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Experimental investigations of Al_2O_3 ablation threshold in XUV capillary discharge sources: comparison to numerical results of 1-D coaxial model

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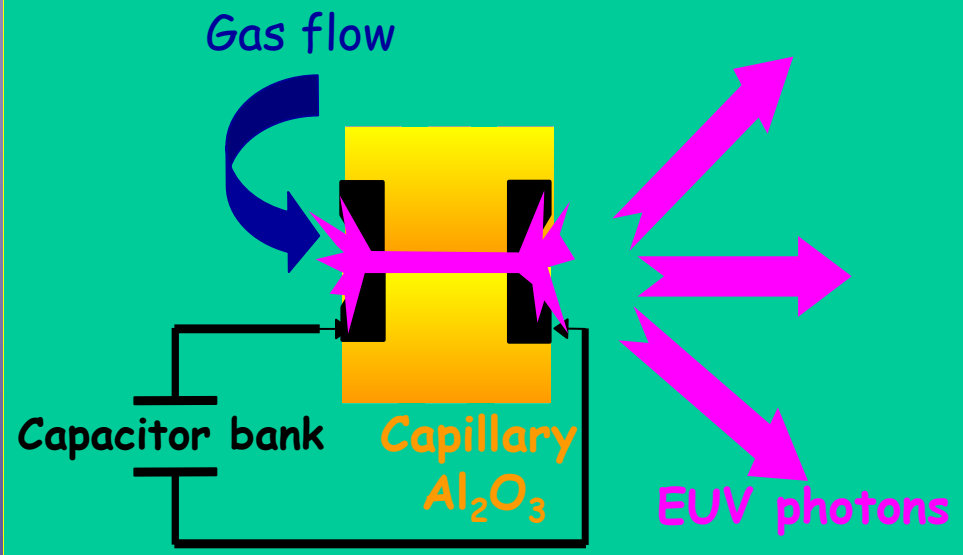
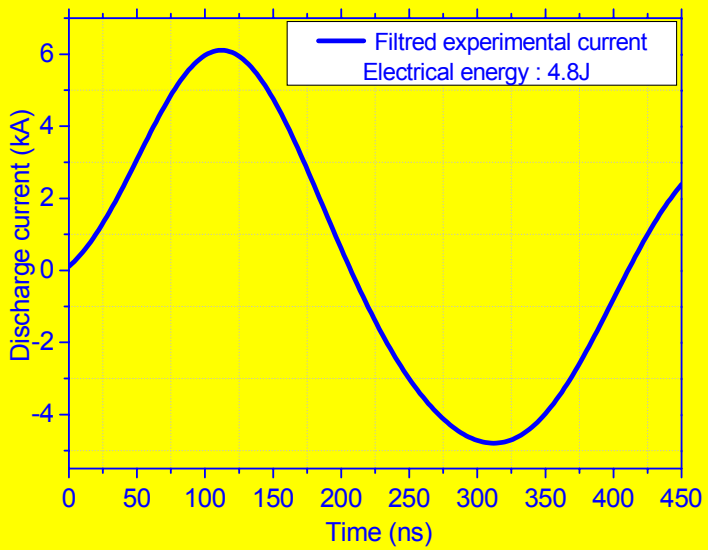
Presentation outlines

- XUV capillary discharge sources
- Spectroscopic diagnostic of the plasma emission
- Observation of an ablation threshold of Al_2O_3 capillary
  - For different gas pressures
  - for different capillary-filled gases
- Coaxial ablation model by plasma
- Conclusion

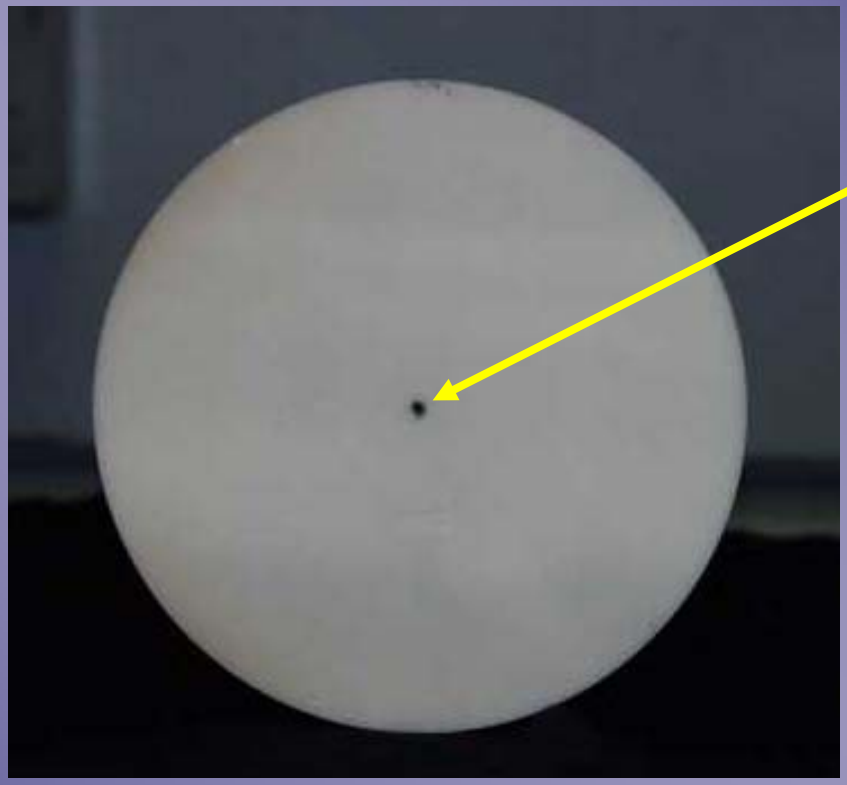
XUV capillary discharge sources





- Voltage up to 25 kV
- Total capacity : 24,4 nF
- Capillary dimensions: **Length: 10 mm & diameter: 1 mm**
- Energy density up to 750 J cm^{-3}
- Maximum current : ~10 kA
- Current period : ~ 400 ns

The Al_2O_3 alumina capillary

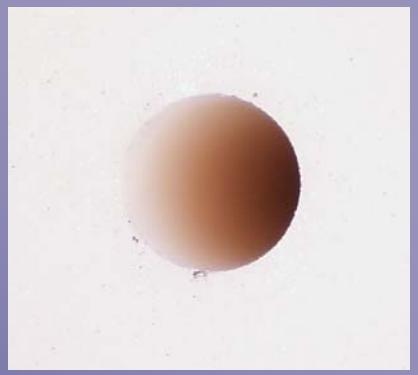


A hole of 1 mm diameter and 10 mm length

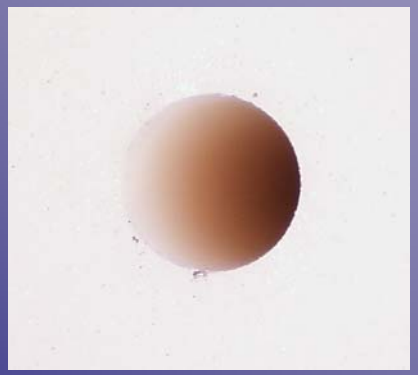
…..But after several hundred of shots

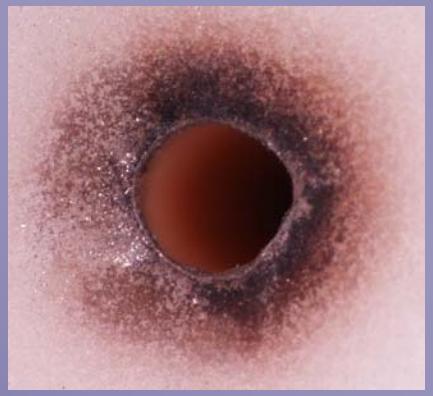
Before

After



Anode



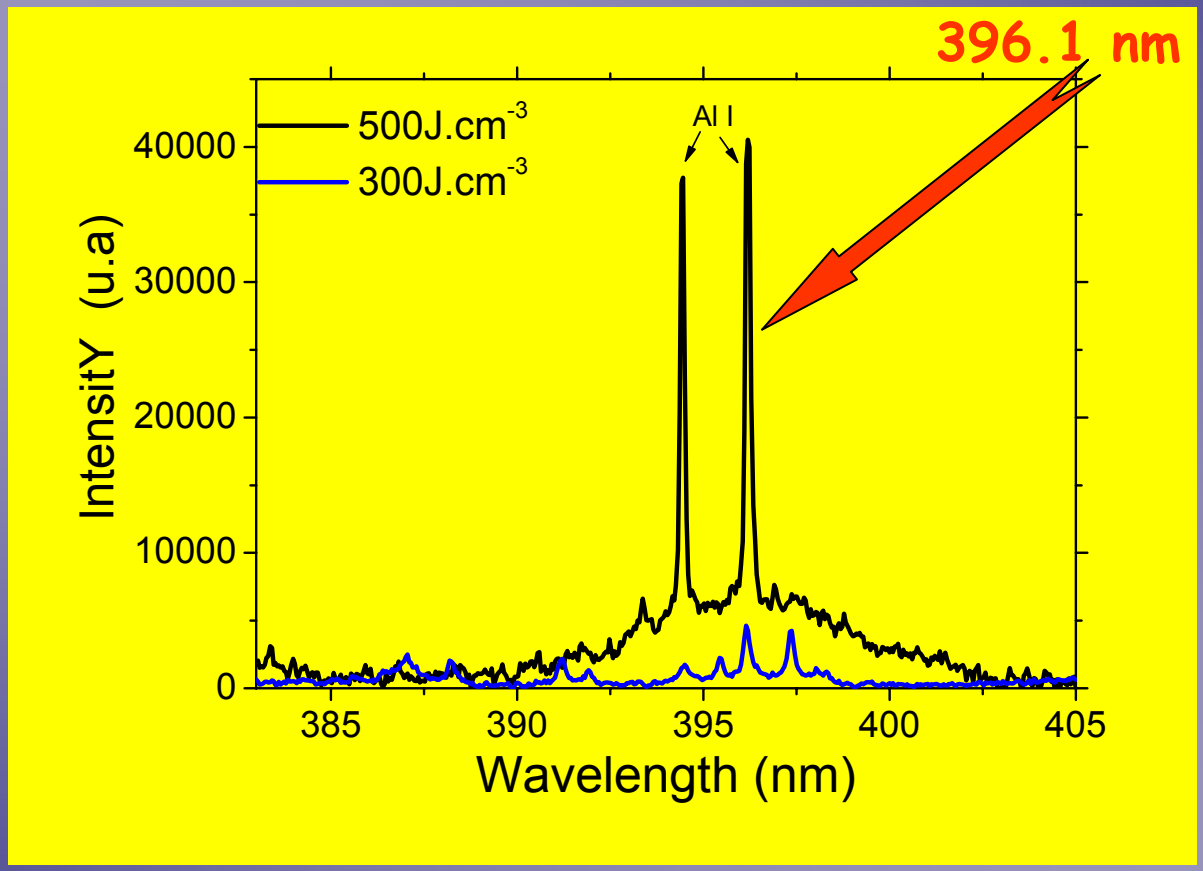


Cathode

Ablation of the capillary wall due to the discharge plasma

Spectroscopic diagnostic of the plasma emission

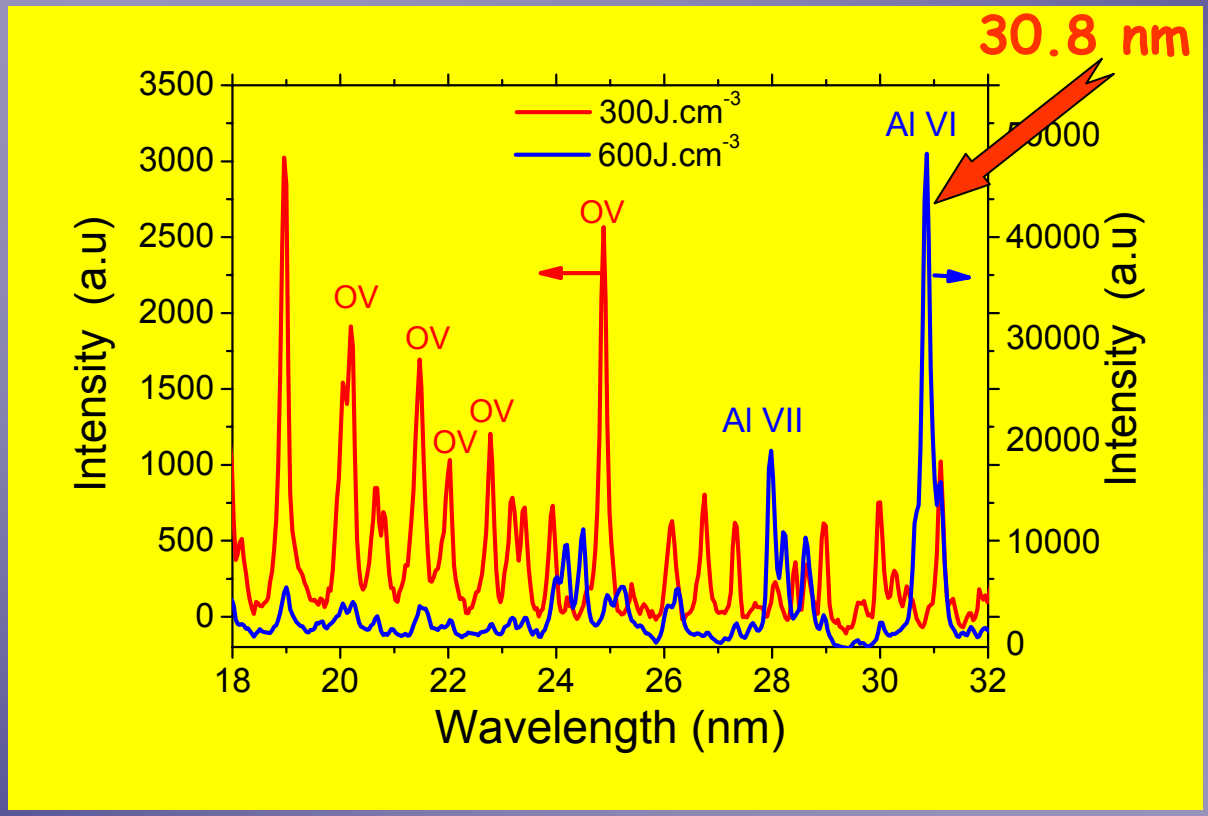
Time integrated UV-visible spectra by helium discharge



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

Spectroscopic diagnostic of the plasma emission

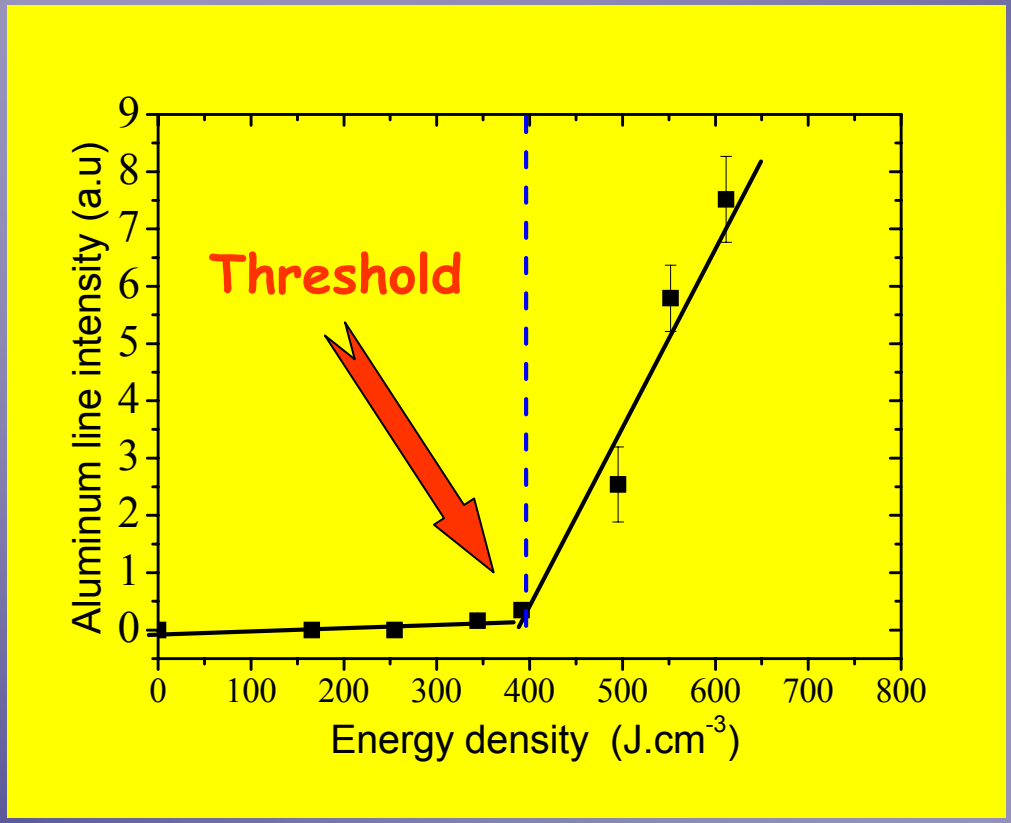
Time resolved XUV spectra by helium discharge



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

Observation of an ablation threshold of Al_2O_3 capillary

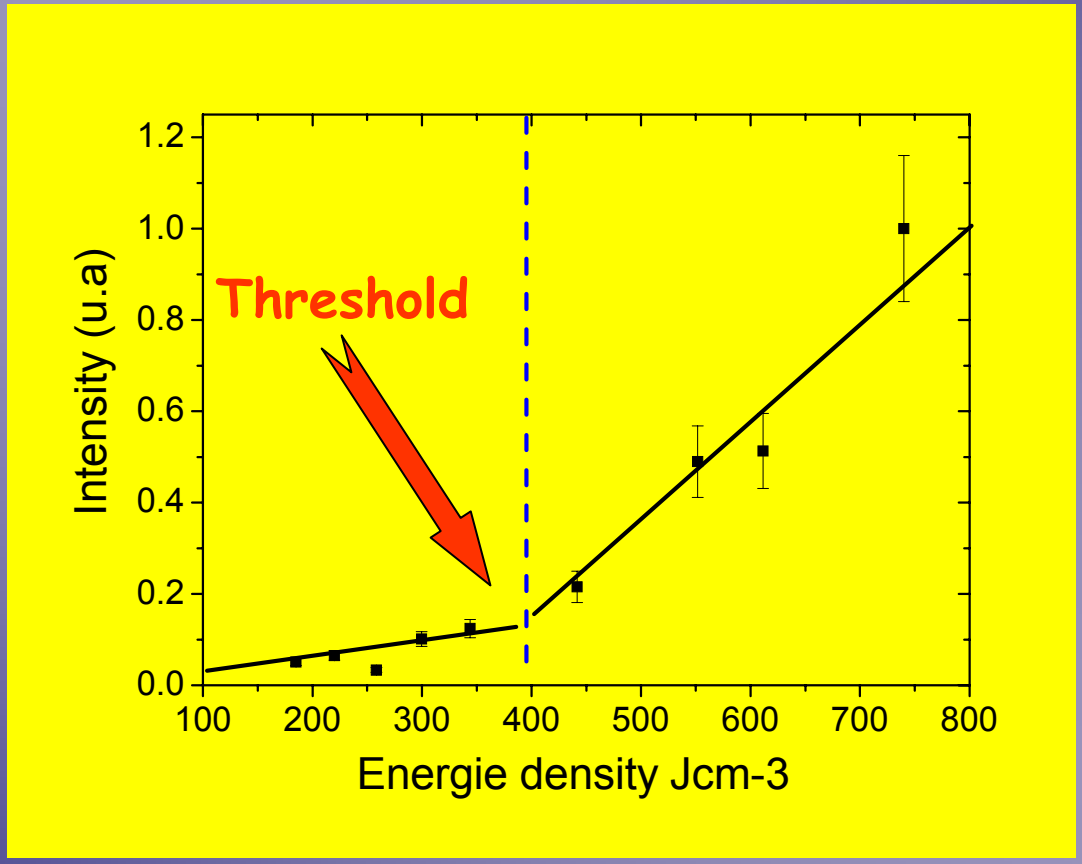
Aluminum line intensity Al I at 396.1 nm versus the energy density for helium discharge



Presence of an ablation threshold of the capillary wall around 400 $J.cm^{-3}$

Observation of an ablation threshold of Al_2O_3 capillary

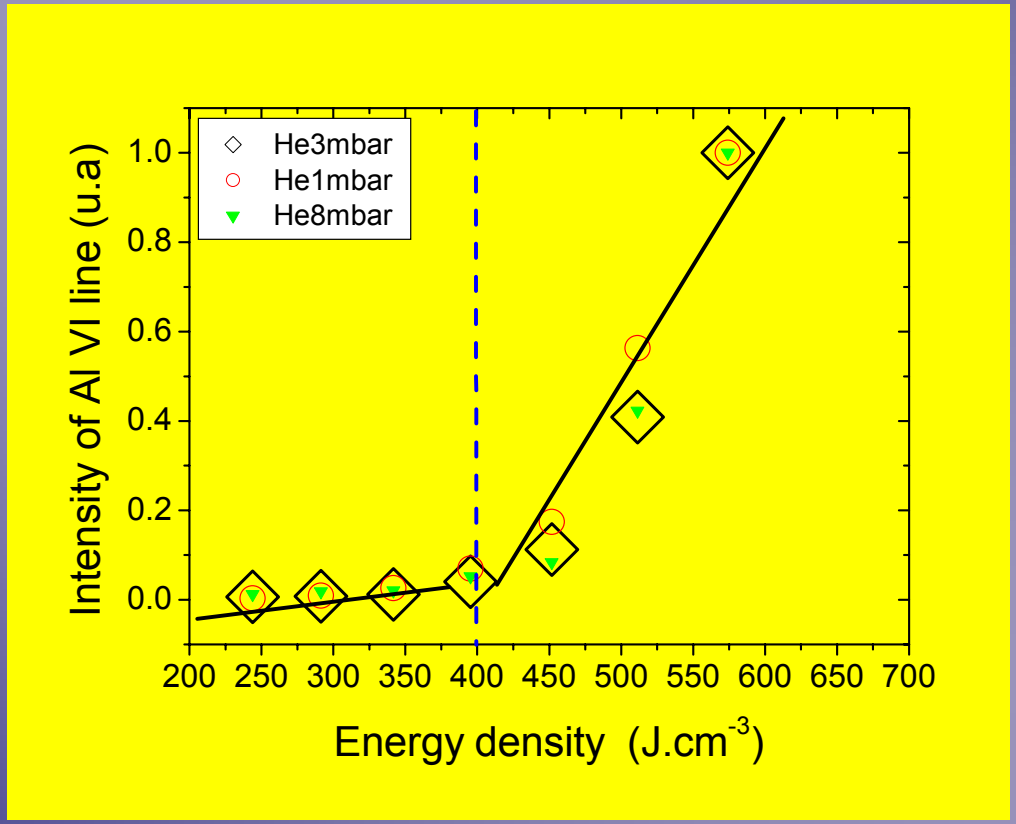
Aluminum line intensity Al VI at 30.8 nm versus the energy density for helium discharge



Existence of an **ablative and non ablative regime** : the ablation threshold is around 400 J cm^{-3}

The influence of the gas pressure on the ablation threshold

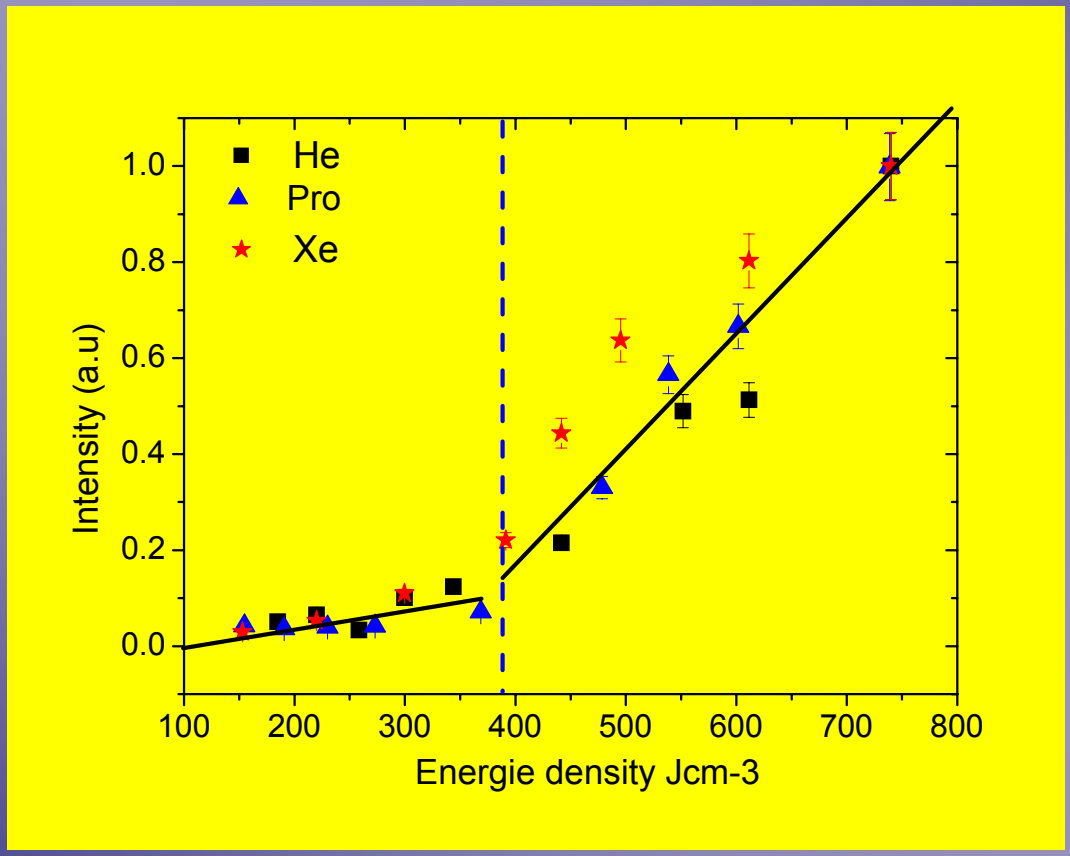
Aluminum line intensity Al I at 396.1 nm versus the energy density for different helium pressures



The ablation threshold is around 400 J cm^{-3} for three different gas pressures

The influence of the gas on the ablation threshold

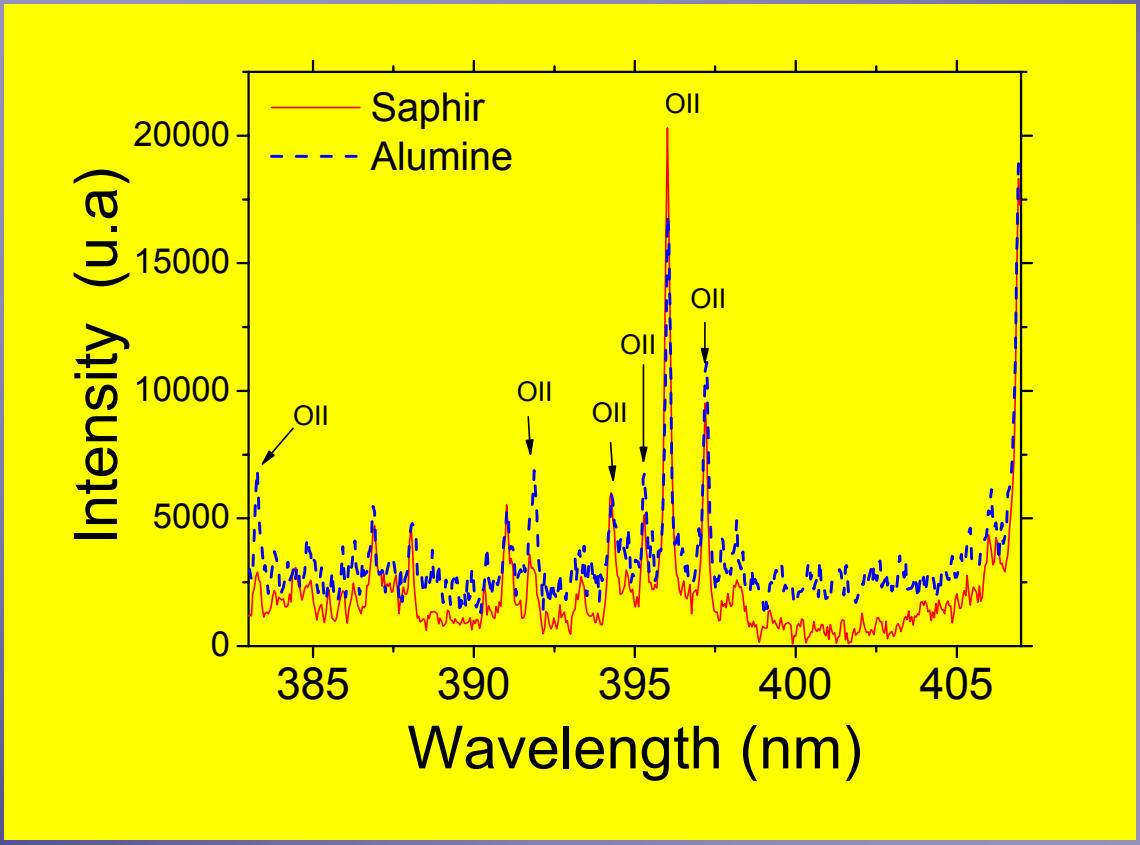
Aluminum line intensity Al VI at 30.8 nm versus the energy density for different capillary-filled gases



The ablation threshold is around 400 J cm^{-3} for xenon, propane and helium gases

The influence of the wall material structure

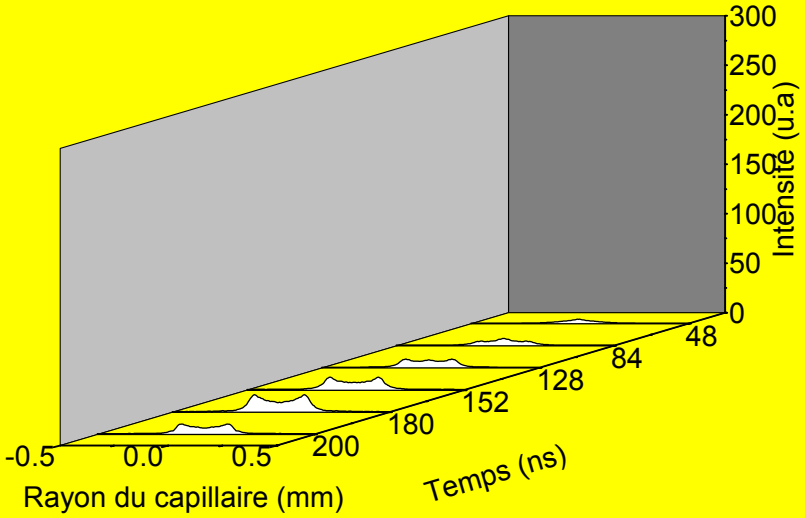
Which one is more ablated Sapphire or Alumina capillary ???



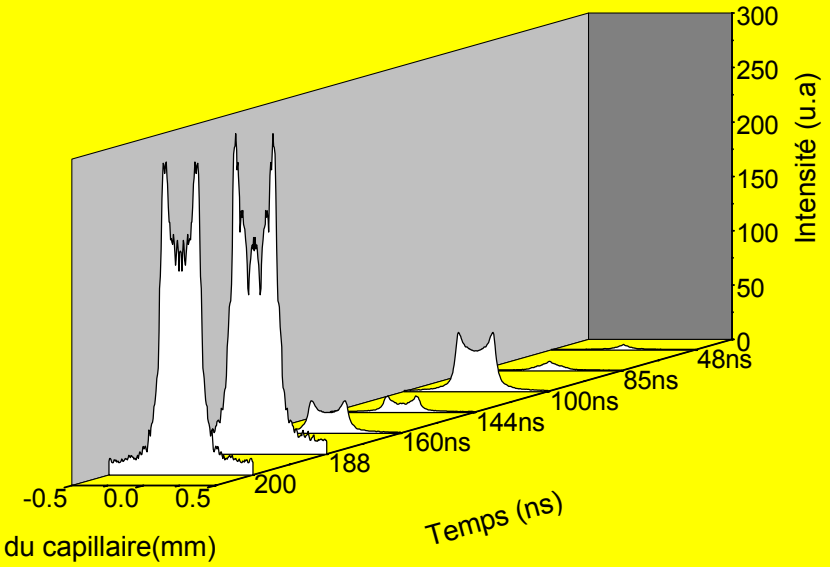
The sapphire capillary was provided by Pr Vrbova from krytur company

The profiles of the plasma emission at 309 ± 10 nm

Régime non ablatif



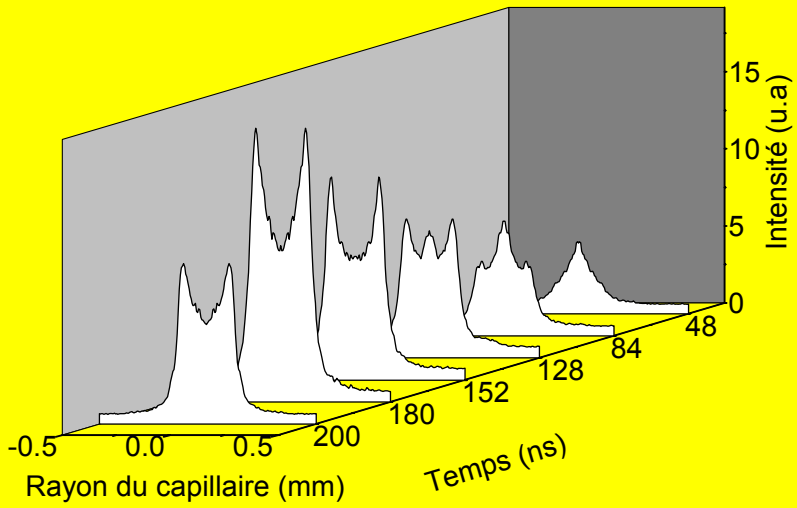
Régime ablatif



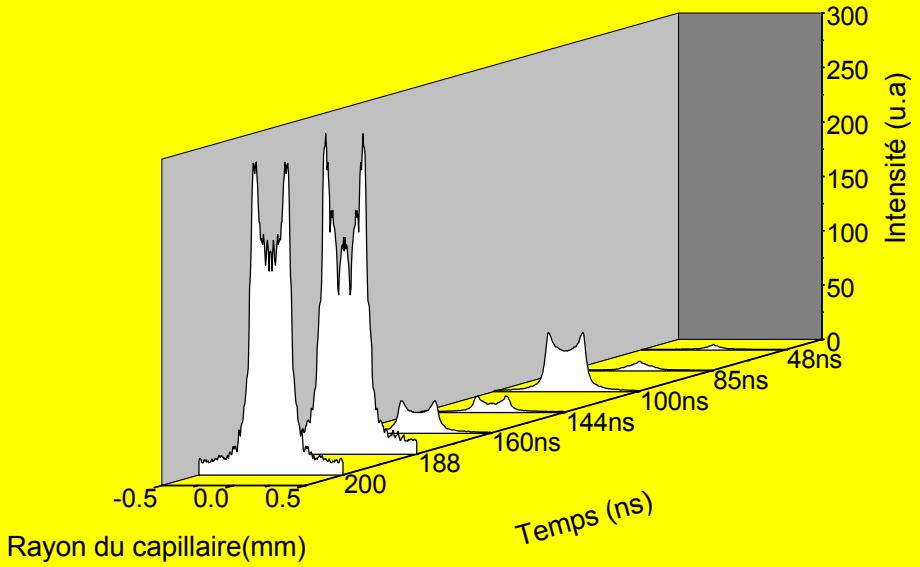
At **100 ns** the plasma emission corresponding to aluminum line Al I at **309.1** nm have **ring-like profile**

The profiles of the plasma emission at 309 ± 10 nm

Régime non ablatif



Régime ablatif



At **100 ns** the plasma emission corresponding to aluminum line Al I at **309.1** nm have **ring-like profile**

Coaxial ablation by plasma:thermal model *

The heat equation

$$D\,\frac{1}{r}\,\frac{\partial}{\partial r}\left(r\,\frac{\partial T}{\partial r}\right)=\frac{\partial T}{\partial t}$$

D: thermal diffusivity r: capillary radius

T: the wall temperature t: time

The plasma heat flux is considered

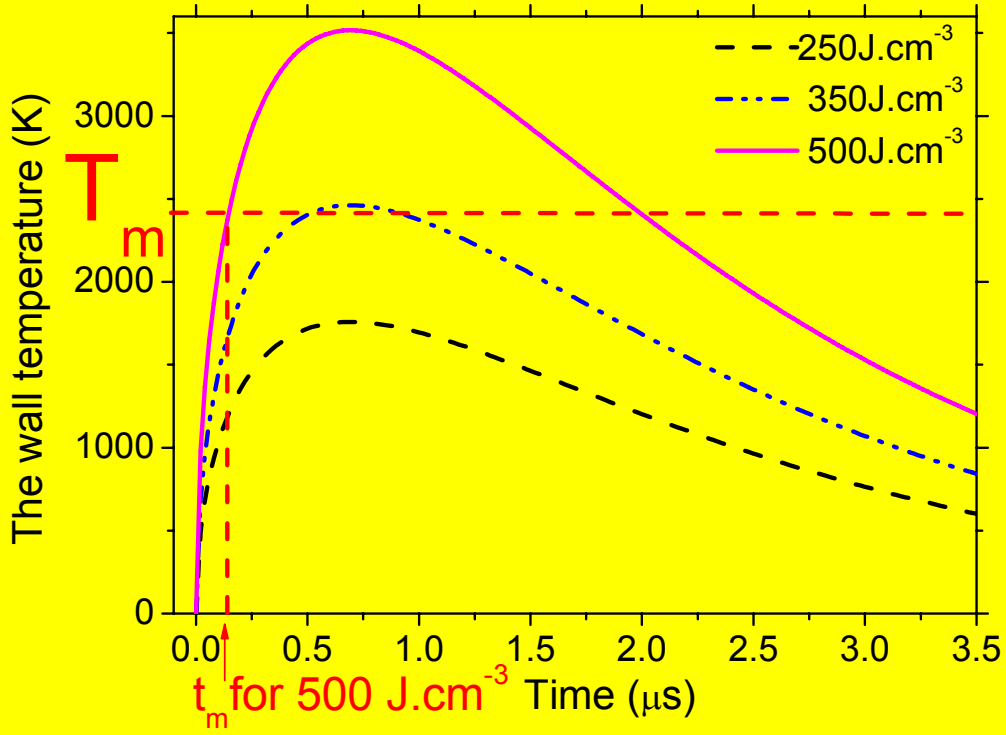
$$\phi(t)=\phi_0 e^{-\frac{t}{\tau}}$$

$$T(a_0,t)=\frac{\phi_0\sqrt{3D\tau}}{3\kappa}\,e^{-\frac{t}{\tau}}\sqrt{e^{\frac{t}{\tau}}-1}$$

* *O.Vallée et al: Surface Review and Letters Vol. 10, No. 1 (2003) 81-85*

Coaxial ablation by plasma:thermal model *

The predicted temporal evolution of the capillary wall temperature for different energy density



The ablation threshold ϕ_s

$$\phi_s = 2C_p T_m \rho \sqrt{\frac{3D}{\tau}}$$

The ablation threshold at **350 J.cm-3**

The wall melting temperature T_m is reached around **150 ns**

Conclusion

- Observation of an ablation threshold in gas discharge produced plasma at 400 $J.cm^{-3}$: ablative and non ablative regime
- The ablation threshold is not influenced by the gas pressure and capillary-filled gas
- The numerical results of the model are in good agreement with the experimental measurements
- The power density corresponding to the alumina ablation threshold by laser pulse (20 ns) is around 50 $MW.cm^{-3}$ and by discharge plasma is around 60 $MW.cm^{-3}$

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Thank you for your attention

Děkuji