



CORE



Extreme ultraviolet alkali metal source at 40 nm

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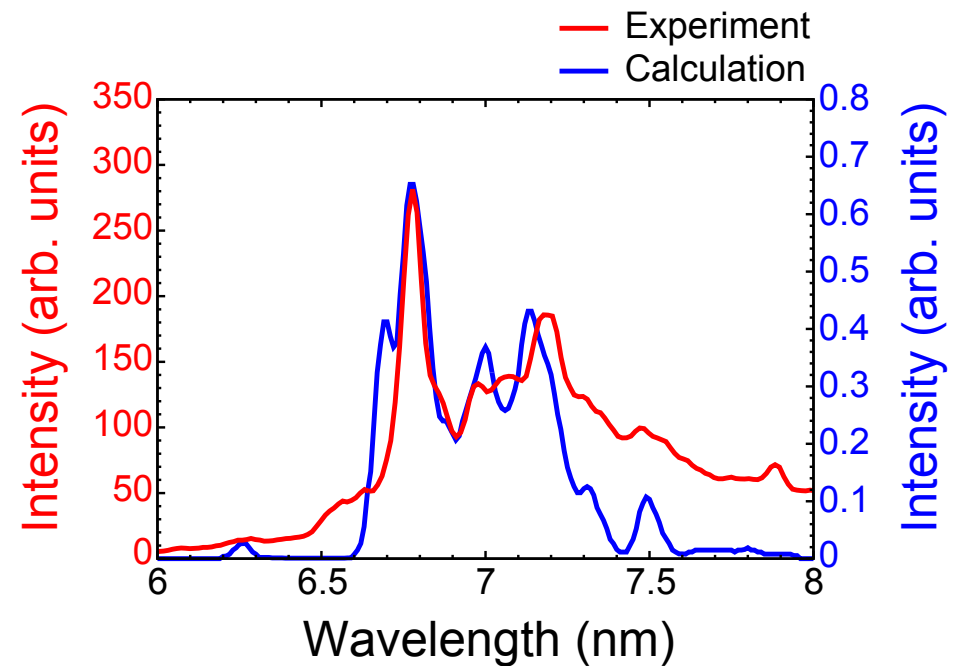
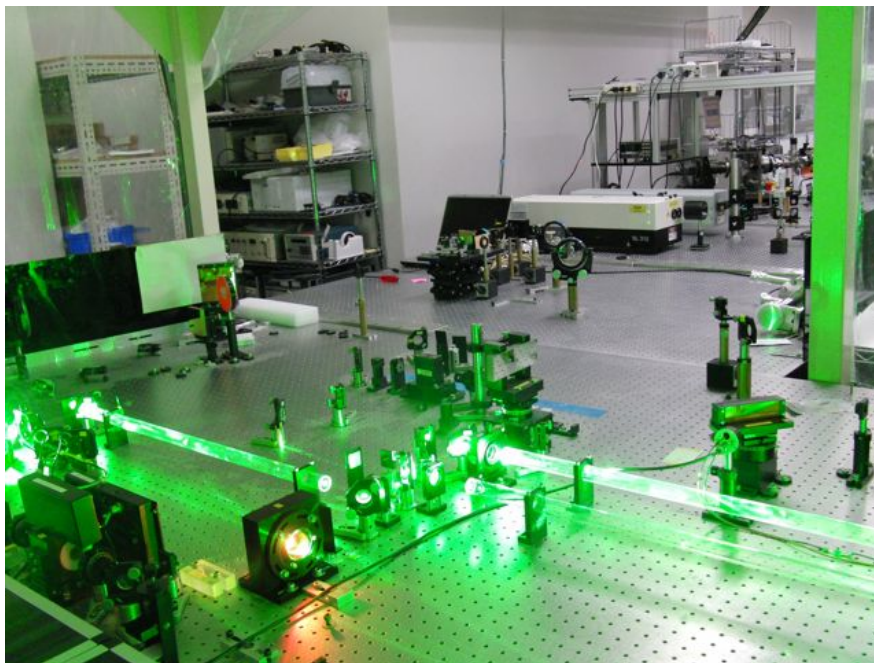
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Research Centre of the Polish Academy of Sciences in Paris

14:35-15:00, Thursday 17 November, 2011

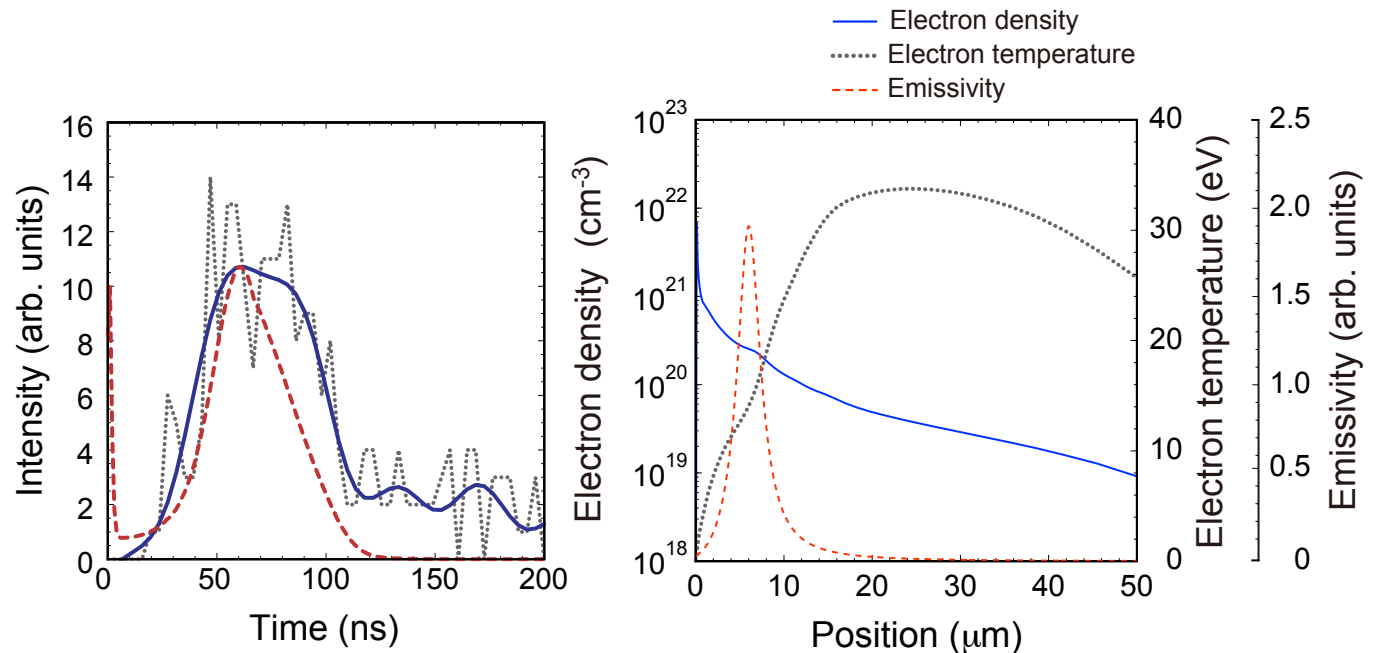
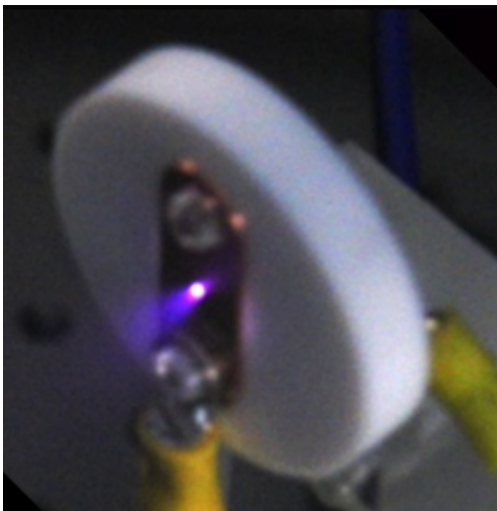
6.X nm with UCD

- (1) Laser-produced plasmas for 6.7 nm using fs, ps, and ns
- (2) Discharge-produced plasma with laser-ablated Gd/Tb vapors
- (3) Atomic processes in plasmas (UCD)



What's new

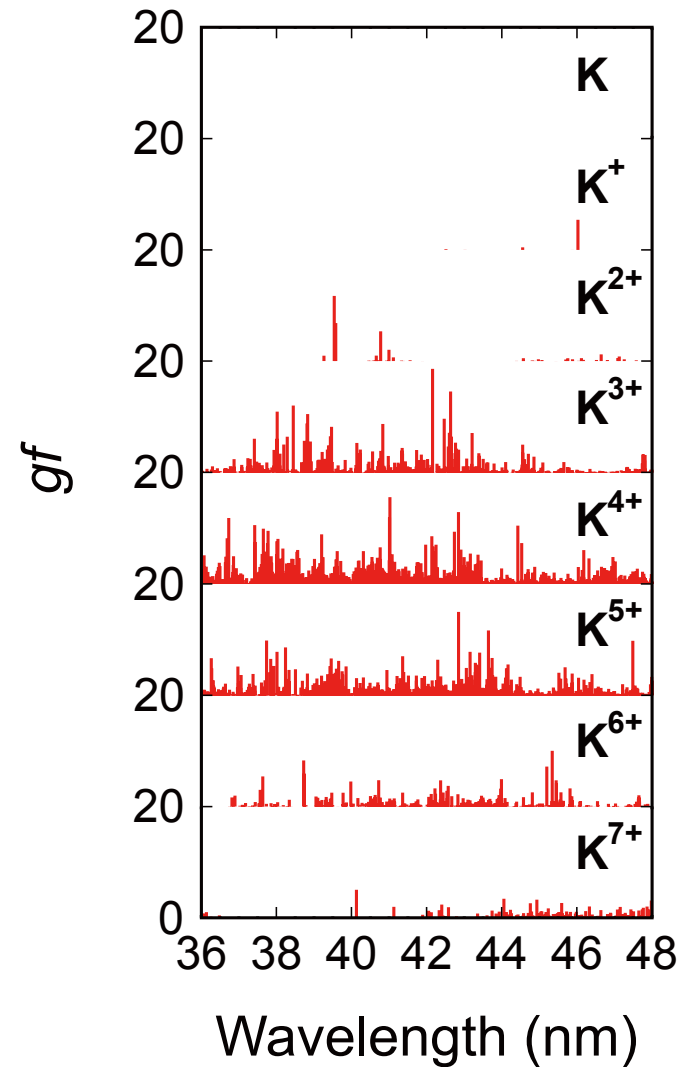
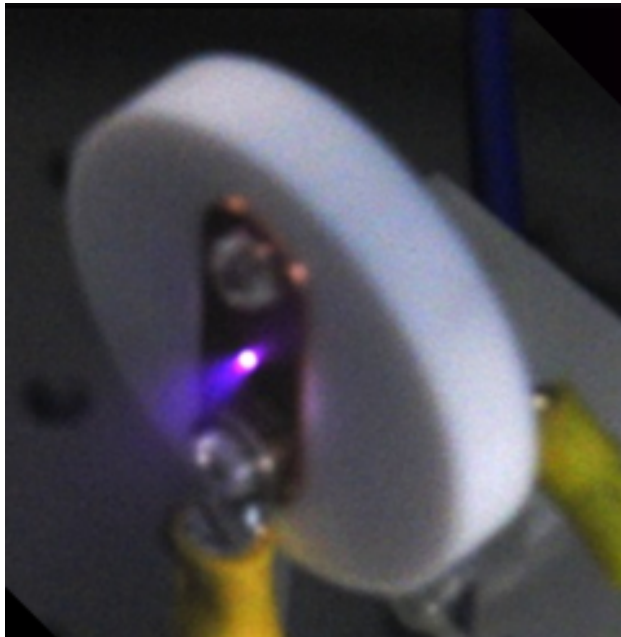
- Observation of the spectra of a potassium plasma
- Evaluation of the multiple charge state ions
- Comparison between LPP and DPP



Why alkali metal XUV?

- (1) Low melting temperature [K (potassium: 63 °C)]
(easy vaporization by discharge)
- (2) Strong *gf* lines around XUV spectral region
- (3) Little study of alkali metal XUV sources
(is equal to little academic paper)

Potassium source around 40 nm



Publication

APPLIED PHYSICS LETTERS 96, 131505 (2010)

Characteristics of extreme ultraviolet emission from a discharge-produced potassium plasma for surface morphology application

Takeshi Higashiguchi,^{1,2,a)} Hiromitsu Terauchi,¹ Noboru Yugami,^{1,2} Toyohiko Yatagai,¹ Wataru Sasaki,³ Rebekah D'Arcy,⁴ Pdraig Dunne,⁴ and Gerry O'Sullivan⁴

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We have demonstrated a discharge-produced microplasma extreme ultraviolet source based on a pure potassium vapor. Potassium ions produced strong broadband emission around 40 nm with a bandwidth of 8 nm (full width at half-maximum). The current-voltage characteristics of microdischarge suggest that the source operates in a hollow cathode mode. By comparison with atomic structure calculations, the broadband emission is found to be primarily due to $3d-3p$ transitions in potassium ions ranging from K^{2+} to K^{4+} . © 2010 American Institute of Physics.

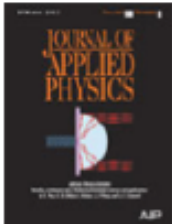
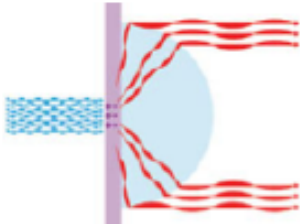
One of JAP Highlights

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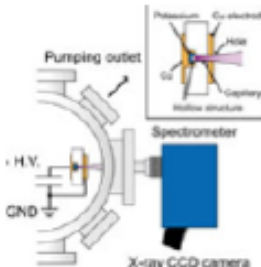
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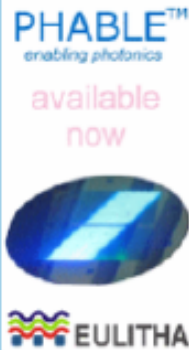

Research Highlights

 **Microdischarge extreme ultraviolet source with alkali metal vapor for surface morphology application**
Takeshi Higashiguchi, Hiromitsu Terauchi, Takamitsu Otsuka, Mami Yamaguchi, Keisuke Kikuchi, Noboru Yugami, Toyohiko Yatagai, Wataru Sasaki, Rebekah D'Arcy, Pdraig Dunne, and Gerry O'Sullivan
We have characterized a discharge-produced potassium plasma extreme ultraviolet (XUV) source. This compact capillary XUV source with a photon energy of 30 eV is a useful XUV emission source for surface morphology applications.

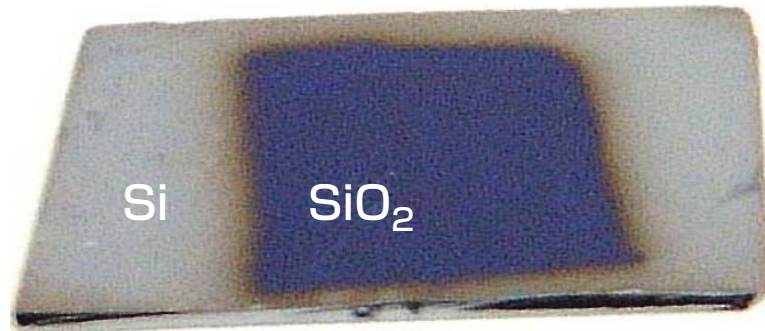
Announcements

Help with language editing
We are excited to announce a new partnership with Edanz to provide language editing services to AIP journal authors at reduced rates. Edanz offers the services of experienced native English-speaking editors with expertise in your area as well as assistance with related activities such as writing cover letters and responding to peer review comments.
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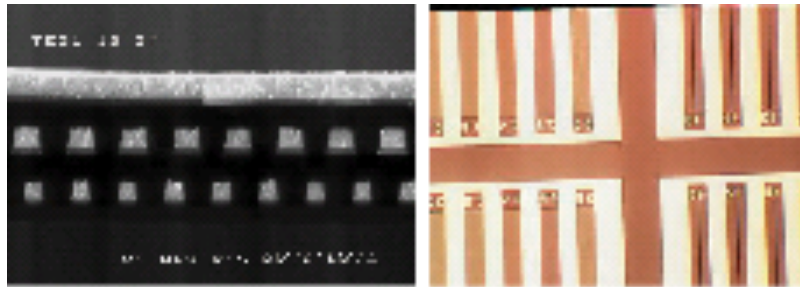
- See 15 Nov '10 Issue for Special Topic on Selected Papers from the International Conference on Flexible and Printed Electronics, Jeju Island, Korea, 2009 | [Read more](#)
- Congratulations to the recipients of the Presidential Early Career Awards for Scientists and Engineers (PECASE), including JAP authors Sergei V. Kalinin, Michael T. Laub, Willie J. Padilla, and Eric Pop.
- See 1 May '10 Issue for Proceedings of the 11th Joint MMM-Intermag Conference



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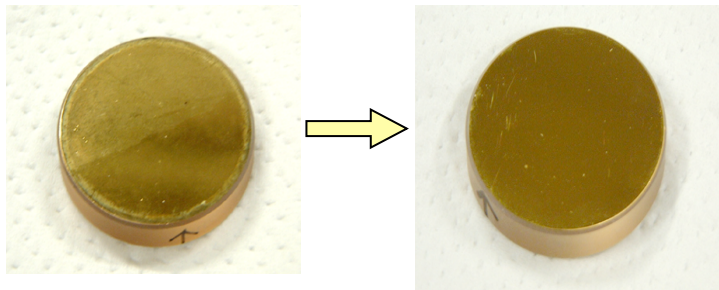
Applications by us



Remove SiO₂ layer

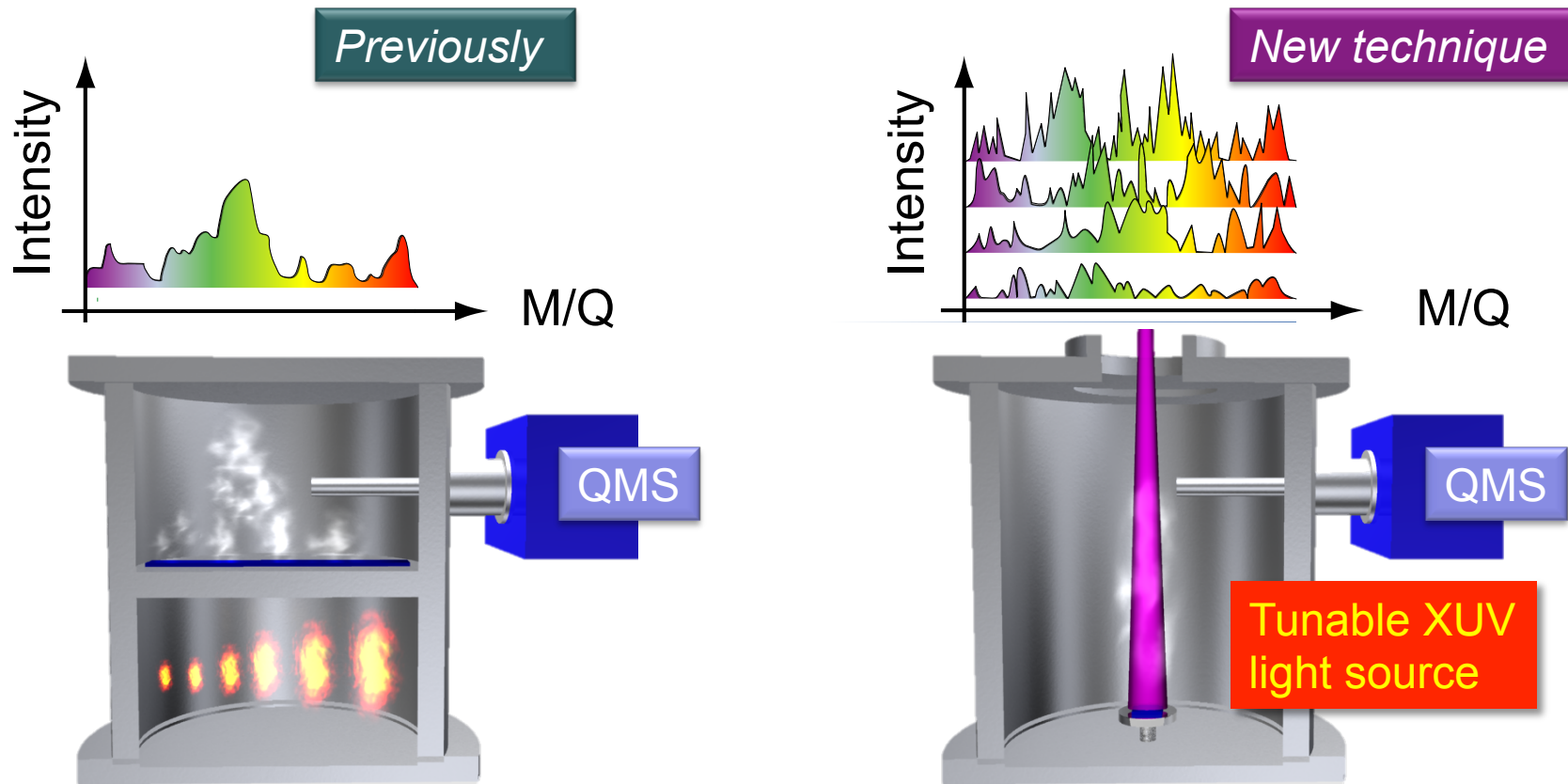


VUV CVD



Cleaning of the grating

Photo-stimulated desorption mass spectrometer using EUV emission

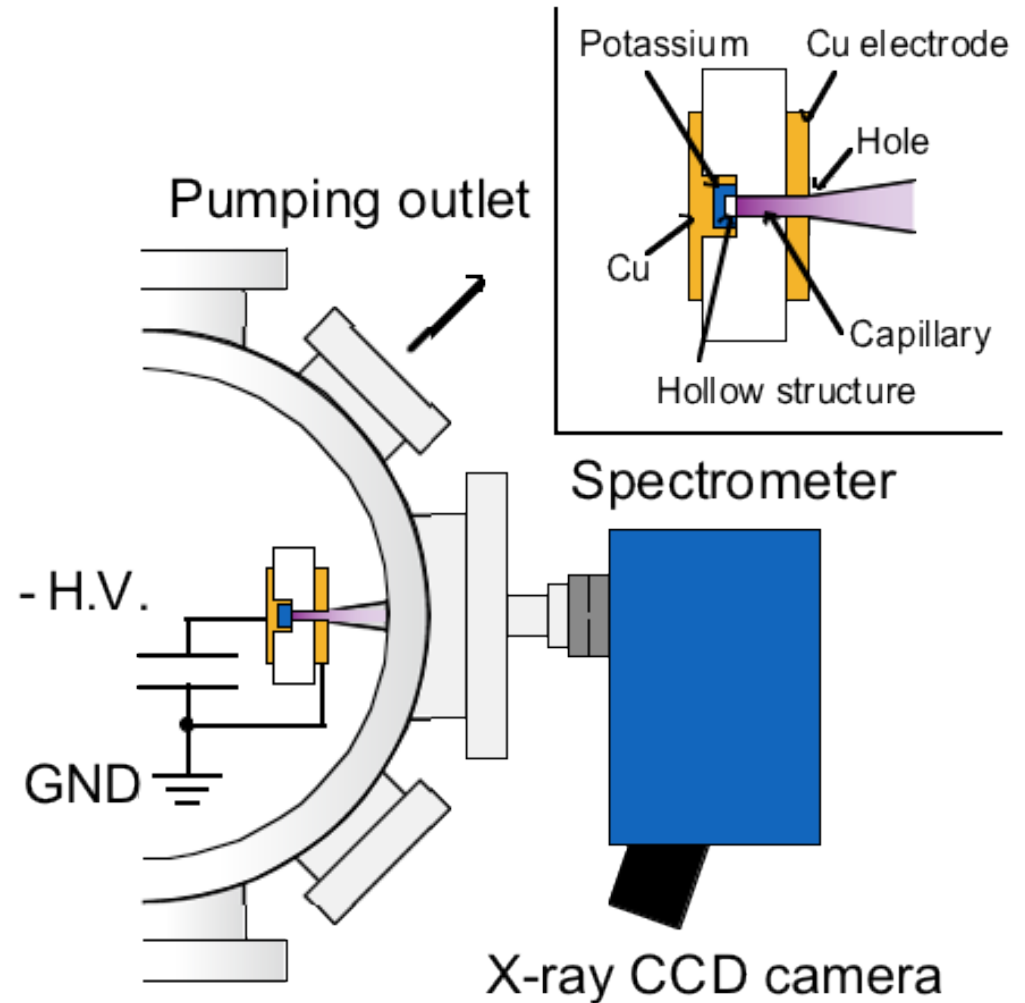
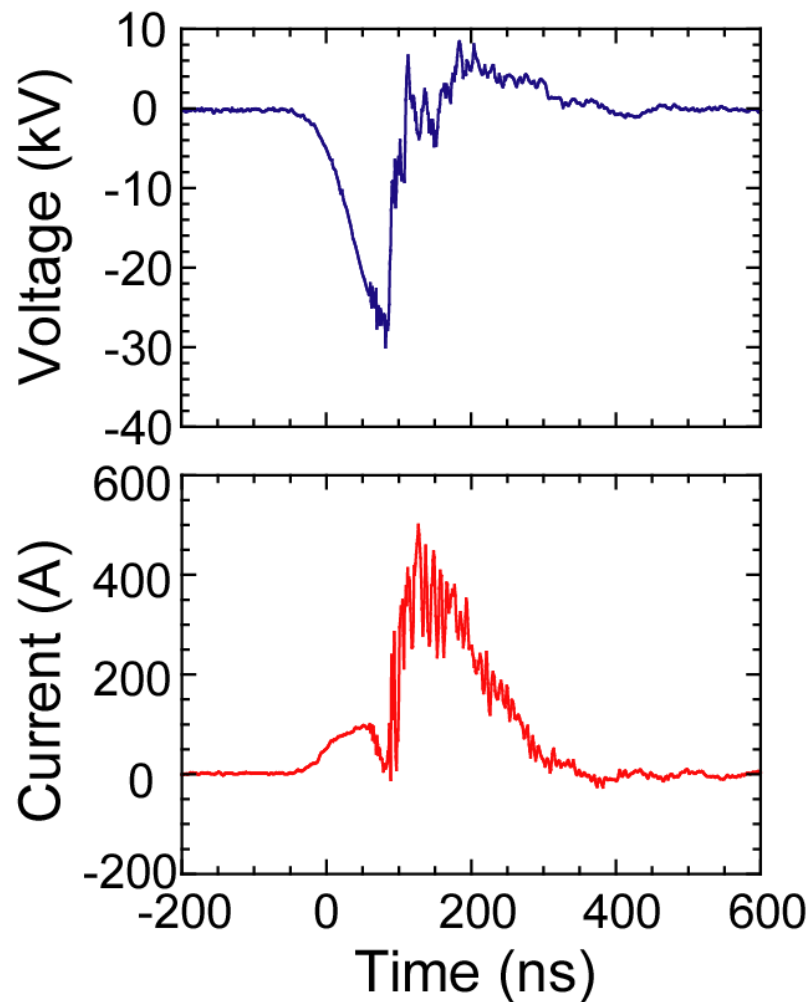


- Photodesorption → No damage
- Tunable XUV light source → Tunable material

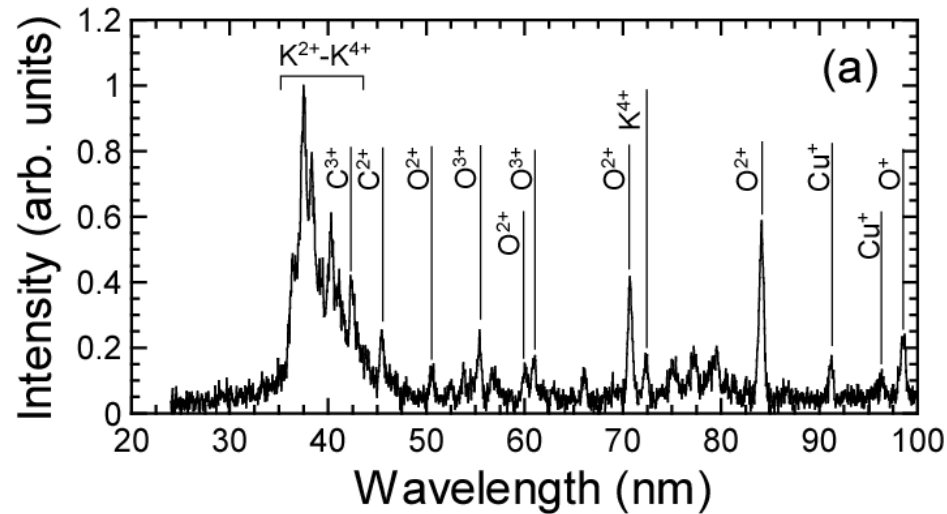
Objective

We characterize the capillary discharge-produced plasma XUV source by use of pure alkali metal vapor.

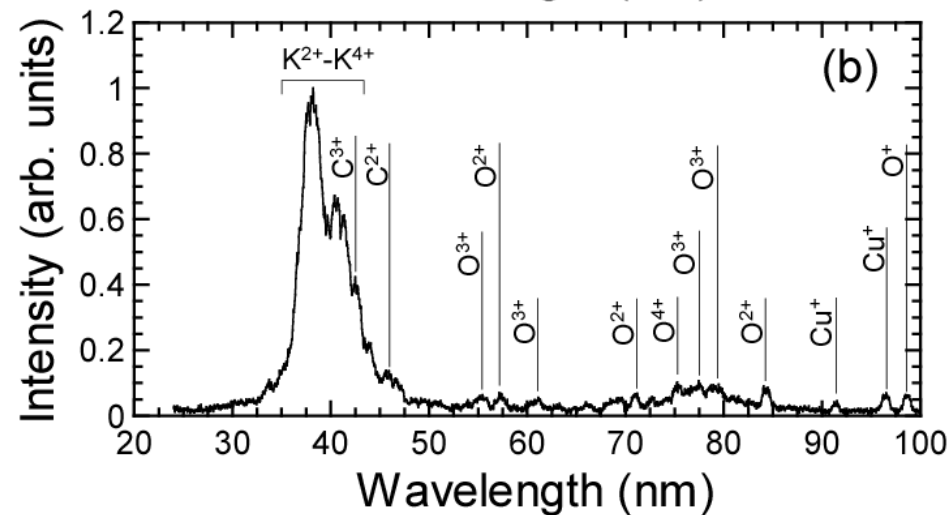
Schematic diagram of the experimental apparatus



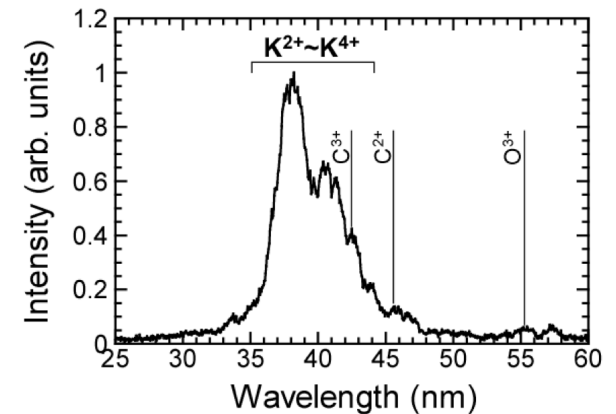
Emission spectra from the different capillary inner diameters



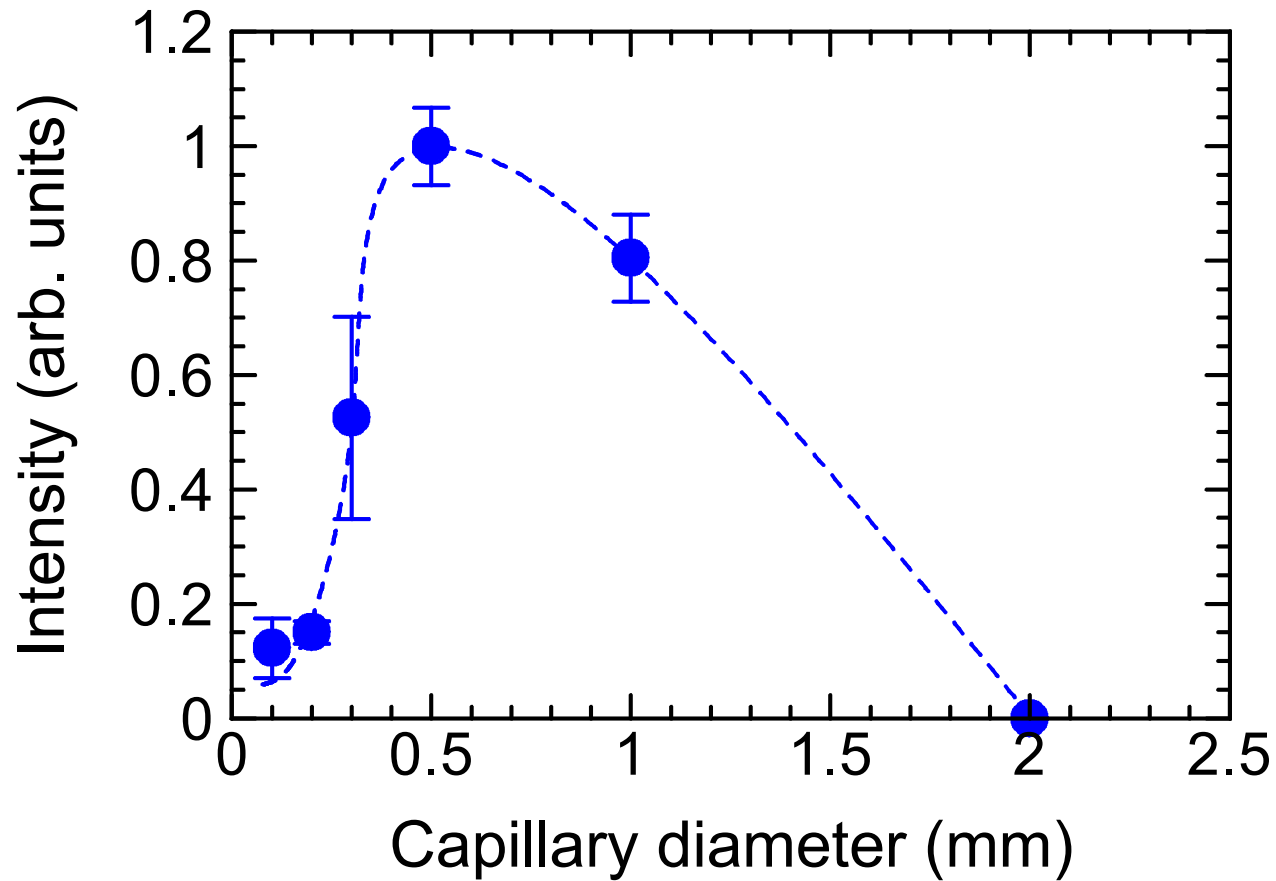
(a) Inner diameter: 1 mm



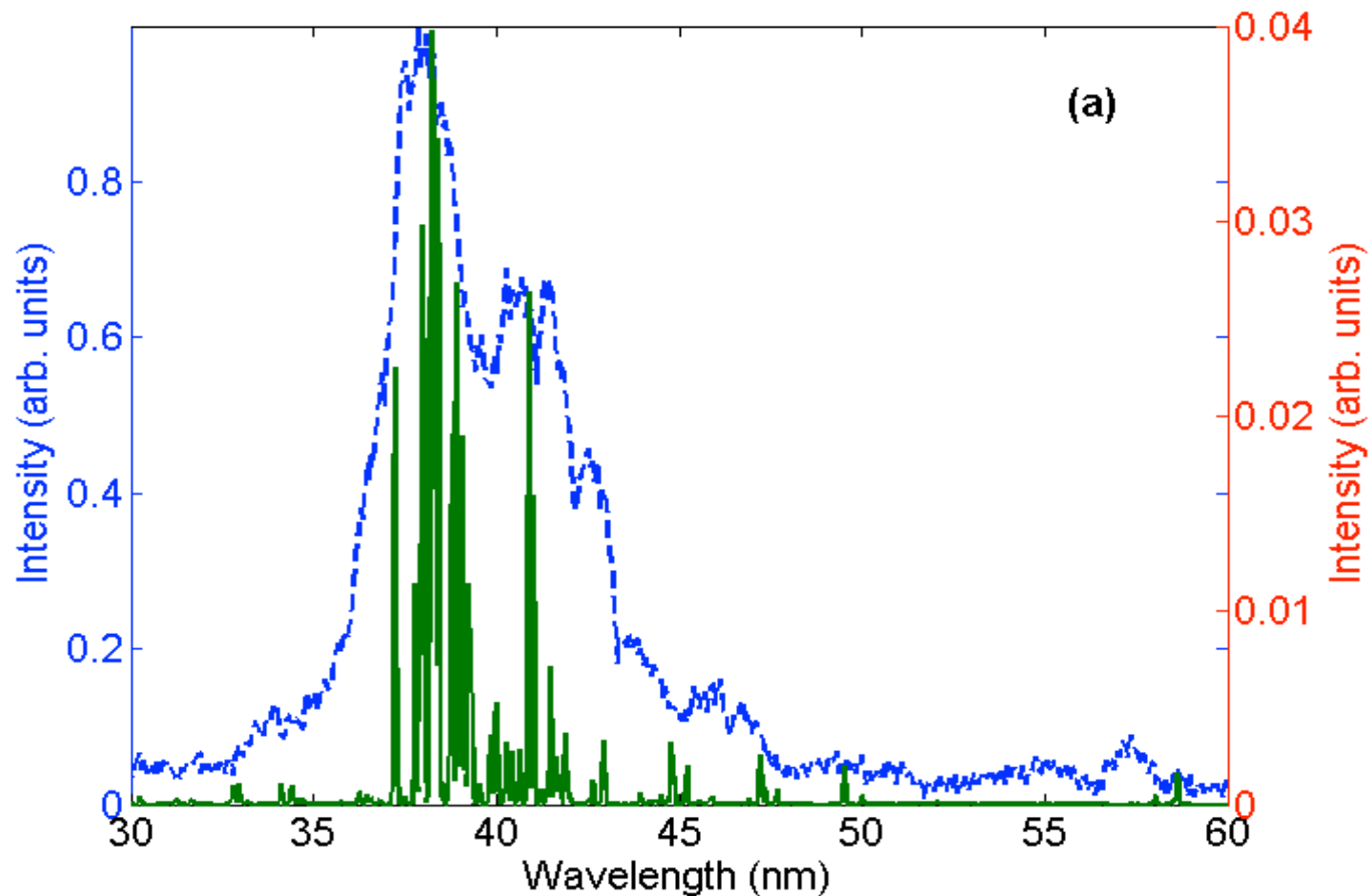
(b) Inner diameter: 0.5 mm



Capillary inner diameter dependence of the emission energy

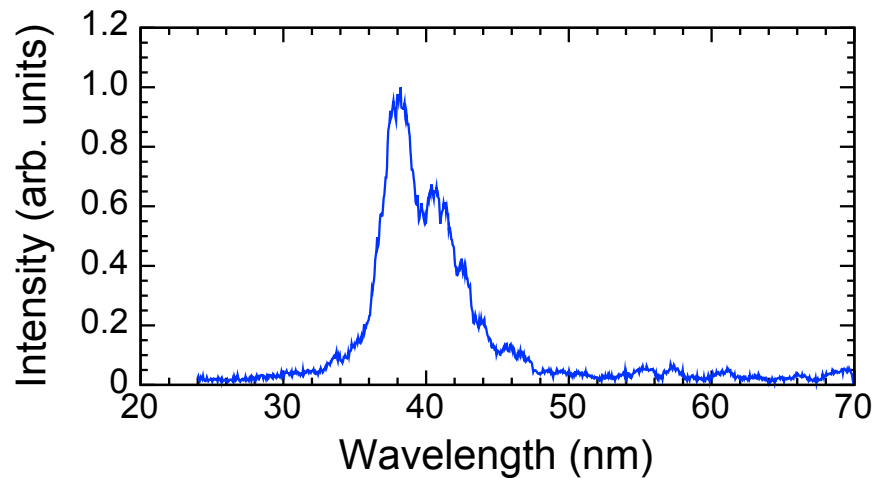


Comparison of experiments and gf spectral line calculation

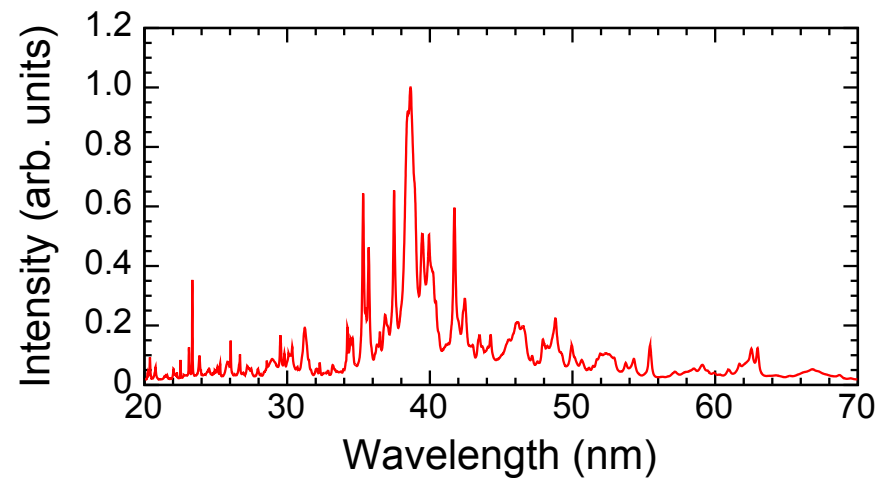


Comparison of experiments and numerical simulation

Experiments

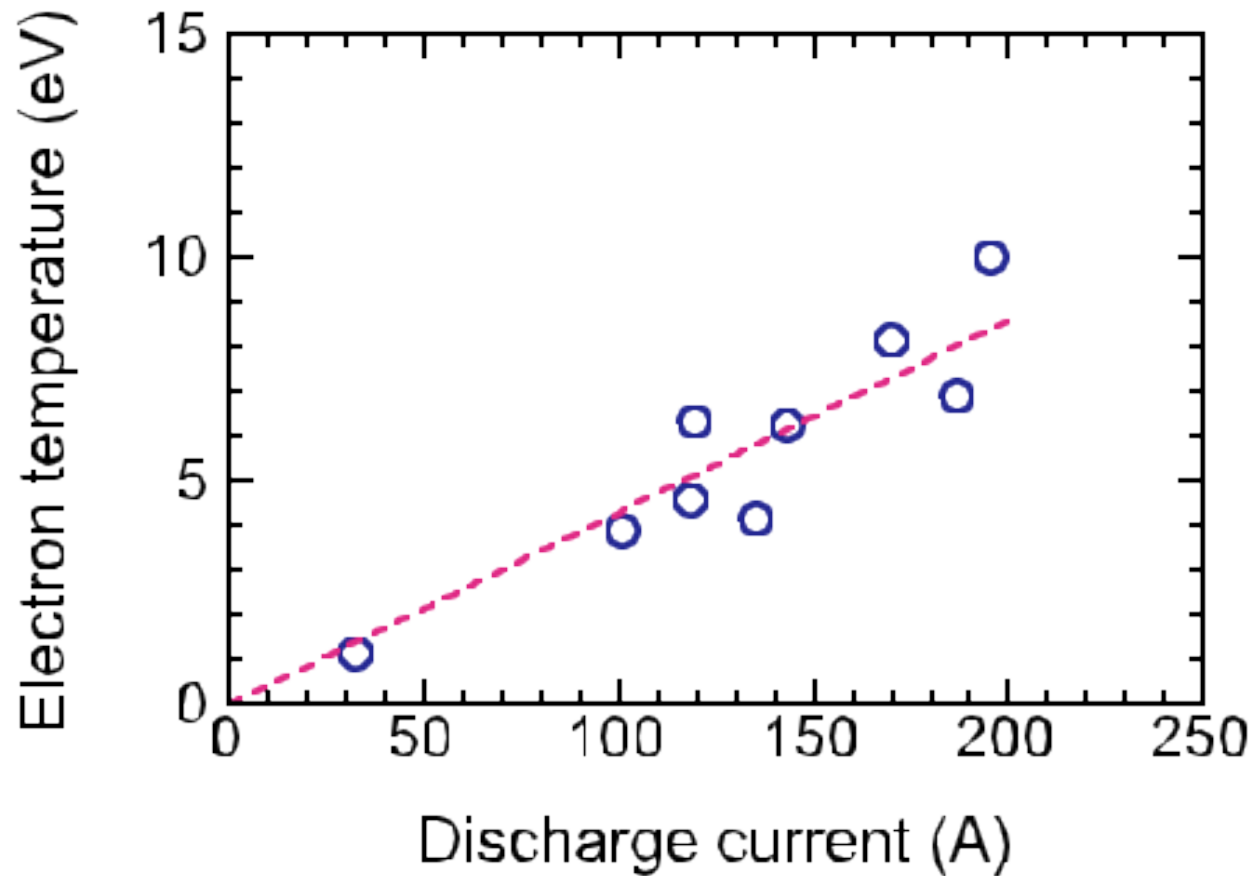


Numerical simulation



Time-integrated electron temperature: 12 eV
Electron density: $1 \times 10^{20} \text{ cm}^{-3}$

Discharge current dependence of time-integrated electron temperature



$$T_e \propto \frac{\Delta E}{\ln(I_1 \lambda_1 / I_2 \lambda_2)}$$

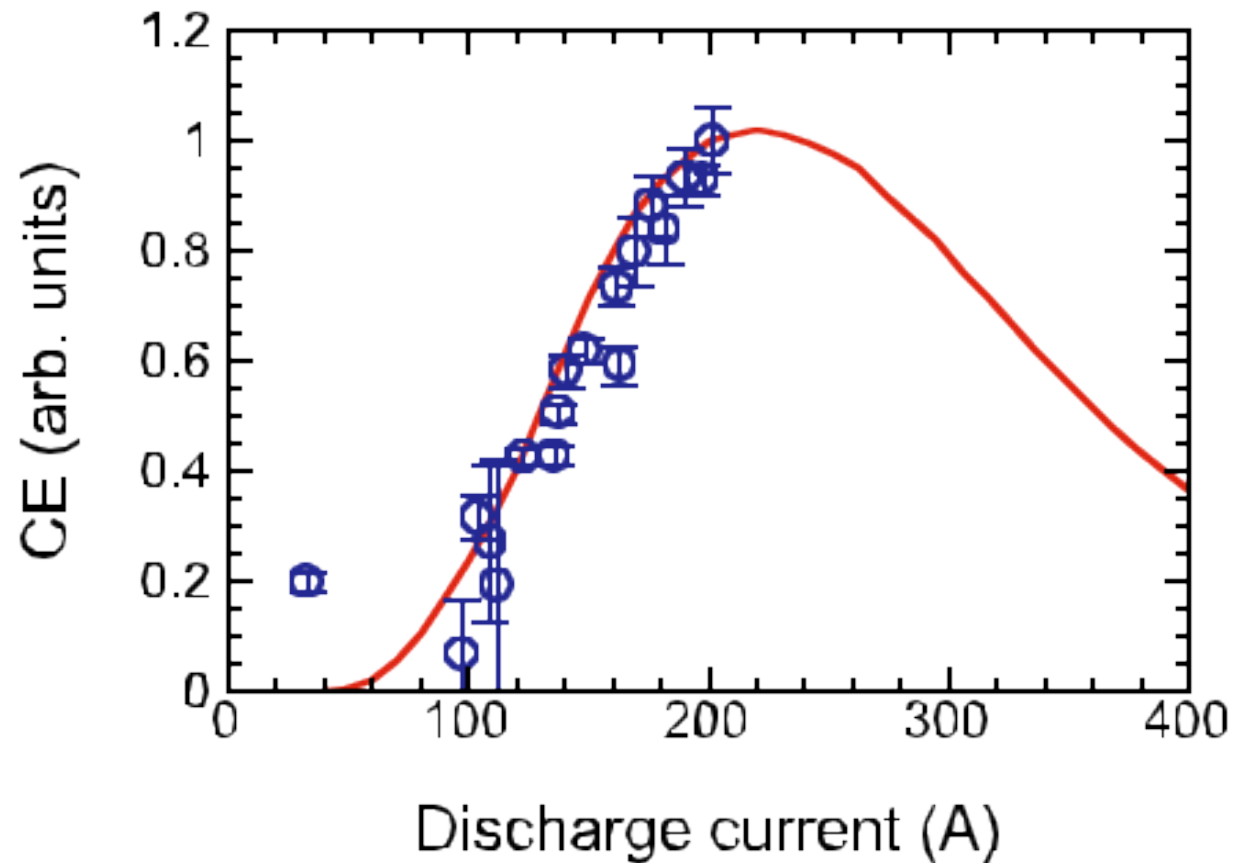
$$\text{O}^{2+}: l_1 = 70.4 \text{ nm}$$

$$\text{O}^{2+}: l_2 = 83.4 \text{ nm}$$

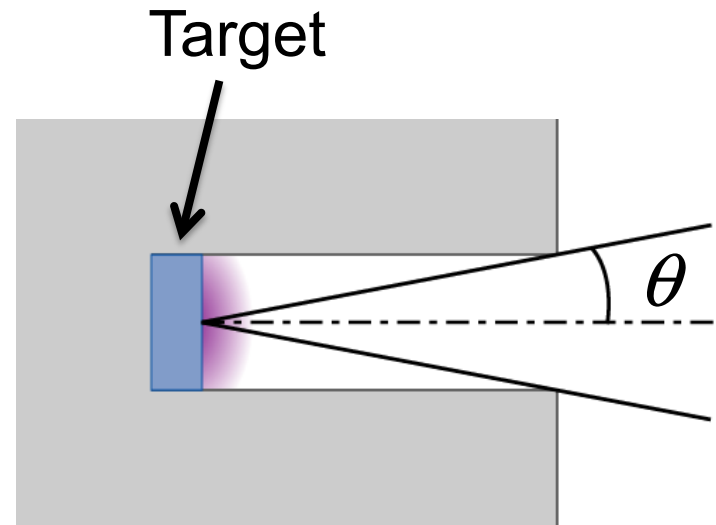
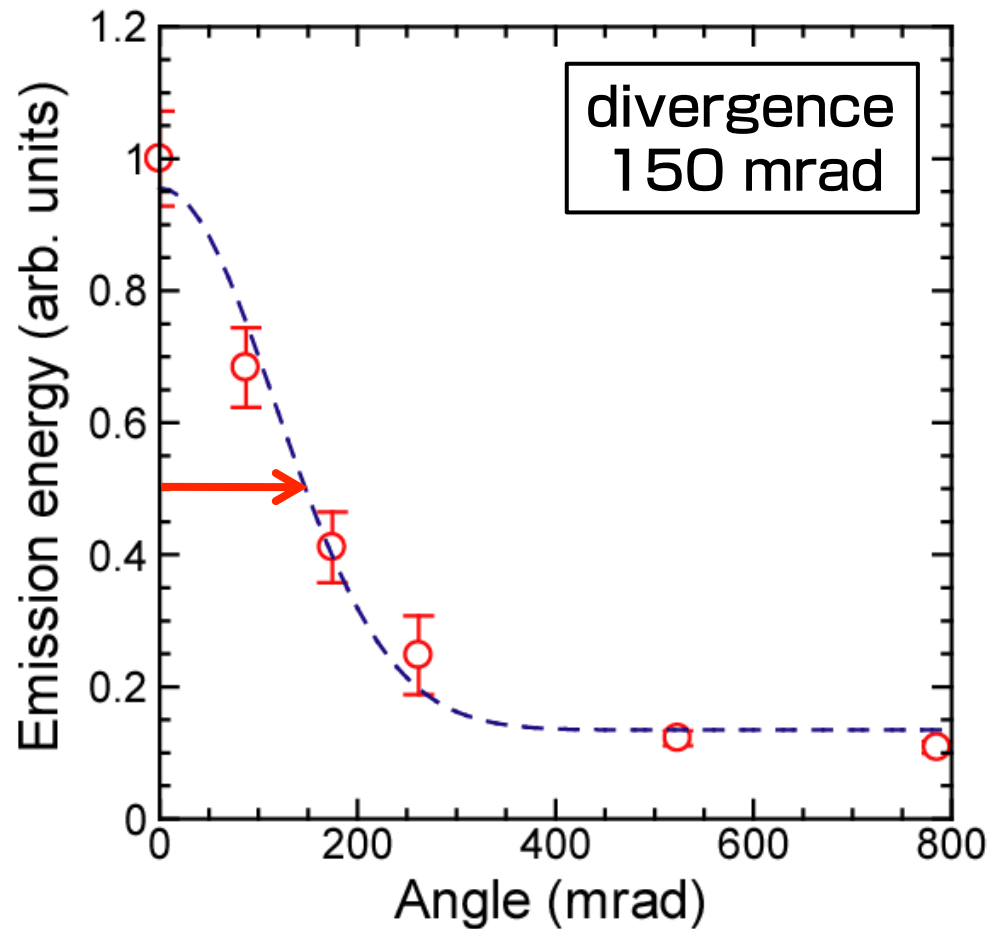
$$\text{O}^{3+}: l_1 = 55.4 \text{ nm}$$

$$\text{O}^{3+}: l_2 = 61.7 \text{ nm}$$

Discharge current dependence of the XUV conversion efficiency



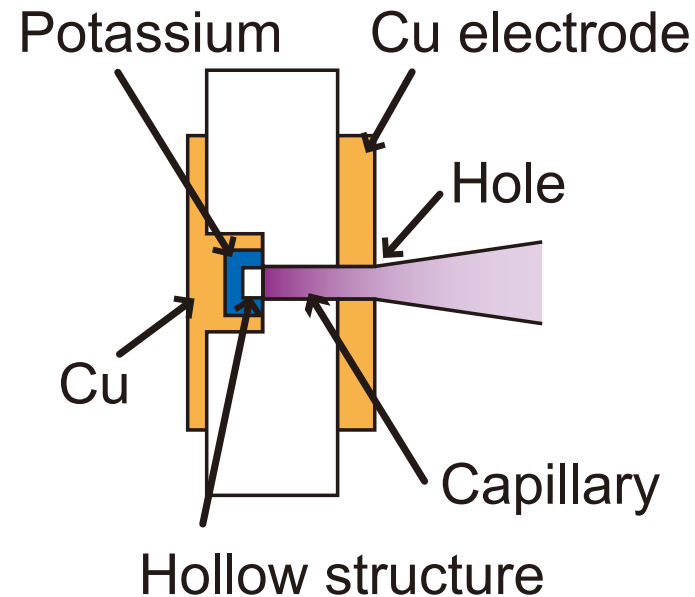
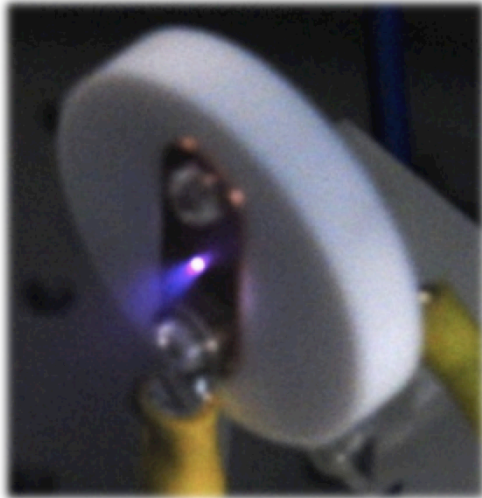
Angular distribution of the XUV emission energy



$$\theta = \tan^{-1} \frac{r}{l}$$

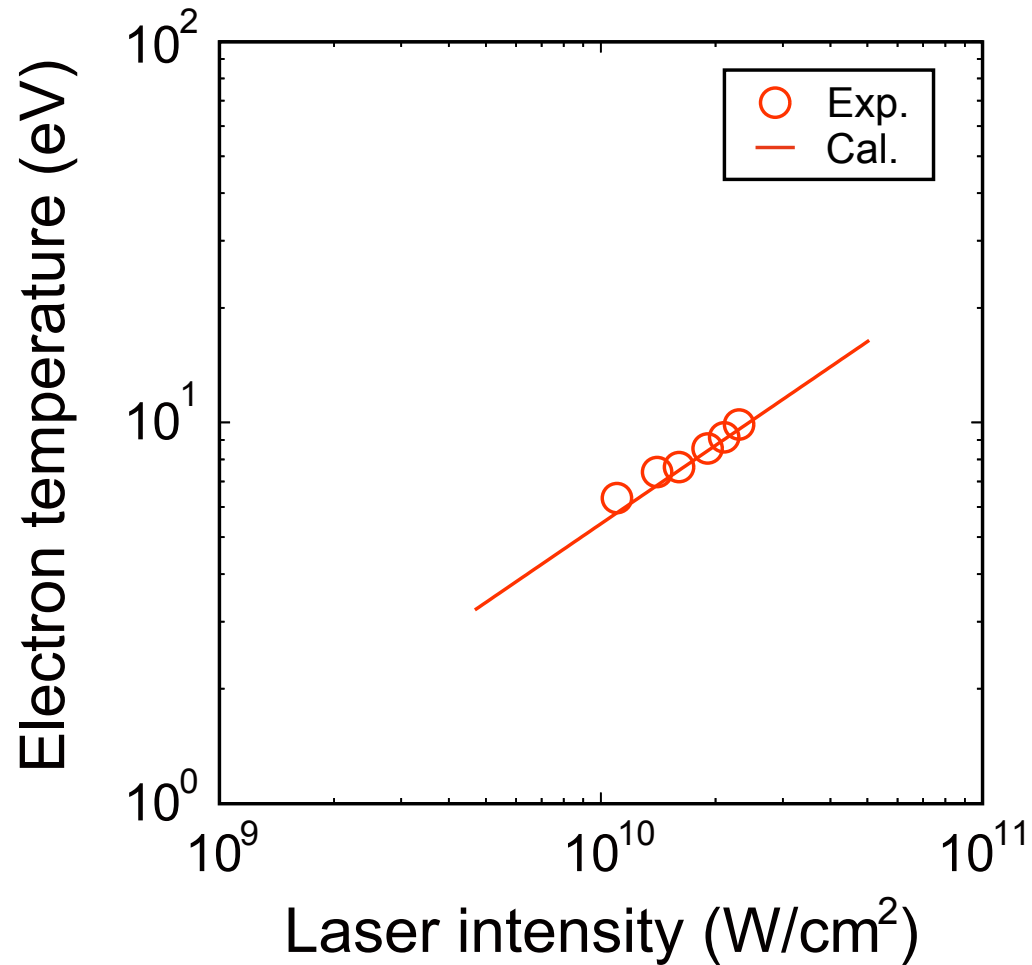
; 170 mrad

Electrode structure

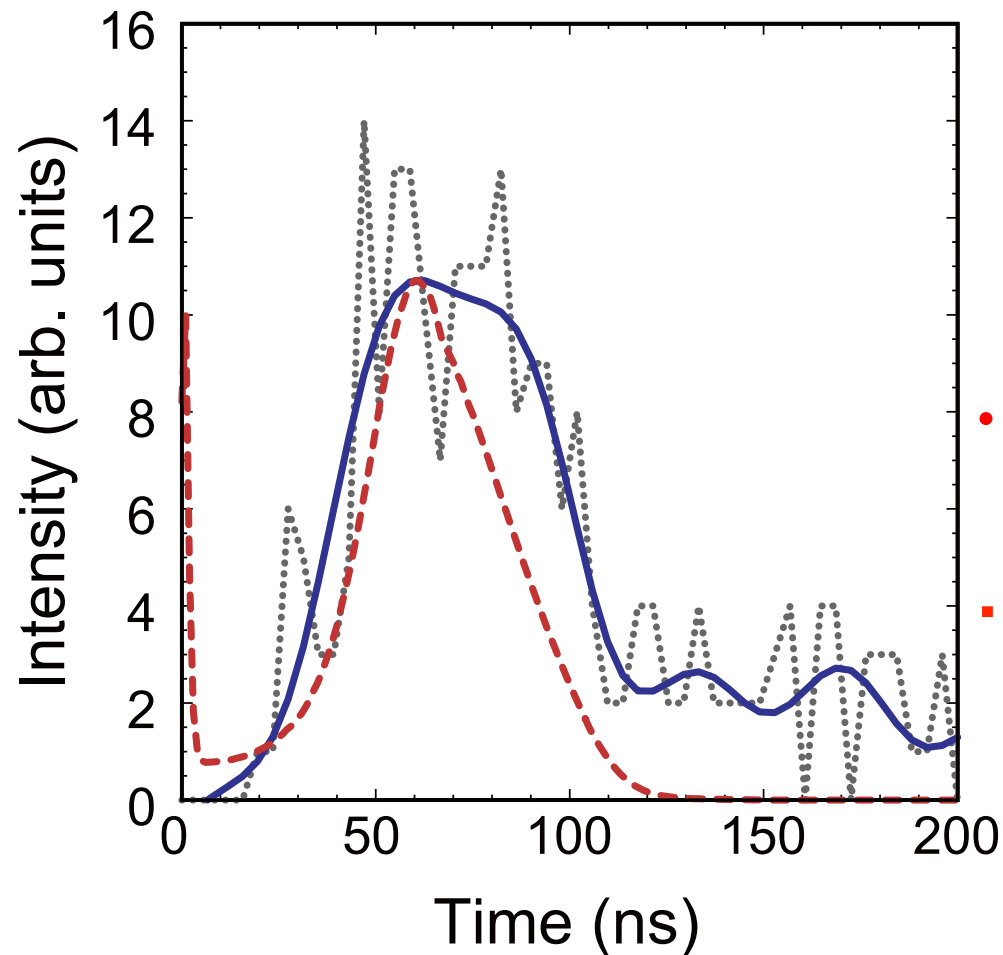


- Limited to the emission region
- Contamination emission spectra, together with the carbon due to a capillary material

Electron temperature to turn 12 eV



Temporal history of the emission at 39 nm

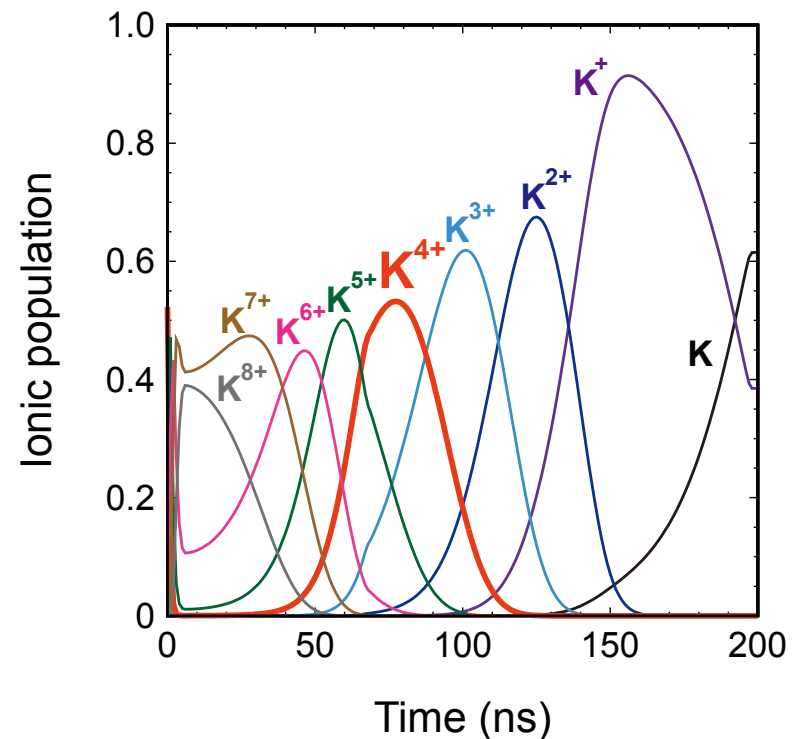
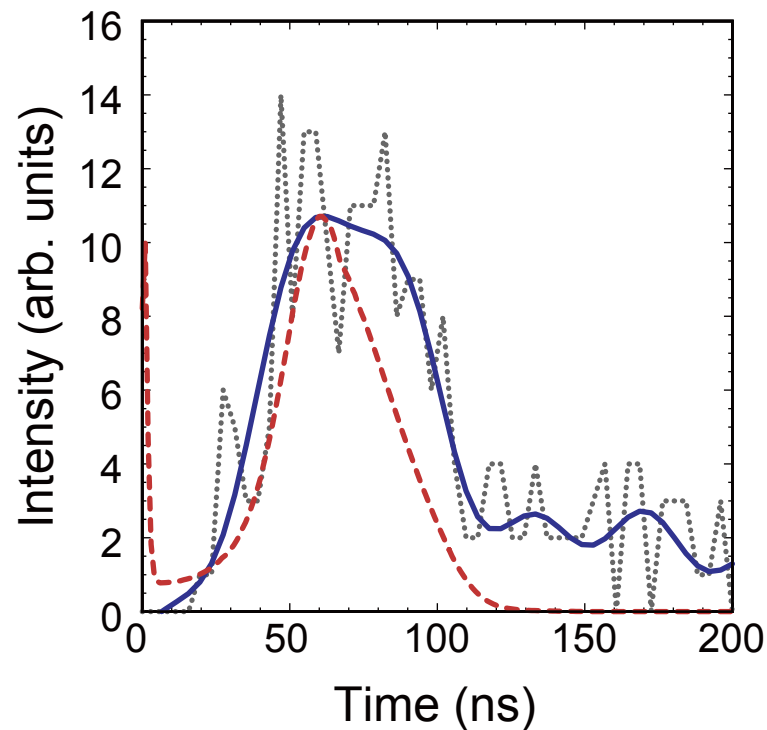


Wavelength: 1064 nm
Laser intensity: 2×10^{10} W/cm²

- The duration of the emission: 50 ns (FWHM)
- Recombination radiation

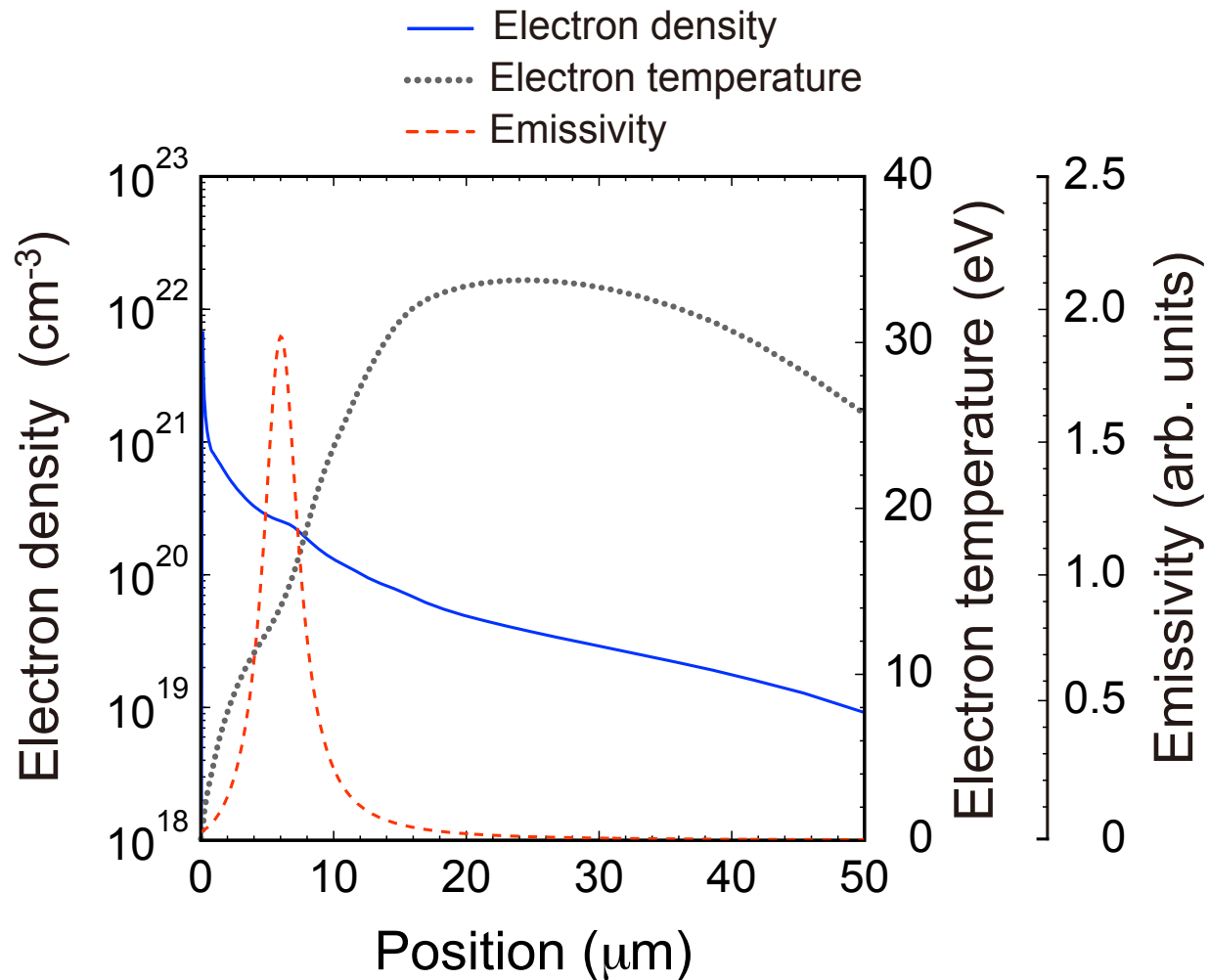
Temporal history of the emission at 39 nm

Wavelength: 1064 nm, Laser intensity: 2×10^{10} W/cm²



- The duration of the emission: 50 ns (FWHM)
- Recombination radiation

Emissivity of the 39-nm emission



Summary

We characterized the emission spectra and temporal history of a pure potassium plasma.

[Microdischarge]

T. Higashiguchi *et al.*, Appl. Phys. Lett. **96**, 131505 (2010).

T. Higashiguchi *et al.*, J. Appl. Phys. **109**, 013301 (2011).

[Laser-produced plasma]

T. Higashiguchi *et al.*, Appl. Phys. Lett. **98**, 091503 (2011).