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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_2O_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

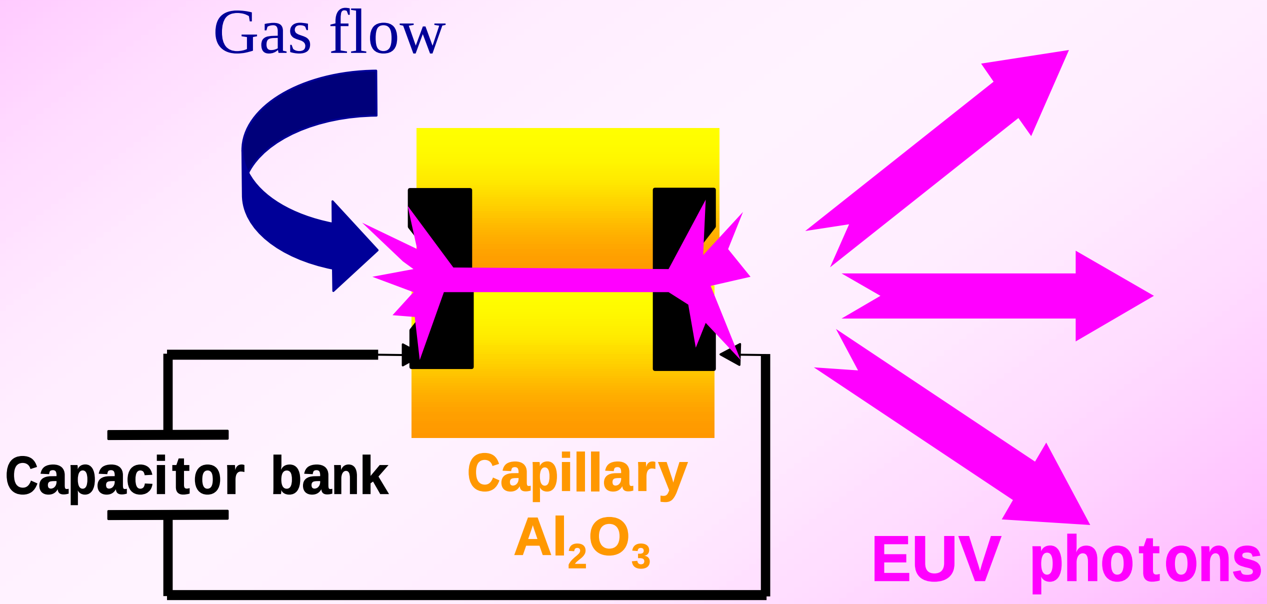
Presentation outlines

- ✔ **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

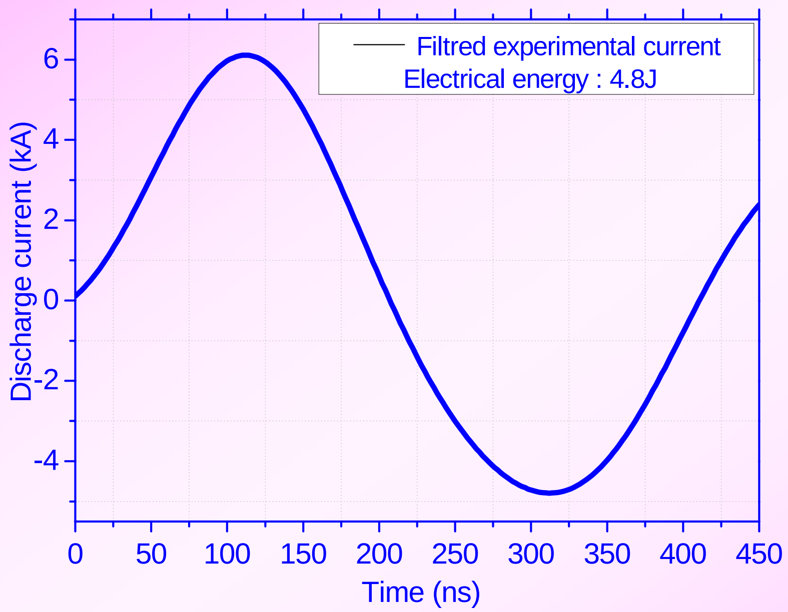


• An active media to generate XUV radiation at short wavelength range

Capillary discharge plasma system

✔Electrical characterisation:

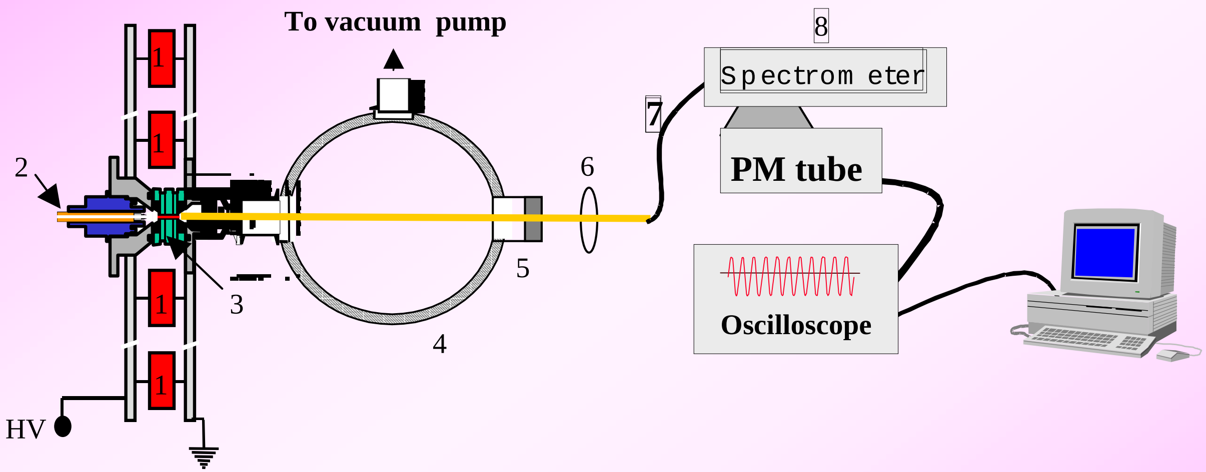
Discharge current waveform by calibrated Rogowsky coil



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

UV spectroscopic measurements

✔ Experimental set-up



- 1: Knob capacitor of 4nF
- 2: Axial view
- 3: Alumina Al_2O_3 capillary
- 4: Detection chamber
- 5: MgF_2 optical window
- 6: Focusing lens
- 7: Optical fiber
- 8: Monochromator

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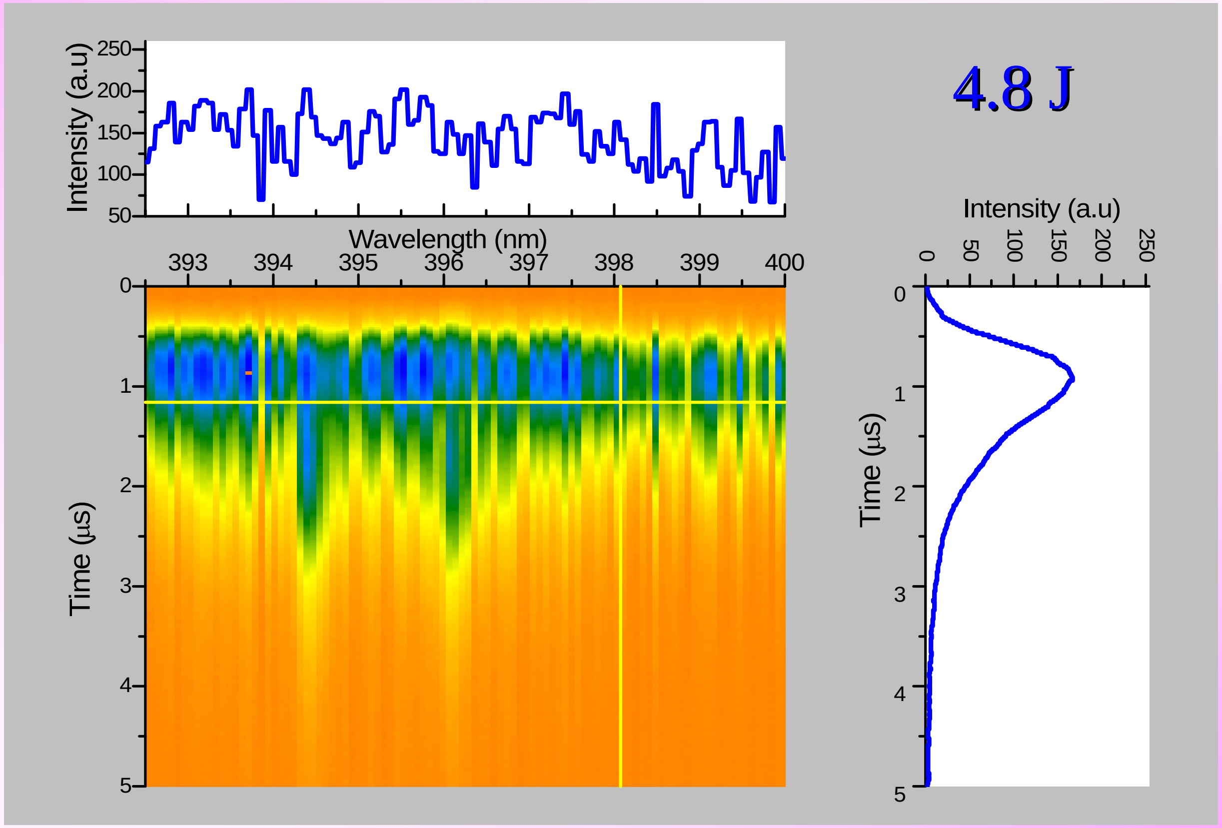
UV spectroscopic measurements

✔ Time resolved UV spectrum by helium discharge

Temporal evolution Profile of the helium discharge spectra

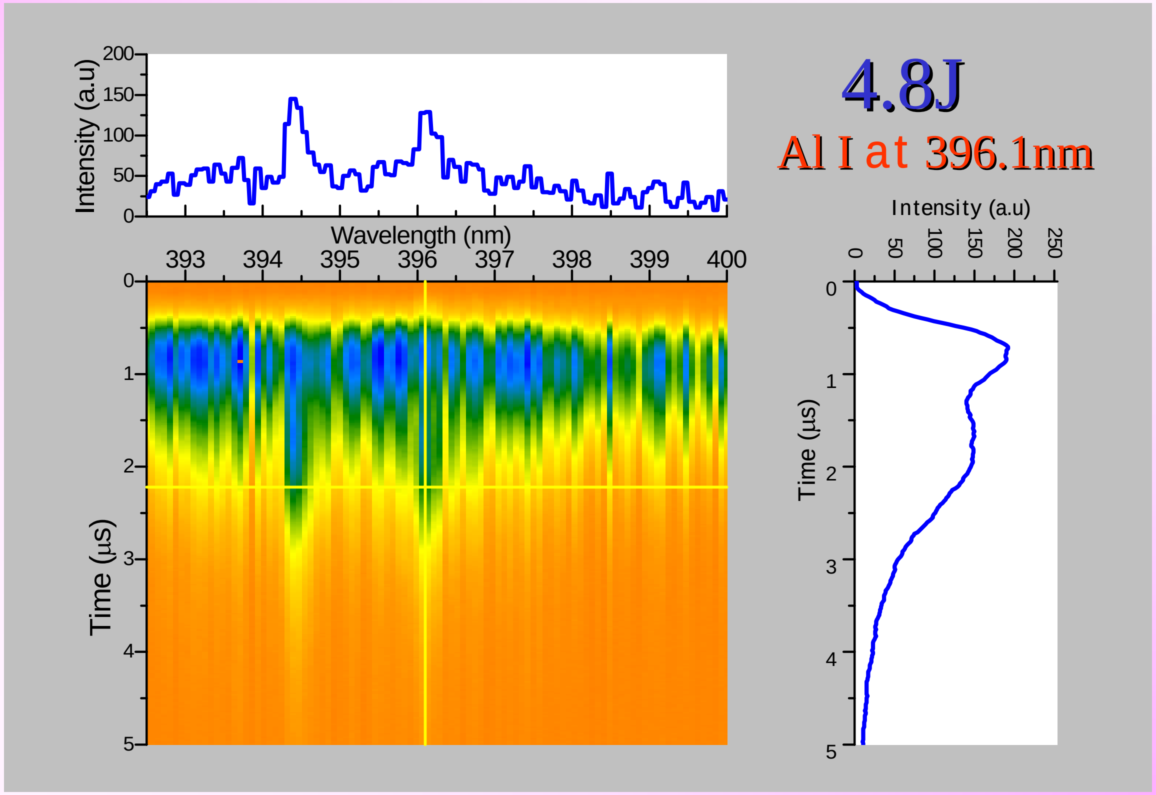


- Identification of aluminium lines on the helium discharge spectrum arising from the capillary wall ablation

UV spectroscopic measurements

✔ ***Time resolved UV spectrum by helium discharge***

Temporal evolution profile of the helium discharge spectrum

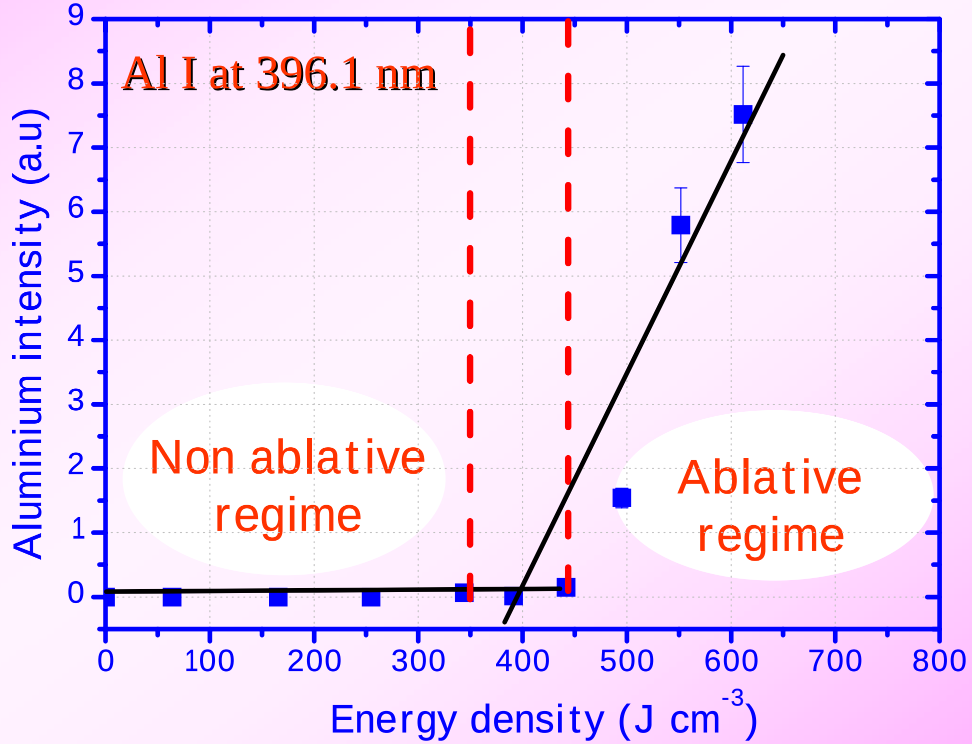


- Strong Al resonance neutral lines at 394.4 & 396.1 on the later stage of the discharge.

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}

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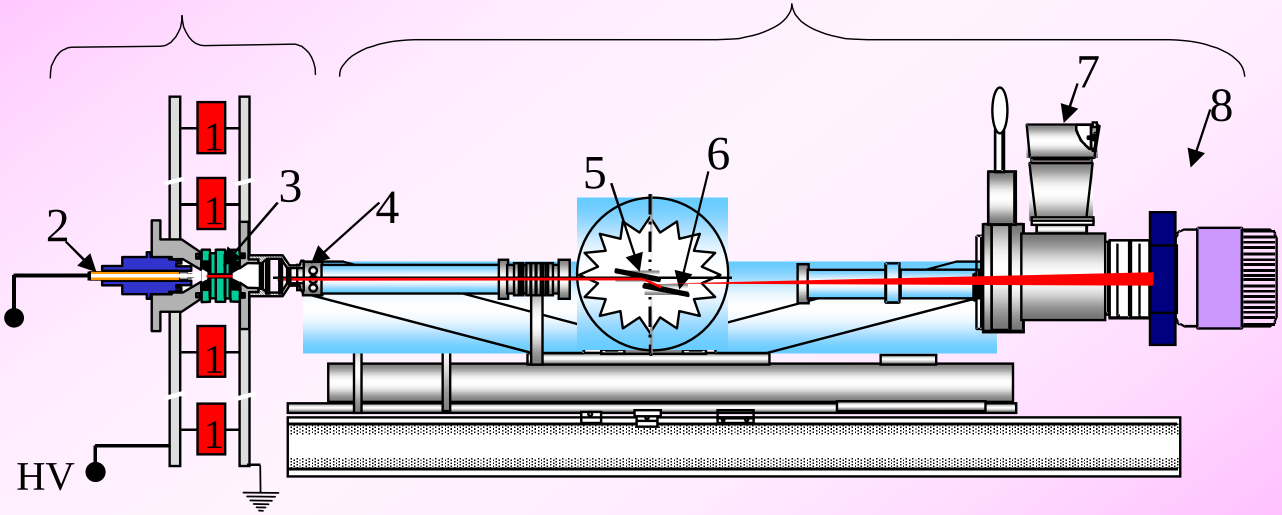
Time resolved XUV spectroscopy

✔ 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 Al_2O_3

4: Entrance slit of the spectrometer

5: Torroidal mirror

6: Reflective grating 800l/mm

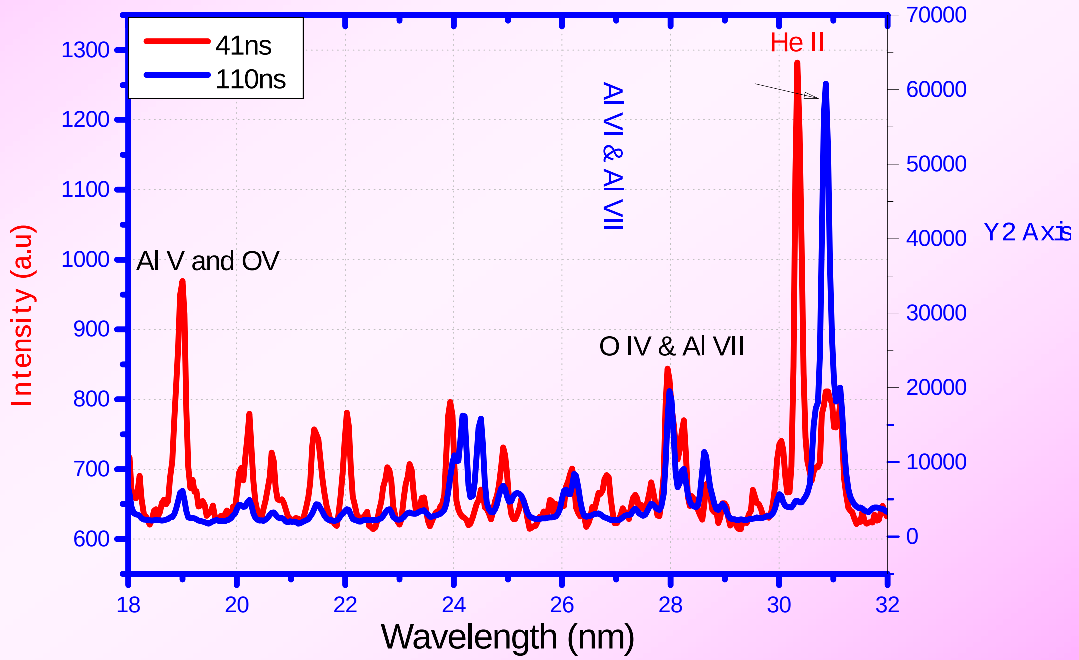
7: Turbo molecular pump

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

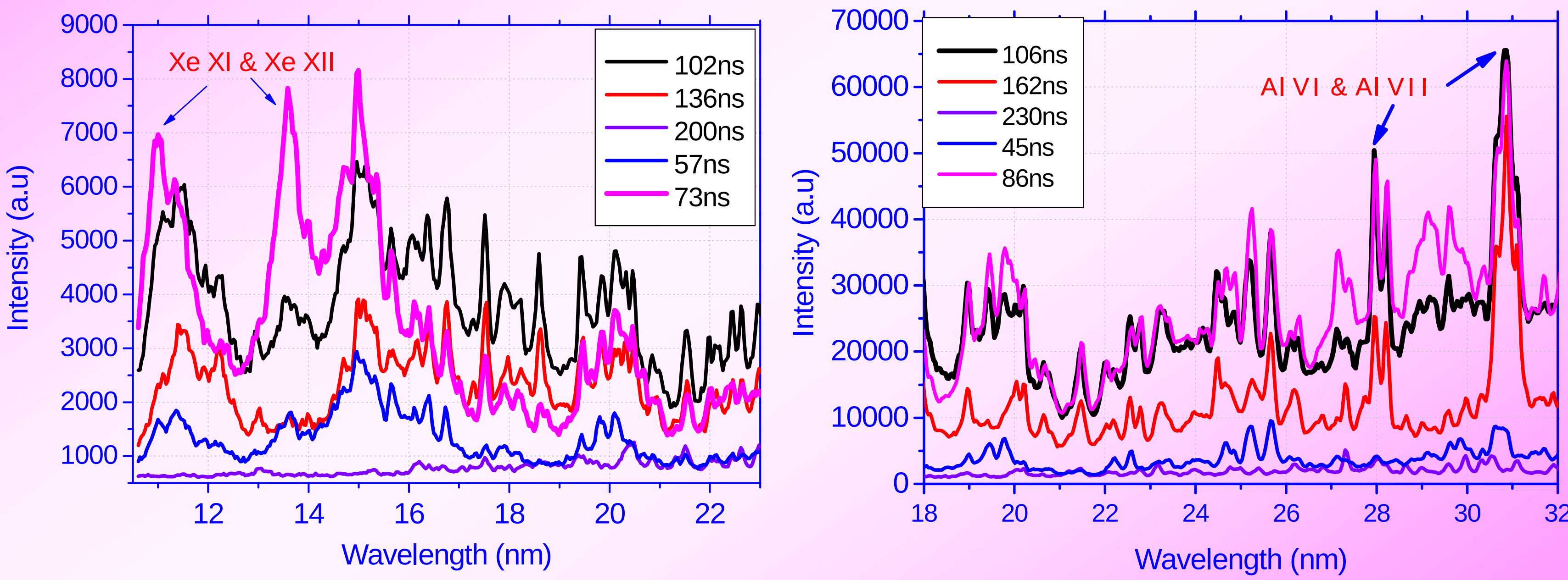


- At the beginning of the discharge mainly helium and oxygen lines and at the later on the discharge strong aluminium lines dominate the spectrum

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

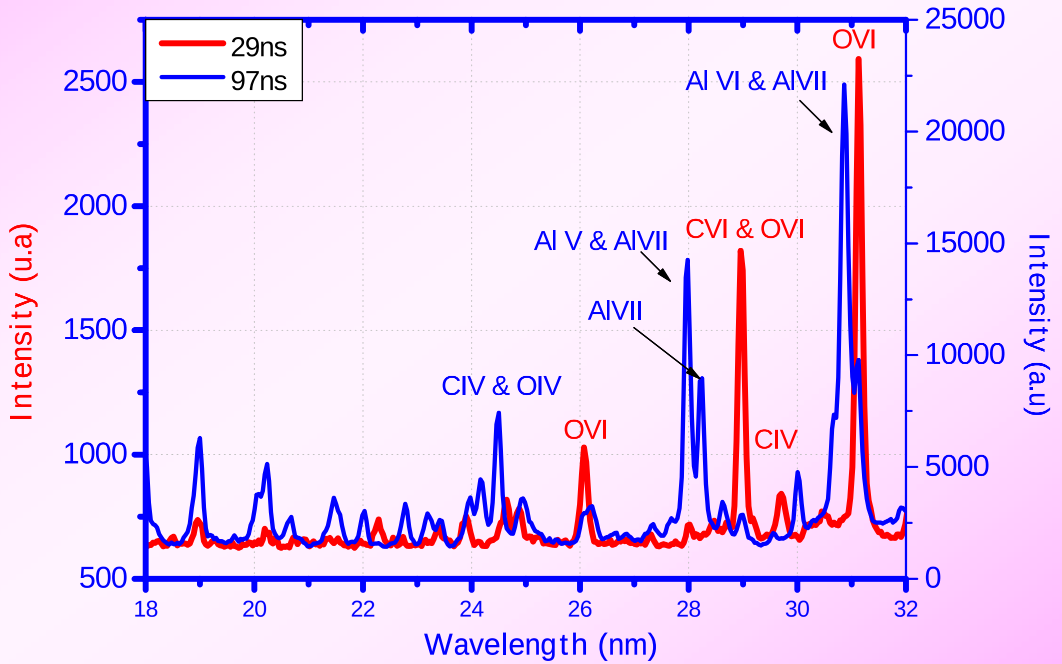


- Identification of aluminium lines on the xenon XUV spectrum arising from the capillary wall ablation

Time resolved XUV spectroscopy

✔ Propane C_3H_6 filled capillary discharge

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

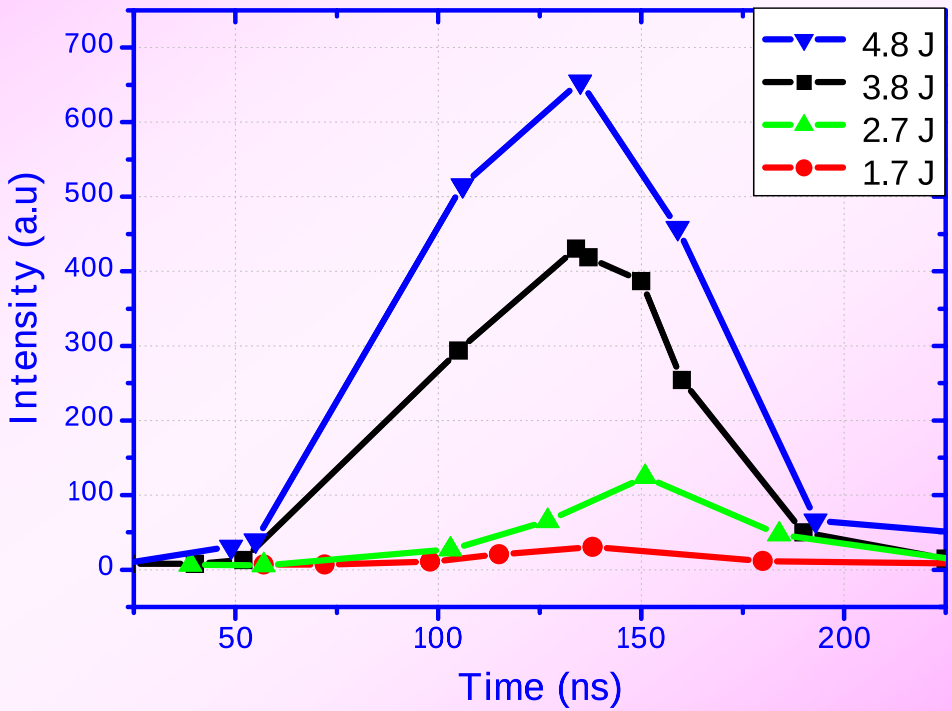


• At the beginning of the discharge mainly carbon and oxygen lines and at the later on the discharge strong aluminium lines dominate the spectrum

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

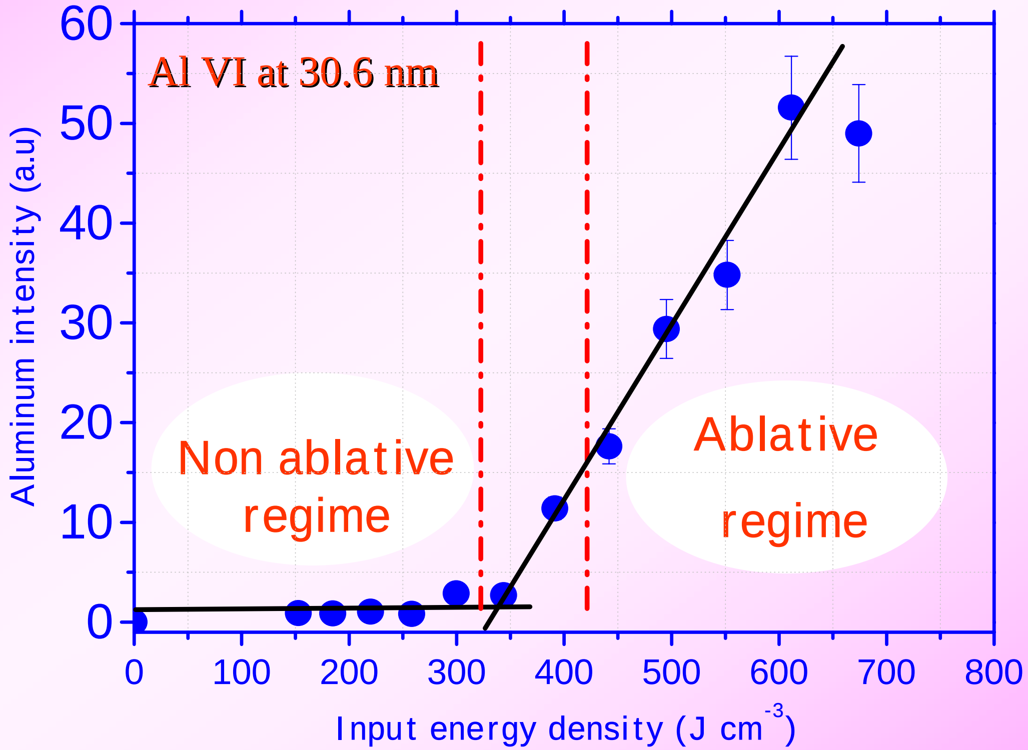


- For an electrical energy greater than 3 J the aluminium line intensity increase considerably

Existence of ablation threshold

✔ Aluminium lines behaviour

XUV aluminium line intensity Al VI at 30.9 nm evolution for various input electrical energy density



- Existence of 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}.

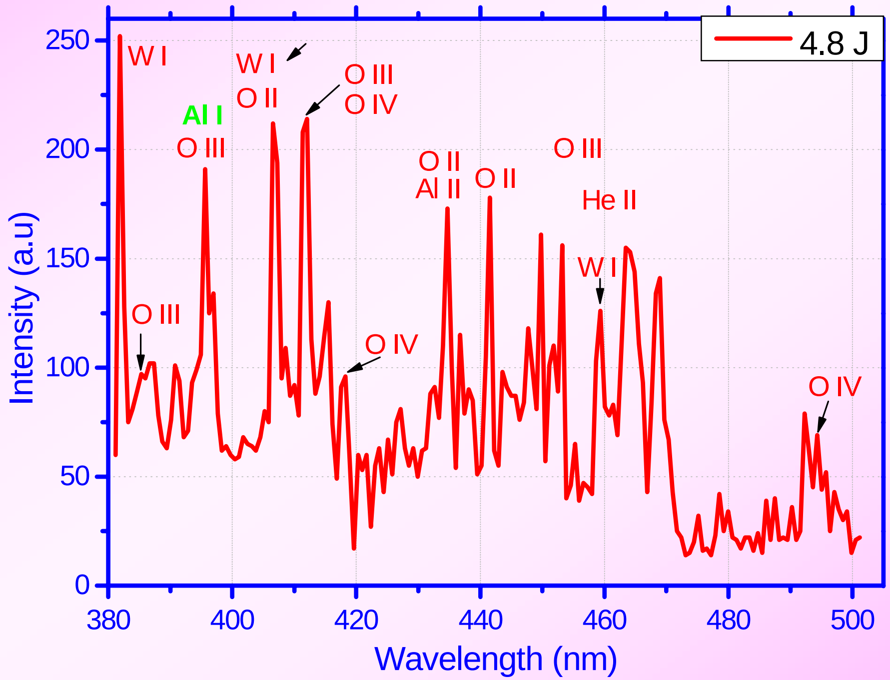
• Complementary measurement by plasma imaging for the different wavelength ranges complete the ablation phenomena study (the following presentation)

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



Complex spectra with many emission lines

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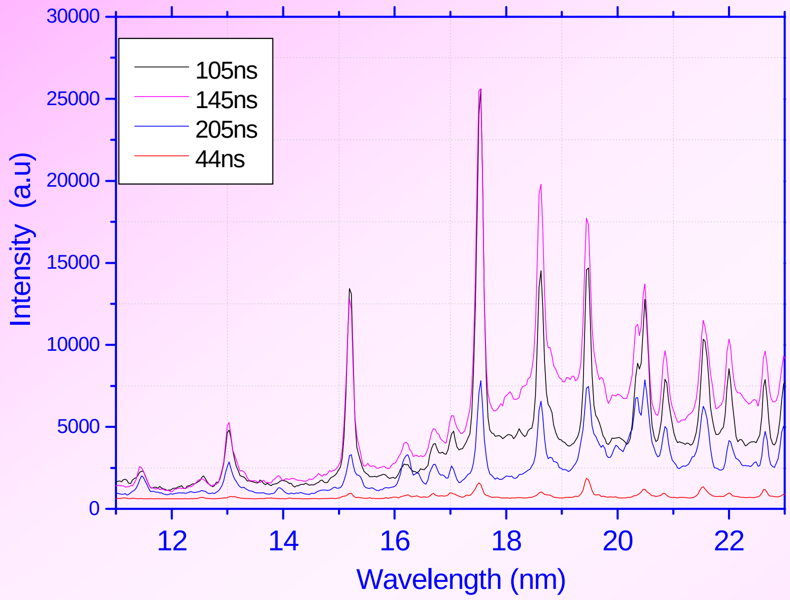
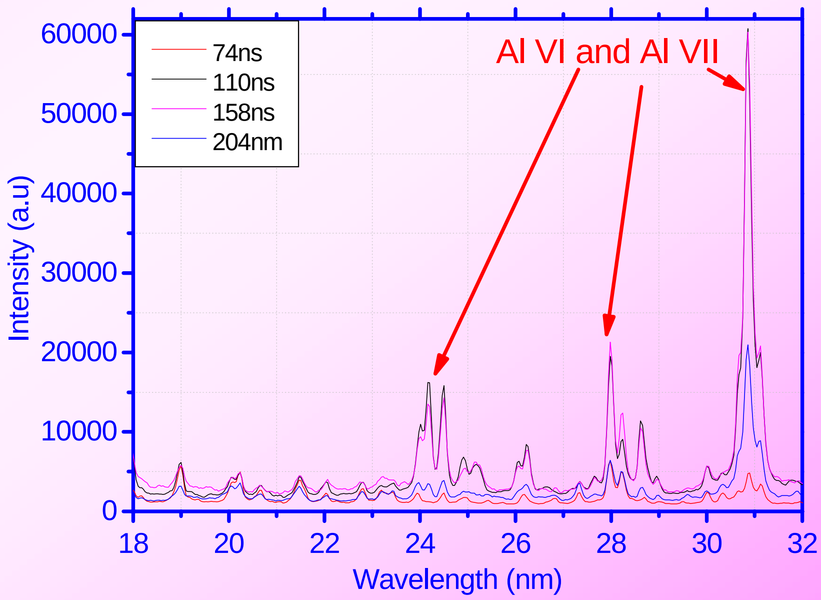
Time resolved EUV spectroscopy

✔ 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

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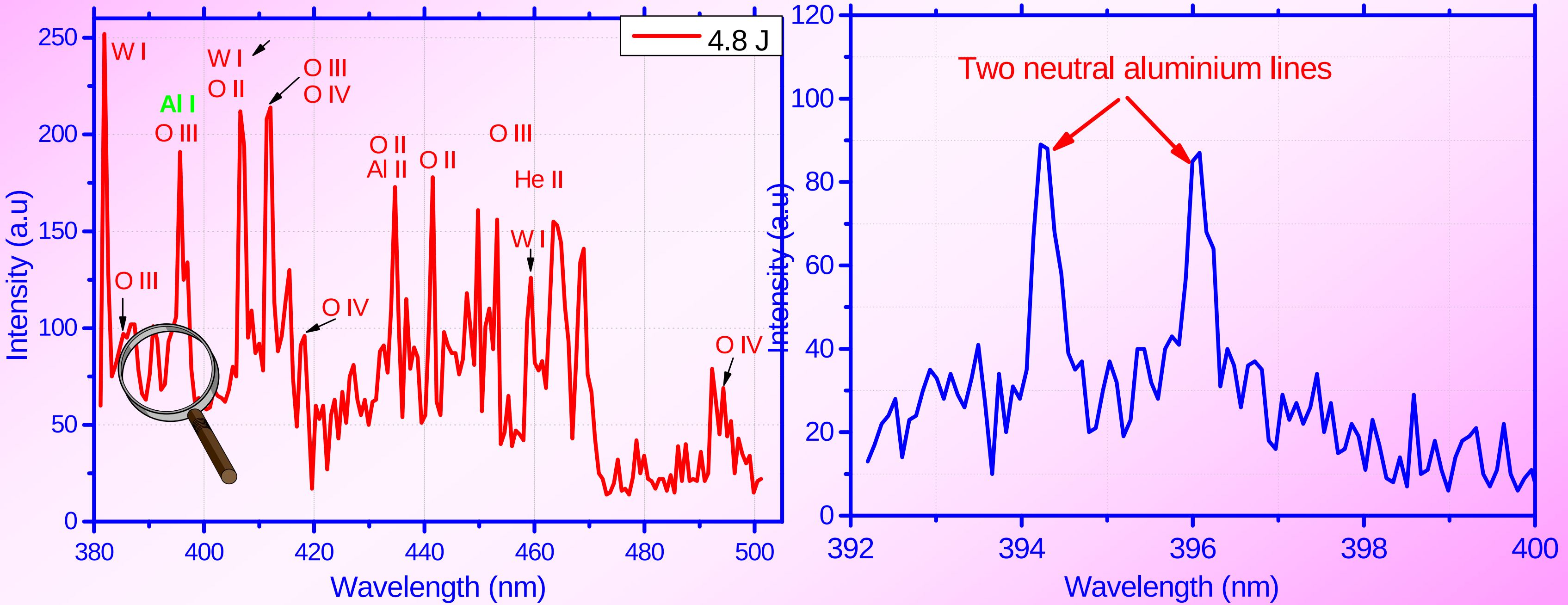
UV-visible spectroscopic measurements

✔ **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

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Time resolved EUV spectroscopy

✔ Helium filled capillary discharge

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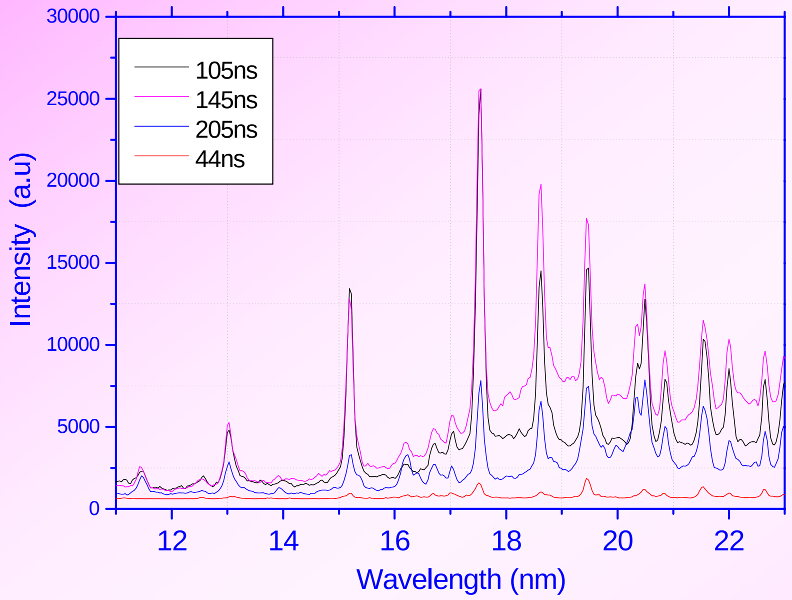

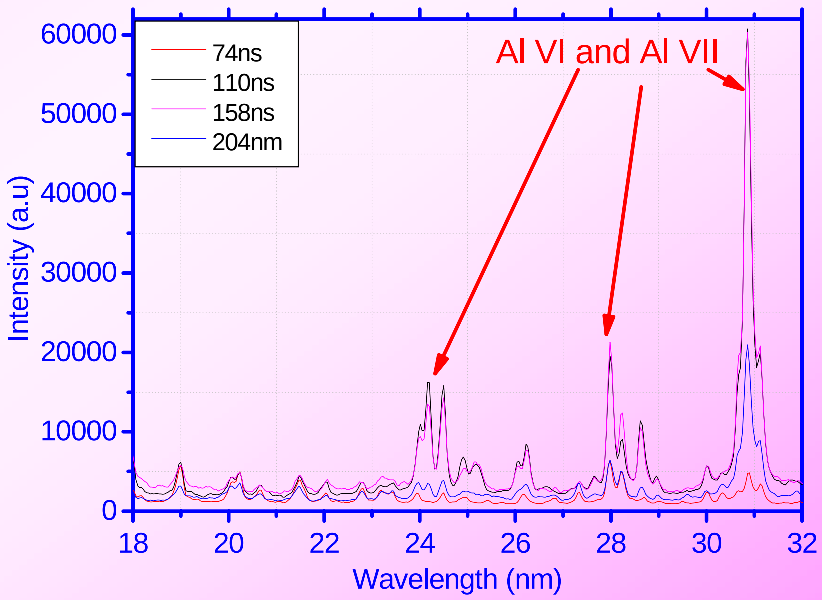

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