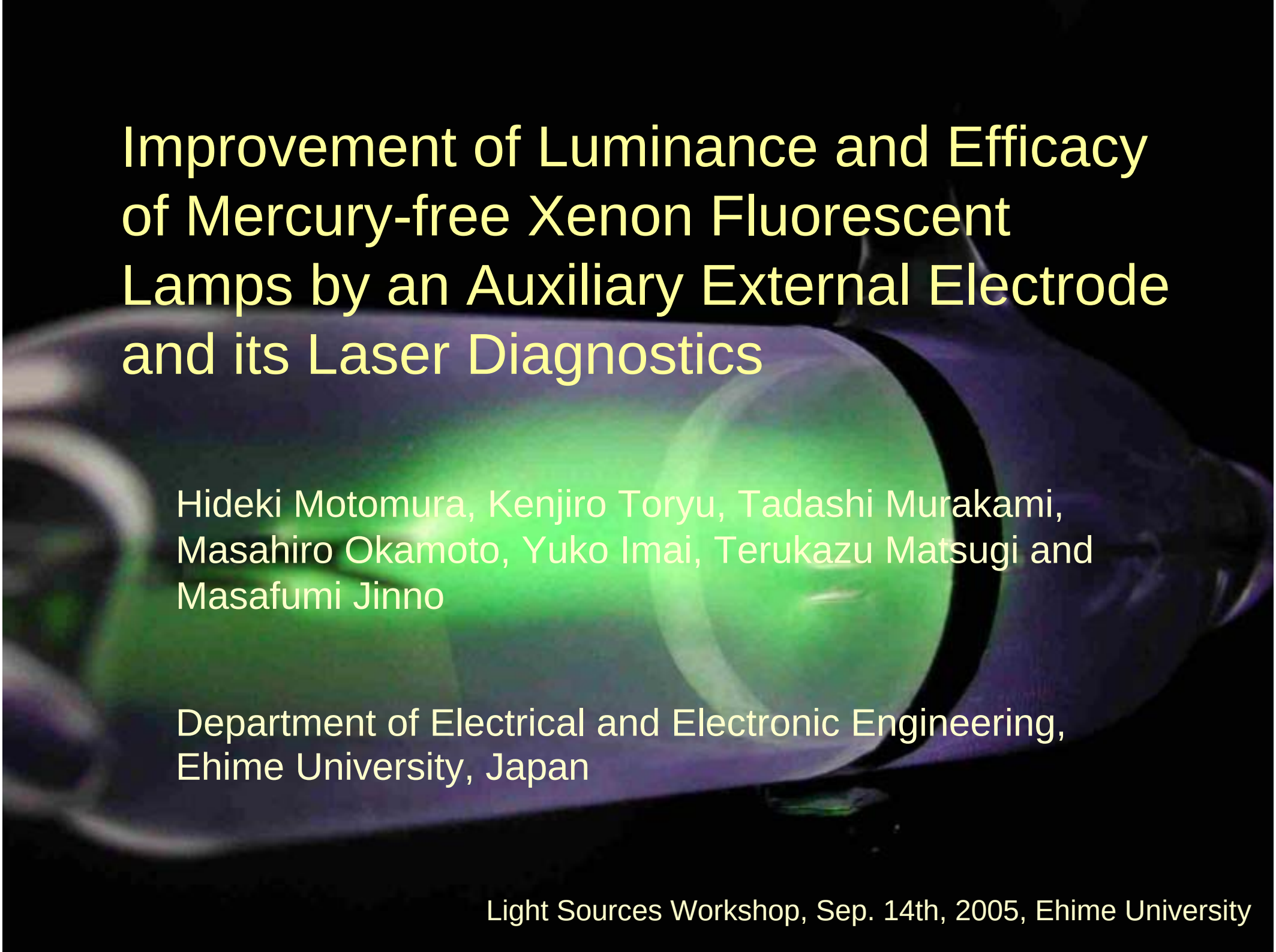

Improvement of Luminance and Efficacy of Mercury-free Xenon Fluorescent Lamps by an Auxiliary External Electrode and its Laser Diagnostics

Hideki Motomura, Kenjiro Toryu, Tadashi Murakami, Masahiro Okamoto, Yuko Imai, Terukazu Matsugi and Masafumi Jinno

Department of Electrical and Electronic Engineering, Ehime University, Japan

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Introduction (1)
~ Problems for fluorescent lamps

Mercury fluorescent lamps

- Widely used /
  Abundant consumption
  (← High efficacy etc.)
- Environmental problems

Xenon fluorescent lamps

- Non-toxic material
- Little influence of temperature on emission intensity
- Positive column contraction problem
- Low efficacy

Introduction (2)
~ Features of xenon fluorescent lamps

Inc. current

Diffuse positive column

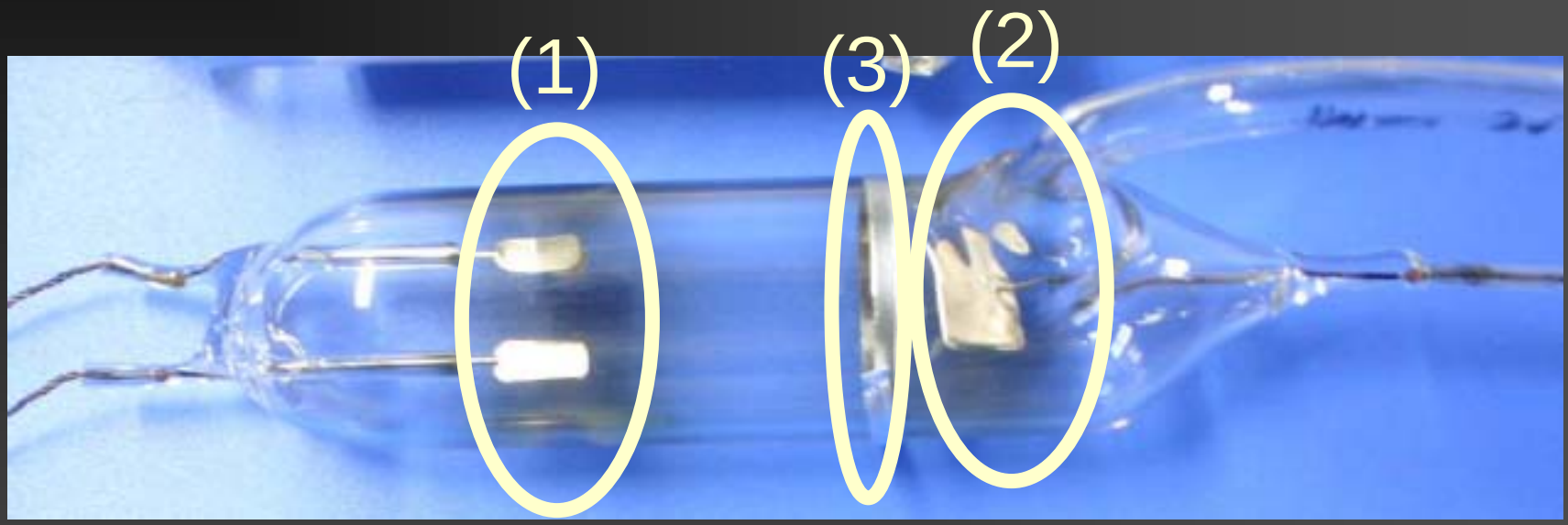
Contracted positive column

Contraction causes…

- Instability
- Decrease in uniformity
- Decrease in emission ratio of VUV to Vis. and Near IR
- Increase in self absorption

→ Difficulty of getting high luminous flux
Low efficacy

To expand the positive column



(1) Double electrodes

(2) Wide single cathode

(3) Auxiliary external electrode (AEL)

Brief review of previous study
~ Double electrodes

Single

6000 cd/m^2, 70 lm/W
(with phosphor)

Double

7000 cd/m^2, 60 lm/W
(with phosphor)

Effect: Positive column expansion
Result: Improvement of luminance (about 20%)
Problem: Decrease of efficacy
Equal current flowing two paths is necessary.

Brief review of previous study
~ Wide single cathode

Double cathode

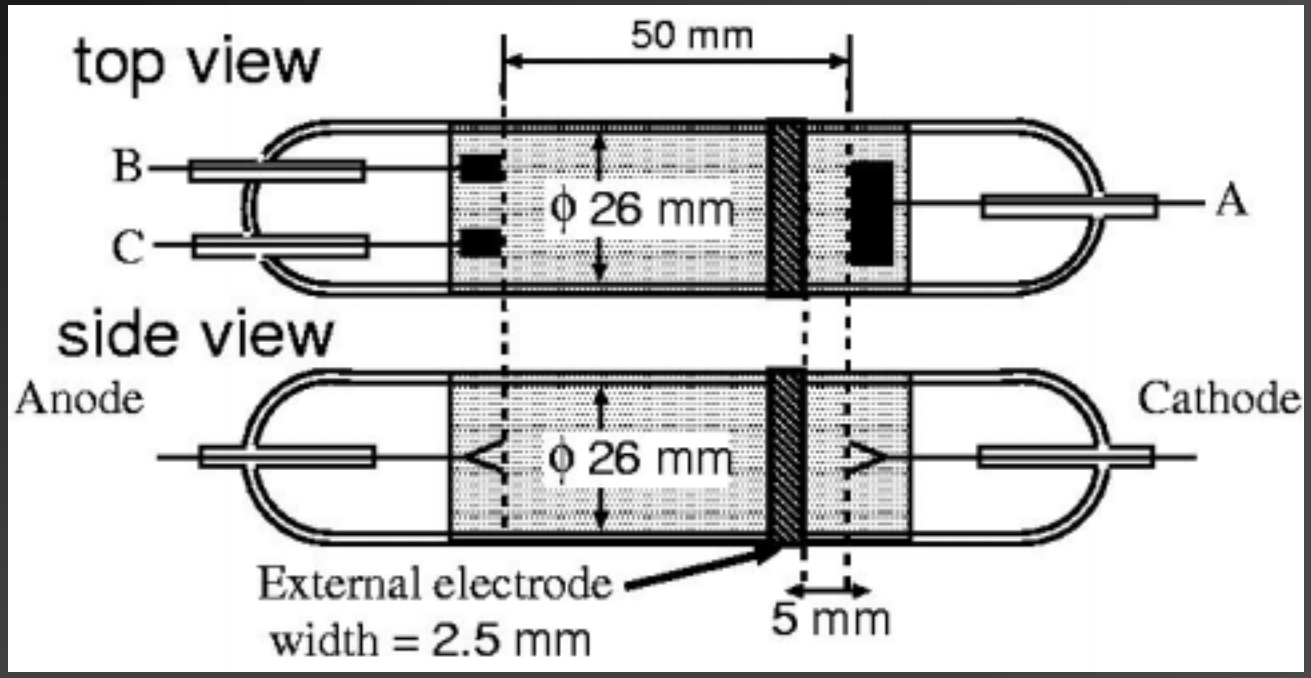
7000 cd/m^2, 60 lm/W

Wide single cathode

10 000 cd/m^2, 65 lm/W

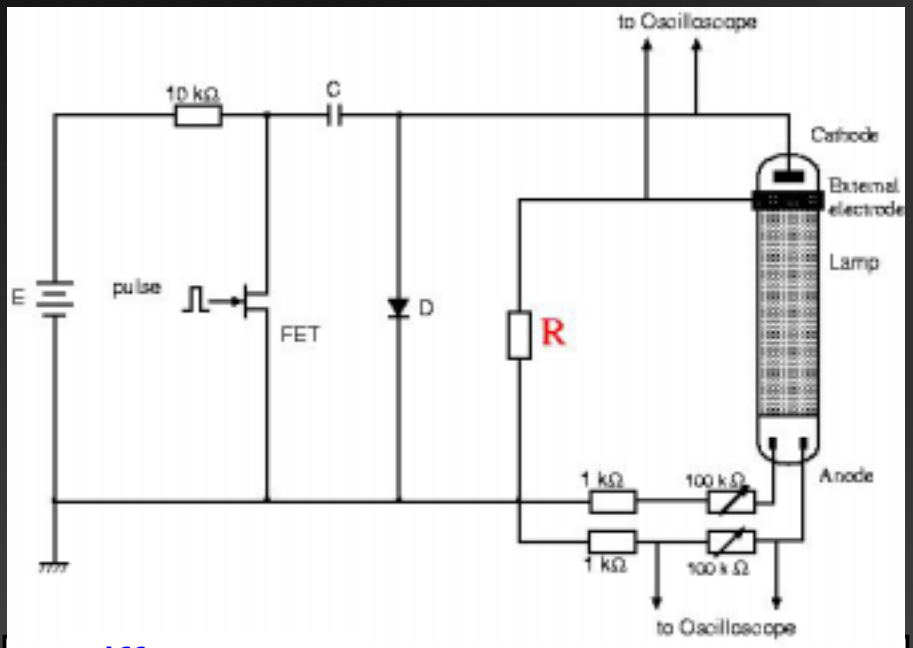
Effect: Stabilization of positive column
Easy to tune the current
Result: Improvement of luminance (about 40%)
Problem: Still low efficacy

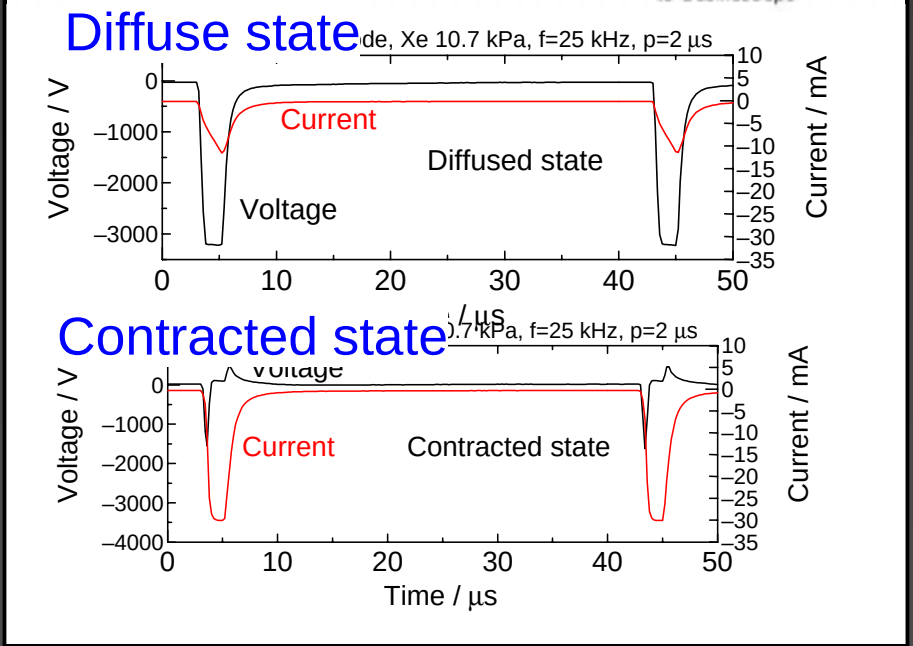
Schematic of the lamp



Gas: Xenon
Pressure: 10.7 kPa
Phosphor: White (Nichia, NP-107, NP-220, NP-360)
External electrode: Aluminum tape, 2.5 mm wide,
5 mm from the cathode

Experiment





- Negative pulsed voltage
  (25 kHz, 2 μs)
- Voltage, current – oscilloscope
  Luminance at the center –
  luminance meter
  Luminous flux – integration sphere
- Resistance *R* was changed –
  restrain the current flowing the external electrode.
- Measurement was done just before transition from diffuse to contracted state (maximum luminance is obtained).

Result (1)
~ without resistor: AEL was directly grounded

w/o AEL

10 000 cd/m^2, 65 lm/W

with directly grounded AEL

13 000 cd/m^2, 40 lm/W

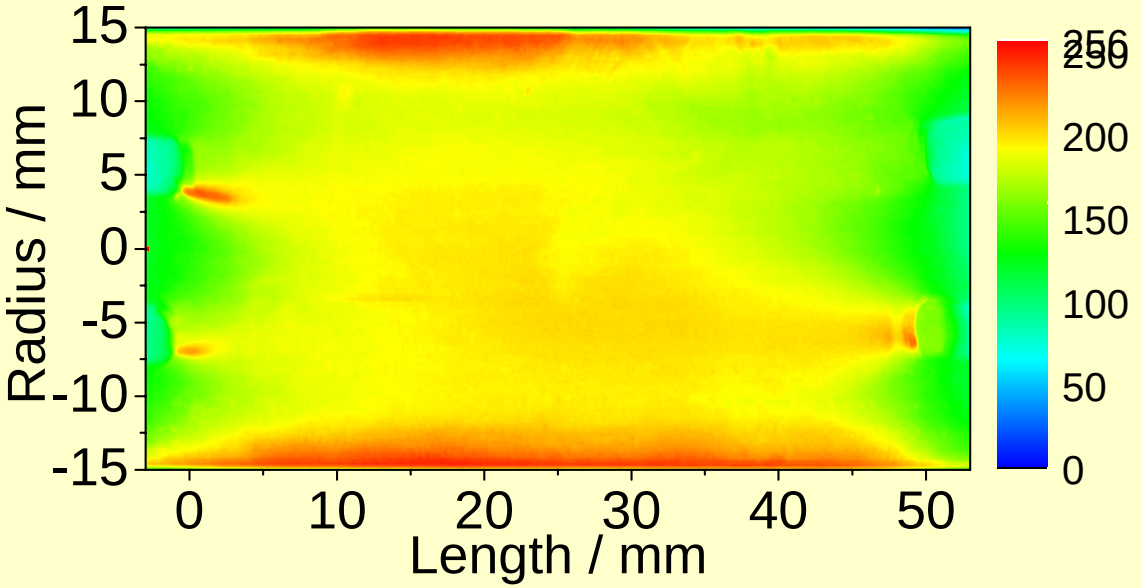
High luminance but low efficacy

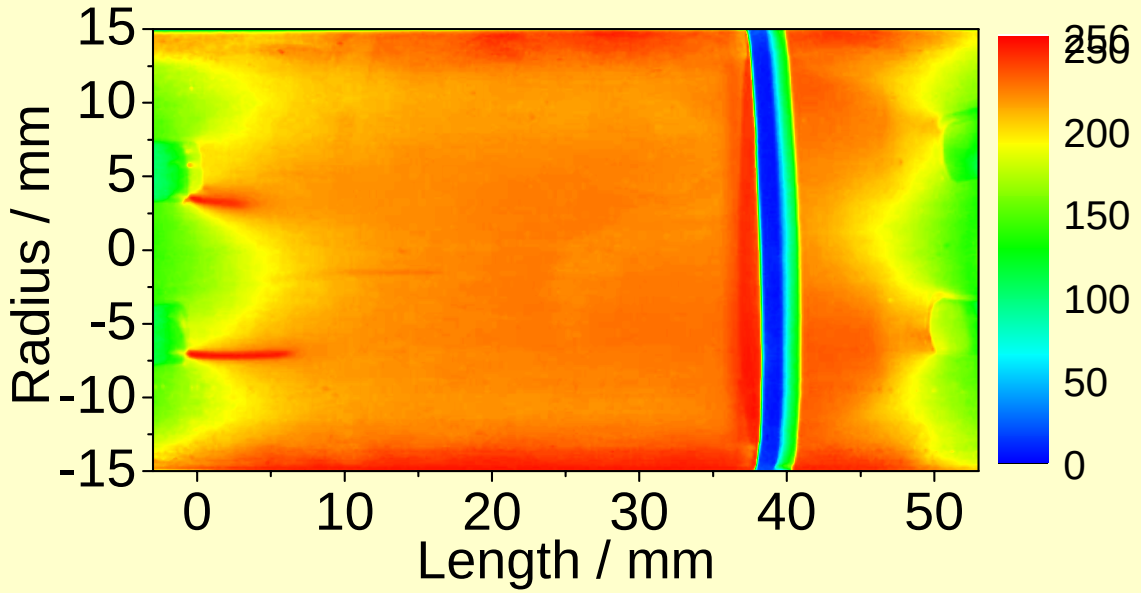
Necessity of suppression of power consumption

Result (2)
~ Influence of AEL on discharge state

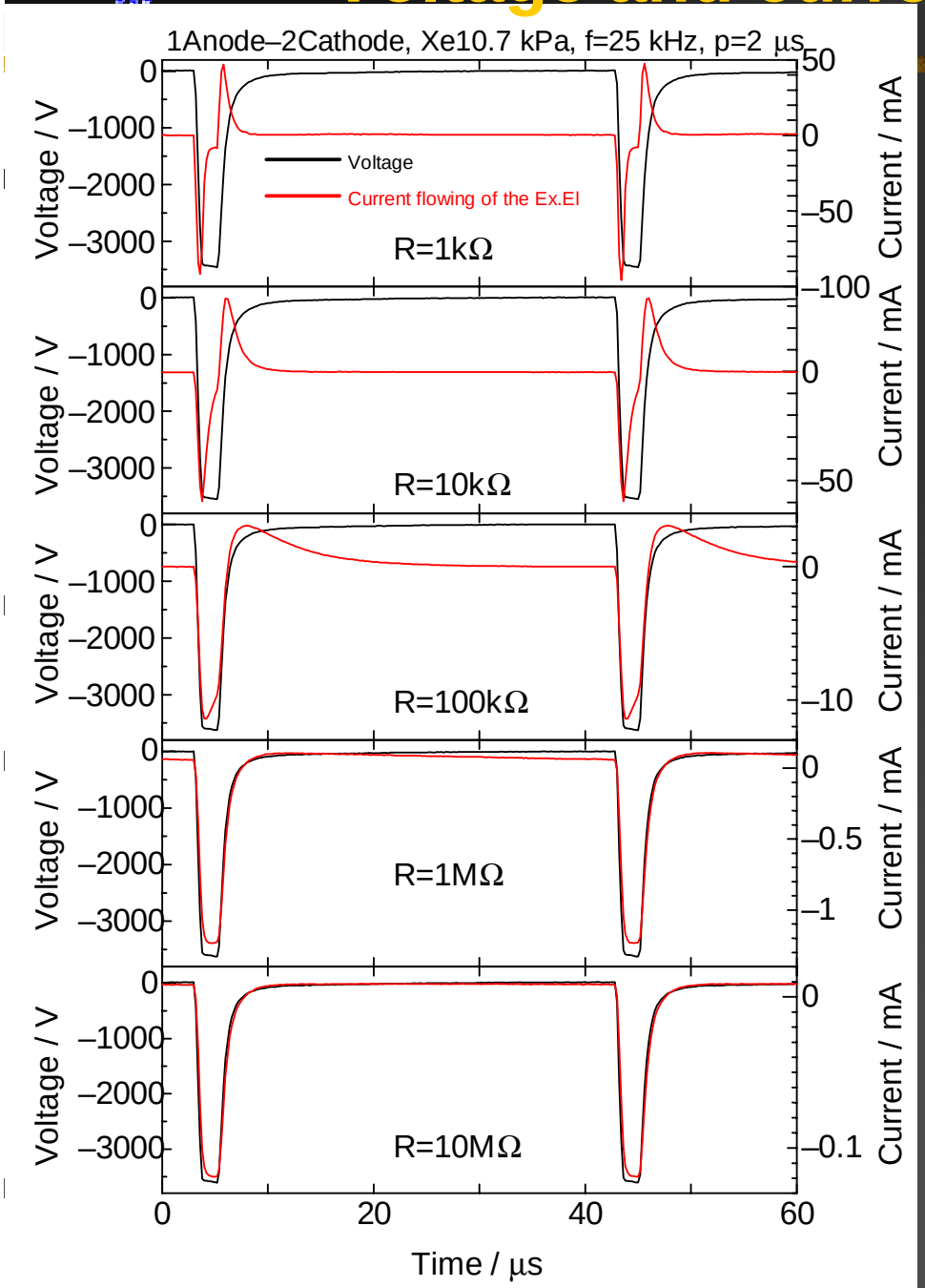
w/o AEL

With AEL





Result (3)
~ Voltage and current (total) waveform



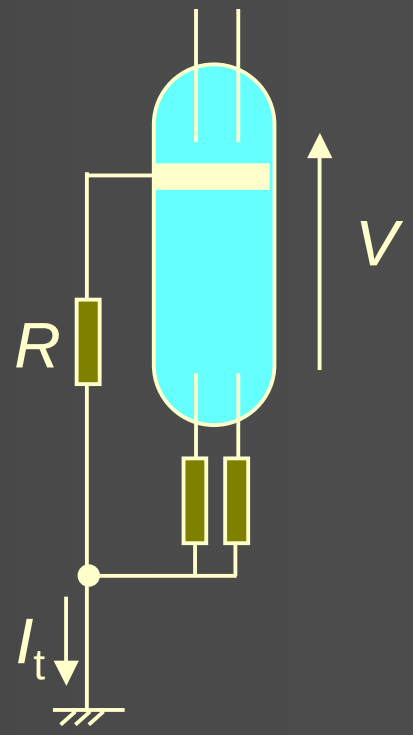
R=1 kΩ -- barrier mode

10 kΩ

100 kΩ

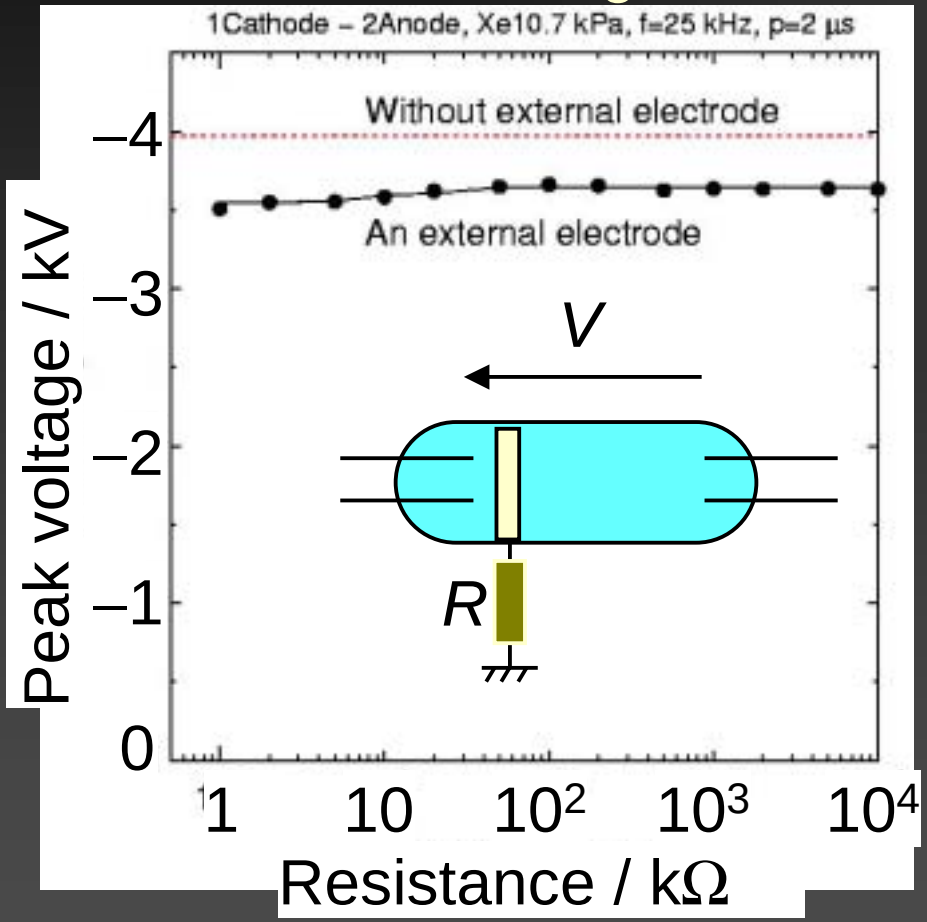
1 MΩ

10 MΩ -- cold cathode mode



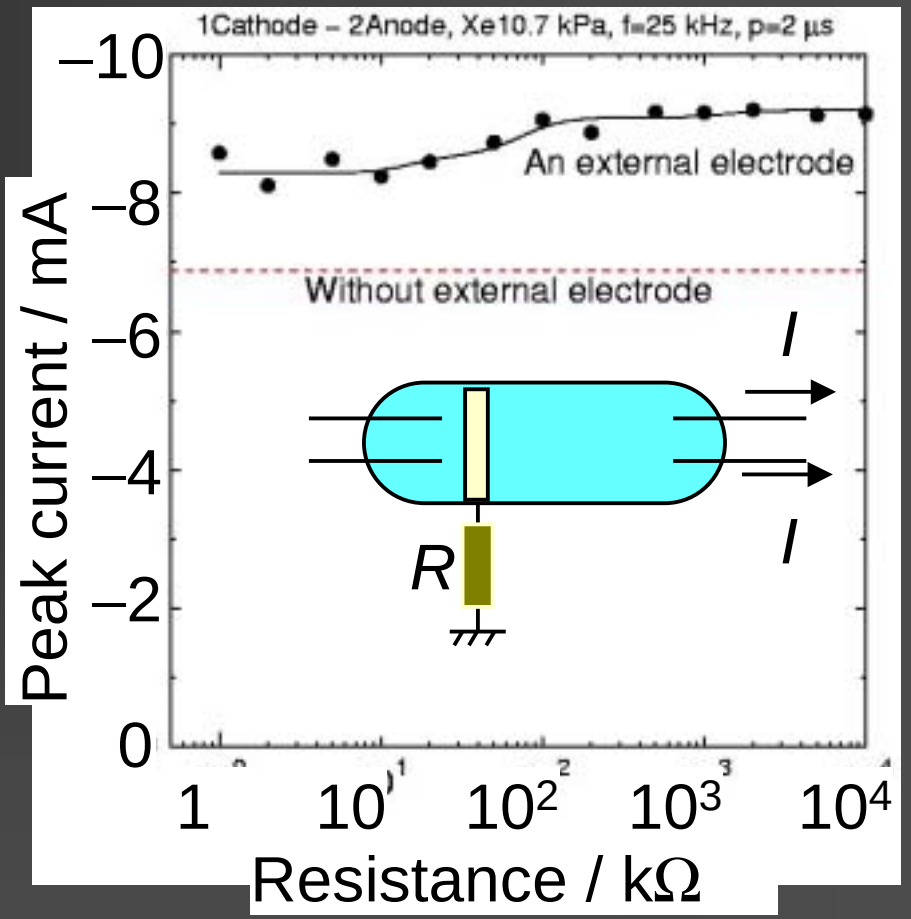
Result (4)
~ Voltage and current peak (internal)

Peak voltage



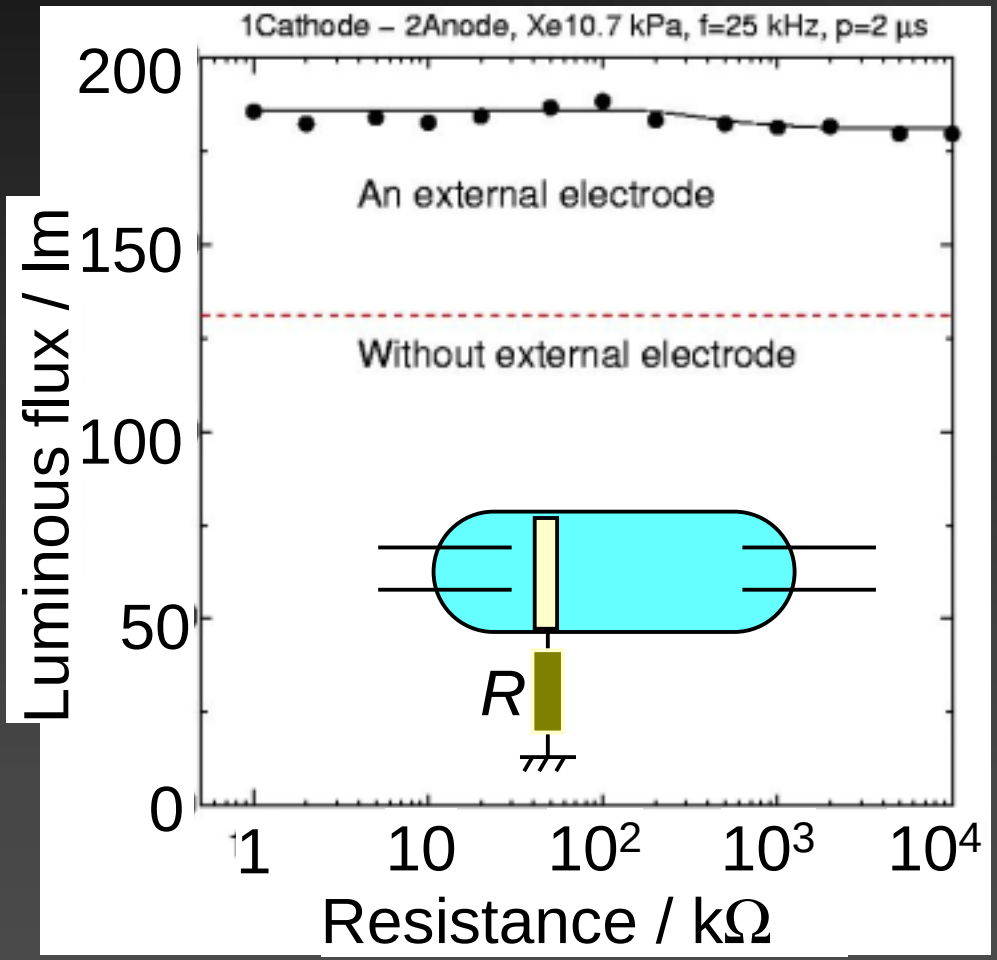
Decrease by AEL
Small dependence on *R*

Peak current



Increase by AEL
Increase by increasing *R*

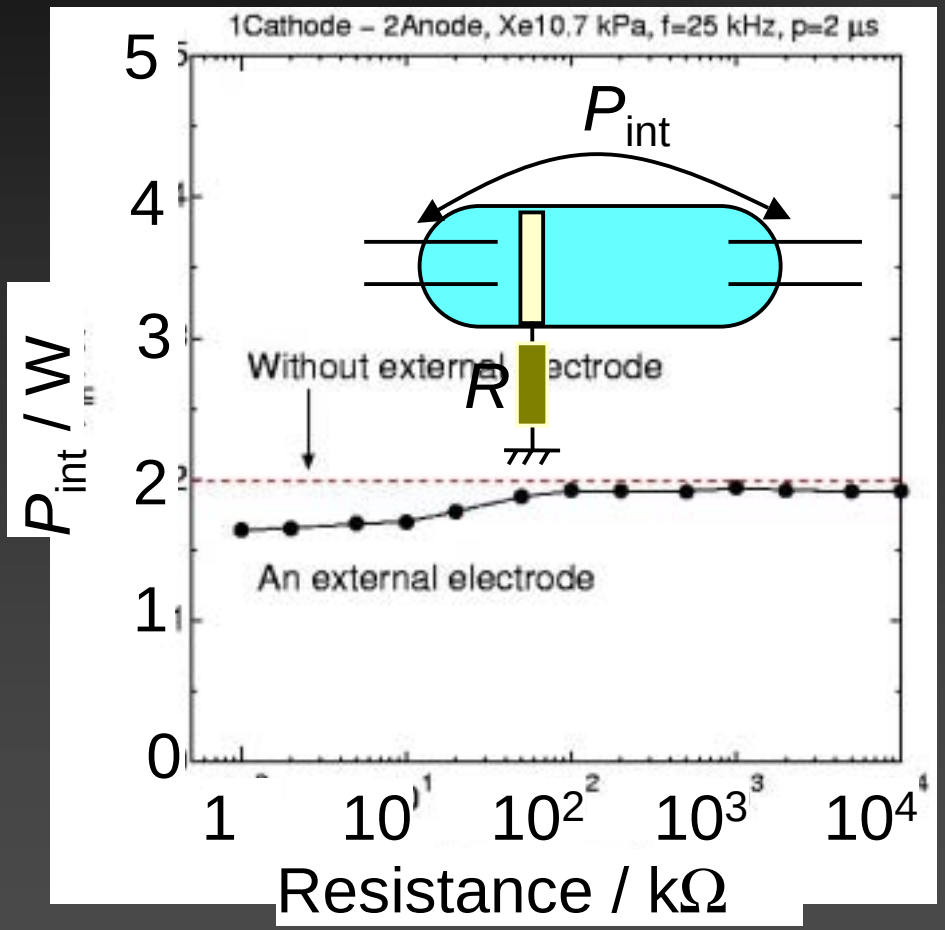
Result (5)
~ Luminous flux



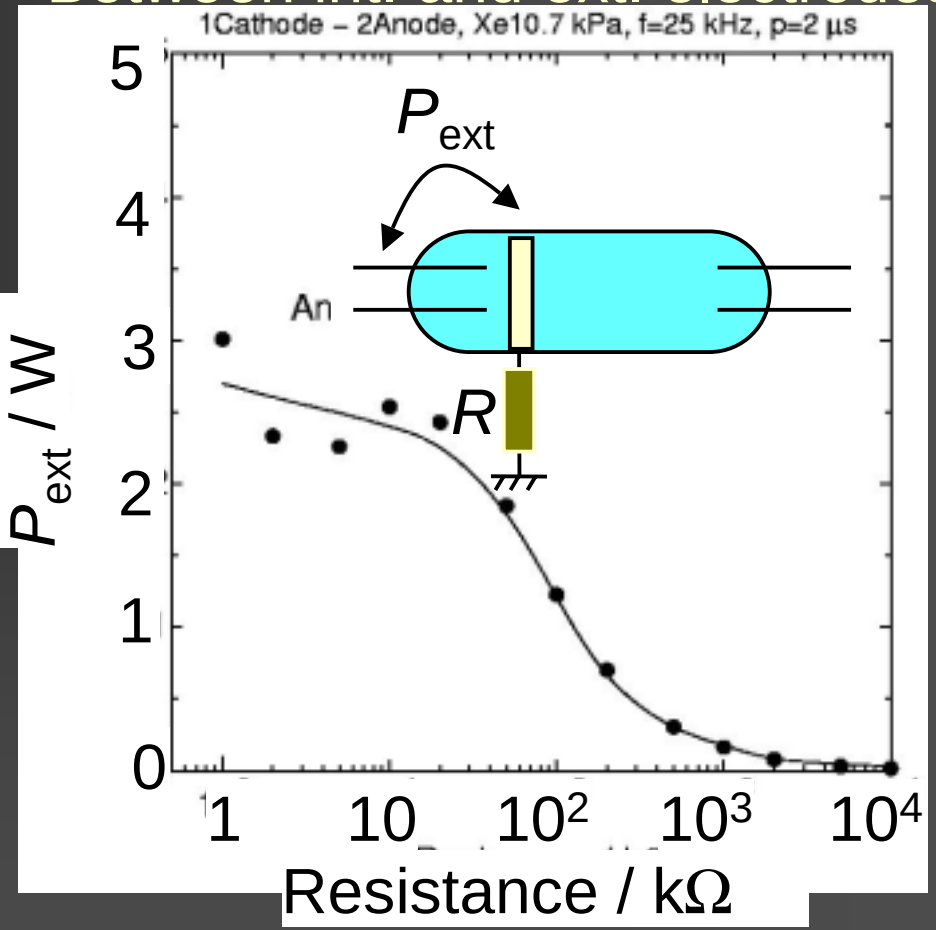
40% enhancement by *R*
Small dependence on *R*

Result (6)
~ Power consumption

Between int. electrodes



Between int. and ext. electrodes

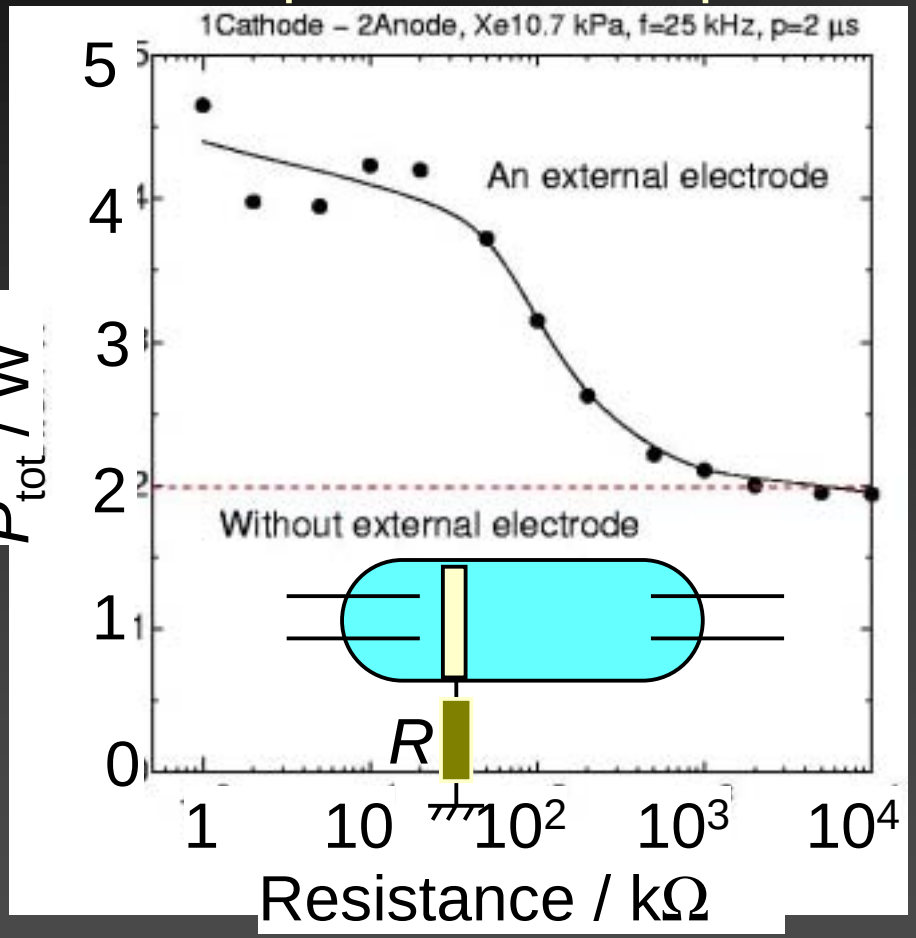


Small decrease by AEL
Increase by increasing *R*
(become equivalent to the case of w/o AEL)

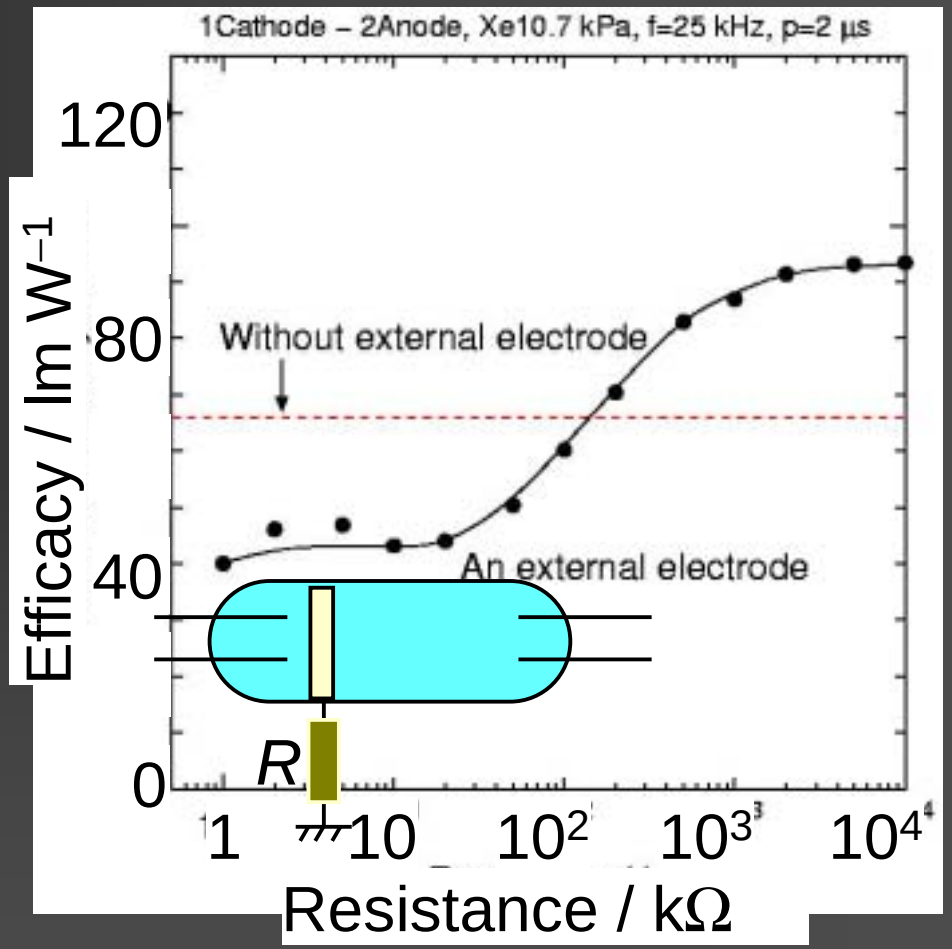
Decrease by increasing *R*
(become almost zero)

Result (7)
~ Total power consumption and efficacy

Total power consumption



Efficacy



Increase by AEL
Decrease by increasing *R*
(become equivalent to the case of w/o AEL)

Increase by increasing *R*
(efficacy improvement)

Summary of the results

	By AEL	By increase in *R*
Peak voltage	↓	→
Peak current (int.)	↑	↗
Peak current (ext.)	–	↘
Power consumption (int.)	↓	↗
Power consumption (ext.)	–	↘
Total power consumption	↑	↘
Luminous flux	↑	→
Efficacy	↓	↗

Discussion
~ Two assumed effects of AEL

Effect A: Current (Barrier discharge)

Wall charge (electron)

Bec Increase in R period

Voltage drop
Current increase

Effect B: Electric field

Positive column is attracted to the AEL

Discharge path expansion

Larger input current with maintaining positive column diffusion

Luminance increase

Discussion
~ Two assumed effects of AEL

Effect B: Electric field

Positive column is attracted to the AEL

↓

Discharge path expansion

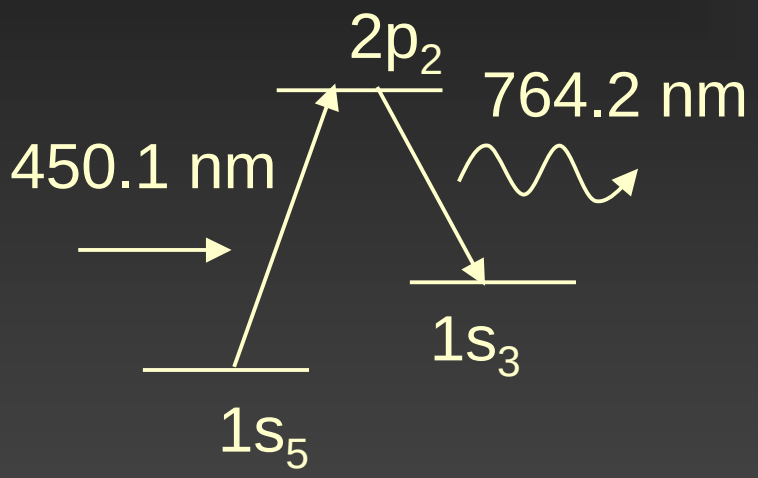
↓

Larger input current with maintaining positive column diffusion

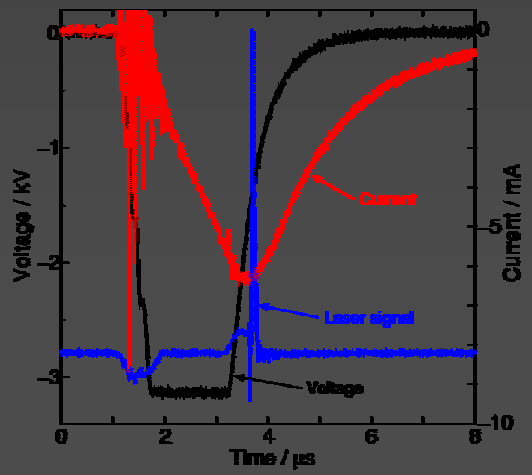
Luminance increase

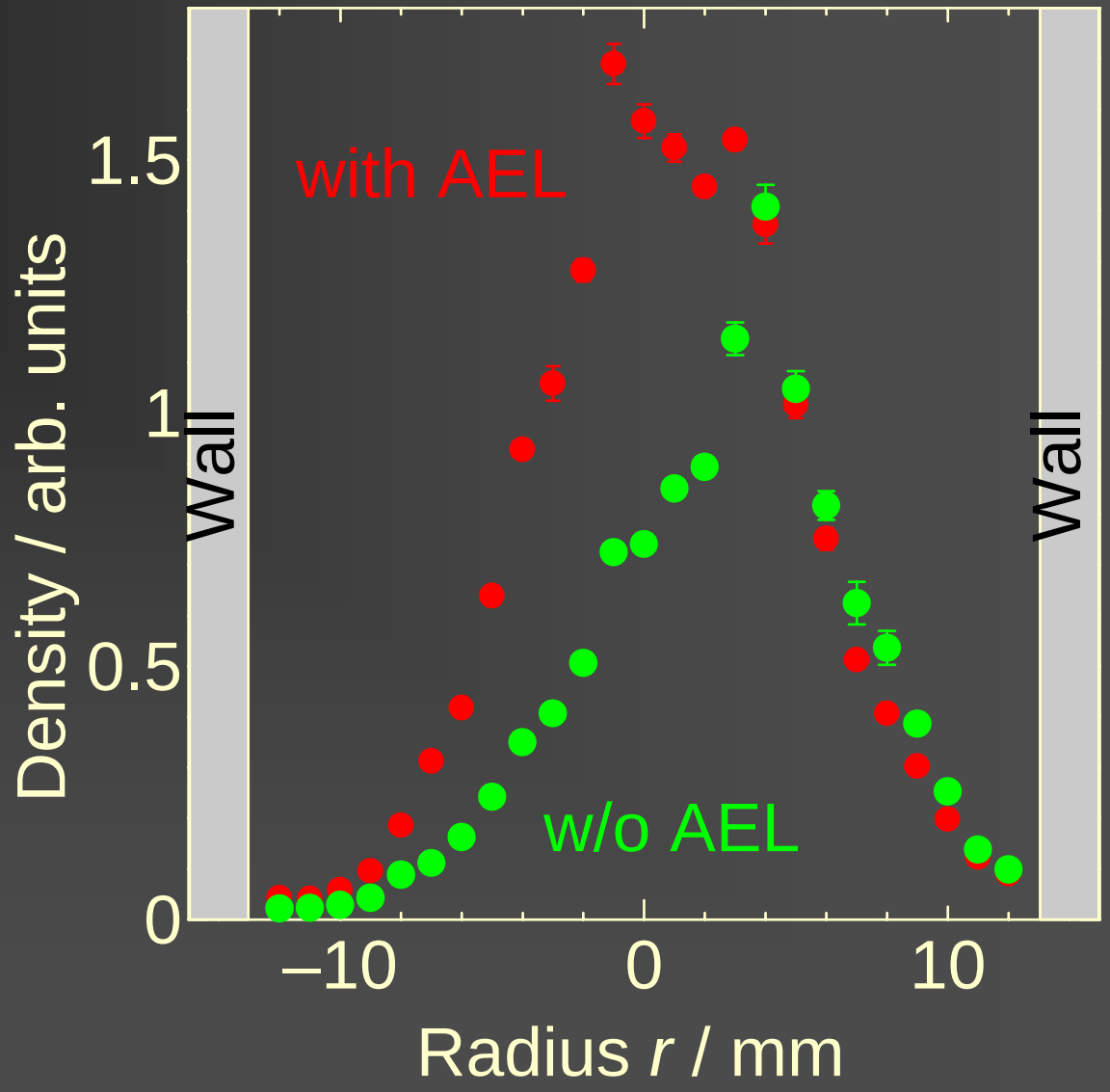
Behavior of metastable atoms

Measured by LIF technique
OPO, 10 Hz, 10 ns



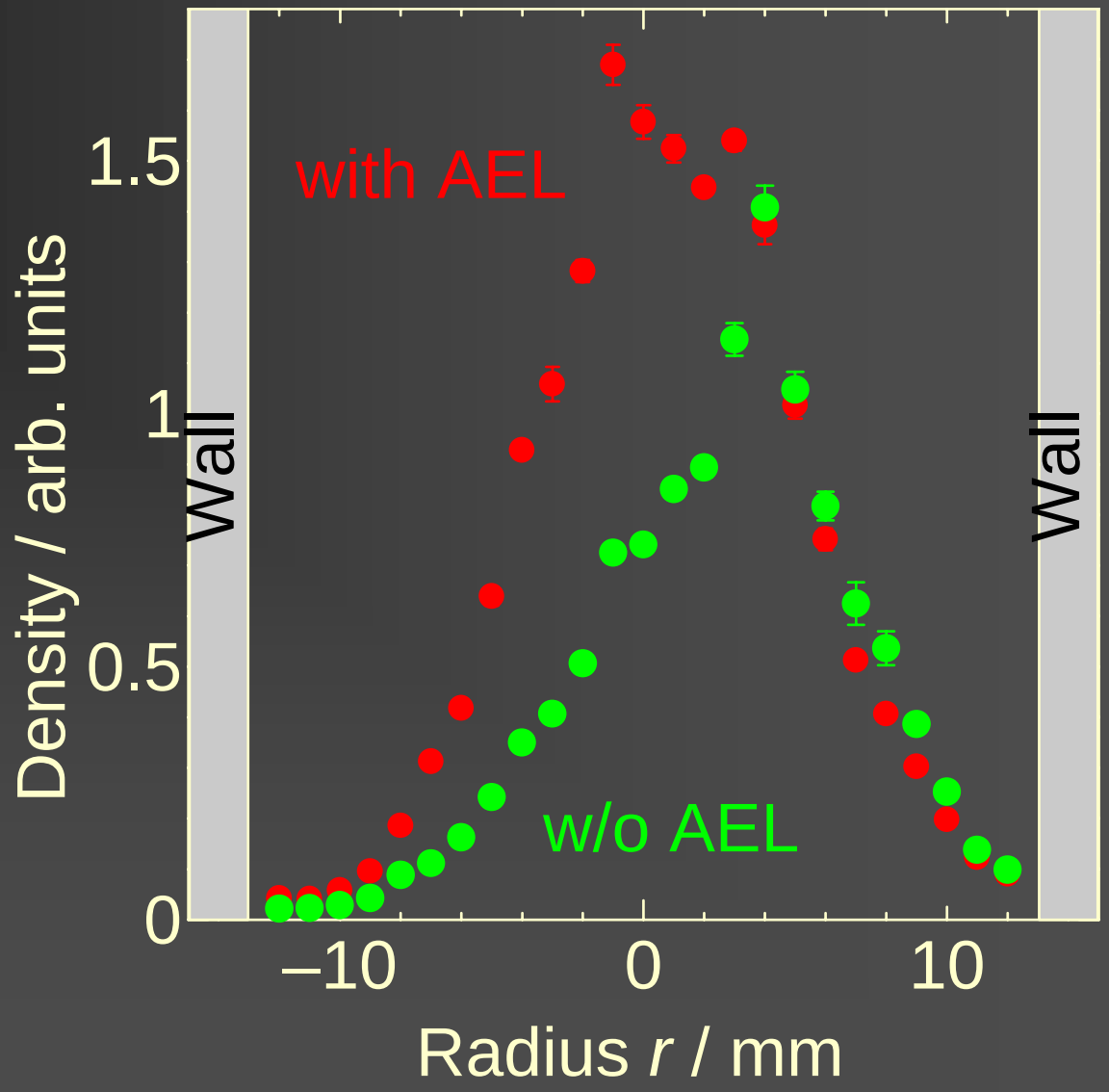
At the current peak





Behavior of metastable atoms

- Increase in total metastable atoms
- Expansion of metastable radial distribution



Conclusion and future work

Conclusion

- Using AEL → Luminance and flux is improved
- Increasing *R* → Efficacy is improved

⇩

13 000 cd/m^2, 180 lm, 90 lm/W

Future work

- Increase in flux
- Systematic investigation of plasma parameter

Acknowledgments

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