Investigation on ablation processes in capillary discharge plasmas for XUV radiation production

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Experiment objectives

✔ Study of plasma formation and dynamics on gas filled capillary discharge plasma

✔ Determine the wall ablation mechanism on alumina Al$_2$O$_3$ capillary filled by different gases

✔ Investigate the required conditions for having a pinch effect on capillary discharge plasma necessary for coherent XUV radiation production
Presentation outlines

- Capillary discharge plasma system
- UV time resolved spectroscopic measurements
  - Existence of ablation threshold
- XUV time resolved spectroscopic measurements
  - Existence of ablation threshold
- Conclusions
Capillary discharge plasma system

- XUV capillary discharge source principle

High temperature and density plasma is created inside the gas filled capillary channel

Gas flow

- An active media to generate XUV radiation at short wavelength range
Capillary discharge plasma system

✔ Electrical characterisation:

- Charging voltage: up to 22 kV
- Current peak maximum: 10 kA
- Total capacity: 24 nF
- Alumina capillary dimension:
  - Length: 10 mm
  - Diameter: 1 mm
- Peak current rise time: 100 ns
- Energy density: 750 J cm\(^{-3}\)

Discharge current waveform by calibrated Rogowsky coil

Filtred experimental current

Electrical energy: 4.8 J
UV spectroscopic measurements

✓ Experimental set-up

1: Knob capacitor of 4nF
2: Axial view
3: Alumina Al₂O₃ capillary
4: Detection chamber
5: MgF₂ optical window
6: Focusing lens
7: Optical fiber
8: Monochromator
UV spectroscopic measurements

✔️ Time resolved UV spectrum by helium discharge

Temporal evolution Profile of the helium discharge spectra

• Identification of aluminium lines on the helium discharge spectrum arising from the capillary wall ablation
UV spectroscopic measurements

- Time resolved UV spectrum by helium discharge

Temporal evolution profile of the helium discharge spectrum

- Strong Al resonance neutral lines at 394.4 & 396.1 on the later stage of the discharge.
Existence of ablation threshold

✔ Aluminium line at 396.1 nm behaviour

UV aluminium neutral line intensity at 396.1 nm evolution versus the input electrical energy density

- Existence of clear boundary between ablative and non ablative regimes: the ablation threshold is around 400 J cm\(^{-3}\)
Time resolved XUV spectroscopy

✔ Experimental XUV spectroscopic set-up

Jobin-Yvon PGMPGS 500 Spectrometer

XUV source

XUV diagnostic system

1: Knob capacitor of 4nF
2: Axial view
3: Alumina capillary Al₂O₃
4: Entrance slit of the spectrometer
5: Torroidal mirror
6: Reflective grating 800l/mm
7: Turbo molecular pump
8: Gated MCP and ICCD camera
Time resolved XUV spectroscopy

✔ Helium filled capillary discharge

Time resolved emission spectrum in the XUV wavelength range for helium discharge at 4.8 J and 2mbar gas pressure

- At the beginning of the discharge mainly helium and oxygen lines and at the later on the discharge strong aluminium lines dominate the spectrum
Time resolved XUV spectroscopy

✓ Xenon filled capillary discharge

Time resolved emission spectrum in the XUV wavelength range for xenon discharge at 4.8 J and 2 mbar gas pressure

- Identification of aluminium lines on the xenon XUV spectrum arising from the capillary wall ablation
Time resolved XUV spectroscopy

✓ Propane $\text{C}_3\text{H}_8$ filled capillary discharge

Time resolved emission spectrum in the XUV wavelength range for propane discharge at 4.8 J and 2 mbar gas pressure

- At the beginning of the discharge mainly carbon and oxygen lines and at the later on the discharge strong aluminium lines dominate the spectrum
Existence of ablation threshold

✓ Aluminium lines behaviour

Temporal evolution of EUV aluminium line intensity Al VI at 30.9 nm for various input electrical energy

- For an electrical energy greater than 3 J the aluminium line intensity increase considerably
Existence of ablation threshold

Aluminium lines behaviour

- Existence of a clear boundary between ablative and non-ablative regimes: the ablation threshold is around 400 J cm$^{-3}$
Conclusions

• Realisation of time integrated and time resolved spectroscopic measurement on visible, UV and EUV for different gases

• Observation of an ablation threshold in gas discharge produced plasma for input electrical energy injected greater than 400 Jcm\(^{-3}\).

• Complementary measurement by plasma imaging for the different wavelength ranges complete the ablation phenomena study (the following presentation)
Thank you for your attention
**UV-visible spectroscopic measurements**

- Time integrated UV-visible spectra by helium discharge

*Time integrated UV-visible spectrum by helium discharge*

![Graph showing complex spectra with many emission lines](image)

*Complex spectra with many emission lines*
Time resolved EUV spectroscopy

✔ Helium filled capillary discharge

EUV discharge emission spectrum for electrical energy 4.8J

Mainly oxygen lines dominate on the helium spectra

Identification of aluminium lines on the helium spectra arising from the capillary wall ablation
UV-visible spectroscopic measurements

✔ Time integrated UV-visible spectra by helium discharge

Time integrated UV-visible spectrum by helium discharge

Identification of aluminium lines on the helium discharge spectra arising from the capillary wall ablation
Time resolved EUV spectroscopy

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