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Dynamics of a nanosecond diffuse pin-to-plane discharge

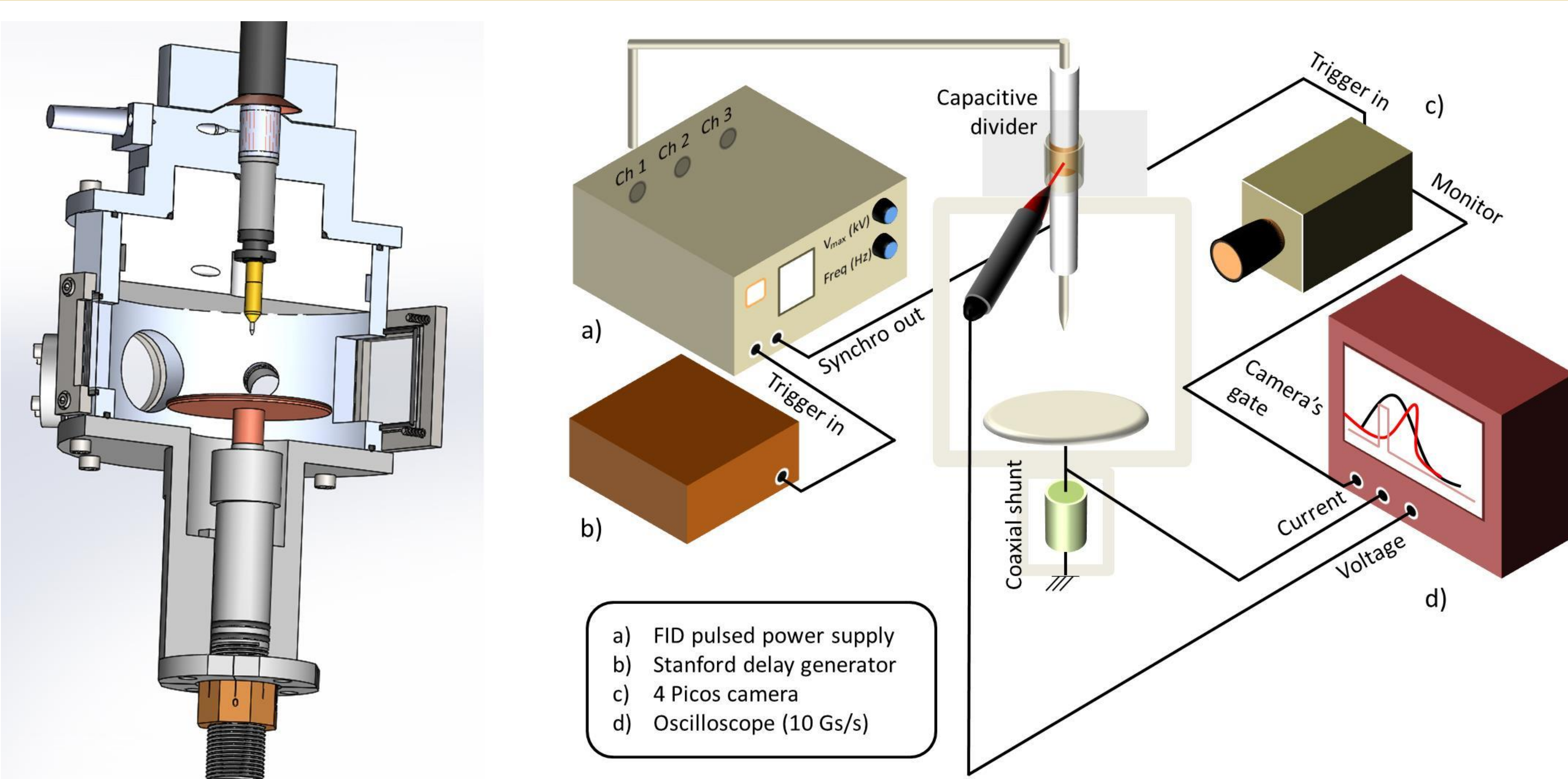
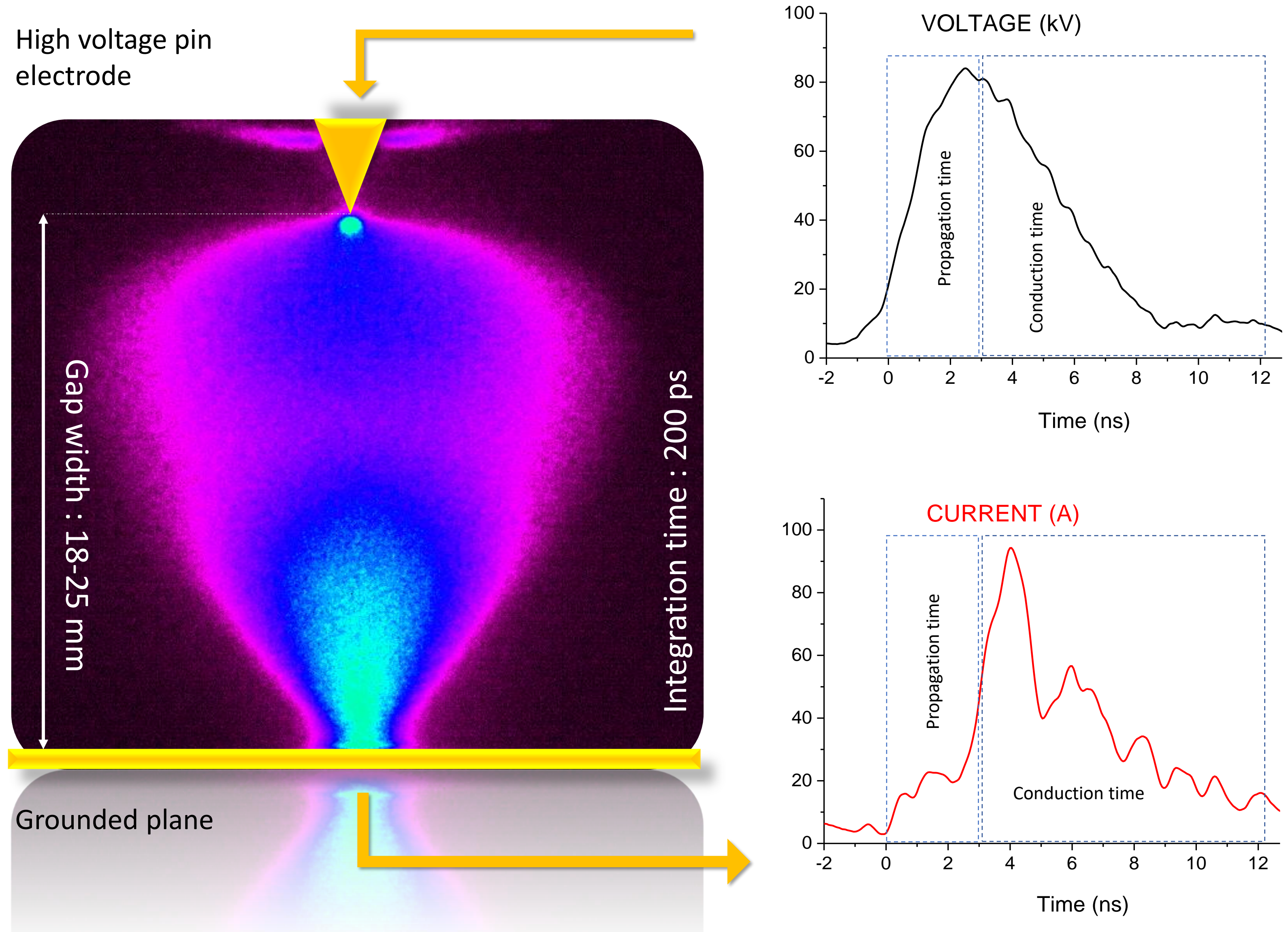
Effects of pin material at high overvoltage

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Summary : The **dynamics and propagation speed of a pin-to-plane discharge** generated in atmospheric air under high nanosecond overvoltage is analyzed and discussed for different pin materials. Pulses of 85kV with 2ns rise time are applied to a conical pin electrode made of different materials: **aluminum, titanium, stainless steel, copper, molybdenum and tungsten**. Discharge propagation speed is derived from sub-nanosecond time resolved imaging of the discharge front location with an accuracy of 0.3 mm/ns. Results clearly show the **slowdown of the discharge with the tungsten electrode** and, to a lesser extent, with aluminum. For these two materials, the average speed can be decreased respectively by 50 and 20 % compared to the case of copper electrode.

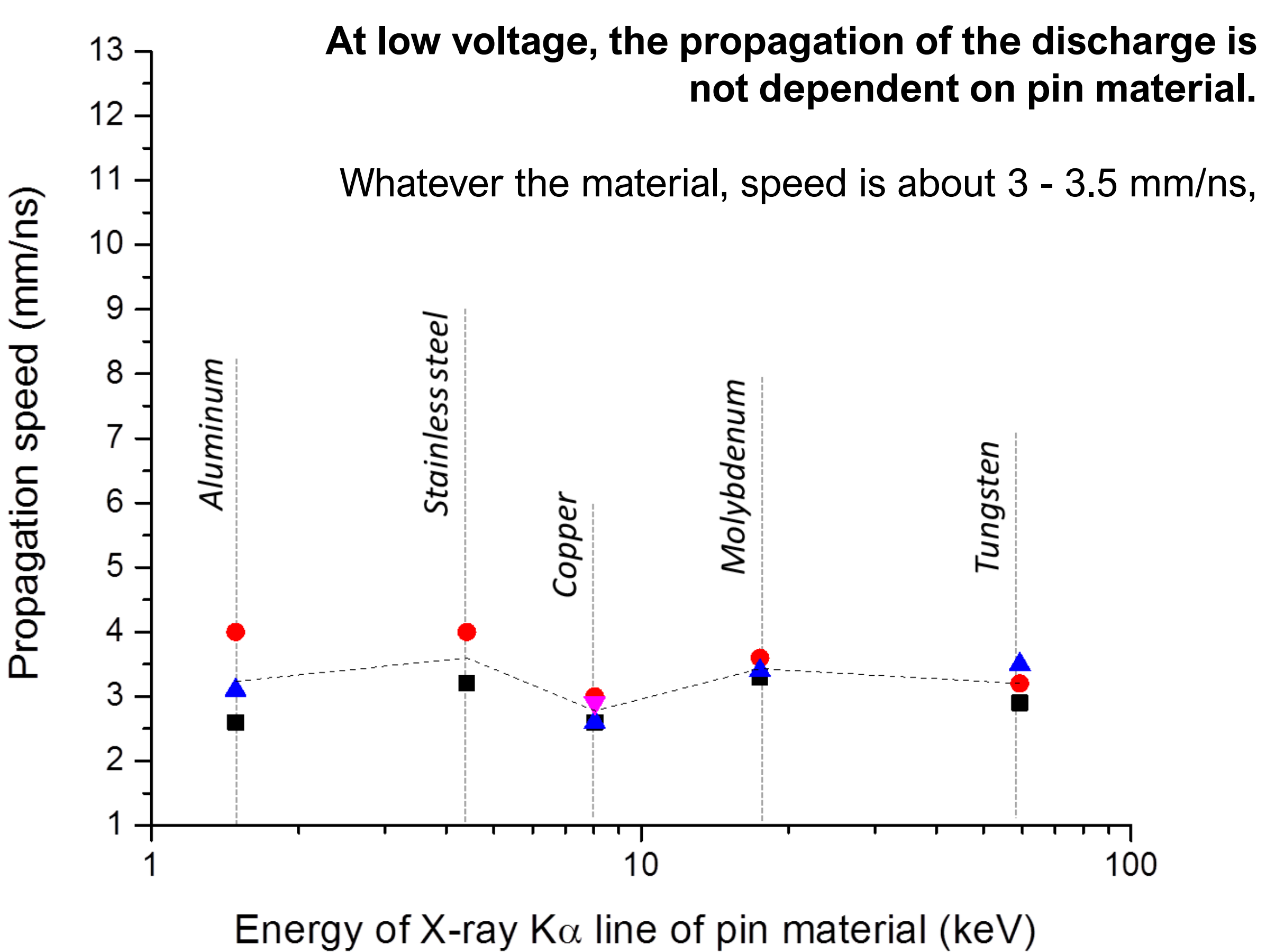
Scope : Pin-to-plane discharges generated under very high overvoltage (> 500%) nanosecond pulses, showing a large and diffuse pattern in atmospheric air, are not extensively studied and fully understood [1]. At such high voltages, the **very intense electric field at the pin** might induce non local mechanisms and specific behaviour (runaway electrons, X-ray emission). Some previous studies, in similar configurations, seem to show X-rays emission from the electrodes [2], which would arise from high energy electrons impact on the electrodes and should depend on their material type through characteristic X-ray emissions. Within this scope and considering that possible X-rays could influence the dynamics of discharges by photo-ionization effects, our study focuses on the only **effect of the pin electrode material on the propagation speed**, all the other experimental parameters remaining unchanged.



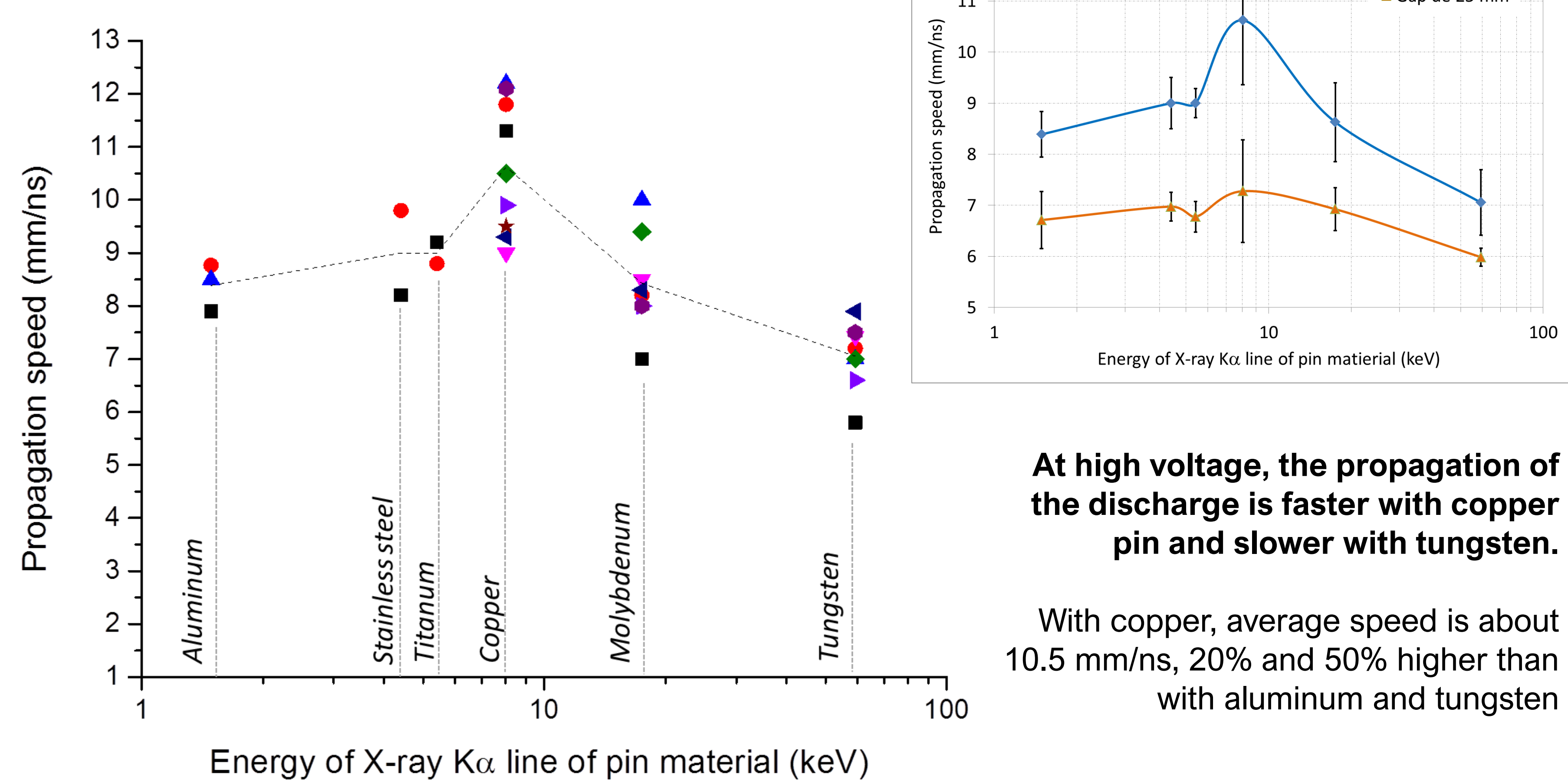
Experimental setup :

- Nanosecond pulsed discharge
 - Voltage : 2ns rise time, 6ns width, 85 kV Vmax
 - Repetition rate : 5 Hz
- Pin-to-plane configuration
 - Pin material : aluminium, titanium, stainless steel, copper, molybdenum and tungsten
 - 18 or 25 mm gap, pin radius between 30 and 60 μm
- Air discharge
 - P = 1atm, 1L/min of synthetic air
- Optical system
 - 4-picos Stanford intensified camera
 - 200 ps time resolved imaging
 - Analysis of the N₂(C-B) system emission
 - Speed derived from discharge front locations
 - Speed Accuracy estimated to ± 0.3 mm/ns

Results at low voltage (45 kV, 18mm) :



Results at high voltage (85 kV, 18 mm) :



Conclusion and outlook : For study and modeling of atmospheric pressure corona discharges at rather low overvoltage, electrodes material is most of the time not considered. Our experimental results demonstrate that this point must be revised for very high overvoltage. At least, speed propagation of the discharge is modified and enhanced with copper pins in our experiment. Interaction of high energy electrons created by local high electric field with pin anode could induce X-ray emission in the gap and promote photo-ionization processes. This interaction depends on the K α energy X-ray threshold of the material. For tungsten, this threshold is too high to be reached and for aluminum, low energy X-rays would be absorbed on short distances and their effect would be limited. Copper, with a threshold of 8 keV, is in between these two situations.

References:

- [1] P Tardiveau *et al* 2016 *Plasma Sources Sci. Technol.* **25** 054005
- [2] C V Nguyen *et al* 2010 *J. Phys. D: Appl. Phys.* **43** 025202

Acknowledgments:

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