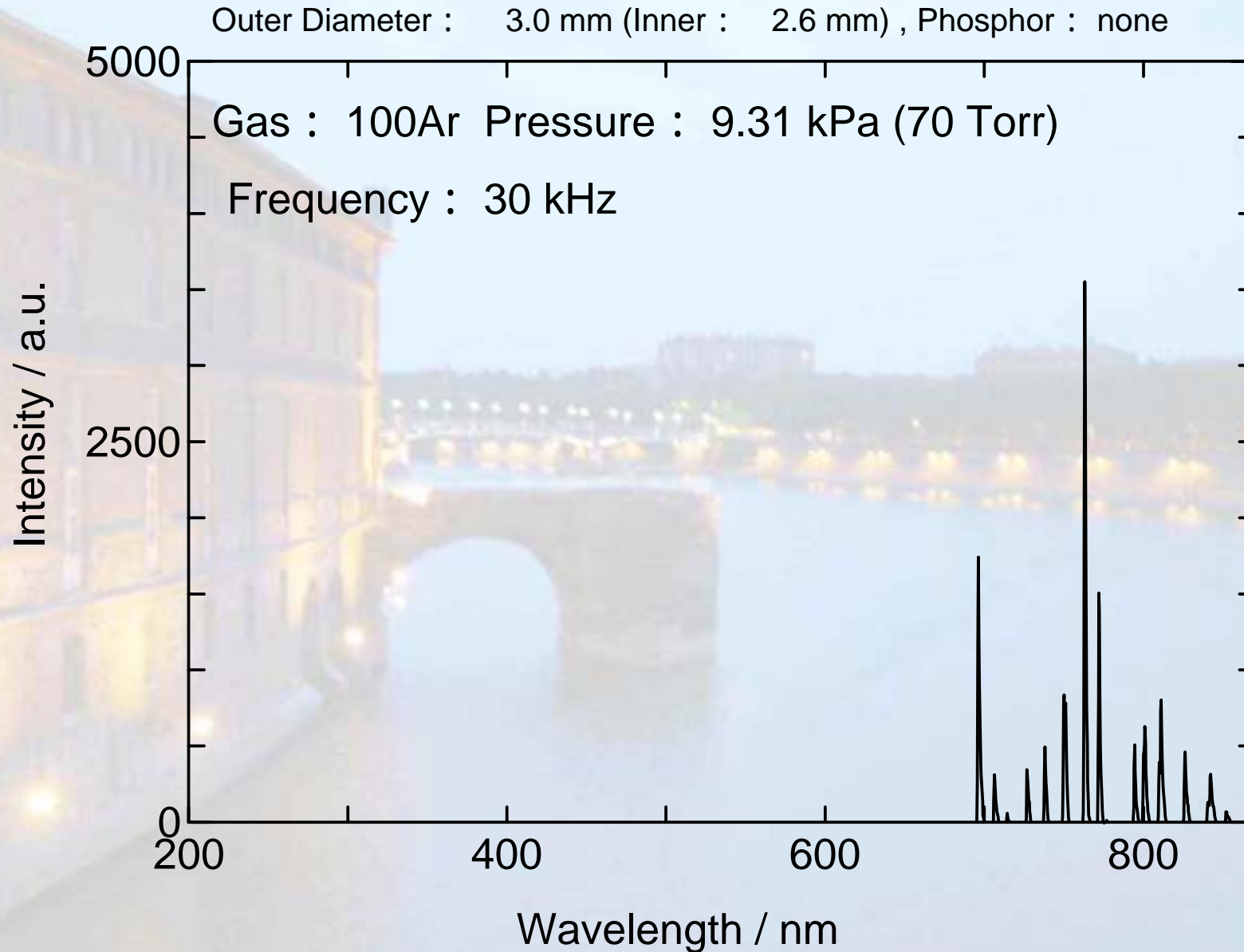
Whity-Red  
Slightly Thick Pos. Col.



Lamp



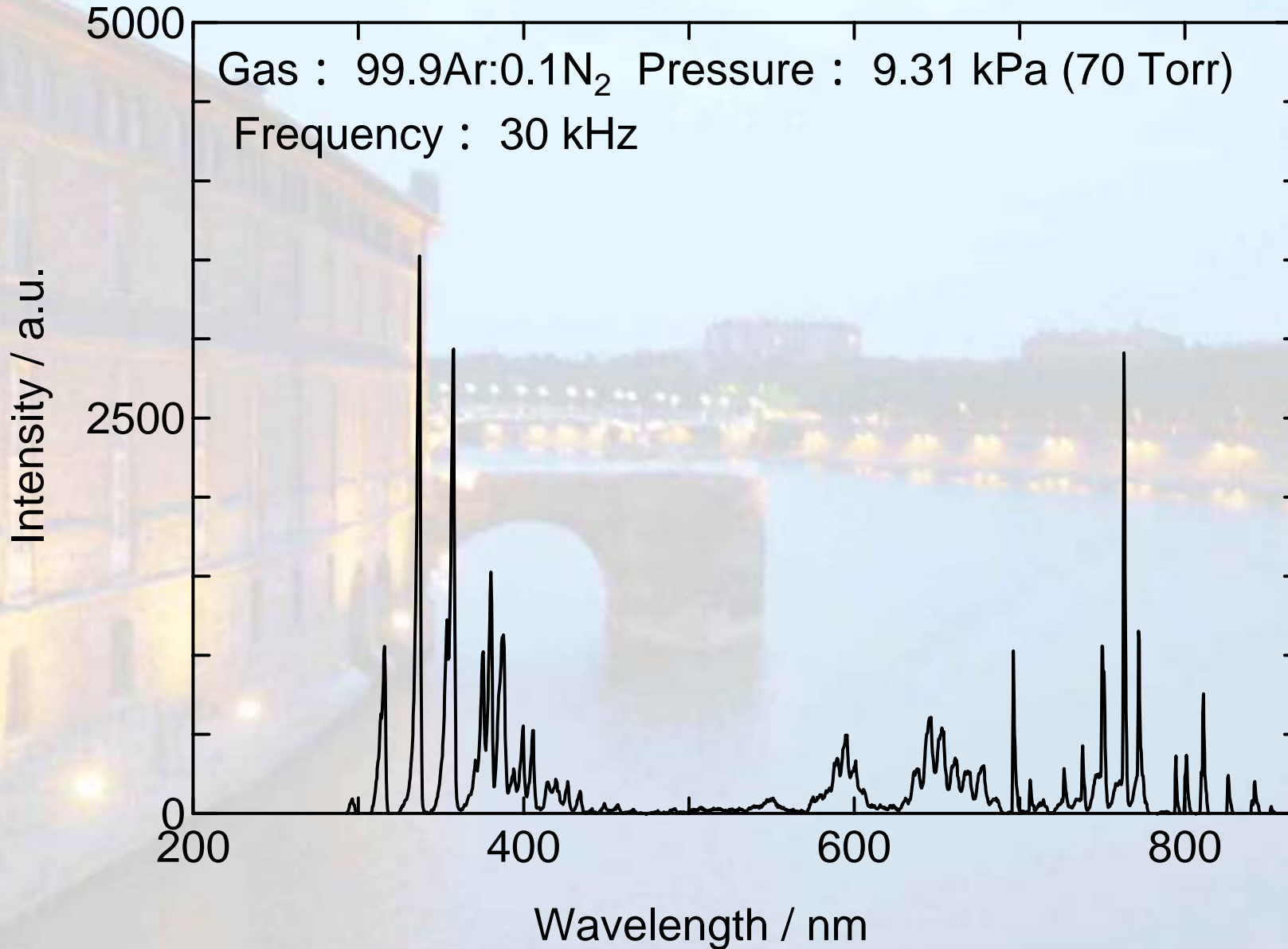
# Spectra (w/o phosphor)





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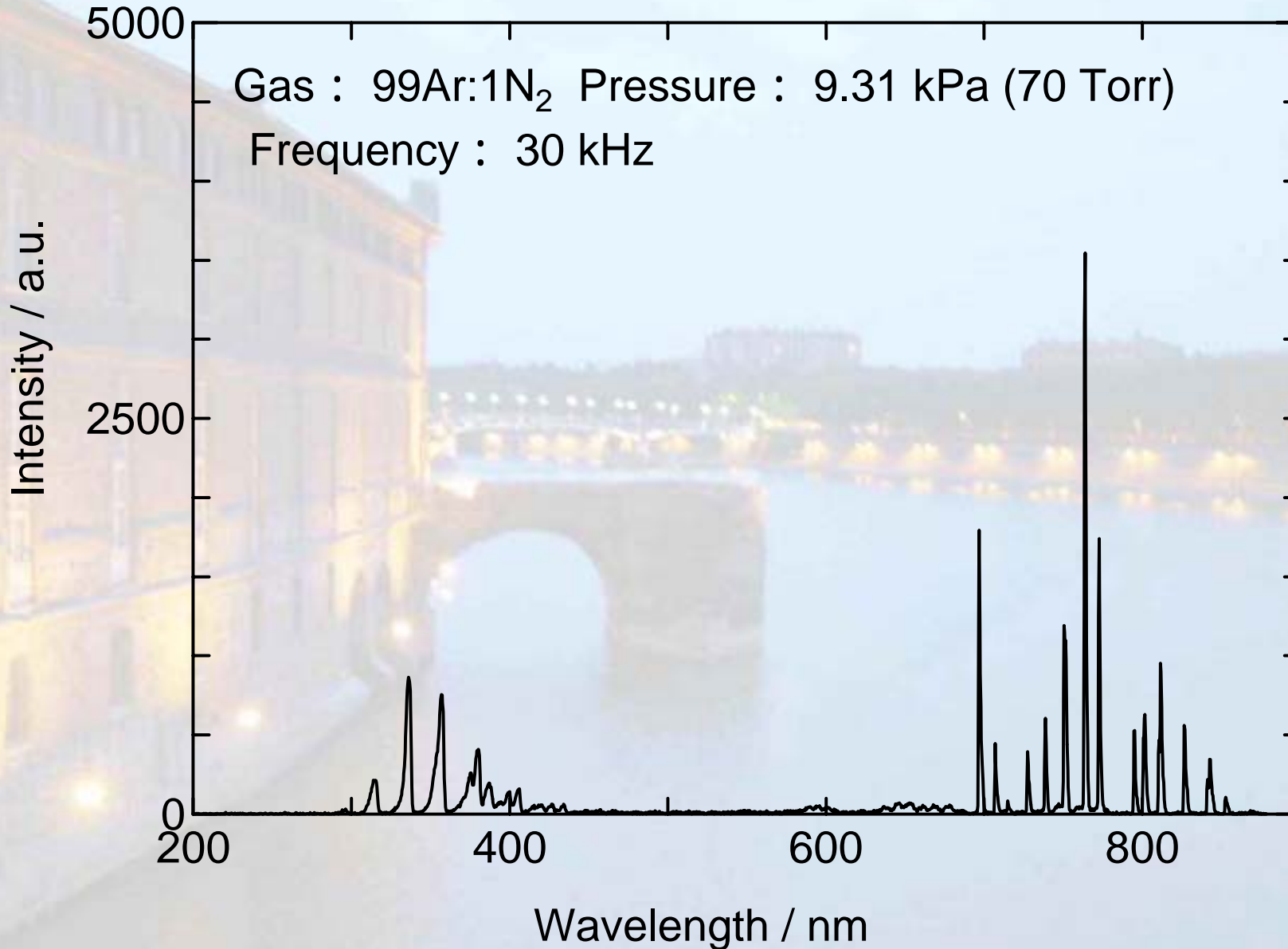
Outer Diameter : 3.0 mm (Inner : 2.6 mm) , Phosphor : none





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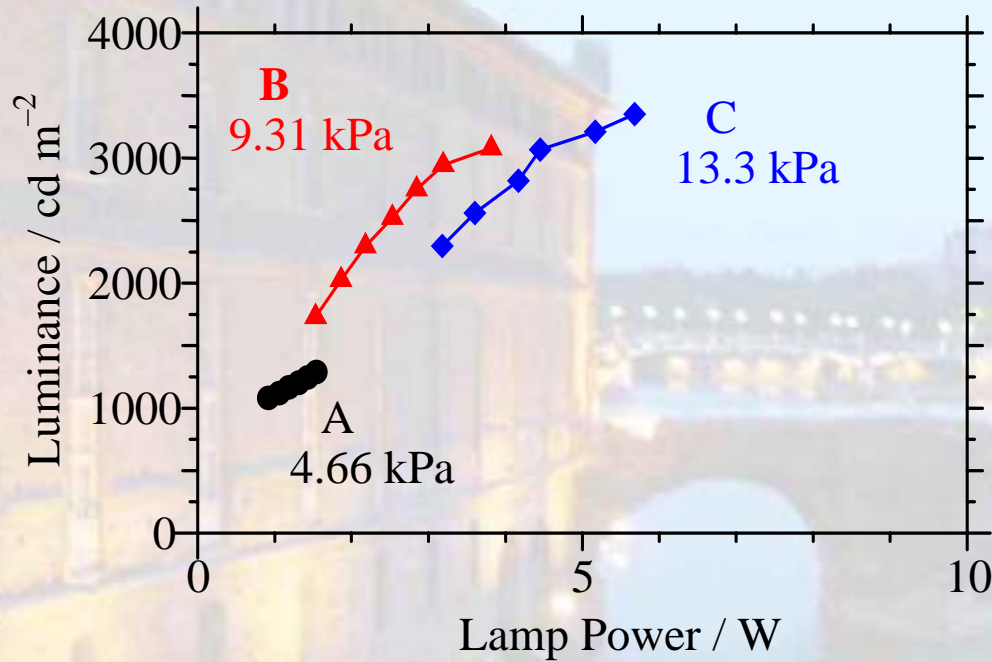




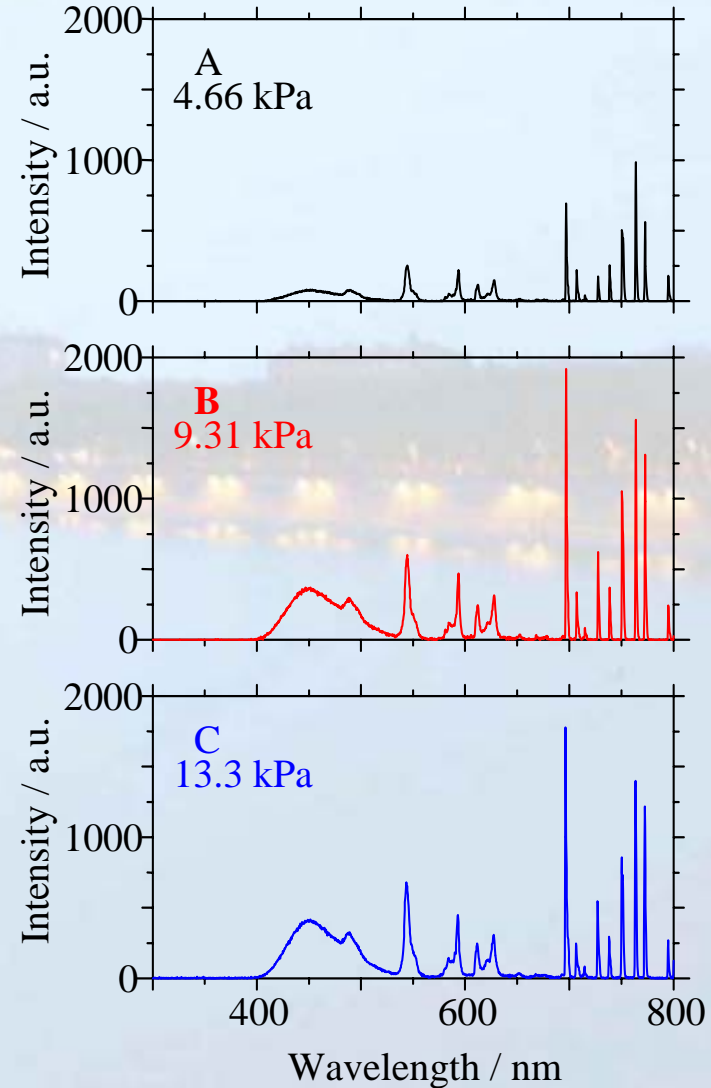
# Ar Fluorescent Lamp



Gas: Ar      Phosphor: NP-107, 220, 360  
Outer Diameter  $\phi$ 3.0 mm      Frequency: 30 kHz



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Outer Diameter  $\phi$ 3.0 mm      Frequency: 30 kHz

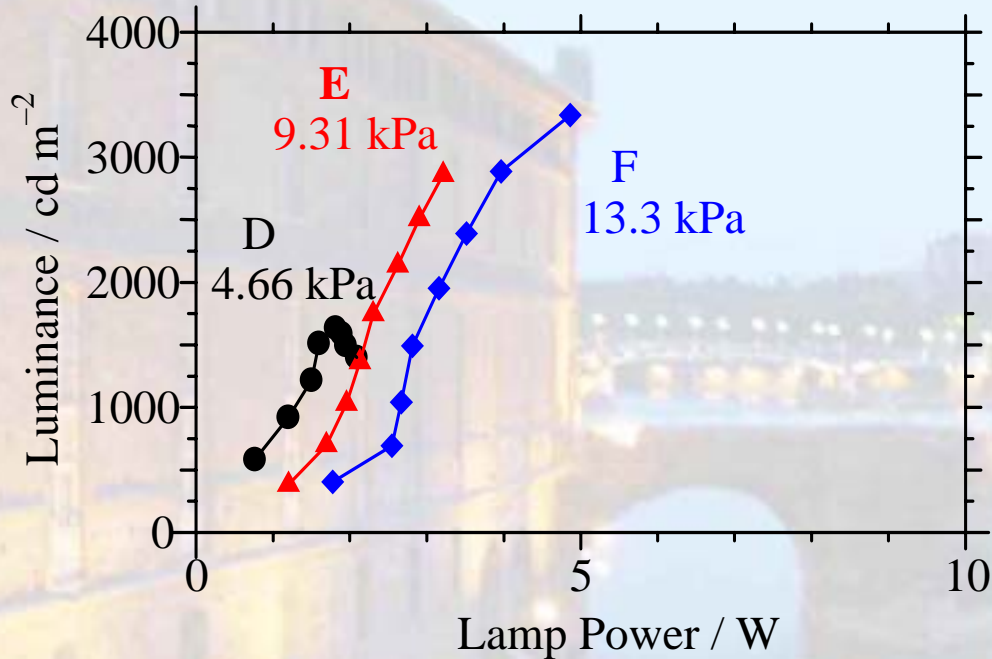




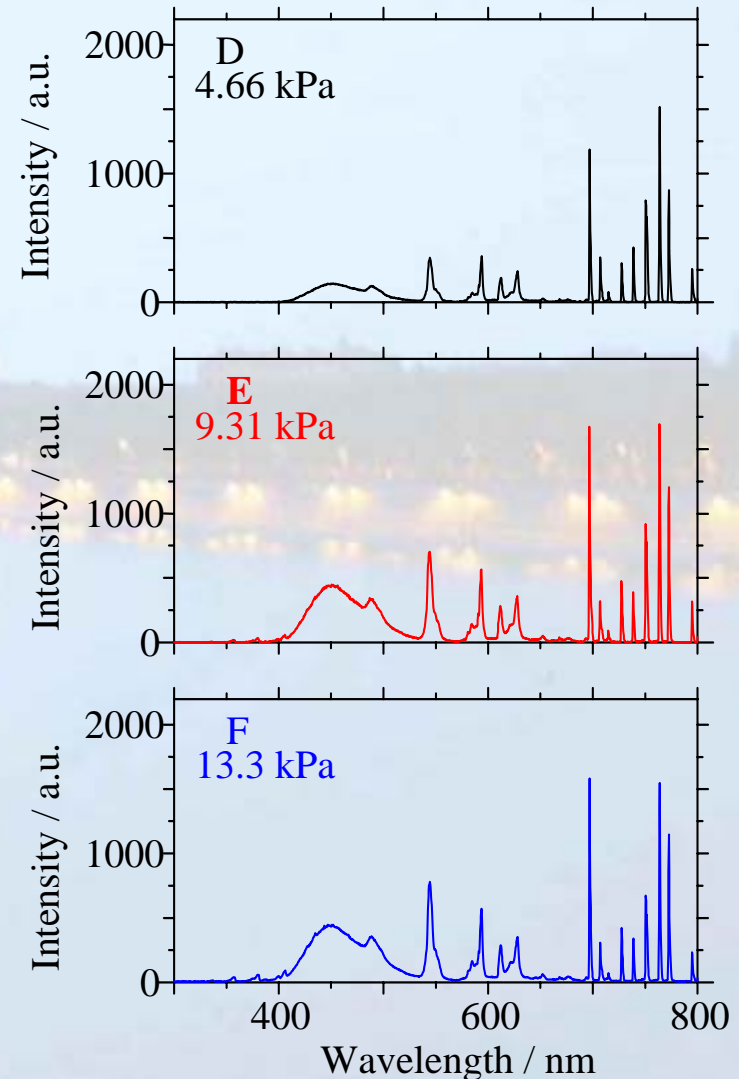
# N<sub>2</sub> 1% Lamp



Gas: Ar:N<sub>2</sub>=99:1      Phosphor: NP-107, 220, 360  
Outer Diameter  $\phi$ 3.0 mm      Frequency: 30 kHz



Gas: Ar:N<sub>2</sub>=99:1      Phosphor: NP-107, 220, 360  
Outer Diameter  $\phi$ 3.0 mm      Frequency: 30 kHz



N<sub>2</sub>を1%封入したランプの分光分布

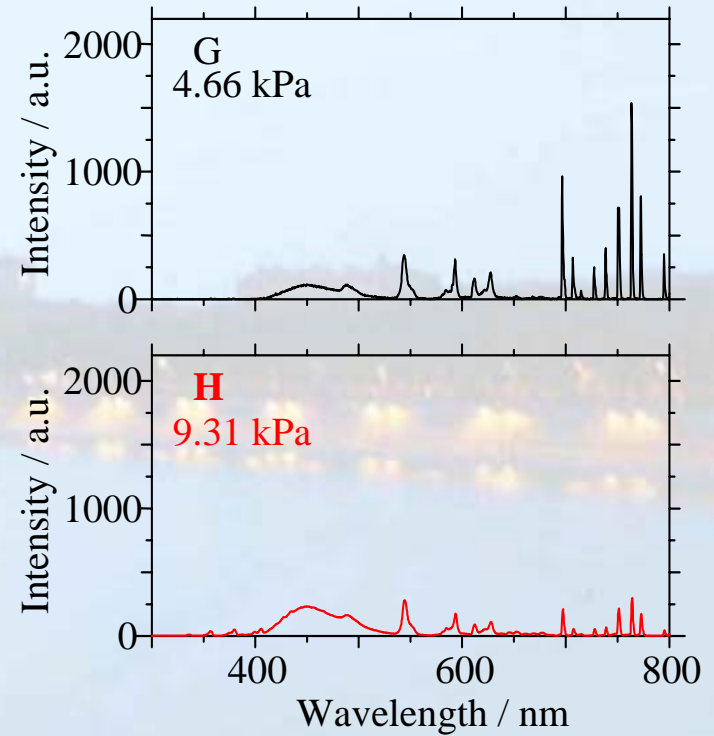
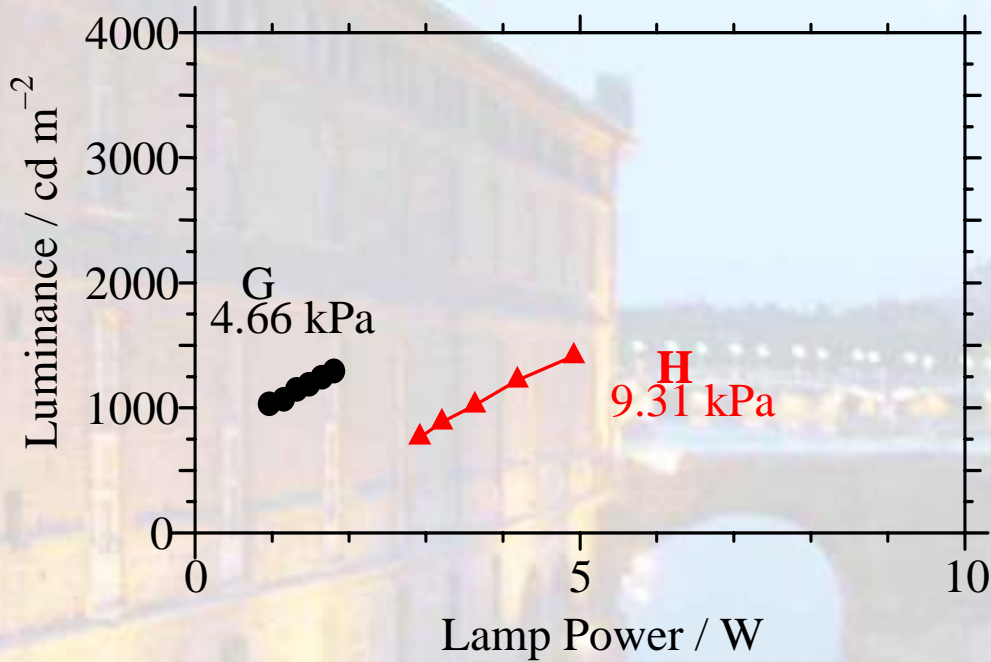


# N<sub>2</sub> 5% Lamp



Gas: Ar:N<sub>2</sub>=95:5      Phosphor: NP-107, 220, 360  
Outer Diameter  $\phi$ 3.0 mm      Frequency: 30 kHz

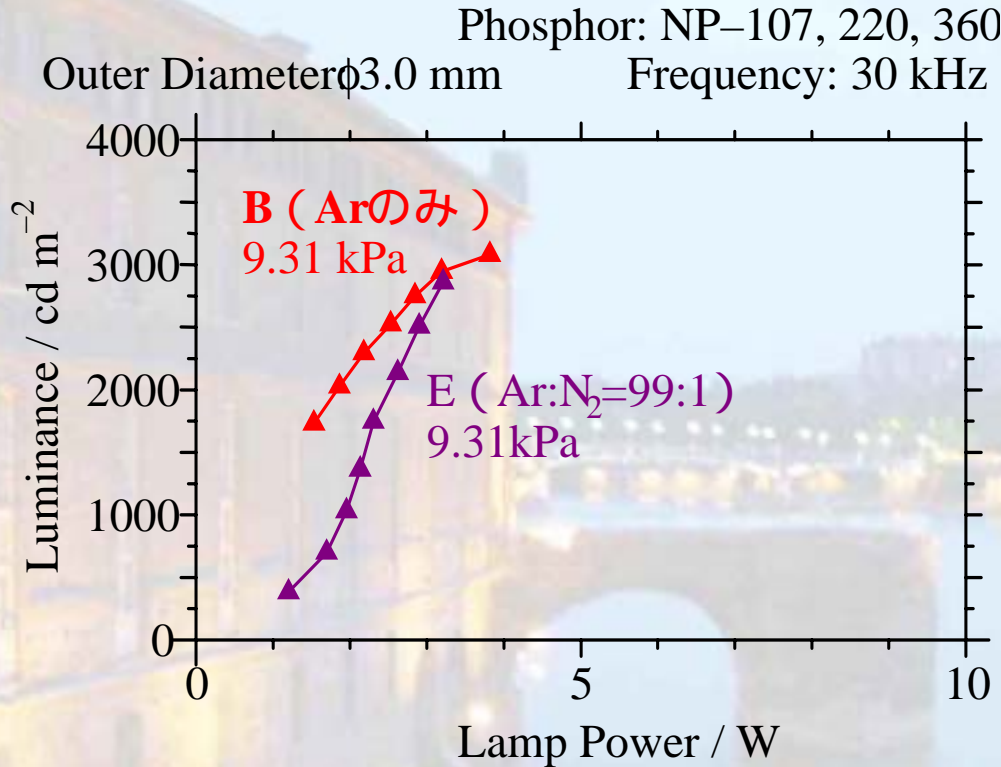
Gas: Ar:N<sub>2</sub>=95:5      Phosphor: NP-107, 220, 360  
Outer Diameter  $\phi$ 3.0 mm      Frequency: 30 kHz



N<sub>2</sub>を5%封入したランプの分光分布



# Luminance



	Luminance cd/m <sup>2</sup>	Dimming %
Ar	1700 ~ 3080	55
Ar:N <sub>2</sub> =99:1	380 ~ 2900	9.7

**Nitrogen stabilise a discharge -> easy dimming**

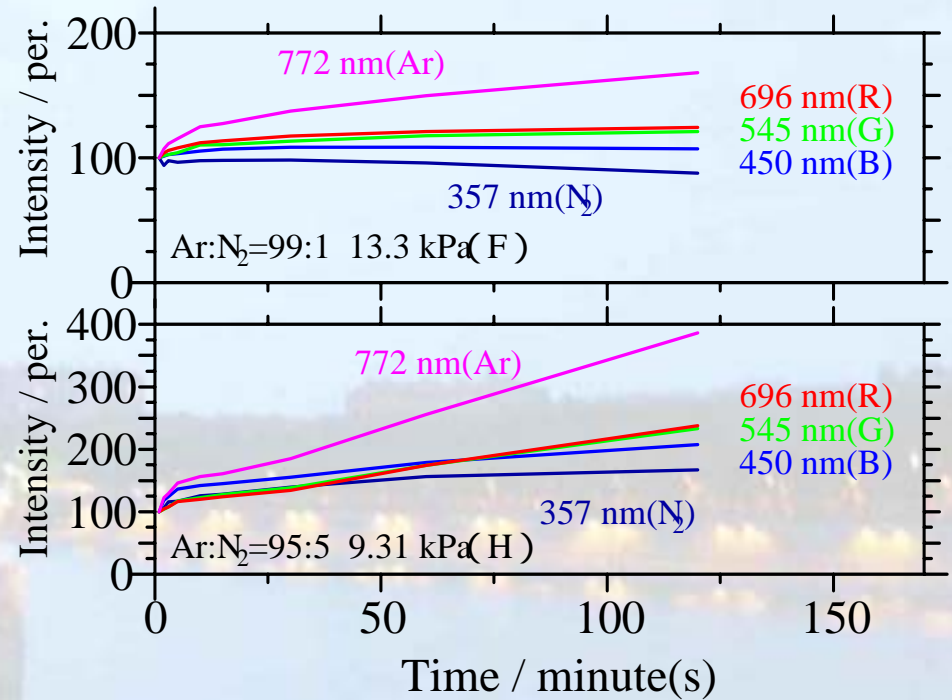
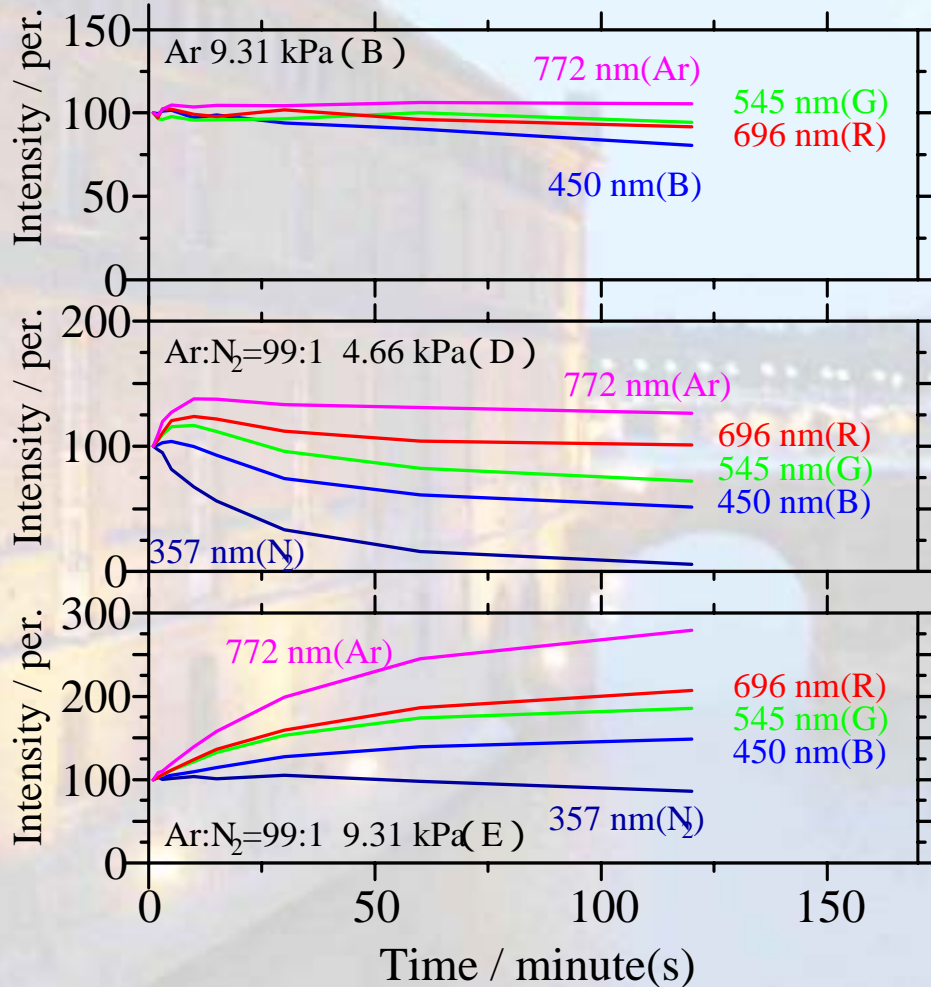




# Time Decay of Spectral Intensity

Phosphor: NP-107, 220, 360

Outer Diameter  $\phi$ 3.0 mm Frequency: 30 kHz



**Red – following Ar(772nm)**  
**Blue-follwin N<sub>2</sub>(357nm)**  
**At 4.66 kPa N<sub>2</sub> ∅Emission Decay**



# Nitrogen Fluorescent Lamp

(1) By Adding small amount of  $N_2$  to Ar, discharge is expanded and stabilized. By 1% of  $N_2$  addition, dimming characteristics is improved from 55%(1700-3080  $cd/m^2$ ) to 9.7%(380- 2900  $cd/m^2$ ).

(2) By adding  $N_2$  to Ar, the energy transfer from Ar metastable to  $N_2 C^3\Pi_u$  happens and  $N_2$  2nd Positive Band emission is radiated.

(3) At a lower pressure (4.67 kPa ) ,  $N_2$  is exhausted.



# Future Works

**Find / Develop best phosphors for Near-UV excitation**

**Stop N<sub>2</sub> exhaustion. (Absorption protecting coat?)**

**Find best conditions (Gas composition, Gas pressure ...)**



# Acknowledgements

**Shigeo Fujita** Professor Emeritus at Kyoto University

**Masaharu Aono** Professor Emeritus at Ehime University

**Hisayoshi Kurokawa** Technician at Ehime University

**Shuji Takubo**

**Yuji Hazata**

**Yusuke Muguruma**

**Tatsuya Matsuda**

**Dr. Spiros Kitsinelis**

**Sapphire (Cavendish Instruments Ltd.)**

**[Shikoku Consortium R&D projects for regional revitalization]**

**Shikoku Bureau Economy, Trade and Industry**

**Harrison Toshiba Lighting**

**Shientech**

**Nichia**